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GAME ON'ASIA 2012

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Preface

Welcome to the Fourth Asian Simulation and AI in Games Conference (GAMEON ASIA 2012) and the Fourth Asian Simulation Technology Conference (ASTEC 2012). These conferences aim at consolidating of work in the technical aspects of games and simulations with special focuses in artificial intelligence, physics and graphics. This year it is our privilege that they are jointly held with the Annual National Convention of Digital Games Research Association JAPAN (DIGRA JAPAN) at Kinugasa Campus of Ritsumeikan University in Kyoto, Japan.

In fact, the root of both GAMEON ASIA and ASTEC could be traced back to the joint symposium held in 2007 at Biwako-Kusatsu Campus of the same university in Shiga, Japan. In 2010 and 2011, they have been successfully held in China and Singapore. GAMEON ASIA represents a prominent avenue for academics and practitioners alike to present novel research work in the video games domain while ASTEC, on the other hand, provides a similar avenue but focuses on work in the industrial simulations domain.

This year, GAMEON-ASIA 2012 brings several cutting-edge research papers in game artificial intelligence, computer graphics & vision, game methodology and speech technology. ASTEC 2012 also presents to you papers from various aspects of simulation methodology. All accepted papers have undergone rigorous reviews from the International Program Committee. Also included in our program are two keynotes, from both academia and the games industry, and one tutorial. With speakers' expertise in computer game development, computer graphics and computer simulations, we believe that much insightful knowledge could be gained to aid your game and simulation projects.

On behalf of the entire organizing committee, we thank all contributing authors for their effort in their preparation to submit their work in these conferences. Our heartfelt thanks also go to all the members of the International Program Committee for their precious time devoted to the review process. We also wish to thank all session chairs, presenters and attendees. Special mention goes to the Executive Editor, Philippe Geril, who has always given his utmost effort in making sure every detail falls into place. Last but not least, our gratitude goes to the European Multidisciplinary Society for Modeling and Simulation Technology (EUROSIS), Ritsumeikan Center for Game Studies, Digital Humanities Center for Japanese Arts and Cultures at Ritsumeikan University, Ritsumeikan Metaverse Learning Project, and DIGRA JAPAN for making this event possible.

Preface

Lastly, we wish all of you a fruitful event and an enjoyable stay in Kyoto, a *City of World Heritages*. Again, we thank you for your valuable time in supporting and participating in these two conferences.

Mitsuyuki Inaba, Ritsumeikan University
Koichi Hosoi, Ritsumeikan University
Ruck Thawonmas, Ritsumeikan University
Akinori Nakamura, Ritsumeikan University
Masayuki Uemura, Ritsumeikan University

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SCIENTIFIC PROGRAMME

TUTORIAL

HOW DO WE SAFELY DISTRIBUTE RANDOM STREAMS TO OUR PARALLEL STOCHASTIC MODELS?

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KEYWORDS
Random numbers, Parallel random streams,
High Performance Computing, Stochastic simulation.

ABSTRACT

High Performance Computing is becoming more and more available to a wider population of scientists. However, the distribution of parallel random number streams still has to be mastered though we have at our disposal statistically sound random number generators according to very tough testing libraries. This tutorial paper will present the different partitioning techniques with their corresponding software from the point of view of a simulation practitioner. Non-specialists in parallelizing stochastic simulations need help and advice in distributing rigorously their experimental plans and replications according to the state of the art in pseudo-random numbers partitioning techniques.

INTRODUCTION

Few surveys have been proposed dealing with the parallel generation of pseudorandom numbers. Many studies are warning us to be particularly careful when dealing with parallel stochastic simulations (De Matteis and Pagnutti 1995) (Hellekalek 1998) (Pawlikowski 2003). Even if many simulation applications can cope with poor randomness, as scientists we have to do our best to avoid producing biased results. This is particularly sensitive for nuclear physics or medicine for instance (Maigne et al. 2004) (Lazaro et al. 2005) (El Bitar et al 2006) (Reuillon et al 2008 and 2011). In (Mascagni 1997) we have the discrete mathematics and number theory behind the use of parameterized pseudorandom number generators (PRNGs) in parallel. In (Srinivasan 1998) (Traore and Hill 2001) (Bauke and Mertens 2007) and more recently in (Hill 2010) we can find surveys dealing with the different approaches. They can be separated into two main categories: the first one deals with the partitioning of a unique random stream, whereas the second approach deals with multiple independent streams obtained by parameterizing a family of generators. We now have at our disposal a set of fine sequential generators according to our current testing standards. Among these, we can recommend the Mersenne Twister (Matsumoto and Nishimura 1998) and WELL (Panneton et al. 2006) families of generators and MRG32k3a (L'Ecuyer et al 2002). A basic use of the "system generator" can lead to really poor results as seen in figure 1. All of them propose efficient parallelization techniques adapted to their structure. We hope that this short tutorial paper will help simulation practitioners to find good references to techniques that will suit their applications.

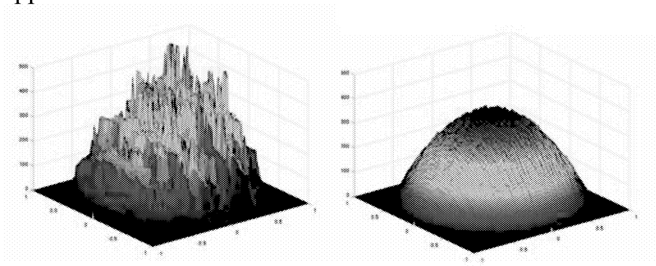

Figure 1: Probabilistic Simulation to Solve an Harmonic PDE
On the left using a default system generator under Linux (not the infamous old Unix rand) and on the right the correct solution using Mersenne Twister (Matsumoto and Nishimura 1998).

RANDOM STREAM DISTRIBUTION TECHNIQUES

Partitioning of a unique random source

Central Server Technique
The central server (CS) approach runs a single PRNG and provides on demand pseudorandom numbers to different logical processors. The main problem of this technique is that it is not reproducible if the number of served processing elements (PEs) differs from one simulation to the other or also because scheduling impacts this technique. The second drawback is that this approach does not scale well and the CS will become a bottleneck if too many PEs are considered.

Boolean Cellular Automata
Boolean cellular automata have been considered to generate parallel pseudorandom numbers and are presented in (Sipper 1996) and (Tomassini et al. 1999). They have tested the generated sequences for distributed environments but we are not aware of any statistical testing of this approach using the latest testing batteries. In addition, since this technique was considered rather slow, a hardware implementation in programmable chips has been considered (Ackermann J, 2001). We have not seen recent modern high performance stochastic simulations using this technique.

Sequence Splitting, Blocking or Regular Spacing Technique
The Sequence Splitting (SS) method is also known as "blocking" or "regular spacing". The principle is to split a

sequence into N non-overlapping contiguous blocks. The length of each block/stream must be chosen so that each stream is long enough to achieve the stochastic simulations assigned to each PE. Overlapping can be easily avoided, but long range correlations in the initial PRNG can lead to small range correlations between the potential sub-streams (De Matteis and S. Pagnutti 1990).

Indexed Sequence, or Random Spacing Technique
The Indexed Sequences (IS) or Random Spacing (RS) partition the generator cycle in streams by initializing the same generator with different random statuses. The term random seeding is still in use for old generators like Linear Congruential Generators, they have to be avoided for scientific applications because of their structural flaws. For modern generators the 'seed' is a more complex status that can be generated with another RNG. In addition, modern generators often present a huge period adapted to this technique. Wu and Huang showed that the minimum distance between n statuses generated in this way is on average $1/n^2$ multiplied by the period length (Wu and Huang 2006). The higher the period, the lower the risk to obtain a bad initialization (two random statuses too close to each other). If we consider a PRNG with a period m, the probability that n sequences of length L, generated by a Random Spacing technique will overlap is given by equation 1.

$$p = 1 - (1 - nL / m-1)^{n-1} \qquad (1)$$

When $n\ L / m$ is in the neighborhood of 0 with a generator proposing a huge period, the probability can be equivalent to equation 2.

$$p = n\,(n - 1)\,L / m \qquad (2)$$

With this random initialization technique, we also have to consider the case of a bad initialization which can impact the quality of some underlying PRNG. Recent history has showed that even some of the best RNG algorithms could fail when badly initialized. For instance, at the beginning of the Mersenne Twister generators, zero excess initial states or the fact that two initial states were too close with respect to the Hamming distance, then the corresponding output sequences were close to each other. Improvements have been proposed to overcome this problem. In 2008, Reuillon proposed 1 million statuses for the first Mersenne Twister (MT) with its $2^{19937} - 1$ period. He used a PRNG with cryptographic qualities to propose independent and well balanced bit statuses (SHA-1 from the java gnu crypto: http://www.gnu.org/software/gnu-crypto/), taking into account that if the MT had a zero excess initialization status, it can take quite a long number of draws to recover good statistical properties (Reuillon 2008). In (Matsumoto and Nishimura 2000), we are warned that this procedure may lead to collision in the case of generators based on a linear recurrence like MT, because the sum of two pseudorandom sequences satisfies the same linear recurrence that may appear in a third sequence.

The Leap Frog Technique
The Leap Frog (LF) distributes pseudo random numbers like a deck of cards dealt to card players. If m is the period of the global sequence and n the number of desired streams, the period of each stream is m/n. When we have a large number of PEs, we may have the same kind of problems encountered with splitting technique. Indeed, the long range correlations in the initial PRNG can lead to small range correlations between the potential substreams. In addition, poor spectral values can be observed depending on the number wished sequences (Wu and Huang 2006). Moreover, if the PRNG does not propose a technique to precompute the next numbers for each stream (Jump Ahead technique that will be exposed later), we encounter the bottleneck problem discussed with Central Server approach.

Partitioning multiple streams

The previous techniques were dealing with the partitioning of a single stream into substreams. A technique called parameterization uses a declination of the same family of generators, used with different parameters for each PE. An interesting approach was proposed in 1998 by Matsumoto and Nishimura and published in 2000 (Matsumoto and Nishimura 2000). Their technique is named Dynamic Creator (DC). This technique is able to generate by parameterization mutually independent Mersenne Twister generators. PNRGs based on linear recurrences defined by matrices with characteristic polynomials relatively prime to each other are supposed to be mutually independent. This technique is available for other generators of the MT family like the recent TinyMT and MTGP for GP-GPUs (General Purpose Graphical Processing Units). This approach is safe according to the scientific community (remember that we have no mathematical proof) and it is however a good practice to test the resulting generators and give feedback to authors. We have done this for MTGP (Passerat-Palmbach et al. 2010).

Classification

In figure 2 we propose a UML (Unified Modeling Language) classification of the main parallelization techniques. The first classification criterion that we retain is linked to the use of either a single stream or multiple streams. In the latter branch (on the right), we find the parallelization techniques named parameterization and the dynamic creation of different generators carefully constructed to ensure independence between their streams. On the left side of this class diagram, we have parallelization techniques that use different partitioning techniques of a unique stream. This includes the centralized approaches of random number distribution that we have exposed, but also decentralized approaches enabling the production of sub-streams with different spacing techniques.

In this classification, we see that partitioning a unique stream may use a technique named "Jump Ahead". This technique was also named 'Cycle Division' in (Mascagni and Srinivasan 2004). When possible it proposes an analytical computing of the generator state in advance after a huge number of cycles (generations) and corresponds to a jump ahead in the random stream. The recent name of this technique is precisely “Jump Ahead” and it was not available for generators with very large periods until recently. Matsumoto and L’Ecuyer teams joined to develop an efficient jump-ahead algorithm for the WELL and MT families of generators (Haramoto et al. 2008). This algorithm takes only a few milliseconds on current processors. As stated previously, this is still slow when compared to what can be obtained with a generator like MRG32k3a. However, the latter is slower to generate its numbers, by a factor of two or three on current computers when compared to MT for instance. The interesting point is having different generators with different structures to test the stochastic sensitivity of our applications. Championing only one approach does not make sense, but the diversity of rigorous approaches is a strength to obtain reliable results.

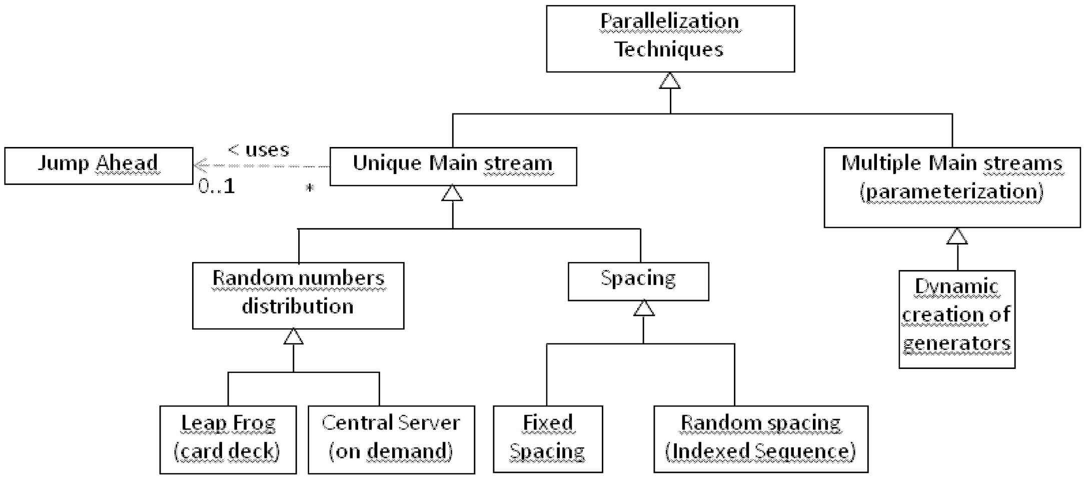

Figure 2: Classification of Parallelization Techniques

EXISTING SOFTWARE TOOLS

Distribution software

The easiest way to parallelize stochastic simulations is to distribute replications. This technique has been in use since the beginning of parallel computing and has been well illustrated since the early nineties (Pawlikowski and Yau 1992). Indeed, at that time Pawlikowski and Yau proposed at the European Simulation Symposium an interesting methodology for the parallelization and the automatic partitioning of stochastic parallel simulations. As in (Hill 1996), Li and Mascagni give advice and show how to achieve safe multiple replications in parallel (Li and Mascagni 2005). A famous reliable and sound library which takes into account the parallelization of pseudorandom numbers is SPRNG (Scalable library for Pseudorandom Number Generation), presented at the end of the nineties by Michael Mascagni (Mascagni 1997). This paper presents the mathematical foundation for random number generators and different implementations of various parameterization techniques for different families of generators. SPRNG also proposes a small test suite and Mascagni also presents a short and interesting discussion around Monte Carlo tools for High Performance Computing at the end of the last millennium (Mascagni 1998). At the same time, Matsumoto and Nishimura prepared the Dynamic Creator software to generate mutually independent Mersenne twister generators for parallel computing, this was published, two years later (Mastumoto and Nishimura 2000). This approach is in our opinion the preferred parallelization technique for MT generators. The jump ahead technique is now available for linear recurrences modulo 2 with huge periods (MT & WELL generators) (Haramoto et al. 2008), despite its relative efficiency, it is still considered as slow by specialists compared to what can be obtained for MRG32k3a with a smaller period. Another interesting study was proposed by L’Ecuyer and his team at the beginning of the millennium. Their proposition led to a package able to produce many long streams and substreams in C, C++, Java, and FORTRAN (L’Ecuyer et al. 2002); a version for R was released a bit later (L’Ecuyer and Leydold 2005). A Java Parallel Random Number Library for High-Performance Computing was released in 2004 (Coddington and Newell 2004). Dealing with Java, we would champion the SSJ package, which provides a RandomStream Java interface that proposed the basic structures to handle multiple streams with efficient methods to move around streams (L’Ecuyer and Buist 2005). At a higher level, some tools help in the deployment of stochastic simulations, particularly for cluster and grid computing (Li and Mascagni 2005). In the past we have proposed DistMe (Reuillon et al. 2008;2011) and a more recent tool OpenMole based on declarative task delegation (Reuillon et al. 2010).

Testing software

Statistical and empirical testing software is a necessity for random streams. Since initial propositions by Knuth in the 2nd volume of the art of computer programming, the DieHard testing suite was highly regarded for many years (proposed by Marsaglia in 1996. In (Coddington and Ko

1998) we find a set of techniques for empirical testing of parallel random number generators. When cryptographic qualities are required, National Institute for Standards and Technology (NIST) proposes the Statistical Test Suite (STS). As mentioned in the previous section, SPRNG is also providing a set of statistical tests. In 2004, Rütti's thesis presents the main statistical tests for pseudorandom numbers and he developed a testing suite with Troyer and Petersen (Rütti et al. 2010). At the same time (Brown et al. 2004) proposed the DieHarder as an update of Marsaglia's work. On top of that, my recommendation would be to use the TestU01 software library (L'Ecuyer and Simard 2007). This is currently the most complete collection of utilities for the empirical and statistical testing of uniform random number generators. Since there is no mathematical proof of independence between the generated parallel random streams, we still recommend thorough testing with TestU01 for sensitive applications. Indeed, we have to rely on the latest proposals of our best mathematician colleagues to carefully avoid long-range correlations. Interesting approaches to control correlations are presented in (De Matteis and S. Pagnutti 1995) and parallel tests are discussed in (Srinivasan et al 2003).

DISCUSSION

To summarize the quick survey we propose hereafter a set of tips that will help practitioners in their implementation of parallel stochastic simulations. First of all, select a fine sequential generator (never rely on system generators) such as generators from the MT or WELL families. Second, do take care of initialization, some very good generators can fail when badly initialized or save a status that can directly lead you in the sequence after the warm up phase. When you have selected your generator, select the partitioning technique that you wish. Splitting a unique stream with the "Jump Ahead" method can be used with MRG32k3a, MT and WELL generators (as well as some other fine generators). If you select the parameterization technique, the MT family will be a nice road companion with the 'classic' MT, tinyMT and MTGP. When you deal with parallel simulations that require more than 10^{14} numbers, and this occurs for modern parallel nuclear simulations and nuclear medicine applications where we launch thousands of independent jobs, each of them needing more than 15 billion numbers; we have to avoid the 'small' period generators. Indeed, in the literature we can find guidelines to avoid drawing more than even a small fraction of the PRNG's period. In the Journal of computational and applied mathematics, Ripley advised not to draw more than the cubic root of the period (Ripley 1990). In the case described, a period above 2^{150} will be perfect. On top of that, if you are in a sensitive research domain, do test your application with more than one generator and even with more than one partitioning technique to check the stochastic variability of the combination you have retained.

CONCLUSION

Complex systems and stochastic models now consume more than 50% of our "supercomputing" cycles... A bad distribution of pseudo-random numbers to parallel processes can seriously affect your results. For more than a decade we have had at our disposal fine pseudo-random generators. For a rigorous approach, one should be sure to use some of the best sequential generators and to test the stochastic variability of the application by changing the generator (ex: going from MTs to MRG32k3a or to WELLs generators for instance. Other sound generators, checked with TestU01 can be considered. In addition, we have to select a distribution technique adapted to the generator in use. In this paper, you can find a rapid survey of distribution techniques and a set of links to existing distribution libraries and tools. Testing libraries are also cited to check the different parallel streams when a sensitive application is under consideration. When testing your application, it is important to keep in mind that we are testing a tuple composed of your application, the distribution technique used to obtain parallel streams, the pseudo-random number generator and its initialization. We have not discussed what we could call hybrid approaches, like the 'shuffling leap frog'. This is a research domain for mathematicians and the author of this short tutorial is just a simulation practitioner. Another point that we have not addressed in this paper is the generation of pseudo random numbers for GP-GPUs, the interested reader can have a look at (Passerat-Palmbach 2011a,b) and for an extensive review in this domain a complete article will appear this year in Concurrency Computation Practice and Experience (Hill et al. 2012).

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SIMULATION AND VR GAMING APPLICATIONS

SIMULATION OF SOFT-LOOKING FACIAL EXPRESSIONS

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ABSTRACT

The approximation of realistic facial expressions is an essential part of many virtual simulations, such as video games or avatar applications. Unfortunately, a lot of manual work is usually needed to create realistic facial expressions. In this paper, we present an automatic way to create soft-looking expressions from the mesh data. We combine a modified version of Waters' vector muscle model to simulate the facial muscles, with a constraint based skin simulation for the generation of real-time wrinkles to achieve this goal. The resulting simulation allows the creation of soft-looking expressions depending on the mesh topology.

INTRODUCTION

With the increase of computing power for personal computers, virtual simulations gain more and more realism. Especially graphics in video games and animated movies improve constantly, and with them the demand for realistic looking virtual humans. The simulation of the human face plays a very important role in creating the illusion of interacting with a real human being. For this simulation, the contraction of the facial muscles has to be approximated, as well as the structure and the wrinkle behavior of the human skin. These wrinkles, which occur due to skin compression, are important so that the face is perceived as soft and more realistic. Unfortunately, this part of facial animation is often neglected, especially in real-time applications. This leads to the problem that the faces of virtual humans are not perceived as soft, and tend to be mask like, showing no real emotions.

To generate real-time wrinkles, it is usually necessary to work with previously created or extracted information, which needs some sort of manual work. In this paper we present the idea of creating wrinkles automatically by using the mesh topology in combination with a set of constraints, to allow wrinkle creation due to surface compression. This technique used together with an appropriate muscle simulation results in a flexible way for creating soft-looking, realistic facial animations in real-time.

RELATED WORK

Shape interpolation, one of the first but still often used techniques for facial animation was first described by (Parke 1972), and has a lot in common with the traditional way of 2D animation, in which the head animator only defines the key poses of a character and then passes them on to an assistant, who draws the frames in between. Similar, for the use of shape interpolation, all the facial expressions have to be created by rearranging the vertices of a mesh, but the transition between the expressions can be calculated. This technique has the disadvantage that each of the expressions has to be recreated for additional models.

A more physics based approach was developed later (Waters 1987), and suggested to simulate the contraction behavior of the individual facial muscles. Using only two muscle types called linear and sphincter muscles, a wide range of facial expressions could be generated. This technique is more flexible than the previously mentioned one, and allows to recreate the expressions on different models by fitting the muscles to them. This model was modified by (Bui 2003a), reducing the calculation speed by defining face regions. The authors also found a way to use multiple muscles influencing a vertex by applying the force bit by bit instead of all at once. A simple approach to generate wrinkles by predefining their height and number of wrinkles is presented too. In a different paper (Bui 2003b) the authors use Radial Basis Functions to map muscles from one model to another. More complex simulations were created by (Waters 1992; Kaehler 2002), using a three layer based approach to simulate skin and muscle forces. These simulations need however lots of computation power, and are therefore not commonly used in real time applications.

A different approach was taken by (Bickel 2007; Alexander 2009) with the use of performance driven facial animation, capturing the facial information from a real person and transferring it upon a virtual character. In (Bickel 2007) the authors used a set of marker points which were drawn on an actor's face and tracked the real face to animate the simulated one. Additionally, wrinkly regions of the face like the forehead were painted with bright colors, and the self-shadowing of the wrinkles was used to capture them. The results showed that with this technique, very impressive expressions can be achieved.

In (Alexander 2009) a complex lighting cage was set up consisting of 156 LED lights and 15 cameras. An actress with a set of 40 marker points on her face was placed in the middle of the cage, and then asked to perform 38 expressions, based on Paul Ekman's Facial Action Coding System (FACS) (Ekman 2002), while multiple photos were taken to capture the face and its skin details, down to the stretching of skin pores. This information was then converted into different texture maps, and blend shapes were created by tracking the marker points. The final video showed tremendous realism. The disadvantage of these two techniques is that a lot of manual work is needed, and the setup is quite costly.

There are also some approaches focusing entirely on the creation of real-time wrinkles. Wrinkle maps are a common solution, and in (Dutreve 2011) a technique is described to retrieve the necessary information from a human face and map it to a character. A different approach was taken in (Bando 2002), where a user is responsible for defining a set of direction vectors and a height, while an algorithm then calculates the wrinkles and deforms the mesh using the mesh structure. This technique was used to create small wrinkles on a virtual hand. Another approach was presented in (Larboulette 2004) where a planar wrinkle curve was defined, consisting of an origin point, a target point and a rest value. Then a set of control points is defined which is equal to the number of wrinkles that should be created. When the original point moves to the direction of the target point, the positions of the control points are recalculated to keep the rest length constant, resulting in bulging the surface.

In this paper we present a novel technique to create wrinkles in combination with Waters' vector muscle model (Waters 1987). The wrinkles are created directly from the mesh topology, allowing to automatically create them on any mesh with proper topology.

SOFT LOOKING WRINKLES

The main goal of this paper is to create facial animations in a way that results in soft looking facial expressions. Therefore, two problems have to be solved. Finding a simulation for the human skin that allows the creation of wrinkles during deformation, and a solution for approximating the facial muscles and their contraction behavior. Both of the solutions must be flexible enough to be easily adjustable for different face models, and require as little manual work as possible. A viable solution for a skin simulation would be one that takes the given mesh model, converts it into a skin surface, and automatically creates wrinkles when compressed.

Our approach is based on soft-body simulations, which are often used to simulate clothing, and are able to create realistic wrinkles for any kind of fabric. They provide the kind of dynamic wrinkle generation which the simulation of human skin needs too. However, there are some differences that have to be addressed. Clothes react to external forces, like gravity and wind, and hang rather loosely on the human body. The human skin on the other hand should not move at all until triggered through muscle contraction. A modified soft-body simulation is therefore chosen to be implemented to simulate human skin behavior.

In order to simulate the human skin by calculating forces on the surface, a special solution is needed for the animation of the face model. This solution is not allowed to deform the surface of the mesh directly, but has to simulate forces that can be integrated into the skin simulation. An obvious choice is given by using one of the muscle simulations we encountered during our research. While the three layer muscle model used by (Waters 1992), and the one used by (Kaehler 2002), reproduce the facial muscle contraction and the visual aspects on the surface very accurately, they seem to be too expensive to be used in real-time. Thus, we choose Waters' Vector Muscle Model (Waters 1987), showing both good performance and believable results. It is, however, necessary to extend this model by introducing our own new muscle type. As a guideline for the muscle implementation the Facial Action Coding System (FACS) created by (Ekman 2002) was chosen, which was also used in Waters' original paper. This manual does not only explain the position of the facial muscles accurately, but also focuses on their visible deformations, which are described through Action Units (AUs). By combining these Action Units, every possible facial expression can be created.

The Skin Simulation

The used skin simulation was derived from a simple soft-body simulation described in (Keng-Siang 2008). A soft-body simulation is used to approximate the physical behavior of a soft object, or even more commonly to simulate clothes. It does that by using a set of springs and constraints. Most common are structural springs, used to keep the horizontal and vertical distances between the vertices, shear springs which are placed diagonally and which prevent the squares to form flat diamonds, and finally bend springs defining the bending stiffness of the clothing. Some of the most commonly used constraints are point and length constraints. Point constraints pin a vertex to a point in space, this being useful for example to pin one side of a flag on a pole. Length constraints in the other hand keep the vertices at a certain distance apart and keep the form of the cloth.

For the purpose of simulating human skin, however, the soft-body simulation has to be modified. The main difference in our approach is that we do not use springs at all. Rather, we solely make us of constraints that should be satisfied. Furthermore, we define that constraints produce forces f_i, which directly act on the positions of the vertices rather than their velocities. By summing up all forces acting on each vertex, and then applying the net force

$$\boldsymbol{F} = \sum_i f_i$$

to its current position $\boldsymbol{V}$:

$$\boldsymbol{V}' = \boldsymbol{V} + \boldsymbol{F},$$

under general conditions, after a number of iterations the positions of the vertices converge to some final position. Furthermore, we do not allow gravity to influence the vertices.

Length Constraints

When skin is compressed, wrinkles must appear due to the basic incompressibility of it. This results in a visual effect likewise to the one presented by (Bando 2002) and can also be implemented similarly. This can be achieved by using strict length constraints, which always try to keep the vertices at their optimal rest distance. Therefore, if the two involved vertices are too close, forces are developed that try to push the vertices in a direction that allows the constraint to achieve its rest distance. When the position change spreads through the simulation, it usually only leaves the surface the option to bulge, and thus wrinkles are created. Between every vertex and its neighbor, therefore length constraints must be defined.
For doing this it is important to know which vertices are connected with each other. This information has to be read from the mesh, and it is therefore necessary to access the model's edge data. For length constraints, however, it is not only necessary to know which vertices are interconnected by an edge, but also the distance between them, which is also calculated from the mesh data at simulation start.
To calculate the force $\boldsymbol{f}_l$ that keeps the vertices at the same distance from each other is the next step. The magnitude M of this force depends on the difference between the original length d_{init} (the desired rest length) of the edge between two vertices, and the current one d_{curr}:

$$M = d_{curr} - d_{init}.$$

If the skin is compressed, the magnitude M of the force contains a negative value, resulting in a compelling force The direction $\boldsymbol{d}$ of the force can be calculated by subtracting the positions $\boldsymbol{V}_1$ and $\boldsymbol{V}_2$ of the simulated vertices from each other and normalizing the result

$$\boldsymbol{d} = \frac{\boldsymbol{V}_1 - \boldsymbol{V}_2}{||\boldsymbol{V}_1 - \boldsymbol{V}_2||}.$$

These constraints produce the desired forces that help to keep the vertices at the same distance from each other, and built wrinkles upon compression

$$\boldsymbol{f}_l = 0.5 \cdot M \cdot \boldsymbol{d}.$$

Both vertices of the constraint are moved in opposite directions relevant to the resulting force, i.e., $-\boldsymbol{f}_l$ is added to $\boldsymbol{F}_1$, while $\boldsymbol{f}_l$ is added to $\boldsymbol{F}_2$. The amount of these constraints is also depending on the mesh resolution, since each vertex has usually between three to eight neighbors.

Position Constraints

Skin can be stretched to a certain amount, but is elastic enough to return immediately to its original state as

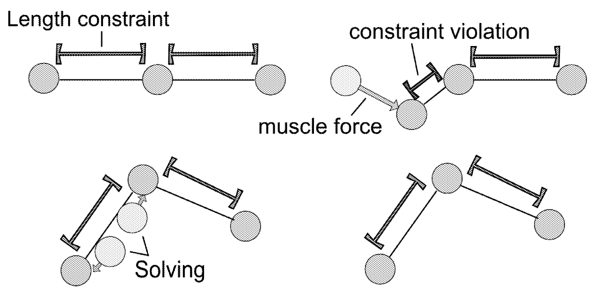

Figure 1: Length Constraint Violation Solution

soon as the force is gone. In other words, every vertex of the mesh should stay in its rest position, until it is deformed due to muscle movement. We thus need constraints that develop a force pulling the vertex back to its original position as soon as the vertex leaves it. This simulates the skin elasticity sufficiently enough for our purposes. Therefore we define position constraints, which are actually more similar to length constraints than to ordinary point constraints. However, while length constraints are implemented between two vertices with a calculated rest length, our position constraints use the initialization position $\boldsymbol{V}_{init}$ and the current position $\boldsymbol{V}_{curr}$ of a single vertex. The desired rest length always has the value zero, i.e., the vertex should return to its initial position. Therefore, as soon as a vertex moves, a force $\boldsymbol{f}_p$ is developed that pulls the vertex back to its original position. This is actually quite similar to length constraints, with the exceptions that the original position cannot change its position, and therefore the whole force is used on the moving vertex. As a result, the force $\boldsymbol{f}_p$ is simply given by the displacement of the vertex (Figure 2):

$$\boldsymbol{f}_p = \alpha \left(\boldsymbol{V}_{init} - \boldsymbol{V}_{curr}\right).$$

Here, $\alpha \in [0, 1)$ is a factor defining the elasticity of the skin. This force is then added to the influenced vertex net force. The amount of these constraints that have to be integrated into the simulation depend on the resolution of the mesh. For each vertex one position constraint is added.

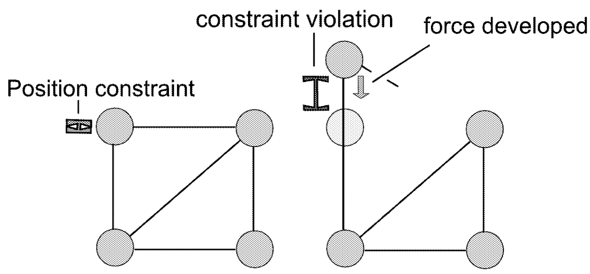

Figure 2: Position Constraint Violation Solution

Position and length constraints already simulate the visual properties of human skin quite accurately, integrating springs in the simulation would only make it more computation expensive. Structural springs for example are used to keep a minimal distance between neighboring vertices. In our simulation, this behavior is approximated by the length constraints being responsible for keeping an exact distance between vertices, and which act as replacements for stiff structural springs, resulting in a desirable incompressible surface. Shear springs keep diagonal vertices apart, which is important to prevent the faces from deforming into flat diamonds. However, this would be only possible in case the mesh is hanging loosely and being under the influence of external forces. Since the human skin simulation used is not influenced by external forces at all, and position constraints keep the vertices at their places, the danger of deforming into flat diamonds is not given. This makes the use of shear springs unnecessary. Also, since the mesh for a human face is very rarely of even topology, bending springs would produce very different results, depending on the part of the model that currently deforms. Furthermore, to produce small wrinkles, a very low bending stiffness is needed, which can be roughly approximated by the value zero.

Muscle Constraints

One more class of constraints is still needed, which has to simulate forces generated through muscle contraction. The muscle constraints, which simulate the influence of muscle contraction on the skin surface, are the most important ones for the creation of facial expressions. They cannot be generated from the mesh model itself, but have to be implemented by the muscle simulation. These constraints need a target position $\boldsymbol{V}_{tar}$ for each vertex at position $\boldsymbol{V}_{curr}$, which is assigned by the muscle during run-time. The force for the muscle constraints allows the face to be animated by the muscle simulation and is calculated by

$$\boldsymbol{f}_m = \boldsymbol{V}_{tar} - \boldsymbol{V}_{curr}$$

and accordingly added to the vertex' net force. For this constraint it is important that, unlike position constraints, the target position is changed and reassigned depending on the muscles contraction during run-time of the simulation.

The final result is actually an efficient skin simulation, consisting of three types of constraints, which are used all over the face mesh and result into wrinkle generation during the deformation. These wrinkles are unfortunately depending on the mesh topology, but need no preparation or user interference at all.

THE MUSCLE MODEL

For the implementation of facial deformations due to muscle contraction we chose Waters' Vector Muscle Model (Waters 1987). Although this muscle simulation consists of only two types of muscles – the linear muscle and the sphincter muscle –, it is indeed very flexible. However, some modifications had to be done, which will be explained later.

The Linear Muscle

This muscle is used to approximate all the facial muscles that pull on a part of the skin surface, which is the majority of them. Linear muscles are described by one end that is attached to the bone, and another end embedded into the skin. While the end attached to the bone, in this paper called the *origin* of the muscle, remains static during contraction, the other end is actually pulled towards it. The contracting (moving) end is embedded into the skin and therefore influences a certain skin area, its *zone of influence*. During contraction the muscle's zone of influence is pulled towards the muscle's origin. This behavior simulates the isotonic contraction of a muscle sufficiently.

In Waters' model the origin of a linear muscle is defined through a single point, while the zone of influence is approximated by a circle. This muscle can therefore be described by three parameters. The first one is a point in space for the origin, the second parameter another point for the contracting end, and finally an angle which describes the width of the muscle, and at the same time the area for the zone of influence. From the two defined points the direction of the muscle can be calculated, which always runs from the origin to the contracting end. The size of the muscle depends on the one hand on the distance between the defined points, and on the other hand on the defined angle. If the muscle is visualized it would have the form of a sphere segment.

These are only the parameters we need to determine the position and the form of the muscle, however. To simulate its contraction behavior, additional parameters are needed. Important is the magnitude of the muscle, telling us the contraction strength at each point on the muscle. The contraction strength is not evenly distributed on the whole muscle but fades away towards the origin point. In other words, the magnitude is zero at the bone attachment, and gradually increases to its maximum at the zone of influence.

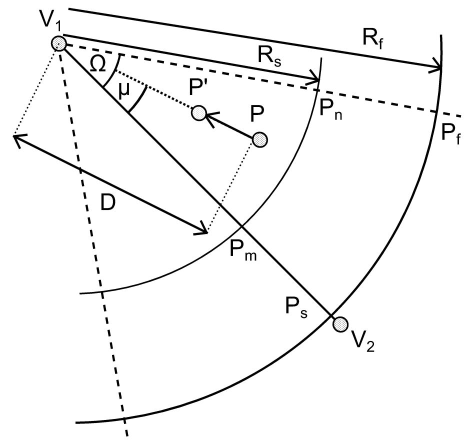

Figure 3: Waters Linear Muscle in a 2D Space

Figure 3 shows the linear muscle applied in a two-dimensional space, which is enough to understand the principles. It can easily be implemented in the same way in a 3D space. $\boldsymbol{V}_1$ defines the origin of the muscle, and $\boldsymbol{V}_2$ the center point of the influence zone. The whole muscle is defined by a circle segment, with the radius $\boldsymbol{V}_1 - \boldsymbol{V}_2$, and the angle μ. For the calculation of the magnitude, two points representing the distance from the origin, are defined. R_s represents the distance from the origin where the magnitude falloff starts, and R_f the distance the falloff ends. For every vertex that is inside the influence zone of a linear muscle, its new position can only be computed by calculating the angular and radiant displacement values for it. In the example shown in Figure 3, a new position $\boldsymbol{P}'$ is calculated for point $\boldsymbol{P}$ by the formula

$$\boldsymbol{P}' = \boldsymbol{P} + \cos(\alpha) \cdot K \cdot \boldsymbol{r} \cdot \frac{\boldsymbol{P} - \boldsymbol{V}_1}{||\boldsymbol{P} - \boldsymbol{V}_1||}.$$

K stands for the muscle spring constant, and $\boldsymbol{r}$ is the radial displacement value. The radial displacement simulates force dissipation in the inverse direction of the muscle and is approximated for nodes inside the triangle $\overline{\boldsymbol{V}_1\boldsymbol{P}_m\boldsymbol{P}_n}$ by

$$\boldsymbol{r} = \cos\left(\left(1 - \frac{\boldsymbol{d}}{R_s}\right) \cdot \left(\frac{\pi}{2}\right)\right).$$

where $\boldsymbol{d}$ stands for the distance from the point $\boldsymbol{P}$ to the origin $\boldsymbol{V}_1$. For vertices inside the trapezoid $\overline{\boldsymbol{P}_m\boldsymbol{P}_n\boldsymbol{P}_r\boldsymbol{P}_s}$ the radial displacement is calculated by

$$\boldsymbol{r} = \cos\left(\left(\boldsymbol{d} - \frac{R_s}{R_f - R_s}\right) \cdot \left(\frac{\pi}{2}\right)\right).$$

These calculations can be adopted into a 3 dimensional simulation as they are, the only difference is that the 2D vectors change into 3D ones.

The Sphincter Muscle

The second type of muscles Waters defined is the sphincter muscle. This muscle is completely different from the linear muscle in shape and behavior. It has a circular shape and instead of pulling on the skin surface, it pulls the skin towards the muscle center. These muscles cannot be found as often as linear muscles in the human face, and exist in fact only three times: around each of the eyes and around the mouth. However, they are nonetheless very important to simulate actions like the puckering of the lips or the pinching of the eye. To define this muscle, at least two parameters are needed: a point that defines the center of the muscle, which is also the origin to which the skin surface is pulled towards, and a radius. This gives us a perfect sphere. However, often it is more advantageous to use an ellipsoid instead of a sphere, to approximate the mouth and eye area more realistically, which means that this muscle needs two or three radii.

For the contraction behavior, a magnitude is needed that defines how strong the contraction influences the skin surface. The formula for the contracted position $\boldsymbol{P}'$ of the point $\boldsymbol{P}$ is

$$\boldsymbol{P}' = \boldsymbol{P} + K \cdot \boldsymbol{r} \cdot \frac{\boldsymbol{P} - \boldsymbol{V}_1}{||\boldsymbol{P} - \boldsymbol{V}_1||} \cdot S.$$

The Rotation Muscle

During implementation, some difficulties were encountered for simulating the opening of the mouth, and the opening of the eyelids. The opening of the mouth is a muscle contraction that triggers the rotation of the lower jaw around a joint positioned near the ear, and is therefore hard to simulate with the Waters muscle model. Another problem was that approximating the behavior of the upper eye lids with linear muscles provided unrealistic results, rather looking as if the lids would be pulled into the head, instead of opening. We found that for simulating an opening eye, it is more realistic to rotate a lid around the center of a sphere. Thus, this rotation is defined using a quarter of a sphere. Therefore we added a new type of muscle to Waters' muscle model, the *rotation muscle*.

These muscles rotate the influenced vertices around a predefined joint. Though they represent rotations, we visualize their zone of influence using a cuboid with side lengths L_x, L_y and L_z (Figure 4). Upon contraction, they develop a rotational force that is equivalent to the degree of the rotation. The strength of the rotation on the individual vertex also depends on its distance to the joint position. If the vertex is further away, it is influenced stronger by the rotation. Two types of rotation muscles were implemented, though their main difference is only the shape, with which they define their area of influence.

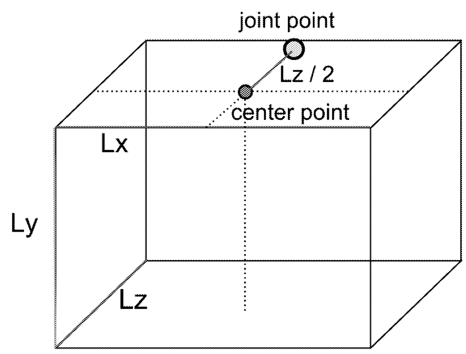

Figure 4: Example of a Rotation Muscle visualized as a Cuboid

Assuming that the provided face model has its eyes closed in the neutral position, it is easier to capture all important vertices for the upper lid with an ellipsoid. The rotation joint is positioned at the back side of the ellipsoid. The position of the joint $\boldsymbol{P}_{joint}$ is derived from the center point $\boldsymbol{P}_{center}$ minus the radius for the z-axis R_z. The value of the contraction strength has to be between 0 and 90 degrees for this muscle, since a further rotation would look unrealistically, and is also not visible from the outside. During the contraction the rotation axis of the joint, which is the x-axis in this case, is calculated and stored as a rotation matrix $\boldsymbol{m}_{rot}$, allowing to calculate the contracted vertex positions $\boldsymbol{V}'_{pos}$ as

$$\boldsymbol{V}'_{pos} = \boldsymbol{P}_{joint} + (\boldsymbol{V}_{pos} - \boldsymbol{P}_{joint}) \cdot \boldsymbol{m}_{rot}.$$

This newly calculated position is then stored into the relevant muscle constraints as the target position. For the simulation of the jaw muscle, the area in which all involved vertices are positioned can be approximated by a cube. The rotation joint is at the back side of this cube. The upper face of the cube is situated at the same height as the lower lip, since upon jaw rotation only the lower lip moves. For the calculation of the joint point, half the length value L_z of the z-axis is subtracted from the center point $\boldsymbol{P}_{center}$ resulting into the joint point $\boldsymbol{P}_{joint}$

$$\boldsymbol{P}_{joint} = \boldsymbol{P}_{center} - (0, 0, L_z/2)^T.$$

The contraction is calculated the same way as the one for the lid muscle is, with a small modification because upon opening the mouth, the lower lip tended to stay too straight. Preferable is that the middle part of the lip opens slightly further, resulting into a light curve. Therefore for each vertex its relative position to the joint $\boldsymbol{P}_{joint}$ is calculated, and depending on the similarities on the x- and y-axis, a slightly additional force calculated by

$$\begin{aligned} V_{pos,y} &= N \cdot \sqrt{|L_x - (V_{pos,x} - P_{joint,x})|} \\ &\quad \cdot \sqrt{|L_y - (V_{pos,y} - P_{joint,y})|}. \end{aligned}$$

where L stands for the predefined length values of the muscle and N stands for a necessary strength multiplier.

IMPLEMENTATION OVERVIEW

The implemented application is built from a set of connected modules (Figure 5). There is the mesh module, which is responsible for the visible part of the simulation. Another module is the skin simulation, which purpose is the creation of wrinkles, and the muscle simulation, which animates the face model.

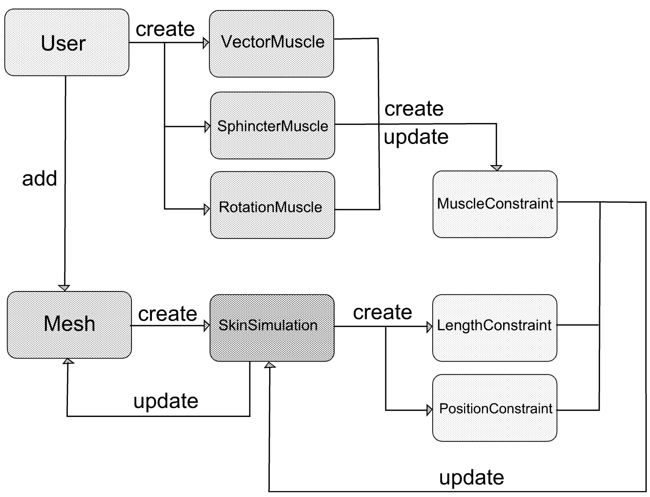

Figure 5: Application Overview

When starting the system, a model has to be loaded, which has to be provided in the Ogre .mesh format,. Since this application was created to simulate human facial expressions realistically, a scanned human face model is ideal, but any model should do. The only property the face model needs to fulfill, is having a minimum resolution, which is important for the wrinkle generation. If the model is too coarse, the muscle simulation still works, however without the wrinkles it is not resulting into the desired soft looking facial expressions. From this added face model, the information needed to create the skin simulation is extracted automatically, and the simulation is then generated. For each of the vertices in the model, the information about its position and its neighboring vertices are gathered, to create the position and length constraints. How many of these constraints are added into the simulation depends on the mesh resolution.

The next step is to add all the necessary muscles to the simulation. Position, size and orientation of all the linear, sphincter and rotation muscles have to be defined and fit to the face model by hand. Depending on the complexity of the desired muscle simulation, this can be a very time consuming process. Fortunately, all the important muscles are already implemented in the application and can be easily modified with an integrated editor. From these created muscles, the muscle constraints are generated automatically and added to the skin simulation. The amount of the muscle constraints depends on the number and size of the integrated muscles, since for every vertex influenced by a muscle, one muscle constraint has to be added.

The skin simulation then works on all previously created constraints. The position constraints to keep the vertices at their original position, the length constraints allowing the creation of wrinkles dynamically, and the muscle constraints that allow the muscle to deform the simulation upon contraction, and to form the facial expressions. If the simulation is started, the following steps happen upon changing the contraction value of one of the muscles.

1. Begin iteration
2. Clear all forces
3. Calculate muscle, position and length forces
4. Add them to vertex force
5. Calculate new vertex positions
6. Continue iteration n times
7. Update mesh model.

As can be seen, the simulation involves an iterative process which will be examined in more detail later. After these steps are done, the deformation is visible on the face model, and all the constraints are satisfied.

The Face Expression Tool Box

We created a tool for experimenting, testing and editing muscles (see `http://www.ani.univie.ac.at/~hlavacs`), using Ogre3d (`http://www.ogre3d.org/`) and QuickGUI (`http://www.quickgui.de/`) for the user interface. Figure 6 shows the toolbox, and the head model we used for testing (`http://bensimonds.com/tag/head/`).However, the tool accepts as input any head defined by a .mesh file and a muscle definition file, which is a simple .txt file. It allows the individual contraction of each of the implemented muscles through a set of sliders which can be combined to create different facial expressions (Figures 6 and 7). Another set of sliders controls a set of predefined emotions which were based upon (Ekman 2002) and were implemented as an example of what results this tool can achieve. The tool also provides a real-time editor, which allows the user to fit the muscles to the model and save the changes. The resulting head can then be used in any Ogre3d based game. Additionally, the function to create fitting phonemes for any input text is provided, which basically is our first step towards the creation of a Text-to-Speech system with fitting lip synchronization.

Figure 6: Simulation with Action Unit 4 activated (Brow Lowerer)

Figure 7: Simulation with Action Unit 9 (Nose Wrinkler) and 20 (Lip Corner Puller) activated

TESTS AND PERFORMANCE

In the following we present results from some performance tests. The simulation was developed and tested on a laptop computer, using an Intel Duo Core processor with 2.52 GHz each, 4 GB Ram and a ATI Mobility Radeon HD 4600 Series graphics card. The performance when running on a PC with modern GPU is therefore to be expected much better. The two most important parameters for the visual performance of the simulation are the resolution of the used face model and the number of iterations. In our experiments we thus concentrated on the influence of these two parameters.

Influence of the Number of Iterations

To test the minimum required number of iterations for the length and position constraints, that would still provide acceptable results, tests were done using the previously mentioned standard head. Since the length and position constraints act as counter forces to the forces of the muscle constraints, it is important to define a high enough iteration number that would allow the surface to create a realistic expression.

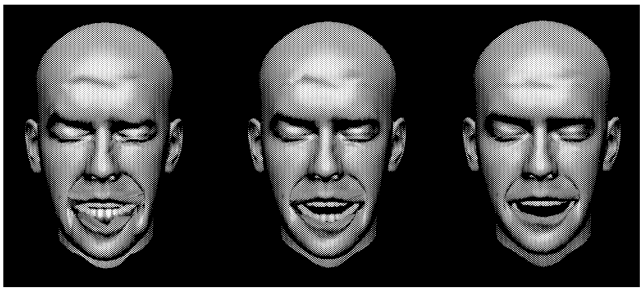

Figure 8: 1 Iteration (Left), 2 Iterations (Middle), 3 Iterations (Right)

As can be seen in Figure 8, the results with a single iteration are not really satisfying. The forehead to start with, is supposed to wrinkle slightly, but instead only one hard wrinkle can be seen which looks rather like two separate scars. It is not perceived as very realistic because of the thickness of the wrinkle. The region around the mouth is the worst, because of its strong deformation. With two iterations per frame the result is perceivably better. However the overall look is still not as realistic as desired, and the generated wrinkles not soft enough. Three iterations are in our opinion therefore the minimum amount of iterations for a satisfying result.

Influence of Model Resolution

The second series of tests used different resolution head models to observe if lower resolution models would still provide soft looking expressions. To allow the comparison of the mesh models, the lower resolution ones were derived from the standard head, by using the poly reducer script that Blender 3D (`http://www.blender.org/`) provides.

For the tests the following three head models were used. The first one is the standard model, consisting of 5596 vertices and 10974 triangles. The second one is a copy of the first one that was reduced by 25 percent and consisted of 4199 vertices and 8207 triangles. The third one is reduced by 50 percent and consisted of 2808 vertices and 5472 triangles. For this comparison one of the pre-

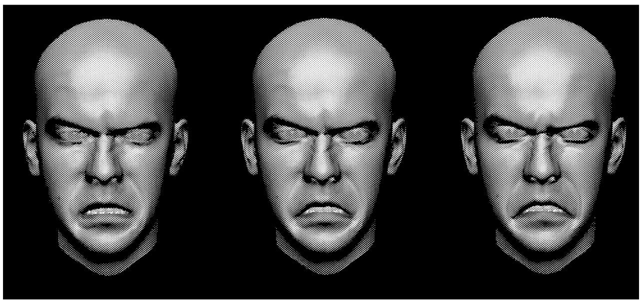

Figure 9: Low Resolution (Left), Medium Resolution (Middle), High Resolution (Right)

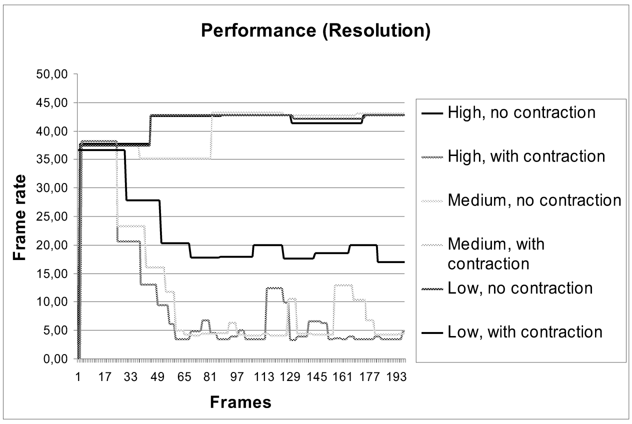

Figure 10: Influence of Different Resolution Head Models on the Frame-Rate

defined facial expressions was used again, but this time it was the expression anger.
Shown in Figure 9, we can see that there are only slight differences between the different resolution models.

Frame Rate

A third series of tests was conducted for the frame rate that the application can achieve. To test the influence of the models resolution on the frame-rate, the same head models were used as described in Section 8.1. The frame-rate was captured without and with simulated muscle contraction. There is nearly no difference in in the frame-rate while no muscle contraction occurs, which can be seen in Figure 10. During contraction however, it is clearly visible that the low resolution model achieves a higher frame rate, due to the fewer constraints it possesses. The medium and high resolution models on the other hand achieve nearly the same result.

CONCLUSION

In this paper we present a method to automatically create soft looking realistic facial expressions from a polygon model and to provide a simple way to animate it. To achieve this, two problems were solved. First, a method was developed allowing the creation of wrinkles due to skin compression, relying only on information from the provided mesh model. Our solution is inspired by soft-body simulations to produce realistic skin. Through the creation of the wrinkles, the facial expression gets an overall wrinkly look, that producing the impression of soft skin. The second problem was to combine the skin simulation with a simple way to animate the face. We use Waters' vector muscle and extend it by a new muscle type.
With the combination of these two techniques, a tool was developed that allows the deformation of a face model with a set of sliders, and also easy adjustments of the provided muscle rig with a real time editor. The resulting heads can be used in any Ogre3d based game. Further improvements will focus on validating our approach on numerous head models, testing visual results on head models optimized for our tool box, and moving the skin simulation to the GPU.

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Eigenplaces for Segmenting Exhibition Space

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KEYWORDS

Visitor Circulation; Eigendecomposition; Museum Environment; Virtual Worlds;

ABSTRACT

In this paper, we aim at segmenting exhibition space inherent in circulation behavior of visitors in a museum-like environment such as a virtual gallery in Second Life or even a real museum at MIT. The segmentation of exhibition space can be achieved with eigenplaces, which is the eigendecomposition of the covariance matrix of the characteristic vectors obtained from visitor dwell time for each time slot. Eigenplaces take advantage of the capability of showing the (first, second, third, and forth) most important circulation behavior of visitors as well as examining the degree of dominance of their corresponding. We, then, adopted the theory of graph spectra for partitioning the exhibit spaces. In experiments, we applied the segmentation approach to the data set obtained from the virtual and real museums: 36 avatars at the Ritsumeikan gallery in Second Life and 45 real visitors at the MIT museum in order to discovering groups of strongly coherent exhibits.

INTRODUCTION

In museums and galleries, the arrangement of their collections is one of the most important key factors that affect visitor impression and satisfaction. The curators, who are in charge of the collections, decide how the objects will be displayed and arranged. They present the collections in an exhibit based on the coherence between objects so that the well-arranged exhibit can tell the story to the visitors. Consequently, the efficiency of the exhibit arrangement has depended upon curators' experience.

The visitor circulation through museums and galleries will determine what visitors will see, where they focus their attention, and, ultimately, what they learn and/or experience Hillier and Tzortzi [1976], Penn [2003]. The move of visitors is not dominated by exhibits but implicitly driven by the space syntax as investigated by Penn [2003]. However, the observation time that a visitors spends on a particular exhibit corresponds to the visitor attention and interest. A number of researches have been published on how people move through museums for many years but none of them addressed the exhibit arrangement correlating to the observation time of visitors.

Related to location-based games, people plays the games related to their location via their GPS-based device Yiannoutsou et al. [2009], Dini et al. [2007]. Such games have a purpose to improve museum visits and entertain visitors especially school kids. The visitor records during their museum trip are also useful for enhancing the the functionalities of exhibitions including collecting, organizing, displaying, etc. On the other words, the byproduct of these games is an implicit indicator reflecting to the engagement and enjoyment of visitors.

In this paper, we introduce how to apply eigenplaces to a problem of exhibit arrangement. Eigenplaces are derived from the covariance matrix of visitor circulation. We can partition off the exhibit space by grouping together similar objects in the same partition. The objects in the exhibit judged as the same or different groups are determined by the set of primary behaviors of the visitors. The primary behaviors are derived from the repeating and common movements of visitors in the same space. For example, in a museum, the most popular objects where a number of visitors spend more time are a potential factor to construct the common behavior structures.

To validate our proposed approach, we tested the approach against the synthesized data of 36 visitors following the four characteristics of visitor styles as well as the real visitor data from a MIT museum.

PREVIOUS WORK

In our previous works in [Sookhanaphibarn and Thawonmas, 2010], the analysis of the visitor circulation in museums and galleries has been investigated in a virtual world. Their findings can take advantage of classifying and identifying the visitor types for a guide system

Table 1: Eigenvalues and the corresponding eigenvectors for the MIT exhibition space

			Eigenplaces (exhibits)											
Score(%)	Eigenvalues		ξ_1	ξ_2	ξ_3	ξ_4	ξ_5	ξ_6	ξ_7	ξ_8	ξ_9	ξ_{10}	ξ_{11}	ξ_{12}
55.91	35.80	$\mathbf{v_1}$	-0.2	-0.3	-0.3	-0.2	-0.4	-0.3	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3
64.11	13.70	$\mathbf{v_2}$	-0.6	-0.4	0.0	-0.1	0.2	0.2	-0.1	0.2	0.4	0.3	0.0	-0.1
71.31	12.85	$\mathbf{v_3}$	0.2	-0.3	-0.4	-0.4	0.4	0.3	0.4	-0.2	-0.2	-0.2	0.0	0.2
78.08	12.45	$\mathbf{v_4}$	-0.2	0.1	0.3	0.2	0.4	0.2	0.3	-0.1	-0.2	-0.2	-0.4	-0.6
84.18	11.82	$\mathbf{v_5}$	0.1	-0.1	0.1	0.0	-0.2	-0.2	0.5	0.3	0.2	0.1	-0.7	0.3
88.52	9.97	$\mathbf{v_6}$	-0.3	-0.1	0.1	0.3	0.0	0.2	-0.1	-0.4	-0.5	0.3	-0.2	0.5

in museums and exhibitions. In terms of information visualization, that paper introduced the visualization for guiding curators to rotate the museum items and arrange the sequence of items. The approach indicated the interesting or skipped items associated with the visiting styles.

Eigendecomposition is adapted in many applications as follows: As Eagle and Pentland [Eagle and Pentland, 2009] concluded, the behavior structures become more apparent when the behavior is temporally, spatially, and socially contextualized, the visitor circulation in the museum space will be dominated by a set of primary structures. Sookhanaphibarn et al. [2010] introduced an eigenbehavior-based approach to determine the primary behaviors of players' movements by extracting their repeating structures. The repeating and common structures are identifiable movement directions of players in the same virtual space. Their proposed technique is employed in a Massively Multiplayer Online Game (MMOG). This is because the locations where players go to receive a service, such as, a quest or assistance, are a potential factor to construct the common behavior structures.

Eigenplaces are named by Calabrese et al. [2010] who applied eigendecomposition to extract the discriminant features from the time-series data (the aggregated network usage). They analyzed and categorized wireless access points based on common usage characteristics that reflect real-world, place-based behaviors. The resulting eigenplaces have implications for research across arrange of wireless technologies as well as potential applications in network planning, traffic an tourism management, and even marketing.

PURPOSED APPROACH

Eigenplaces

For segmenting a museum-like space, we represented the dwell time of visitors proximity to an exhibit as a vector and assembled the observations from all visitors into a single covariance matrix. Applying eigendecomposition to visitor circulation data yields many eigenvector and coefficient pairs; the latter's magnitude establishes the vectors's ranking according to their value in reconstituting the original data. Using the mean-square-error test, we can determine the number of pairs that is required to lower this error.

Theory of Graph Spectra

According to the Rayleigh-Ritz theorem Merris [1998], the components of the eigenvector with the second largest eigenvalue give a cluster weight assignment which is orthogonal to the cluster weight assignment (eigenvector) with the largest eigenvalue. Thus, we can use this orthogonality constraint to define disjoint clusters.

Any two exhibits (ξ_i, ξ_j) are in the same cluster by considering the components of an eigenplace that denotes the exhibit ξ_i in the associate cluster. Following the aforementioned definition, the function of testing whether two exhibits are in the same cluster, $\Psi(\xi_i, \xi_j)$, is written below where the considering set of eigenplaces is denoted by V'.

$$\Psi(\xi_i, \xi_j) = \begin{cases} 1 & ;\forall_{k \in V'}(sign(v_{k\xi_i}) = sign(v_{k\xi_j})) \\ 0 & ;otherwise \end{cases} \tag{1}$$

Let us describe how to employ Equation (1) by example. Suppose that we have already obtained a set of eigenplaces of the visitor circulation at the MIT museum as shown in Table 1. Given $V' = \{\mathbf{v_1}, \mathbf{v_2}, \mathbf{v_3}\}$, we will have four resulting clusters as follows: [1,7,12],[2,3,4],[5,6,11], and [8,9,10].

Segmenting Exhibit Space Algorithm(SESA)

Given a set of visitor dwell time associated with various exhibits, our segmentation algorithm consists of the following steps:

1. Compute a visitor association with each exhibit by using the Logarithmic transformation of visitor dwell time.
2. Construct an association matrix representation, X,

where each row referred to as a summary of a visitor's association with various exhibits during a given time slot.

3. Perform Singular Value Decomposition (SVD) of the association matrix X.

$$X = U \cdot \Sigma \cdot V^T \quad (2)$$

4. Compute the significance score ($score$) that is correlated with the percentage of power in the original matrix X captured in the rank-k reconstruction by using the equation below:

$$\text{Score}(\%) = 100 \times \frac{\sum_{i=1}^{k} \sigma_i^2}{\sum_{i=1}^{Rank(X)} \sigma_i^2} \quad (3)$$

5. Indicate a set of primary Eigenplaces $\mathbf{v}_i$ with a desired significance score.

6. Partition the exhibits with the set of primary eigenplaces.

Note that the SESA algorithm uses the natural Log transformation of the visitor dwell time because there is evidence of substantial skew in the raw data as shown in Fig. 1 (a) and Fig. 2 (a) . After applying the data transformation, the logarithm of the dwell time is called the visitor association and its histogram is shown in Fig. 1 (b) and Fig. 2 (b).

For Step 2, the association matrix is $\mathbf{X} = \{x_{ij}\}$ where an entry represents the dwell time of i^{th} visitor stopping at the j^{th}object. In other words, each column vector corresponds to the popularity for an object across time as well as each row vector corresponding to an association vector for a time slot.

EXPERIMENTS ON TWO USE CASES

For validating the effectiveness of the SESA, we use two data sets:

1. The data set obtained from [Sookhanaphibarn and Thawonmas, 2010] and based on the four animal metaphors.

2. The data set obtained by Sparacino as addressed in [Sparacino, 2001] for developing "The Museum Wearable project."

We describe the data set and its representation following the obtained findings with implications.

Ritsumeikan Digital Archiving Pavilion (RDAP) in Second Life

We synthesized the visitor trajectories based on the metaphor of four animals – Ant, Fish, Grasshopper, and

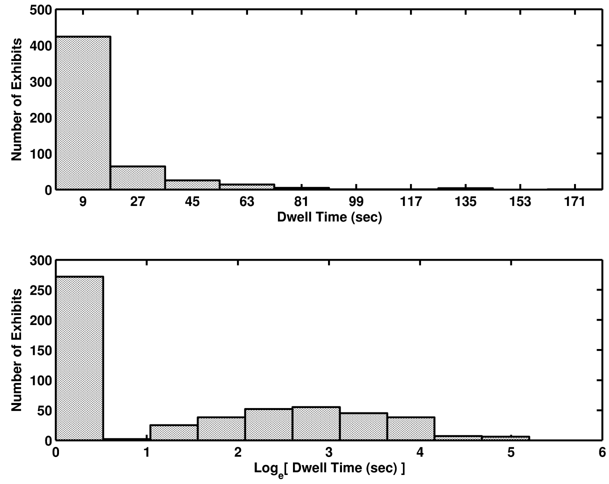

Figure 1: Histogram of visitor dwell time at a set of exhibits in the MIT museum.

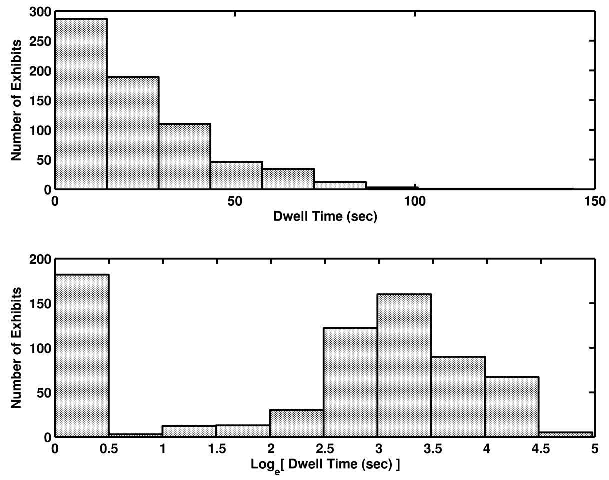

Figure 2: Histogram of visitor dwell time at a set of exhibits in the virtual Ritsuemikan gallery (RDAP).

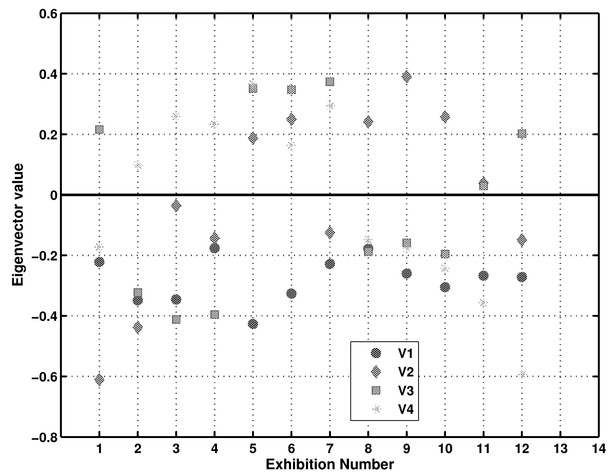

Figure 3: Eigenplaces of the exhibit space in the MIT museum of 12 exhibits where the four symbols (dot, diamond, square shape and asterisk) are used to represent $\mathbf{v_1}$, $\mathbf{v_2}$, $\mathbf{v_3}$, and $\mathbf{v_4}$.

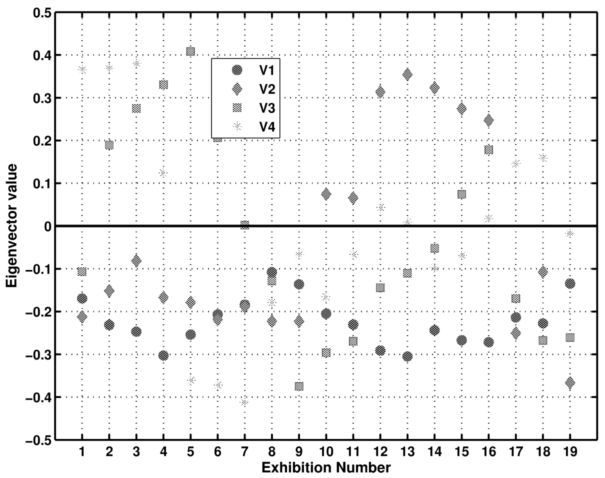

Figure 4: Eigenplaces of the exhibit space in the RDAP of 19 exhibits where the four symbols (dot, diamond, square shape and asterisk) are used to represent $\mathbf{v_1}$, $\mathbf{v_2}$, $\mathbf{v_3}$, and $\mathbf{v_4}$.

Butterfly visiting styles– as defined in [Sookhanaphibarn and Thawonmas, 2010]. These styles are as follows:

1. The ant visitors spend quite a long time to observe all exhibits and walk close to exhibits, but avoid empty spaces.
2. The fish visitors prefer to move to and stop over at empty spaces, but avoid areas near exhibits.
3. The grasshopper visitors spend a long time to see selected exhibits, but ignore the rest of exhibits.
4. The butterfly visitors observe almost all exhibits, but spend varied times to observe each exhibit.

The total number of synthesized trajectories is 36 where each visiting style has nine trajectories in the 3D virtual museum, named RDAP. RDAP, owned by the Global Center of Excellent in Digital Humanities Center for Japanese Arts and Cultures, of Ritsumeikan University, was created in Second Life. An objective of RDAP is to disseminate Japanese costumes, Kimonos, preserved them in a digital achieving system.

The MIT museum

We applied our approach to the visitor tracking information from 45 visitors. The visitor information is raw data, that is the number of seconds that visitors stayed in front of the corresponding objects. All these objects were visited in a linear sequence, that is one after the next, with no repetitions or change of path. The total number of objects is 12.

Results and Their Implications

We found that the segmentation of the exhibit space of MIT and RDAP can be achieved with four eigenplaces when the significance score was initially set to 78.08% and 93.48%, respectively. Four eigenplaces of the associated matrix of the MIT and RDAP exhibitions are shown in Figures 3 and 4, respectively. Basically, the first eigenplace cannot be used for partition because its components are all negative (even or all positive). When increasing the size of set V', we can obtain more number of cluster where the size of clusters will be smaller. The resulting segmentation of exhibit space according to both MIT and RDAP is shown in Figures 5 and 6, respectively.

For the MIT exhibition space, the following implications will be beneficial for the designers and curators. There are some groups of exhibits [1,12], [2,4], [8,9,10] with the strong relevance as shown by their scores of greater than 84.18%. In some situations such as the re-arrangement of exhibits, the designers should not disperse groups [2,4] or [8,9,10], but replace a group of them with another. The resulting segmentation also reveals that the first and last exhibits as analogous to the introduction and conclusion parts because the group [1,12] has the strong relevance.

Since we used the synthesized data set of visitors in the RDAP exhibition space, the clusters would be rather related to the four visiting styles (ant, fish, grasshopper, and butterfly). To understand the implications, we must interpret the result based on the visiting styles as well as the gallery layout and the segmenting space. They are as shown in Figures 7. The findings are summarized below.

1. By $V' = \{\mathbf{v_1}, \mathbf{v_2}\}$, two clusters [1-9,17-19] and [10-16] correspond to the common visited items and the rarely visited items, respectively. This results from the butterfly visitors who likely skip only a few.
2. By $V' = \{\mathbf{v_1}, \mathbf{v_2}, \mathbf{v_3}\}$, two interesting clusters are [1,8-9,17-19] and [15-16].
   (a) The former is fragmented from the common visited items because they are arranged at the entrance of hallway and the end. This group of [1,8-9,17-19] has received more attention than group of [2-7]. Although the fish visitors preferred to observe the atmosphere, they often stopped near the entrance of hallway and the end. This is a reason of segmenting [1,8-9,17-19] into [1,8-9,17-19] and [2-7].
   (b) The latter is fragmented from the rarely visited items because they are placed near T-junction that a small number of visitors would stop at them. If they stopped at 15, they would be stop at 16 but not further continue 13, 14. This might causes from the butterfly and grasshopper visitors.

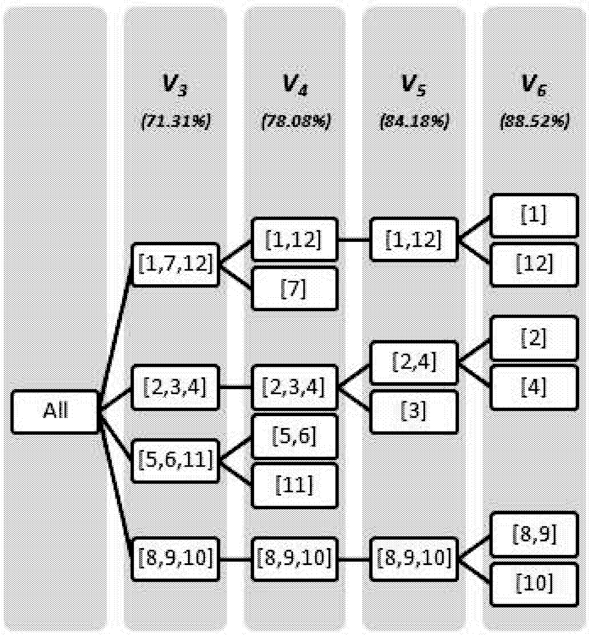

Figure 5: Cluster tree of exhibits in the MIT.

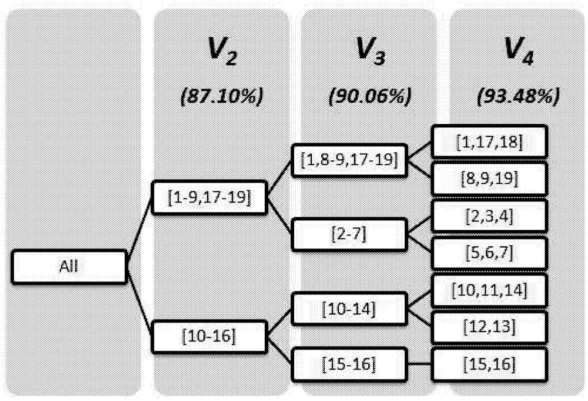

Figure 6: Cluster tree of exhibits in the RDAP.

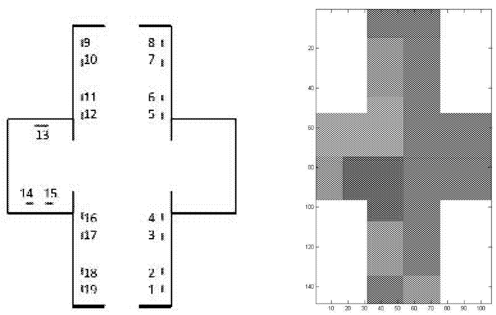

Figure 7: Resulting segmentation of RDAP: (a) Gallery layout of exhibits in the RDAP and (b)Segmentation of the exhibit space by using $V' = \{\mathbf{v_1}, \mathbf{v_2}, \mathbf{v_3}, \mathbf{v_4}\}$ in the RDAP museum of 19 exhibits where areas with the same color belong to the same cluster .

CONCLUSIONS

This paper introduces how to use eigenplaces with theory of graph spectra as potentially valuable applications for designing exhibition space and arranging exhibit items. The dwell time during their trip in exhibition is used for identifying a degree of visitor attention and exhibit interesting. To validate our approach, two use cases shows that our approach is practical for a real application in both real and virtual worlds.

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GAMER ANALYSIS AND GAME MANAGEMENT

A GAME ON PROFILING LEARNING STYLES

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KEYWORDS
Education Game; Learning Styles

ABSTRACT

Learning Styles refer to the way one learns, specifically, how one begins to perceive, process, and retain new information. Recognizing students' preferred learning styles can be advantageous. Teachers can leverage on this knowledge to provide more effective teaching for their students. Similarly, students aware of their preferred learning styles are able to improve their learning achievements. We propose profiling students' learning styles through computer games. Computer games provide interesting capabilities (e.g., immediate feedback, adaptive progression) to allow for the reconstruction of learning environments in an interactive stimulating environment. In this paper, we describe an educational game that we have developed for the purpose of profiling players' learning styles based on the Felder-Silverman learning styles model. The game was tested to determine how motivated students were playing the game. Results of the test session are shared in this paper.

INTRODUCTION

To date, much research is conducted on learning styles. While learning styles still attract controversy in terms of their existence, use and benefit (Coffield et al. 2003, 2004; Pheiffer et al. 2003; Reynolds 1997), much research is still conducted to demonstrate their existence, use and benefit (Becker et al. 2007; Dunn and Dunn 1999; Dunn and Griggs 2000; Felder and Silverman 1988).

One of the schools of thought in the literature and practice advocates that an increase in instructional efficiency is associated with matching teachers' teaching styles with students' learning styles. The premise of this matching approach is that students have preferred learning styles and that they learn easier if they learn through their preferred learning styles (Dunn and Griggs 2000; Felder and Silverman 1988). As teachers have their own teaching styles (Prosser and Trigwell 1999), in teaching a group of students, some of these students' learning styles will be met while others will not. The central motivation of this approach is that the closer the match between teachers' preferred teaching styles and students' preferred learning styles, the higher the level of achievement in teachers' teaching efficiency and students' learning. As such, recognizing students' preferred learning styles is advantageous.

Computer game playing has evolved to a point where it is no longer just a hobby but almost a daily need for some. For the year 2000, the computer and video gaming industry was a $17.7 billion global industry (Lange 2002). According to a report released by PricewaterhouseCoopers (2008), the total revenue of the games industry will reach US$68.3 billion by 2012.

Besides the popularity of this medium, computer games provide interesting capabilities (e.g., immediate feedback, adaptive progression) to reconstruct learning environments. In terms of learning styles, we can thus reconstruct the learning environment around specific styles in a multi-modal Interactive and Digital Media (IDM) environment. Computer game playing may be effective not just because of its fun factor, but because it allows players to be immersed in the game while empowering them to frequently make choices and uncover information in order to progress in the game. As such, computer games provide a rich platform to facilitate the profiling of learning styles.

RESEARCH QUESTION

The literature provides a range of working models on learning styles (e.g., Kolb 1984). In all the different models, profiling is usually done through the completion of a static list of questions. The downside of using this mode to determine one's learning styles profile is that an assumption is made on the questionnaire-takers' part - that he understands the questions and selects the best possible answer to the questions. Questionnaire fatigue can also increase inaccuracy to questionnaire data. When it comes to the profiling of young students, such an exercise can be especially daunting for these students.

To address this issue, we propose using computer games to profile a player's preferred learning styles. Based on a player's response and the choices he makes during game-play, profiling will be carried out. For our research, the Felder-Silverman learning styles model (FSLSM) is adopted. The FSLSM is used extensively (Felder and Spurlin 2005). It describes a learner's preferred learning style more explicitly and makes it more suited for implementation in learning-based technologies (cited in Graf et al. 2007).

The four bipolar dimensions of the FSLSM are active (doing) versus reflective (thinking); sensing (facts, processes) versus intuitive (concepts, relationships); visual (seeing, picturing) versus verbal (hearing, reading, saying); and sequential (step-wise) versus global (leaps, random) (Felder and Silverman 1988).

APPROACH – A PROPOSED PROFILING GAME

For our research, we have thus far developed a simple puzzle game. In this game, the player is expected to fulfill shirt orders within a given time limit. For each shirt order, players are required to "tailor" the shirt by following certain required designs. An important component of the designs includes a print which involves matching words/phrases from two lists provided by teachers - the matching pairs provide a means for teachers to reinforce students' understanding of teaching content. A shirt order is complete only when a correct match is made. Ratings of "Perfect", "Good", "Fair" and "Poor" will be given after each shirt order based on the number of attempts before a correct matching is achieved, as well as how closely the final shirt looks when compared to the desired shirt order.

Profiling for the different FSLSM dimensions are carried out as follows:

- Visual vs. Verbal

  Visual learners prefer to learn information in pictures, graphs or maps, while verbal learners prefer to see written or verbal information. In the game, players can choose the mode in which shirt orders are presented. They can choose between pictorial or textual orders. Refer to Figures 1 and 2.

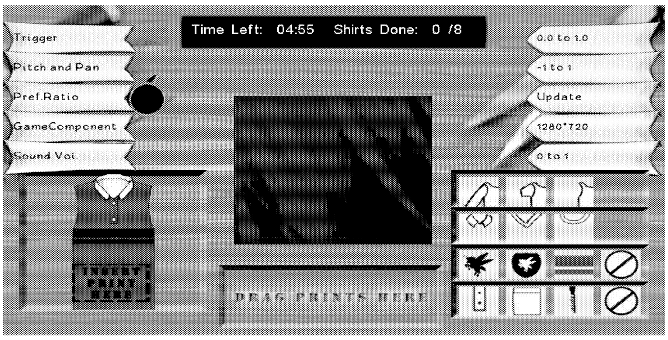

Figure 1: Orders Displayed in Visual Mode

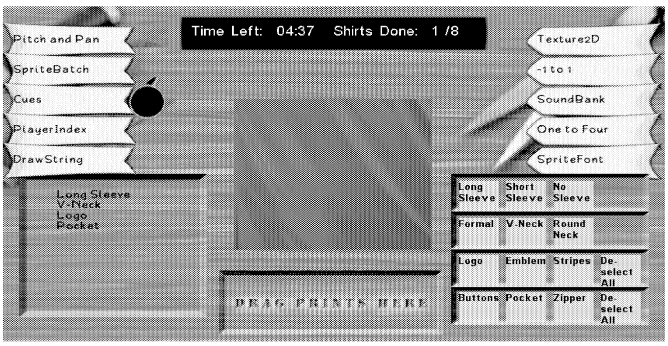

Figure 2: Orders Displayed in Verbal Mode

- Active vs. Reflective

  Active learners understand information better after trying things out, while reflective learners understand better after thinking things through. In the game, players have a choice of either selecting a practice mode to try out the game, or watch a tutorial in video mode to find out how to play the game.

- Sensing vs. Intuitive

  Sensors are learners who would rather be considered practical, while intuitors are learners who would rather be considered creative. In the game, once the required order is completed, players are rewarded with a bonus round where they can help to design either a functional or creative shirt.

- Sequential vs. Global

  Sequential learners prefer materials to be presented step-by-step while global learners prefer to get an overview. In the designing of their own shirt in the bonus round, players get a choice to either design the shirt based on a step-by-step guide, or after an overview showing how to proceed with the design.

PLAYERS' MOTIVATION

When designing a game to profile learning styles, certain decisions will need to be made for the purpose of profiling which might jeopardize the "fun" factor of the game. To attain a certain level of playability, at a minimum, we need to ensure that the game will have the following characteristics: challenge, fantasy, curiosity, and control (Malone 1980; Malone and Lepper 1987) which are identified as essential ingredients of good games. These characteristics are elaborated as follows:

- Challenge – provide clear and fixed objectives that are relevant to the player;
- Fantasy – provide imaginary situations that appeal to the emotions and cognitive process of the player;
- Curiosity – stimulate sensory and cognitive inquisitiveness in the player; and
- Control – provide the player with a sense of self-determination in the game play.

We attempted to include some of these characteristics in the game but, because of how subjective these are, we could only know for certain if they were met by conducting test sessions.

RESULTS OF PLAYTEST

To determine if the game developed contained the essential ingredients of good games (Malone 1980; Malone and

Lepper 1987), a preliminary test was conducted where the game was rolled out to 17 students of which 15 were males and 2 were females. With the exception of three students who are in the 20-23 age group, the rest of the students are in the 16-19 age group. These students are pursuing their tertiary studies in game development, and are part of a game programming class using Microsoft's XNA Game Studio (XNA game programming). Table 1 shows the average number of hours these students spend playing computer games in a week.

Table 1: Times Spent Playing Computer Games in A Week

Number of hours spent playing computer games in a week	Number of students
0 - 1	2
2 – 6	3
7 – 14	6
More than 14	6

In the game, students were required to match phrases/words from two lists on key concepts and knowledge covered earlier in their semester, related to XNA game programming.

To gather the students' general reaction to our game, we asked them to rate the game. Majority indicated that the game was fair or better with 18% of the students giving the game an excellent rating. However, we also noted that 18% of the students indicated that this was the worst game they have ever played. Refer to Figure 3 for students' rating of the game.

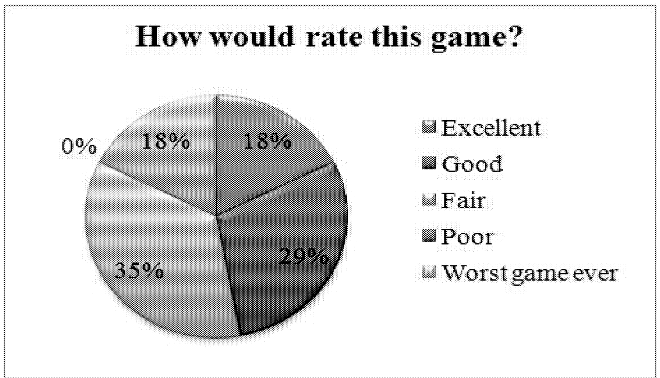

Figure 3: Students' Rating of Game

To determine the challenge factor of the game, we asked students whether they were motivated to move on to the next task after completing the previous task. 65% of the students indicated they were quite motivated with 6% of the students indicating they were very motivated.

With regard to the curiosity factor, we asked students what their reaction was after five minutes into the game. The majority of the students indicated that they remained playing the game. Only 24% indicated that they wanted to walk away.

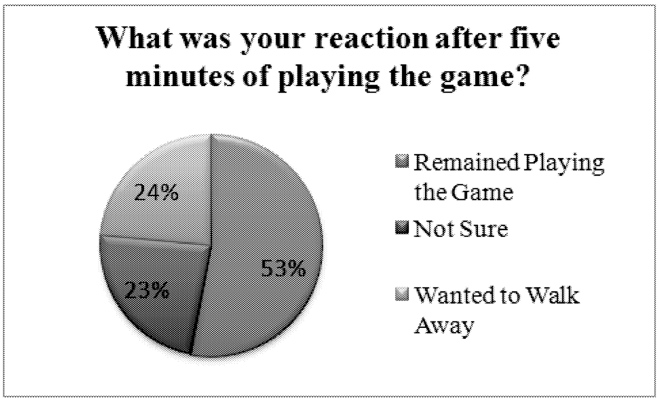

Figure 4: Students' Response After Five Minutes into the Game

When asked whether it was clear what they could or could not do during the game to ascertain the amount of control students had, 71% of the students indicated quite clear or very clear. Refer to Figure 5.

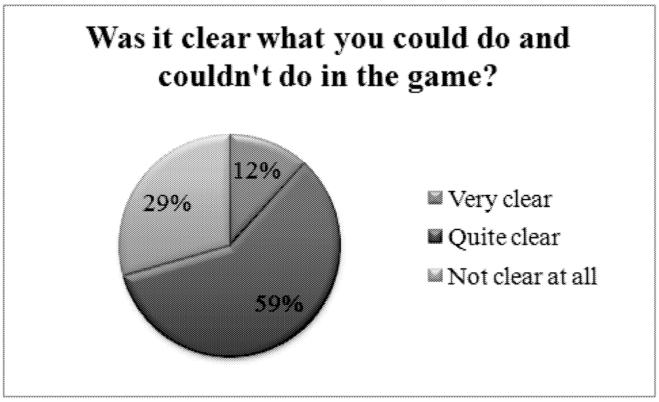

Figure 5: Students' Response on Control

As the game was designed to check students' understanding about XNA game programming, we asked students what was gained through the playing of the game. "Adequate information about XNA game programming" was the top choice followed by "Game playing skills" and "Thinking and memory skills".

The fantasy factor was not explored in the playtest as the element of fantasy emulated in the game is termed as extrinsic fantasy (Malone 1980) since the fantasy depends on the skill learned in the game but not vice-versa. What this means is that to play the game, the extrinsic fantasy depends only on whether the skill (i.e., choosing the correct matches of XNA game programming related concepts from the two lists) is correctly used but knowledge of XNA game programming is not intimately related to the game play itself. The speed in answering questions also affects extrinsic fantasy. As such, we did not measure the level of "Fantasy" achieved in the game.

Players' responses suggest that majority of the students agree that important ingredients (i.e., challenge, curiosity and control) of good games are present in the proposed game.

CONCLUSION AND FUTURE RESEARCH

A major contribution of this research is to assess the feasibility of using educational games to profile learning styles. The success of this research can lead to more research on adaptive learning by leveraging on the knowledge of a player's learning styles. Adopted into teaching, further research can be conducted to explore customizing teaching to students' learning based on their learning preferences.

The current game on its own is insufficient in determining the learning styles profile of a player. Similar to learning styles profiling questionnaires, the profiling of learning styles through game play require sufficient instances of each profiling dimension of the FSLSM to be collected before proper profiling can be carried out. The next steps in the research will include the development of more profiling games so that experiments and analysis of using computer games to profile learning styles can be conducted. We will compare the profling results between questionnaire and games to ascertain the validity of using games for profiling learning styles.

ACKNOWLEDGEMENT

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USING MONTE-CARLO PLANNING FOR MICRO-MANAGEMENT IN STARCRAFT

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KEYWORDS

RTS games; StarCraft; Monte-Carlo Planning; Micro Management

ABSTRACT

This paper presents an application of Monte-Carlo planning for controlling units in a RTS game StarCraft. We developed an original simulator for applying Monte-Carlo Planning (MCPlan) to solve the problem of random and simultaneous moves in the RTS game. We also apply an $\varepsilon - greedy$ algorithm to model the opponent in a simulation for improving MCPlan's performance. Experimental results are provided at the end of this paper, which shows the potential of MCPlan in this domain.

I. INTRODUCTION

StarCraft is one of the most popular RTS game developed by Blizzard Entertainment. The extremely balanced gameplay and easy access to the game engine not only provides players with multiple options, but also enables it to be an ideal platform to test different AI approaches. So far, although some work has been done on building human-level AI for StarCraft, because of the real-time properties and largely unpredictable random, it is still a challenging game for AI research.

The main issue in this paper focuses on the micro management of StarCraft gameplay. Micro-management is a series of actions that issue commands to each unit of a certain group for maximizing their effectiveness during combat. Good micro management is a significant part of RTS game in which it can bring player advantages in the game, even change the results of a whole match.

There have been a number of previous works that have been done on both unit control issues and the application of MC simulation in RTS games. Unit control problems are usually handled by finite state machines, script or neural networks etc. For example, Weber and Michael used hand authoring ABL behaviors to handle micro-management task in StarCraft (Weber 2011). A Bayesian model is applied to StarCraft for unit control by Gabriel and Pierre (Synnaeve 2011). Monte-Carlo method in RTS games also can be found from previous work. Such as applying MCPlan for high-level planning (Chung 2005), or combining Monte-Carlo method with non-linear value function approximation (VFA) and text recognition technique as a solution for large sequential decision making problems (Branavan 2011). However, these works mainly focus on high-level planning and MC simulation can rarely be found in low-level AI modules such as micro management.

Since MC simulation has an advantage of selecting the best choice without relying on too much expert knowledge, this enables the AI to explore possibilities and perform creatively. Therefore, we try to build an expert AI for micro-management in StarCraft by applying MCPlan and test how it performs.

The contributions of this paper are as follows:

- Implementation of the MCPlan with expert knowledge for micro-management in StarCraft.
- Design of a simulator for complex commercial RTS game combat scenario and a general characterization.

II. METHODOLOGY

Monte Carlo Planning

MCPlan is a mechanism that is based on simulation and does a stochastic sample of possible choices. It determines the best statistical result after multiple roll-outs. It is an effective method to handle random and imperfect information problems with alternating moves, such as chess and poker. A great advantage of MCPlan is the reduction of expert knowledge required, instead of defining every detail through expert biases; MCPlan relies on an effective evaluation function.

Simulator Design

As one of the most important parts in MC Simulation, the simulator is a model that is used to simulate reality and aid in making predictions. In our case, the simulator is for creating possible game scenarios of the near future. However, unlike high-level strategy, for a micro-management simulator, it has to emulate real-game moves as much as possible as even a small detail could affect the game result greatly.

Generally speaking, three major works in our simulator are as follows:

A) *Character modeling:* Characters should be exactly the same as in real game, including character's hit-points, attack range, special skills etc.
B) *Map modeling:* Map modeling should consider of different terrains, characters' location, and unit overlapping problem.
C) *Enemy behaviour m*odeling: Rather than randomly move, we adopt ε -greedy algorithm to define enemies' movement in simulator. The evaluation function and plans for enemy heuristic are basically the same as MCPlan AI.

III.APPLICATION TO STARCRAFT

We apply our MCPlan algorithm to micro-management part of the game Starcraft by accessing the game engine through BWAPI.

Plan Definition

We try to avoid too complicated a plan in order to give MCPlan enough space for search. But expert bias is still needed. So we mix few complex plans with simple plans. In this way, we not only avoid too much expert knowledge, but also try to improve the effectiveness of plans.

Simulation roll-out

Each roll-out contains two plans: one is fixed and the other one is stochastic. The fixed one is the certain plan that is being chosen for simulation, so it is always be executed first. After that, the program will randomly pick another plan and continue the simulation process. After simulating both plans, the evaluation step begins.

Search Algorithm

Here's our algorithm for searching best plan, namely, UCB1 algorithm.

$$UCB1(i) = R_i + C\sqrt{\frac{\ln N}{N_i}} \qquad (1)$$

In the formula, i is index of each plan, R_i presents the reward that plan i obtained from the evaluation function. C is a predefined constant, N and N_i are the overall number of run times and number of times that plan i has been visited respectively.

The basic view of our MC simulation is as follows:

1) Loading predefined plans one by one to the simulator.
2) Simulate each plan (both fixed one and random one), evaluate the whole roll-out and reward the plan.
3) Choose the plan with the highest evaluation based on UCB1 function, then simulate and reward it again.
4) Repeat step 3.
5) Choose the plan with best average result for the AI player in a real game.

Evaluation function

An evaluation function is used for measuring the effectiveness of each plan in different situations. Our evaluation function is designed based on individual units and basically contains 4 aspects as seen below:

$$Q = \omega_1 HP + \omega_2 DM + \omega_3 SP + \omega_4 EG \qquad (2)$$

In this function, four elements are individual unit's hit-point, damage to enemy, move speed and remained energy respectively. And we manually set value for the four weights ω based on expert bias.

IV.EXPERIMENTS

We designed three experiments to test MCPlan AI's by comparing with other subjects. Each experiment is a different combat scenario of Terran against Zerg. Experiments ran on PCs with 3.20GHz CPU and 4G RAM.

Experimental Scenarios

We did all the experiments in a small map with all plain terrain and limited space (game map size 16×16). Two forces were placed in short distance but can't attack each other at the beginning of game in order to make sure all units get involved in combat as soon as possible.

The game techniques and skills that be used are : U-238 Shells, Stim packs for Terran Marine, healing for Terran Medic and Metabolic Boost for Zerg Zergling. For more detail of units and skills, we refer reader to blizzard official website.

Experiment 1: Four Terran Marines against six Zerg Zerglings.

Experiment 2: Three Terran Marines aginst 1 Zerg Lurker.

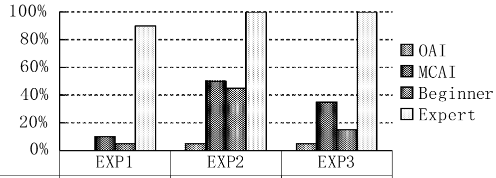
Experiment 3: Five Terran Marines and one Terran medic aginst six Zerg Zergling and 1 Zerg Lurker.

In order to highlight the effectiveness of micro management, unbalanced military forces were distributed to two sides. That is, Zerg force has advantages in all experiments and is always controlled by the original AI of StarCraft. We then applied different subjects to control the Terran force against the Zerg. They are the original AI of StarCraft, MCPlan AI, and various-level human players respectively. Moreover, the difficulty of the experiments are descending (E1>E2>E3), whereas the complexity of scenarios are ascending (E1<E2<E3).

We ran each experiment 20 times for each subject, and human players were allowed to get familiar with each experiment by 5 trials and then compared their performance by wins rate.

V. EXPERIMENT RESULTS

The experiment results are shown in Figure 1. The results in this figure show the win rates of different subjects. It shows that the original AI can hardly win a game in all experiments under disadvantage situation and even failed all games in experiment 1. The results also suggest that MCPlan AI has potential to overcome unbalanced number of units to defeat weaker AI, and has better performance than beginner players, but still far from expert human player whose wins rate over 90% on the average.



	EXP1	EXP2	EXP3
OAI	0%	5%	5%
MCAI	10%	50%	35%
Beginner	5%	45%	15%
Expert	90%	100%	100%

Figure 1: Win rate of subjects in three experiments

**OAI: Original AI of StarCraft *MCAI: Monte-Carlo Planning AI*

VI. CONCLUSION AND FUTURE WORK

This paper has presented a preliminary work on solving the problem of micro-management in RTS games. We have described a mechanism of applying MCPlan to the game Starcraft. After we analyzed and identified the domain, we successfully developed a simulator for the game and tested our method. Our work includes plans design, game process simulation and evaluation function creation. From our experiments, we got initial results which indicated a promising potential of MCPlan in this domain, but still not high enough for real play.

For future work, we intend to improve simulator which requires more accurate game simulation and more efficient evaluation function. We also try to seek a better way to improve simulation speed, which is an essential problem in Monte-Carlo simulation.

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ENHANCED REALITY GAMING

Device-to-Device Communication Framework Supporting Indoor Positioning System for Location-aware Interactive Applications

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KEYWORDS

Device-to-Device Communication Framework, Wi-Fi Based Positioning Systems, Alternative Reality Games, Cloud Computing Environments

ABSTRACT

This paper proposes a device-to-device communication framework supporting indoor PS (positioning system) for location-aware interactive applications. The framework is useful for developing especially entertainment applications like ARG (Alternate Reality Game) that uses geographical data because such a game employs a virtual game world mixed with the real world and the framework supports indoor PS data based on Wi-Fi technology for that. In ARG, we can often use mobile devices as HID (human interface devices) of the game because modern mobile devices have GPS and several sensors like a touch panel, an acceleration sensor. Generally, a certain device is not designed to transmit its sensor data to other devices so that usually we can't use the device as any interface of a game running of a PC without making its dedicated interface programs. The proposed framework makes it possible to exchange sensor data including indoor PS data among several devices so that with the use of the framework, it is possible to develop entertainment applications like ARG easily without making any dedicated interface programs. To clarify the usefulness of the framework, this paper introduces one actual game and one prospective game example developed or to be developed using the framework.

INTRODUCTION

Recently, mobile and portable devices such as iPhone, Android Phone and tablet PC have become common and popular. These devices can be used as HID (human interface devices) of video games because they generally have several types of sensors such as a touch panel, accelerometer/gyro sensor and so on. For example, we can use an Android Phone as an input device of a video game running on a PC. However, generally, a certain device is not designed to transmit its sensor data to other devices so that usually we can't use the device as interfaces of any game running of a PC without making its dedicated interface programs. In order to make it easy to develop applications that support mobile devices as their HID, we have been developing a device-to-device communication framework called OpenDDC (Open Device-to-Device Communication).

In fact, before OpenDDC, we have already developed a HID (human interface device) framework called OpenDC (Open Device Control) in order to support the development of a serious game of a rehabilitation training [Kaneko, Okada, and Matsuguma, 2011]. Because there are various types of rehabilitation trainings, serious games dedicated for them have to support various types of sensor devices for capturing various types of rehabilitants' physical motion data. In order to make it easy to develop such serious games, we developed OpenDC. Our OpenDC also supports Kinect, the motion capture device produced by Microsoft Inc., as the HID for rehabilitation trainings. Kinect is useful for such serious games like rehabilitation games besides standard video games because the device directly captures human actions using its two cameras and one depth sensor and applies them into the game world without holding any real device [Shotton, et al., 2011].
Besides serious games, we are supposed to use the framework for several interactive applications like web contents and data broadcast contents [Okada and Takano, 2011] in ubiquitous environments as shown in Fig. 1. For them, we extended the functionalities of our OpenDC framework in order to make it work as not only HID framework but also mobile communication framework in ubiquitous environments. Interactive applications that work in ubiquitous environments have to support various types of mobile devices and the functionality to exchange their sensor data with each other. Our extended framework enables them.

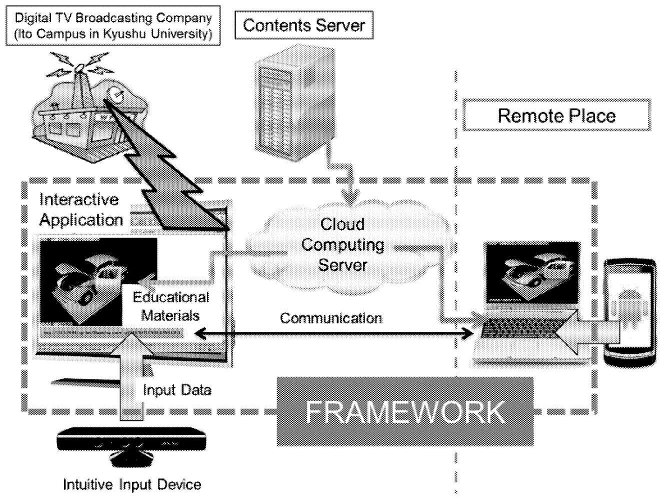

Figure 1: Interactive applications in ubiquitous environments supporting various intuitive interfaces

Recently, location-aware entertainment applications like ARG (Alternative Reality Game) have become popular and GPS data is commonly used for such applications. However, standard GPS works based on the information from a satellite so that the accuracy of its data is not so high and the system is not available inside buildings. Instead of using GPS, we tried to build Wi-Fi based indoor PS (positioning system) and extended our proposed framework to support such data for location-aware interactive applications. In this paper, we explain the mechanisms and functionalities of our indoor PS and also introduce one ARG and one prospective application developed or to be developed using the functionalities of our proposed OpenDDC framework.

The remainder of this paper is organized as follows: in the following sections, we explain the architecture of our device-to-device communication framework focused on the method of indoor PS and introduce real ARG and prospective example game that use or will use our framework. Before that, we introduce related work in the next section. Finally we conclude the paper in the last section.

RELATED WORK

As similar approach to our extended OpenDC, there is VRPN [Russell M. Taylor II, et al.,]. VRPN (Virtual Reality Peripheral Network) is dedicated for Virtual Reality devices like Phantom, Cyber Gloves, Motion sensors, but it does not support smart devices such as iPad and iPod as input devices. Also, our framework supports interactive web contents and data broadcast contents as client applications although VRPN does not support such client applications.
From the viewpoint of positioning systems, there are several methods depending on what kinds of sensors used to calculate location information. For example, the method proposed in [Ciavarella, and Paternò, 2004] employs the infrared ray sensor. Although this method can output position data more accurately than methods using the signal strength of radio wave, it needs many infrared ray transmitters because its performance is strongly affected by light conditions. Therefore, there have been some researches on methods using signal strength of radio wave so far, e.g., Bluetooth and RFID tag. Similarly to the Wi-Fi method, it is possible to calculate position data from the signal strength of Bluetooth [Aalto, et al, 2004] or the RFID tag [Ni, et al, 2003]. The passive RFID tag is very portable rather than the active RFID tag, i.e., no buttery, not expensive, and so on. However, practically the passive RFID tag is not available for positioning systems because it needs to be passed over its reader device very closely. On the other hand, in the use of the active RFID tag, there is not such a restriction. We should choose the passive or active RFID tag according to types of applications [Tesoriero, et al, 2008]. In this way, there are several approaches for positioning systems. However, we did not employ such the infrared ray, Bluetooth or RFID tag because these sensors are not so popular sensor on mobile device rather than the Wi-Fi sensor. There are several researches to use Wi-Fi for positioning systems. Mostly these methods are based on the received signal strength indication (RSSI) [Zàruba, et al, 2007][Lassabe, et al., 2009], and some researcher focus on algorithms to calculate location information more precisely. The positioning system proposed in [Rodríguez, et al, 2004] is used for hospital works to check location information about workers. The back-propagation neural network is employed to calculate location data in this system. There are other methods using several different types of sensors combined together such as Wi-Fi and RFID [Chen, et al, 2005] or Wi-Fi and Inertial Navigation Systems [Evennou and Marx, 2006]. These systems using several different types of sensors can output more accurate position data rather than ones using single type of sensor. In our research, as its first step, we focus on the use of single type of sensor, Wi-Fi. Our Wi-Fi based positioning system was actually applied to an exhibition event in a real museum [Kim, D., Lee, J., Kaneko, K.]. Wi-Fi based positioning system explained in this paper is extended from the above by improving its positioning algorithm.

ARCHITECTURE

In this section, we introduce the overview of our OpenDDC framework and explain Wi-Fi based indoor PS.

Device-to-Device Communication Framework

The components of our OpenDDC framework besides Indoor PS module are almost the same as those of our previous framework OpenDC. It consists of mainly four modules, i.e., Input Client Module, Output Client Module, Server Module and Indoor PS module as shown in Fig. 2.

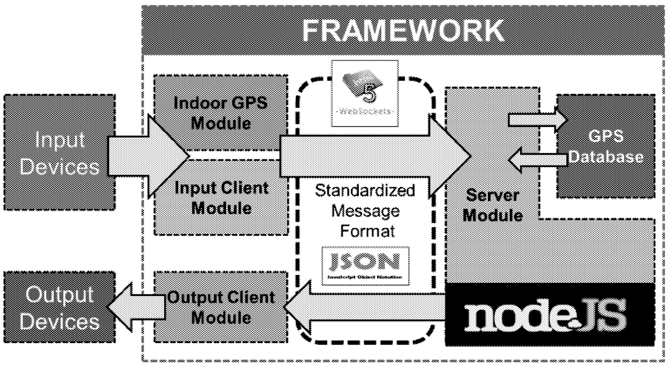

Figure 2: Overview of OpenDDC framework

Input and Output Client Module work on a client application. Server Module works as a server for exchanging data between input client and output client applications. This module also works with Input Client Module on an input device or with Output Client Module on an output device in cases that there is no server. Exchanges of data between Input Client Module/Output Client Module and Server Module are carried out by IP communications on the Internet. Indeed, we use Websocket Protocol in this framework for the communications. For its details, see the paper [Kaneko, Okada, and Matsuguma, 2011]. In the following section, we will mainly explain the indoor PS module.

Indoor Positioning System

Inside buildings, standard GPS cannot be used because of its lower positioning accuracy. We have to use another system or sensors. There are several sensors that can be used for indoor PS, i.e., a camera, Bluetooth receiver and infrared ray receiver. In our framework, we adopted a Wi-Fi radio wave receiver as a sensor to calculate a user's position because of the following reasons. The first one is the compatibility of our OpenDDC framework to Wi-Fi environments because the framework always uses the Internet as its communication system. The second reason is that indoor PS using Wi-Fi radio wave is an automatic sensing like GPS so that users do not need to move his/her sensor device close to a sensing target object unlike for instance, a RFID tag that should be moved close to its reader. The third reason is robustness against some condition inside a building. For instance, Wi-Fi based positioning system is not affected by the light condition of a room although image recognition based positioning system using cameras is strongly affected by the light condition and cannot be used in dusky rooms like a cinema or a museum. Finally, the most significant reason is the popularity of Wi-Fi devices. At present, most of the mobile devices have a Wi-Fi radio wave receiver. Application systems developed using our framework often runs on such mobile devices. Therefore, Wi-Fi based positioning system is suitable for our proposed framework.

In our indoor PS, to calculate a user's position it uses a Wi-Fi radio wave receiver. We use a Received Signal Strength Indication (RSSI) value from a Wi-Fi radio wave transmitter. The process to obtain the position is shown in Fig. 3. At first, our framework on a Wi-Fi mobile device calculates RSSI values of the current position from Wi-Fi radio waves and sends the RSSI values to the dedicated database server. Our framework on the server refers contents of its position database constructed beforehand and calculates similarity values between current RSSI values and RSSI values about several positions stored in the position database. Finally, our framework on the server returns position data corresponding to the highest similarity value.

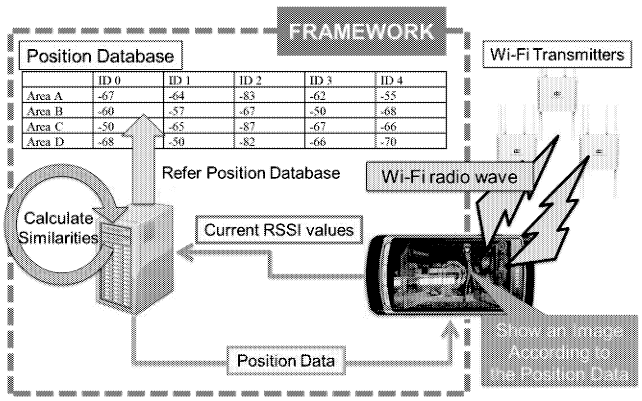

Figure 3: Indoor PS in OpenDDC framework.

In our framework, we use Cosign Similarity for the similarity calculation because its implementation is simple, its calculation is fast and its accuracy is enough to obtain position data by devising a configuration of Wi-Fi radio wave transmitters we will introduce in the following section. This type of indoor PS is almost enough for entertainment applications like ARG. In our framework, we use the following equation as Cosign Similarity.

$$S_i = \vec{X} \cdot \vec{P_i} \, / \, |X||P_i|$$

$\vec{S_i}$ is the similarity between $\vec{X}$ and $\vec{P_i}$. $\vec{X}$ means $X(RSSI_0, RSSI_1, \dots)$ and it has each RSSI value from each Wi-Fi radio wave transmitter as its element. $\vec{P_i}$ means one of $P_0(RSSI_0, RSSI_1, \dots), P_1(RSSI_0, RSSI_1, \dots), \dots$ and it has RSSI values on a certain place i those are beforehand investigated and stored in the database.

EXPERIMENT

We used the functionality of indoor PS in our framework to build one ARG, which actually took place as a cinema service, and to check the accuracy improvement of current indoor PS compared with our previous indoor PS [Kim, D., Lee, J., Kaneko, K.]. In this section, we will introduce the ARG and an experimental report about indoor PS of the game.

Example ARG

To clarify the usefulness of our proposed framework, we introduce one ARG developed as a cinema service using the framework. This application software runs on an Android Phone/Tablet. This ARG leads visitors to the cinema to its entrance gate using the AR (Augmented Reality) application shown in Fig. 4. In the game, the system displays several characters by AR technology. So the background of this figure is the real scene of the cinema. In the upper right part on the figure, the user's position and target character position are indicated. If the user launches the application, the application checks the user's position using our framework and shows a certain character movie corresponding to the position. If the user chases the character in the game, then the character escapes from the current place to another place. After the user chases the character several times, finally the user arrives at the gate of the cinema. This is a good example of navigation systems using Gamification method.

Figure 4: Cinema service ARG using OpenDDC framework.

Experimental reports

This section indicates several experimental data of the ARG. Figure 5 shows the map of the lobby of the cinema. The lobby is about 20x20[m^2] area. The red circle points represent positions of Wi-Fi radio wave transmitters. To calculate position data from RSSI values of some positions, differences of those RSSI values should be large. Empirically, 5[m] interval is necessary at least. So we put four Wi-Fi radio wave transmitters each of which covers

5x5[m^2] area indicated as each of four rhomboid areas shown in Fig. 5. Indeed, we put one more transmitter on the center position of the all rhomboid areas to improve the accuracy of position data. To obtain more precise RSSI values, each rhomboid area was divided into four sub-areas and we investigated RSSI values in a certain duration time about 16 sub-areas, and then we adopt the 16 average values in the duration time as shown in Table 1. ID number means its corresponding Wi-Fi radio wave transmitter. No value cell in the table represents not used areas as shown in Fig. 6. In fact, for the simplicity of the implementation and the reduction of the calculation cost of position data, we used average RSSI values about four large areas shown in Table 2. The four areas are as shown in Fig. 6.

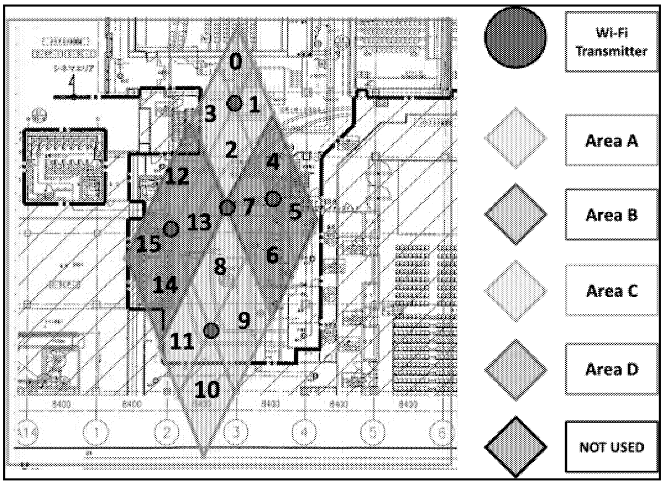

Figure 5: The floor map of the cinema and an ideal areas of each Wi-Fi radio wave transmitter.

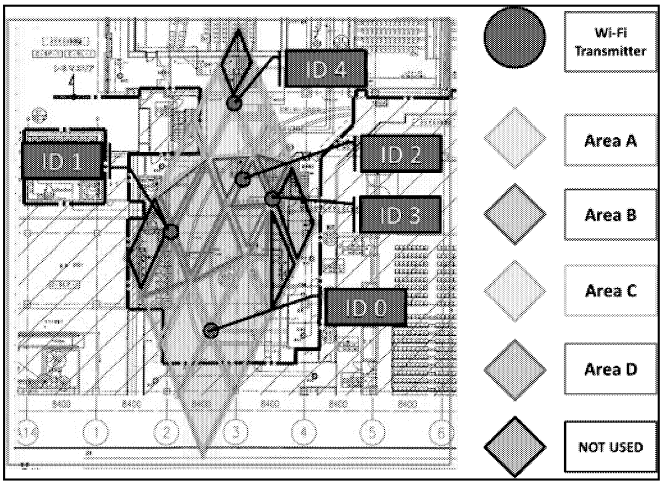

Figure 6: The floor map of the cinema and the actual areas of each Wi-Fi radio wave transmitter.

There were some errors in each of the areas because their radio waves are often shut-downed by several obstacles located in the cinema. In the borders between two areas, “chattering” took place because it was difficult to distinguish which area between them the user was located in. To avoid the chattering, our framework several times took the action that searches current RSSI values and sends them to the server to obtain stable position data.

Table 1: RSSI values about 16 sub-areas.

[dBm]

	ID 0	ID 1	ID 2	ID 3	ID 4
Area 0	-70	-67	-93	-60	-54
Area 1	-72	-68	-79	-70	-55
Area 2	-62	-64	-76	-63	-55
Area 3	-65	-63	-83	-55	-50
Area 4	-64	-60	-68	-50	-44
Area 5	-	-	-	-	-
Area 6	-	-	-	-	-
Area 7	-43	-55	-67	-55	-62
Area 8	-55	-55	-83	-60	-65
Area 9	-46	-62	-94	-89	-71
Area 10	-66	-67	-86	-75	-63
Area 11	-55	-76	-86	-67	-67
Area 12	-70	-62	-84	-51	-64
Area 13	-62	-44	-80	-58	-60
Area 14	-72	-53	-81	-60	-86
Area 15	-	-	-	-	-

Table 2: RSSI values about four areas.

[dBm]

	ID 0	ID 1	ID 2	ID 3	ID 4
Area A	-67	-64	-83	-62	-55
Area B	-60	-57	-67	-50	-68
Area C	-50	-65	-87	-67	-66
Area D	-68	-50	-82	-66	-70

In this cinema service, we used PCWL-0100 produced by PicoCELA Inc. as the Wi-Fi radio wave transmitter. The reason why we use the device is that it is very convenient for applications that use the Internet because several PCWL-0100 can easily build a mesh wireless network. This service was available in the cinema of TJOY HAKATA of Fukuoka City for several months.

PROSPECTIVE APPLICATION EXAMPLE

To clarify the usefulness of our framework, we also propose one prospective application example that is a treasure hunting game as shown in Fig. 9. This kind of game can take place in a cinema, an event hall or a museum. Using our framework, we can easily develop such a kind of game. In this game, to let users know the locations of treasures, we use a digital signage device which shows a map near around the user and indicates important information of the game corresponding to its location. All users have their mobile device to check their position or to control the map shown on the signage device.

The data flows of the game are as follow: at first, indoor PS module running on a mobile device sends its RSSI values to a map server. The server refers to its position database and returns the position data corresponding to the received RSSI values to the mobile device. Also, the server trims the map according to the position information and sends the map image data to the mobile device. And then, the user can see the map. Meanwhile, the mobile device is also used as the input device to control the map image shown on a digital signage device. With the use of our device-to-device communication framework, these data flows are easily carried out. We can also use various types of devices like iPhone or Android Phone as input devices of the game.

The merit of the use of indoor PS is that we need not prepare local resources (maps in this case) for each digital signage device. To refer a map, we just store the map resource only on a map server. This kind of service is suitable for Cloud Computing Environments. Therefore, it can be said that our framework is available for the development of any interactive applications run on Cloud Computing Environments.

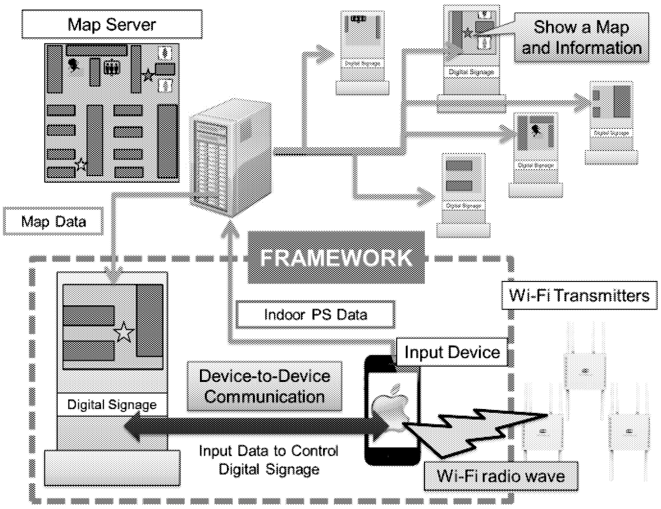

Figure 9: Treasure hunting game example.

CONCLUSION AND FUTURE WORK

In this paper, we proposed the device-to-device communication framework called OpenDDC and explained its architecture. Furthermore, we introduced an experimental report of the ARG developed using the functionality of indoor PS in the framework. In this experimental report, we explained the method to obtain position data inside buildings. We also showed the treasure hunting game as prospective application example of our proposed framework to clarify the usefulness of the framework. OpenDDC can be used for the development of various types of interactive applications besides video games, e.g., web contents, data broadcast contents, remote control for robots and so on. We will develop various applications using OpenDDC to clarify its usefulness as one of our future works.

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Changing the Rules: Acquiring Quality Assured Geospatial Data With Location-based Games

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KEYWORDS
location-based games, crowdsourcing, volunteered geographic information, geospatial data, data quality

ABSTRACT

Location-based games (LBGs) can be used to motivate players to create geospatial data as a by-product of game play (Matyas et al. (2009); Bell et al. (2009)). However, no general design framework for such games identifying all relevant design decisions has been proposed yet. Especially the problem of quality assurance has not been addressed properly in current game design. This paper introduces a new design framework for LBGs specifically targeting at the collection of quality assured geospatial data. The framework uses a game design pattern that aims for quality assurance by using positional accuracy as a quality indicator. We empirically evaluate our approach by comparing the positional accuracy of data collected with and without the game design pattern. Results from the LBGs *GeoSnake* suggest that our pattern results in a significant quality improvement.

Introduction

Previous research by von Ahn and Dabbish (2008) has shown that regular Internet users can be motivated to solve simple tasks, such as HITs (Human Intelligence Tasks) on the Mechanical Turk (www.mturk.com) platform without monetary incentives. Using simple web games (www.espgame.org/gwap/) they were able to gather large amounts of a data, such as semantic tags for images.

Matyas et al. (2009) have demonstrated that von Ahns basic idea can be adopted for the creation of geospatial data by volunteers with the help of LBGs. However, they reported that, unlike in a pure web-based context, volunteers of LBGs are reluctant to review data created by other players. In contrast to approaches, such as in *Wikipedia* (www.wikipedia.com), the evaluation of geospatial data, such as GPS coordinates, can only be done reliably on the ground and not from the computer in your living room. In contrast to previous approaches, such as an external cash-based reward system (refer to Mechanical Turk) or a special review board (refer to Casey et al. (2007)), the approach presented in this paper is inspired by the wisdom of the crowd idea (Surowiecki (2004)). It is realized as a game design pattern that can be integrated in any kind of LBG and succeeds in "persuading" the players to create accurate data right from the start. This pattern, first introduced in Matyas et al. (2011) is now integrated in a design framework and analyzed and discussed in detail.

The main contributions of this paper therefore are: (1) We introduce a new framework for the design of LBGs that motivate to create quality assured geospatial data. (2) We revisit the *wisdom about the crowd* game design pattern (Matyas et al. (2011)). (3) We show that the appraoch results in an improvement of the positional accuracy of the geospatial data collected by the players. We will use the location-based game *GeoSnake* in an experimental setting to evaluate our claim in one case study carried out in the city centre of Bamberg (Germany).

The rest of the paper is structured as follows: in the following section we introduce our design framework that elaborates on three issues important when designing a LBG for the collection of geospatial data: 1. the structuring of a real-world game field 2. motivational game patterns for data collection and 3. strategies for quality assurance. We discuss related work using the concepts of the framework. Then two sections describe the LBG *GeoSnake* and an experiment with this game in which we evaluate the *wisdom about the crowd* pattern. We finally summarize the outcomes of the study and give an outlook on upcoming work.

*special thanks to Kunieda-san and Yamada-san from NEC CCIL

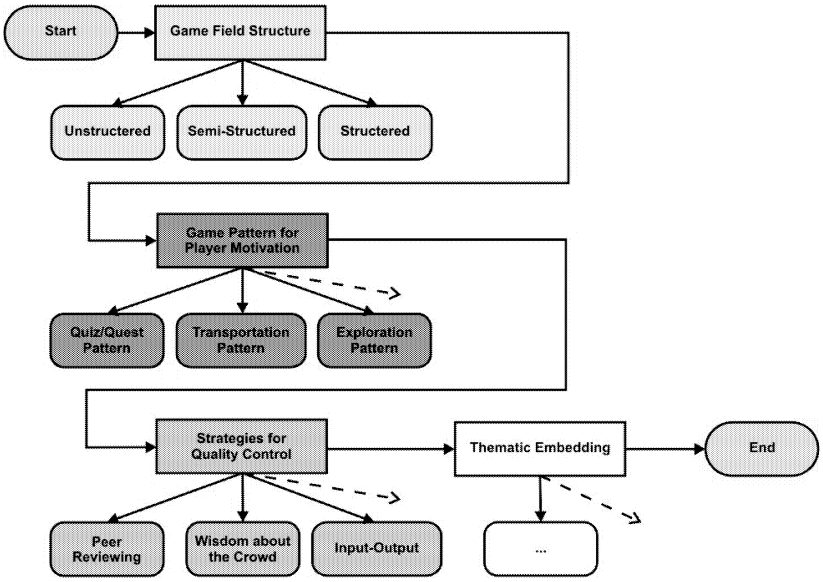

Figure 1: One workflow through the design framework

Design Framework and Related Work

The framework that we introduce is based on the analysis of more than 130 LBGs. This sets our approach apart from previous analyses in the literature of pervasive games - like Montola (2005) - and human computation games - like Yuen et al. (2009) - as they are only used to categorize research fields. A full overview of the analyzed games can be found in the location-based games database (LBGDB) [1] which includes research prototypes and commercial games. Every game was manually encoded with 15 independent attributes ranging from the number of players the game can be played with over the structuring of the game field to the spatial and temporal classification of the game play - see Matyas et al. (2009). Additionally, we looked at existing LBGs that are already used for the creation of geospatial data and analyzed their game elements separately. We could derive three unique attributes for this type of games that also form the basis of the design dimensions of the proposed framework.

As figure 1 illustrates the framework consists of three important design questions:

- *Game field structure:* How should the real-world game field be structured with regard to which type of geospatial data is going to be created with it?
- *Player motivation:* What kind of game elements motivate the players to create geospatial data?
- *Quality control:* How is the quality of the created data assured and evaluated?

Note that Fig. 1 only describes one possible way to use the framework. In fact, the design dimensions - game field structure, player motivation and quality assurance - can be seen as independent from each other. As will become apparent in the following discussions, there are patterns for player motivation and game field structures for example that naturally go better together than others (e.g., an unstructured game field fits well with the exploration pattern). But in terms of game play, any combination is possible.

In most cases, the three fundamental design issues can be addressed in the following order (see Fig. 1): the first question is how the real-world game field should be structured as it influences also which kind of geospatial data types can be created - see also Matyas et al. (2009) on this topic. So far, LGBs feature either an unstructured (no game-relevant locations are predefined), semi-structured (some game-relevant locations are predefined) or an structured game field (all game-relevant locations are predefined). The game found in Tuite et al. (2011) is a recent example for the usage of an unstructured game field. In this game the players themselves have to figure out/freely choose where they can/want to perform an game action. They can take photos of any building they want in the game. *CityExplorer* - in Matyas et al. (2009) - was the first LGB designed with the primary goal to create geospatial information. It is designed in a way that players create complex geospatial data sets, composed of two GPS coordinate pairs, image data, and a semantic tag, while playing. It features a semi-structured game field by restricting game actions to take place inside a

[1] http://www.kinf.wiai.uni-bamberg.de/lbgdb/about.php

predefined tile-based game field. But inside each tile players can choose freely where to take a game action (where game actions in this game mean taking a photo and geo-referencing a building).
LBGs that only log the motion track of each player but allow game actions only on predefined locations on the real-world game field, feature a structured game field.

The next step in the framework is choosing the optimal motivational strategy for the actual data creation part. From the patterns shown in Fig. 1, only the *Exploration* pattern has been used so far - e.g. Matyas et al. (2009) or Tuite et al. (2011). This pattern basically states that players are free to perform game actions anywhere on the real world game field. The two other patterns, the *Quiz/Quest* pattern and the *Transportation* pattern, require the game designer to create some geospatial data before the game, and are therefore not so popular for geospatial data creation LBGs. In the first, players try to solve some sort of quiz or perform some action at a specic location in the real world. In the latter, players bring a game related object from one location to another.

The open problem for all of the previously mentioned approaches is how we can guarantee quality assurance for the collected geospatial data. So far either none - Drozd et al. (2006) - or a point-based review system (*Peer Reviewing* pattern) - Casey et al. (2007), Matyas et al. (2009), Bell et al. (2009)[2] - was used to validate the correctness of the player-created data. Regardless of how one classifies the quality assurance game element of each game, Bell et al. (2009), Casey et al. (2007) and Matyas et al. (2009) reported nearly the same results of how much data was actually reviewed by the players of their games. The review rate was always between 30% to around 40%. Though one could doubt whether these studies constitute a represenative sample they are a strong hint that the upper bound for the quota of data that gets checked with a review-based system is indeed around 40%. But that also means that with such a system half of the collected data has to be seen as of unknown quality as it is only provided by a single non-expert player. Though the quality indicators of the players hardware (e.g. a GPS device) could be known and used as quality indicators, one cannot guarantee that the players have provided false data on purpose. So the review system also serves the role of an anti-cheating tool - Matyas et al. (2009) - and cannot be replaced with some automatic process.

The low evaluation quota motivates our search for other game elements that can be used to assure quality and fairness, while at the same time reaching a higher evaluation quota than 40%.

[2]One could argue that they used the *Input-Output* pattern instead which is based on the idea of a creation and evaluation cycle. Data that is created in one game round is being taken as base data for the next round.

Wisdom about the Crowd Gaming: GeoSnake Study

To overcome the above-mentioned limitations of a game-based review system we propose a new kind of quality assurance strategy for LBGs. The strategy is based on the wisdom of the crowd idea discussed in Surowiecki (2004). With this motivation, and in the spirit of Björk and Holopainen (2004) comprehensive survey of game patterns, we propose the following general game design pattern (shortened version, originally proposed in Matyas et al. (2011). Note the difference in emphasis between "wisdom of the crowd" and "wisdom about the crowd". The former refers to the aggregation of the observations of many individuals while the latter refers to the ability of an individual to make an educated guess about the decisions of others.:

Wisdom about the crowd
Players are retained to take into account the anonymous majority decision of the other players when generating game-based geospatial data.

Although this might not seem very obvious at first sight we will demonstrate the usage of the pattern with the introduction of a simple location-based game, *GeoSnake* - a variant of the popular video game *Snake*. Like the video game, *GeoSnake* is a single-player game. In contrast to the genuine, players have to visit a known number of places and choose appropriate GPS coordinates for them. Players get points for every correctly placed GPS coordinate. Points are deducted if a player crosses his previous path (one point) or takes a path twice (two points) - so every street can be seen as a one-way street and the tail of the snake is growing continuously alongside the path the player takes. Now this might appear easily done, in a real world city wide game field it is quite a challenge. To make the game even more challenging players do not see their already covered path on their mobile device. If a tie in points should occur between two or more players, the one with the shortest path is declared the winner.

For *GeoSnake*, we formulated the following two game rules for how the players should pick a GPS coordinate of a place in the game. The first one is the normal rule that one would expect as a result from the game description we gave above. The second one represents the implementation of the *wisdom about the crowd* pattern:

1. Choose a GPS coordinate that identifies the place without a doubt, so located inside or as near as possible to the place. (rule V1)

2. Choose a GPS coordinate, that you think the other players also chose. (rule V2)

For V1 points were awarded as long the chosen GPS coordinate was reasonable near the place in question. For V2 only those players received points whose coordinate pair belonged to the biggest cluster of coordinates chosen by all players for a place.

The hypothesis is that the players will produce more accurate geospatial data under rule V2 than under rule V1. To judge the accuracy and therefore the quality of the provided geospatial data we proceed as follows with the GPS coordinate of V1 and V2: (1) We compute the cluster centers for all places and then (2) measure all distances between them and the associated GPS coordinates. We then end up with a table that holds all distances for a GPS coordinate to its associated cluster center for both rule variants. Note that although we are looking solely on the positional accuracy of geospatial data here the design pattern can be used with other data types like semantic data (tags) too. To evaluate the effect of the employed rules a generalized linear model (GLM) is estimated Fahrmeir and Tutz (1994).

Case Study: Set-up and Results

In the study 12 students and employees of the university of Bamberg with a background in either computer science (8) or humanities (4) took part. Gender was equally split with 6 male and 6 female participants. The age mean was 26,6 years. All players received an introduction into the game rules and hardware usage shortly before they played the game. All hardware was handed out to the players, a Nokia 6630 smart phone and a XAIOX Wonde-XL that features a Nemerix GPS chip. The game field consisted of twelve places in the city center of Bamberg (Germany) that the players had to choose GPS coordinates for - ranging from places over streets to wide squares. For the evaluation we could get in the best case six GPS coordinates for every place under both rules (V1 and V2) without risking some kind of dependency in the data. To accomplish this, we let the player start with one rule variant and gave them the other inserted in an closed envelope. After six of the twelve places the players had to open the envelope and finish the game using the other rule variant. By changing the starting rule variant with every participant we expected to get an somewhat equal share of GPS coordinates for every place under both rules. The players were free to choose in which order they wanted to visit the 12 places.

Applying the data to the estimated model, which is performed with the *R* software package[3], produces the following results:

[3] `http://www.r-project.org/`

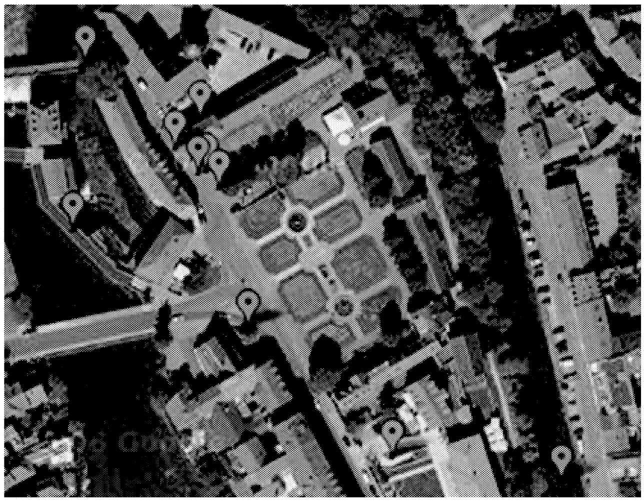

Figure 2: Created GPS coordinates under V1 (red markers) and V2 (blue markers)

For the reason of estimating a GLM with canonical link of a Gamma distributed response with *R*, the directions of the effects have to be interpreted oppositely in table 1 as *R* reports the inverse as response. Therefore, *rule 2* is significantly better than *rule 1* though the significance level is only at 0.1.

This result confirms our hypothesis given in section . Furthermore, two interesting results emerged from the informal interviews conducted with each player after they played the game and from a detailed look at the places with a strong data basis. We focused the question if the change in game rules resulted also in an intentional change in user behavior. All of the players reported that they didnt change their "choosing" behavior despite the rule change. This is therefore of great relevance as from a point-wise perspective one would anticipate that the players are more concerned about choosing the "right" GPS coordinate under each game rule. But apparently that is not the main motivator for the behavior change that the data indicates, regardless of the given answers in the interview rounds. As can bee seen in figure 2 - for the area-based place "Geyerswörth" - players choose under V1 GPS coordinates that satisfied their game strategy in contrast to players under rule V2. They choose to set their GPS coordinates near a building that is commonly identified with the place name "Geyerswörth" in Bamberg. The data furthermore shows that for point-

	Coefficient	Std. Error
rule 1 (Intercept)	2.964e-02	5.468e-03
rule 2	1.131e-02*	6.271e-03
time	2.736e-05	6.376e-04

Table 1: Source: *GeoSnake* Game. Remarks: *** < 0; ** < 0.05; * < 0.1

like places like small buildings, places or monuments the difference in accuracy between rule V1 and V2 is negligible. Here the differences only result from the different GPS signal conditions, but not from different player behavior. With these results in mind we prepared a second study which is described in Matyas et al. (2011) and results in a support of our hypothesis with a high significance level of 0.05. It also solved hardware problems that let players record an equal share of GPS coordinates for every place that was not achieved in the above described study. For some only small numbers of coordinate pairs were available.

Conclusions and Outlook

In this paper we have shown that the problem of low participation rate which is common for review systems of location-based games can be overcome by implementing the *wisdom about the crowd* design pattern. We presented the general design pattern and the location-based game *GeoSnake* to illustrate its use. Additionally we used the *Geosnake* game in the course of two case studies to validate the hypothesis that with my proposed game pattern the spatial accuracy of the collected data can be increased. Informal interviews and detailed data analysis point out that these results are independent of the point-based game rewards used in *GeoSnake*. Related work suggests, e.g. Casey et al. (2007), that when geospatial data creation is paired with a location-based game players are more concerned about the game and not so much about the data creation task at hand. Our research indicates that this behavior changes when the *wisdom about the crowd* pattern is applied to the game. In our future work we will investigate more design patterns to tackle the information quality problem that comes with the usage of location-based games as crowdsourcing tools for geospatial data. Bishr et al. (2008) Bishr and Mantelas (2008) have already argued that quality is one of the most pressing matters when it comes to "Collaboratively Contributed Geographic Information (CCGI)" - their name for VGI data. They presented a model to compute the quality of a CCGI by using trust as a proxy. We would like to combine trust and quality values in a unique quality assurance method in the future.

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GAME SPEECH TECHNOLOGY

Towards Usability Heuristics for Games Utilizing Speech Recognition

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KEYWORDS

Usability heuristics, games, speech interface, speech recognition, voice interaction

ABSTRACT

Speech recognition technology has reached the maturity required by serious business applications, and the game industry is increasingly adopting the technology. Since usability is one of the key elements of enjoyability and, thus, the successfulness of games, a thorough analysis of the elements, properties and effects of this new user interface is needed. However, there seems to be no existing speech interface usability analysis methods for computer games. A pragmatic and rigorous framework, which the game industry could easily adopt, could help the utilization of speech recognition technology. In this paper, we discuss the usefulness of voice recognition in games and propose usability heuristics for games utilizing speech recognition.

INTRODUCTION

Speech recognition has been developed intensively since the 1950s and the core technological problems can be seen as solved. The computer game industry has also utilized voice and speech interfaces for the past decade. However, no commercial breakthroughs have yet emerged within products using proper speech recognition technologies. The success of Nintendo Wii's motion sensor controller is driving the industry to develop new kinds of game experiences and control interfaces. Speech-based control is a strong candidate for the next potential success technology. This argument is supported by the launch of new accessories. For example, Microsoft's Xbox 360 Kinect offers already Windows speech recognition API for easy application programming. The device has sold millions of units for the video game console, and the manufacturer has announced that it will be offered also for PCs. Therefore, the user base has already reached a critical mass to be commercially viable.

Speech recognition technology offers various new possibilities to the game industry and players. Following the example of motion sensors, the technology will open a gate for new kinds of games that utilize the ability to give speech commands. Also, the technology can reduce the complexity of button sequences to guide, for example, wingmen. One important aspect is also that speech recognition can be used to improve the immersion of a game – instead of choosing a word to 'say' from a given list, the player can actually *say* the word and participate more intensively in the game. Furthermore, speech recognition combined with motion detection offers even more possibilities.

However, re-engineering user interfaces and controls poses a challenge for game developers. Usability is crucial for computer games, because the players can freely choose which games they play in contrast to, say, the office software used in work places. Thus, games with unnatural and unusable interfaces are likely to be abandoned.

In this paper, we study the usability of speech recognition in video and computer games. The aim of the research is to develop a set of usability heuristics, *i.e.* a set of usability guidelines (Nielsen and Mack, 1994), that developers and evaluators can use to recognize and fix possible usability defects in the artifact. Although a few heuristics for game usability and playability do exist, and even design principles for speech interfaces have been presented (see section Usability in Games), there does not seem to be any heuristics for evaluating the benefits of speech recognition in games.

Based on the work of Weinschenk and Barker (2000), we present a proposal for a set of usability heuristics for games utilizing speech recognition. The presented heuristics is preliminarily analyzed in the context of *Tom Clancy's Endwar* (Ubisoft, 2008).

The paper is structured as follows. The next section will shortly present the work related to the playability and usability analysis of games. The following two sections discuss speech interface design guidelines and the proposed heuristics. The final two sections describe briely the preliminary study done in this area and conclude the work with ideas for further research on the topic.

USABILITY IN GAMES

Usability is a central concern in game development. Therefore, some general heuristics for the usability of computer games have been proposed, the earliest of them being the work of Federoff (2002). She presented an exhaustive list of forty criteria addressing game interface, game mechanics and game-play. Desurvire *et al.* (2004) expanded upon these usability heuristics by going further into the game's story and proposing a heuristic for evaluating *playability*.

Korhonen and Koivisto (2006) presented a specialized heuristic for playability in mobile games, but their criteria for usability were largely in line with the work of Federoff and Desurvire *et al.* They continued their work and proposed playability heuristics for mobile multi-player games (Korhonen and Koivisto, 2007). Pinelle *et al.* presented general usability heuristics for video game design (2008a; 2008b) and later expanded it for the special case of network games (2009).

In this study, we will focus only on usability and surpass the playability aspect. One might question this decision, especially given that we are dealing with games. However, Desurvire *et al.* (2004) demonstrated that usability is but a component of playability, which also includes *e.g.* a game story. We base our choice on the assumption that it is first essential to evaluate the usefulness and performance of a new input technology before tackling the question of playability.

SPEECH INTERFACE DESIGN

Utilizing speech technology in different information systems and applications has been studied for decades. For example, Jones *et al.* proposed seven classes of design guidelines for interfaces with speech recognition as early as 1989. Yankelovich *et al.* (1995) studied speech-only interfaces and suggested that speech interfaces should be designed from scratch instead of transfering them from graphical ones.

A comprehensive study of the usability of applications utilizing speech technology is given by Weinschenk and Barker (2000). They list 20 laws of interface design, from which they derive 11 guideline categories for designing a speech interface. These categories include, among others, feedback, command confirmations, and social and environmental issues. The guidelines are intended for both speech-only and multi-modal interfaces.

However, as Weinschenk and Barker point out, their focus is on the applications that help a user to complete a task that involves real work. They knowingly do not handle computer games that also try to challenge and entertain the players instead of only helping them to achieve some work-related goals.

HEURISTICS PROPOSAL

We propose a set of eight usability heuristics for analyzing games utilizing speech recognition, which is presented in Table 1. The heuristics are derived from suitable parts of Weinschenk and

Barker (2000) and it is further improved capitalizing on the authors' experiences with games and speech recognition interfaces.

We restrict the study to electronic games played in front of a screen where speech is one or only controlling device. For us there is no difference between controlling single player games and shared control games. Furthermore, the proposed heuristics concentrate only on the usability of speech recognition interfaces and, thus, they should not be taken as comprehensive usability heuristics for games. They should be used to support other usability evaluation tools.

To utilize the heuristics S01–S08, the following questions should be addressed when evaluating how well some game fulfills the selected criteria:

S01 Does the game properly respond to the player's commands using aural, visual or other feedback?

S02 Are the voice commands distinct from one another and unambiguous?

S03 Is the player clearly aware which commands he can use at any given time?

S04 Do speech commands feel sensible and practical?

S05 Are the speech commands used for actions the player actually wants to use with speech?

S06 Does the game provide a practice feature for getting familiar with the speech control?

S07 Is the game able to learn the way the player speaks? In addition, can the game differentiate one player from another?

S08 Can the player configure or add new speech controls?

The heuristics can be grouped to a few subgroups. Heuristic S01 addresses the feedback given to the player, including the response time. Heuristics S02–S03 are related to controlling via speech and S04–S05 are related to the integration of a speech interface to the rest of the game.

Heuristics S06 and S07 concentrate on training of both the player and the game. Heuristic S07 is useful for reducing the effects of the player's accent or dialect and general background noise. In serious games an achievable goal might be teaching the correct pronunciation for the player. In this study, we are focusing on games the sole purpose of which is just to entertain, and thus the game should be the one adapting to the convention of the player. However, as the player always somewhat adapts to the game, player's adaptation should be as subtle and unnoticeable as possible.

Table 1: Set of heuristics for evaluating usability of games utilizing speech recognition.

No.	Description
S01	Multi-modal feedback is used
S02	Controls are accurate
S03	Limitations of using speech recognition are explicit
S04	Speech recognition is a practical way of controlling the game
S05	Speech recognition is a coherent part of the gaming experience
S06	The player can practice the use of speech control
S07	The game learns to recognize the voice of the player
S08	Controls are configurable

Configurable controls (S08) are a very general usability issue, but they are mentioned here for the possibility of adding new voice commands, *e.g.* speech macros to implement player specific command terminology. This could also include the possibility of applying proper NLP methods to understand what the player means even beyond the specific pre-set key phrases.

PRELIMINARY STUDY

To preliminarily verify the proposed heuristics we analyzed a commercially available speech controllable game using the heuristics. *Tom Clancy's Endwar* (Ubisoft, 2008) represents a modern Real-Time Strategy (RTS) where voice control can be used to command troops in the battlefield. The game was advertised as being fully controllable via speech interface. Although the game is published for various platforms, in this study we focus only on the Windows version.

The preliminary study was arranged as follows. Three authors of the study played the game separately with their own computers. One of the testers used a table microphone and the rest used headset microphones. Evaluators made lists of issues they found and analyzed them individually against the heuristics. After the tests, the encountered issues were discussed in a meeting and the final list of observations was shaped, regarding both the heu-

Figure 1: Example of visual feedback when giving speech commands in *Tom Clancy's Endwar*.

ristics and the game.

Since we are not actually evaluating the product, but rather the heuristic, we specifically report the individual findings of the heuristics: whether the heuristic applies to the game as described, whether the lack of following the heuristic reduces the usability of the game, or whether the heuristic is not relevant to this particular product. We found out that all the proposed heuristics are found — in one form or another — in the game, either followed or lacking.

As can be seen from the following example, the heuristic seems to work for this particular experiment. Regarding the set of heuristics, the following observations were made:

S01 The game provided feedback with both voice and graphics. However, on the battlefield, after the voice control training and, the vocal feedback became somewhat drowned. Sometimes the graphics indicated that a command was given properly, but the game did not accept it. This may have been due to releasing the push-to-talk -button too early.

S02 One of the testers had his commands often misinterpreted as *"Delta"*, which caused errors. Recognition worked best when commands were given as well-flowing sentences, but this was problematic if the player had to check the available commands from the gradually expanding command menu.

S03 The command menu, pictured in Figure 1, helps the player to realize and remember which commands are available at a given time. Giving commands was well separated from other gameplay with the use of space bar as a push-to-talk -toggle, although this took some time getting used to.

S04 Using speech commands was not always as quick as manual controls; sometimes the orders came too late which lead to losses in battle. This was found frustrating. Some speech controls were missing that would have been required for a good gaming experience, such as *"take cover"*, which was available as a mouse command, or *"support another unit"*, which was not present in the game.

S05 Using speech commands to order one's troops around felt like a natural way to control the game. In this regard the training program was especially well embedded to the game.

S06 The player had a chance to practice the use of voice commands even before the tutorial proper begins. Then he was gradually introduced to the finer details of the interface.

S07 The game did not seem to learn from the player. The player learned what the game expected. The testers found this feature annoying because the normal rhythm of speech had to be changed, either slowed down or speeded up.

S08 The speech commands for the game were not configurable. The players did yearn for configuration of certain commands for shortcuts specifically.

As the result of this preliminary study, the proposed heuristics capture the issues that were clearly present in the game. In addition, the testers did not find issues that were not covered by the heuristics. However, it should be noted this experiment focuses on what is done, not what is possible with speech recognition. For example, a game could interpret non-discrete commands such as speech volume, tone, and pitch.

CONCLUSIONS

In this ongoing study, we assessed the possibilities speech technology can bring to the game industry and analyzed the risks of integrating the technology to computer games. A central threat to the technology breakthrough is a lack of usability in the products. Therefore, this paper proposes a set of usability heuristics for games utilizing speech recognition. The preliminary study showed that our approach is promising. However, we are aware that the proposal is not complete and it should be investigated further. Thus, future work includes a usability expert analysis of the heuristics and a field study with players from different backgrounds and expertise levels.

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BIOGRAPHIES

AKI HALONEN was born 1979 in Pieksämäki, Finland. Currently he studies Software Engineering at the University of Turku, Finland. His studies, as well as other interests, are heavily biased towards computer games.

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TIMO KNUUTILA reiceived his M.Sc., Ph.D. degrees, and Adjunct professorship in computer science from the University of Turku, Finland, in 1987, 1994 and 2005, respectively. Currently he is working for Business and Innovation Development unit at the University of Turku. His main research interests includes, but are not limited to, cheating prevention in multi-player on-line games, optimization algorithms and grammatical inference.

JOUNI SMED got his first computer at the age of thirteen – and ever since he has been keen in designing, programming and playing computer games. But there is more to computers than just games, so he got serious for a while and received his PhD in Computer Science and became an adjunct professor in the University of Turku, Finland. Jouni Smed has organized and taught game development on diverse topics ranging from game algorithms and networking in multiplayer games to game software construction, game design and interactive storytelling. His research interests range from code tweaking to software processes and from simple puzzles to multisite game development. He lectures, he supervises students, and yes, he still likes to design, program and play computer games.

HARRI HAKONEN is an optimistic nerd who likes startup companies. He enjoys solving problems, writing code, fiddling with object-orientation, working with pros, learning new stuff, and above all, adding value. Team, technology, and traction, those he finds alluring.

3D Terrain Generation and Texture Manipulation by Voice Input

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KEYWORDS

Computer Graphics, Terrain, Voice Input, Storytelling, Textures.

ABSTRACT

Computer graphics have been used for creating real and imaginative worlds by artists and programmers in mediums like games and commercial movies. Although the impact of 3D graphics has been immense, but the techniques for generating the virtual content have never become easy. As a result, the common user has remained detached from this area and people have not been able to create animated stories of their own. This paper introduces a new and novel way of storytelling by letting the users generate their own 3D content through voice input. This paper covers terrain generation and texture manipulation through voice input which helps the users define the basic scene layout of their stories. The content that is generated is currently limited; however with time, this will increase and also provide the user with more control over manipulating the generated content.

INTRODUCTION

Stories have provided entertainment to people for a very long time. A story helps users to tap into their imagination and create a world according to their liking. In the past, the better you wrote a story, the easier it was to imagine the world, the characters and the environment. Later, with the invention of paper, coloured ink and printing press, the stories were presented in the form of books where pictures were added to the stories to give a good sense of the world that the writer had envisioned. With the coming of the multimedia devices, the stories moved from books to live action movies and currently, into computer generated worlds.

We can distribute the mediums of storytelling into many forms. A story can be told verbally, through a story book or through a multimedia device like TV, cinema or a computer. However, any form of storytelling requires the user to be adept at handling one of these mediums. Only a good writer can produce a good book. A good director can produce a good movie and a good animator can produce a good animation. These skills are hard to acquire for every person which limits the extent of creativity that one can achieve.

As shown in Figure 1, this paper provides an interesting way by which the user creates 3D scenes easily without requiring any special skills except the user's voice (Fukutake et al., 2006). The basic idea is that a user starts to tell a story and the computer starts to create 3D content and animation based on the user's story. This helps the user to set up the scene for the story in which everything takes place.

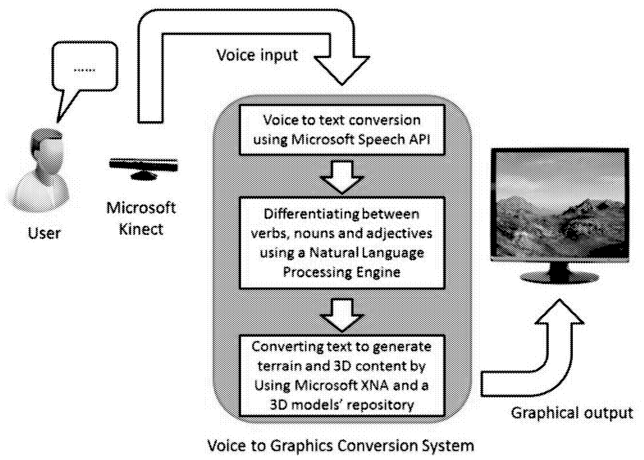


Figure 1: Software Application Overview

RELATED WORK

The closest research for this type of work has been done by Kelleher (2006) where she created the software "Storytelling Alice" as part of her PhD dissertation. The aim of this software was to help middle school students, especially girls to get attracted towards computer programming. The software provides a very easy to use tool, which is controlled by a mouse and keyboard to help the users build a story by attaching functions to objects.

It shares a few similarities with the current work as both allow the users to tell their own story. But the similarity stops there as the topic for this paper is about allowing the user to create a complete graphical animation with no knowledge of the underlying tool or programming, whereas Kelleher (2006) proposes a tool that can help users learn the basics of programming.

Coyne et al. (2010), has proposed a system called WordsEye, which converts the text into meaningful graphics. This software is mainly used for generating 3D scenes from the text that is input by the user. This is again close to the current research, but the graphics that are generated are static. They represent a certain happening in a scene, but do not represent the entire story. Coyne, Sproat, and Hirschberg (2010) have also worked on spatial distribution of objects in a scene which helps is properly setting up the objects in a scene.

The research explained in this paper takes the same concept of scene generation and implements it in real-time through voice input. This provides a great potential for using this application for educational and entertainment purposes (Greuter et al., 2003). The voice input is used for generating text that is then used for creating 3D content and animation.

TECHNOLOGY

The aim of this research was the creation of an application that provides a quick and easy way for the generation of 3D content and animation. For this reason Microsoft's Kinect device was used in conjunction with the XNA Game Development Library. Microsoft's Kinect device supports a microphone array that performs better than the ordinary microphone. Microsoft's Speech API was used for speech recognition so that the computer knows what the user has spoken.

APPLICATION DESIGN

The application consists of 2 major parts. The first part includes the acquiring of voice input from the user and translating it into meaningful text. The second part converts the text into meaningful graphics. Both parts of this application will be discussed now to show how this software works and what will be its future.

Voice Input Recognition

The first part of the application is centred on the recognition of the voice input. Microsoft's Speech API does this by getting the input from the Kinect device and then translates it into meaningful text. We first need to develop the grammar that will be understood by the GrammarBuilder class. Every word that is part of the grammar needs to be created by declaring it as a Choice object which works only with the GrammarBuilder class. Once the grammar has been completed, every word is allocated a separate function.

For the current application, there were two roles that were associated with the sound input. The first being the terrain manipulation and the second being the changing of textures in real-time. Both of these roles play a major part in the generation of the terrain as one decides the features of the terrain by creating mountains and rivers, whereas the other decides the overall theme of the terrain by changing its textures.

For making the terrain change in appearance, two common features were added to it; one being mountain and the other being river. The goal was to generate a mountain when the user utters the word "Mountain" and to generate a river, when the user utters "River". Currently the software is not a terrain shaping tool, but instead, it is a tool that creates terrain randomly, so as to reflect the user's needs.

CONVERTING TEXT TO GRAPHICS

Microsoft's Speech API converts the spoken word into text which is then used to create meaningful and accurate graphics. Every story requires the storyteller to define the scene in which the story is taking place. There can be many possibilities through which the storyteller sets up the story and the user might think of changing in between them in real-time.

As the user gives voice input, the terrain is altered and new textures are applied. Declaring the terrain as a grid of polygons has a lot of advantages, the most being that we do not need to store the actual position of all the points, but just their height maps, thus saving a lot of space (Grumet, 2004). Hence, the data structure that has been used is a two dimensional array that stores the entire height map.

Creating Mountains

There are different ways for creating mountains out of which, the methods that involve recursive subdivision produced the best results as they are linear in time (Gavin, 1986). Diamond-square algorithm is one of the most promising of such methods; it is very similar to the mid-point displacement algorithm but produces better results. The mid-point displacement method works by recursively calculating the missing values halfway between already known values and then adds a random offset to the new values inside a range which is determined by the current depth of the recursion (Olsen, 2004) as shown in Figure 2.

Whenever a user utters the word "Mountain" the application takes a small area of the terrain and changes the height maps of all of its vertices. You can see the transition of the flat terrain in Figure 3(a) to one which has mountains as shown in Figure 3(b).

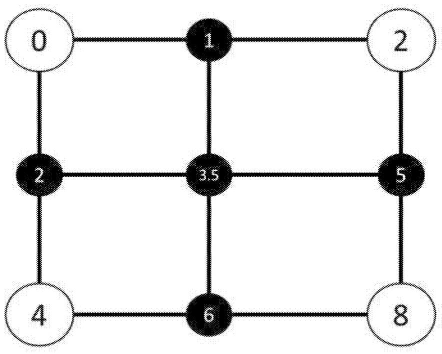
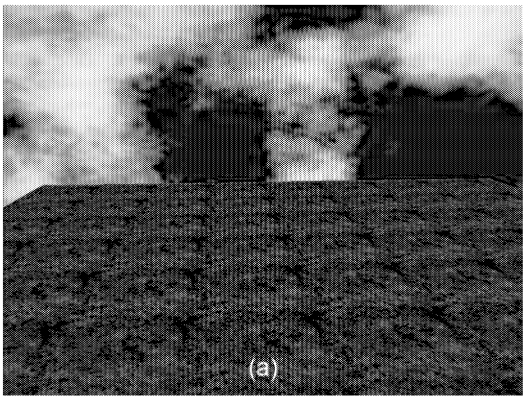


Figure 2: Diamond-square Algorithm; Allocation of Height Values to the Sub-rectangles

Diamond-square algorithm works on the concept of fractals. A fractal has a simple and recursive definition which makes it a great choice for crafting optimized real worlds on a computer. Since it is a mid-point subdivision method, it takes linear time rather than the *O(NlogN)* time taken by the Fourier filtering method (Macklem 2003).



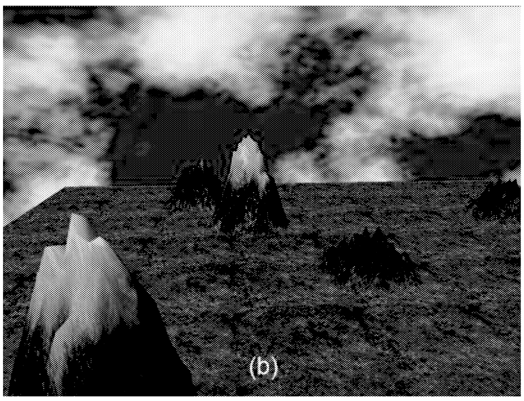


Figure 3: (a) The Initial State of Terrain (b) Mountains are Created by Saying the Word "Mountain"

Creating Rivers

Another major feature that was included in the current application was the presence of rivers. Rivers are important as they provide a distinct shape and water. Also, they provide an area of the terrain that cannot be traversed through normal means.

The user can create a river by uttering the word, "River". Cubic Bezier Curves are used to create a curving river. A Cubic Bezier curve requires four control points to approximate a curve between the four points. Another important feature of the Bezier curve is that, it always passes from the start and the end point. As a result, a line is divided into several points and then Bezier curves are drawn between the points to have a continuous winding river as shown in Figure 4.

As the river passes through land, it forms a V-shaped valley, which has a maximum depth at the middle of the river. Therefore as we move towards the edge of the river, the height decreases until it reaches the river's bank (Teoh, 2008).

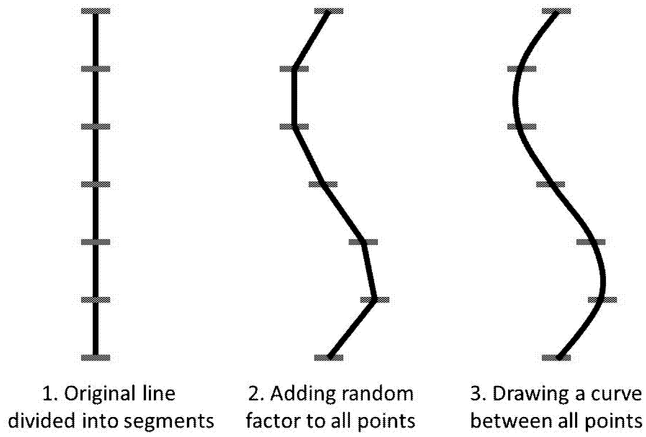


Figure 4: Creating a River Using Cubic Bezier Curves

Once the height maps of all the vertices that constitute a river have been defined, the height maps are transferred to the original terrain at a random location where the river is drawn.

Terrain Texture Manipulation

A land is composed of several land types and normally, one type of land transitions into the next type; which is more pronounced when there is height involved.

Currently, multi-textures are being used to define the different terrain types. Multi-texturing is an effect that displays two texture images on one surface. This can be done by sampling two texture images and using the colour of the first texture times that of the second texture as the final pixel's results (Sherrod and Jones 2011). By applying this technique, four different textures with separate order are passed to the vertex shader to define a terrain configuration. Similarly more texture combinations can be created and linked to a separate word for creating more terrain types.

WATER MANIPULATION

For any scene, water plays a major role in defining a landscape. Adding water to the river brings life to the entire seen and as a result the scene looks more realistic.

As soon as the first river is created, the water appears in it which is moving in a predefined direction, thus simulating wind. The user then has the option to make the water move left or right (by saying the words "left" and "right") and to increase or decrease the height of water (by saying the words "higher" and "lower").

CHANGING THE SKY TEXTURE

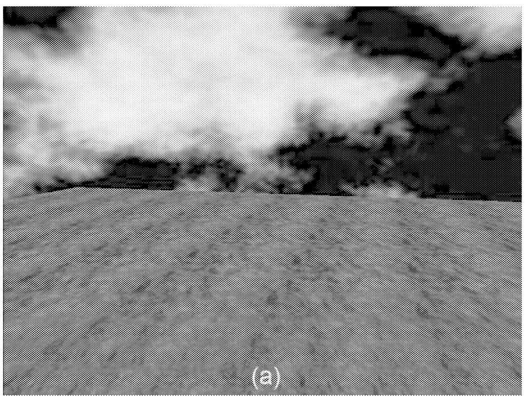
Currently, the sky is made up of 3D model, which is a half sphere. It was important to test, whether a model, when loaded into XNA can change its textures or not. It was a critical issue as many of the future implementations relied on this to work.

In future, many objects will be loaded by the software in real-time and they will all contain some default texture. The user will be given the facility to change the texture of the object in real-time.

RESULTS

Currently, the software has worked well with the amount of details that have been presented in this paper. The user starts the project with a flat surface and as the user speaks the correct words, the land changes accordingly. Most of the decisions like where a certain terrain element is generated are taken by the computer automatically. Figure 5 (a) shows the state of the terrain when a user starts the application and Figure 5 (b) shows the state of the terrain when the user has spoken the proper words. The user can define the type of terrain, the state of the weather, the direction from where the wind is blowing and the amount of water that is present on the terrain.

In future, the user will be given the liberty to make changes to the terrain at will but that will be a separate part of the project altogether.



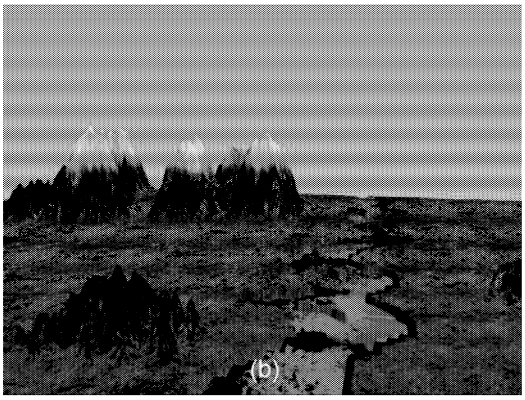


Figure 5: Changing the Default Terrain (a) to a Detailed One (b) by Changing Textures and Adding Terrain Features

FUTURE WORK

Creating 3D content through voice commands has a series of challenges that need to be overcome in future before this method for content generation is deemed viable. The current technique works on a few words only and there is no system set up that can recognise and understand a sentence.

Natural Language Processing

Words are the basic components that need to be understood for this application to work, but we cannot rely on words alone as that takes the user away from the concept of storytelling that is based on a combination of sentences.

The real question is, whether we need the computer to understand what the user is saying through a complicated natural processing technique or is there a way around it? Different sentences can have the same meaning or we can say that in English, which is the language that is being used for this application, we can convey the same meaning from two different sentences. A good example can be given from the following two sentences:

1. Mary had a little lamb.
2. A little lamb was owned by Mary.

The two sentences have a totally different structure, but they are conveying the same meaning. Most languages work the same way; so in reality, the structure is not necessary to convey the meaning, but in fact, the verbs, nouns, adverbs and adjectives play the most important role in conveying the meaning.

Now, if we look at the first sentence, the important information that we get from the sentence is the two nouns, "Mary" and "lamb" and the adjective "little". Since Mary is the name of a girl, the system will generate a general model of a girl and tag it with the name of "Mary". It will then create a general model of a lamb and make its size small as defined by the adjective "little".

The computer can ignore the other particles and words as they do not give any important information that can be used for generating a meaningful animation. The same can be said for the other sentence as the main components of that sentence are also, “Mary”, “little” and “lamb”. Again, the computer has the information about the objects that it needs to generate; only the order in which they are generated will be different. It is believed that this will not affect the overall generation of 3D content and animation.

Creating and Manipulating 3D Objects

The next stage of the project includes the manipulation of the 3D models in real time. In order to do this, a new system for the definition of 3D models needs to be designed. 3D models are a collection of meshes, but the same way for defining a model will not be suitable for the current project. It should be kept in mind that during the story a user can create any strange entity and the computer needs to follow it accurately. For example, a user can say that a horse has wings. In such a scenario, the computer needs to create a horse and then add wings to it. In order to accomplish this, the user needs to define every 3D model as a combination of 3D components as done by Yoshiyama et al. (2005). The components should exist individually and also as a combination of each other. The application will remove and attach new 3D components intelligently to keep the alteration within an object smooth.

Making Terrain More Realistic

One of the shortcomings so far has been that the terrain features like rivers and mountains do not share the same land space. If a terrain contains a river, a mountain can be generated right in the middle of it, rather than around it. Prusinkiewicz and Hammel (1993) have provided an interesting partial solution that uses the mid-point displacement method to generate fractal mountains with rivers, which will be studied more to produce a much more dynamic and realistic looking terrain.

Every terrain contains many elements and doodads like trees, rocks, stones, etc., that change the overall look of the terrain. Intelligent placement of these elements is another major area that needs to be visited. Fukutake et al. (2006) define contact constraints to setup these elements through a parent-child relationship which governs their relative placement in a 3D scene. It is quite likely that the same approach will be used for spatial distribution of objects.

CONCLUSION

When a person tells a story, a whole world is created in the listener's mind and all the characters interact in that world. This application aims to bring that imagination into the virtual world of computers, so that the listeners can not only hear the story, but experience it being created and animated visually. This opens the door for users to create stories of their own which can be used for both education and entertainment.

Using voice input for storytelling was considered to be the best choice as it is the most natural way of communication and the same was adopted for this project. As the project develops and more features are added, the gap between telling a story and imagination will be reduced drastically and people will come up with new and innovative ideas for stories and will be able to convey them to others visually.

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SIMULATION METHODOLOGY AND AI

BOCBPN: AN OBJECT-ORIENTED PETRI NET FOR CELL MODELLING BASED ON SOFTWARE ENGINEERING CONCEPTS

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Bioinformatics, Cell Modelling, Object-Oriented Petri Nets (OOPN).

ABSTRACT

Modelling is one of the main topics in bioinformatics and has emerged as an important open challenge in bioinformatics. Much work has been done in this context where it has been studied from various aspects. Petri-Nets (PN) is one of the powerful modelling tools that are used in bioinformatics. This research introduces a new Object-Oriented (OO) PN for cell modelling. The introduced OO-PN tries to incorporate the existing unique capabilities of each PN (e.g. Time concept from Timed PN) in order to present a more complete PN for modelling the cell environment. By being OO, it presents a conceptual view more in compliance with the modern software engineering concepts. In order to achieve this, the CRC cards (Class–Responsibility-Collaborator) and the concept of Role are used as the main modelling tool. A set of simple steps, incorporating all the mentioned concepts, expresses the required activities for obtaining the final model. The resulting model has the following capabilities: discrete/continuous places, timing, probability, the ease of use and re-usability. The resulting model can be especially useful to Computer Scientists who seek a PN based on Software Engineering concepts and also to bioinformatists and biologists as a common modelling tool.

INTRODUCTION

One of the challenges in biology is its complexity (Mazzocchi, 2008), particularly at the cellular level, where it is difficult to understand the functional aspect of the cell (Stephanopoulos, et al., 2004). Longtin suggested that the system biology is a relevant approach to understanding the biological complexity(Longtin, 2005), other investigators revealed that computation is a consistent solution for this complex problem (Burrage, et al., 2006); Ehrenberg et al. agreed that system biology revolutionized the biological disciplines by modeling the biosystems (Ehrenberg, et al., 2003). System biology is defined as the interaction of different hierarchy components of the biological structure resulting in coherent and dynamic systems at the cellular, tissue, organ and ecosystem levels (Burrage, et al., 2006). One of the main focuses in the system biology is the signaling in the cells through plasma membrane (Chen, et al., 2005). Computational biology deals with simulation and modeling of intracellular and intercellular events in spatiotemporal and temporal domains at different scales using differential equations, Petri nets, cellular automata simulators, agent-based models and pi calculus (Materi, et al., 2007).

PETRI NETS

Modeling can be interpreted as one of the most important aspects of the ever growing field of bioinformatics. The main reason for this interpretation is the fact that whatever resides within bioinformatics is information and thus, an underlying model must exist for building up the knowledge needed in order to solve the problems in this field. Apart form this rather philosophical view, modeling in bioinformatics eases the understanding and solves the problems by eliminating the unnecessary elements of the environment (Tarihi, 2009).
Various ways were proposed for modeling the environment, which can roughly be categorized into two main groups: differential equation-based and non-equation based models (Tarihi, 2009). The reason for this categorization is the fact that historically, the biochemical's view of the cell has been that it is a collection of complex reactions and the de facto solution for understanding the complexity is to break up the smallest and most basic reactions. Because of this, the modeling of the biochemical environment of the cell has been presented into the above two categories (Tarihi, 2009).
The equation-based models are build on mathematical basis, mainly underlying kinetics equations and tend to present a set of equations the solution of which has a biological meaning, such as a possible protein translation and so on (Tarihi, 2009).

As the term bioinformatics consists of bio and informatics and is viewed by researchers from both sides, this paper intends to view the modeling through computer science. To achieve this, the modeling method needed for this research should belong to the jargon of both sciences. The chosen method is Petri Net (PN), which is a tool used in both computer science and bioinformatics (Tarihi, 2009).
Formally, PN is considered as a directed bipartite graph consisting of transitions, places and directed arcs. The transition represents an event or an active system element. Accordingly, the circle represents the condition, and directed arc is either precondition (input) or post condition (output) which connects places with transitions.

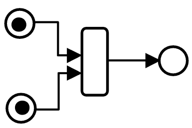

Figure 1: The circles represent places, the box represents a transition, the arrows the direct arcs and the black dots the tokens.

As the needs arose, several types of PNs were proposed: the Stochastic Petri Nets (SPN) considered the concept of probability in the PNs(Bause, 2002); the Continuous Petri Nets removed the restrictions for discrete events from the PNs; the Timed Petri Nets made the timing possible and more real-time environments could be modeled with them(David, et al., 1998); the Hybrid Petri Nets (HPN) are capable of combining both Discrete and Continuous Petri Nets for more complicated environment(David, et al., 1998); the Hybrid Dynamic Petri Nets (HDN), allowed the use of functions on continuous arcs; and the Hybrid Function Petri Nets (HFPN) integrated three PNs: HPN, HDN and Hybrid Object Nets (Troncale, et al., 2006).

OBJECT-ORIENTED AND MODELLING

Object-Oriented (OO) has been around in the Software Engineering jargon for many years. Its main concept is the objects which reflect the real entities in the environments upon which the modeled environment is created via their interactions (Pressman, 2001). For example, when a home security system is analyzed by OO methods, there are two main *classes* of objects: Sensor and Alarm. There are many objects of the sensor class, called *instances* of the Sensor class, and perhaps one object of the Alarm class. The class resembles the general type of an object whereas the object represents a real entity in the environment. In this example, the sensors sense any disturbance (i.e. opening a door) and inform the alarm; and the alarm goes on alert. In this very simple introductory example, the goal of the system is carried out by the interactions of the objects of two classes. There is much more in the OO than what is said in this paper but going deeper into it would be a diversion from the main purpose, thus we leave further and deeper discussion of OO to more professional references (Pressman, 2001).

Object-Oriented Petri Nets

Because of the influence and the concepts of OO on one hand and the importance and applications of PNs on the other hand, there have been several modelling techniques which proposed OO Petri Nets. LOOPN++, G-Nets, COOPN/2, HOONet, OOPN and OCP to name but a few (Tarihi, 2009). Mostly they add notations or modifications alongside the PN rules in order to achieve the OO concepts. The resulting PNs differ from the conventional PNs used in bioinformatics, which introduce difficulties, especially for the bioinformatists with no or little OO background. Therefore a simpler concept is needed which this research found in the use of CRC cards.

CRC card

Among the views of OO, there is a rather simple view which considers the objects as a triple of: *class* (literally represents the entity of the object), *responsibilities* (what they must do e.g. sensing breach for a sensor) and *collaborations* (the relation between the objects); thus giving the CRC name to this view (by taking the first letter of each part) (Shams Aliee, 1996). The CRC appears as a set of cards, each has three parts. The name (e.g. sensor) is written in the class part then the responsibilities (e.g. sensing the door/window open) are written in the corresponding part. For each responsibility must be seen whether the class can do it on its own or needs another object (Shams Aliee, 1996). In the home security system, the sensor needs to alert when a breach is detected, but a sensor on its own can't do that, it needs the help of an alarm class, thus in the collaboration part in front of the alert responsibility the name of the collaborator class is written. Figure 2 shows the cards for the classes.

Sensor	
- Sense breach - Alert	- Alarm

Alarm	
- Alert	-

Figure 2: Figure Shows the CRC cards for the example of the home security system. The responsibilities are written on the left side, while the collaborators are on the right side of the card.

The system modeling proceeds via identifying the classes. It stops when the set can carry out all of the goals of the system, and all the responsibilities of classes can be carried out by themselves or by the aid of some existing cards (Shams Aliee, 1996).

CRC CARDS AND PNS

The proposed PN of this study is based on (Shams Aliee, 1996). Shams has combined the CRC and PNs via the concept of Role (Shams Aliee, 1996), which can be thought as the general responsibility of one or more classes. For instance in the example of home security system, alert would be a name for the Alarm's role or Sensor would be both the name and the role for the Sensor class.

This method which will be called OCBPN throughout this paper (taken from the abbreviations of Object Collaboration Based Petri Nets) used a level called the role level, were in which the environment was captured in the form of roles via the CRC cards. Then the roles were expressed in PNs. The method consist of the following main steps (Shams Aliee, 1996):

Capturing the Roles with CRC cards: Used the cards as explained before in order to capture the roles in the environment.

Using Path Expressions (PE) for ordering the steps: Simply stated, it used a simple math-like notation in order to denote the sequential/parallelism relation between the responsibilities of a card. It combined parenthesis with the (;) sign for sequential and the (+) for parallel responsibilities. By default all the responsibilities were parallel.

Converting each CRC card into proper PN: A classical PN was used. Each responsibility was represented as a transition and connected with respect to the PE. For each (;), the transitions must occur one after the other and for (+), they must be in parallel. The places were used according to the transitions. Since the responsibilities like the real environment occurred repeatedly (e.g. biochemical cycles), the PN enclosed means that the last transition would be connected to the first.

Add collaborations: The collaborator section was the card used in drawing the relationships between the roles, which is carried out via places in the PN that were shared: Output to the first and input to the next.

Verifying the model and simulating: these steps ensured that the model met its goals in the way it meant.

As seen, once the CRC cards are understood the rest is fairly simple for this reason, the proposed PN is based on OCBPN.

THE PROPOSED PN

The BOCBPN (Bio-OCBPN), the name chosen for the proposed PN, mainly enhances the OCBPN for the modelling requirements needed for bioinformatics, i.e. the PN capabilities by supporting some of the main capabilities present in the PNs used in bioinformatics. Thus the steps are fairly the same as OCBPN. The reason behind this support is to make BOCBPN more general for modelling different situations and make the use of CRC cards available to wider audience. The supported PNs are as follows (Tarihi, 2009):

Continuous/Discrete Places/Transitions: By using Continuous and Discrete Places and Transitions, the main capabilities of HPN are supported. The same notations and rules are valid.

Time: Timing capabilities is added to the Places and the Transitions in the form of the delay needed for firing tokens from the places or the transitions. The delay is shown as a number between a pair of parenthesis.

Probability: The main requirement for this is the addition of a possibility factor to the PN noted in a pair of brackets. It is a statistical mechanism for choosing the path in the situation that the flow is not completely deterministic.

The combination might look hard at the first sight, but the following rule makes it fairly simple: Probability applied then timing. The reason behind this is because the probability determines the path to be used. Thus all the timings come after the path had been chosen. This combination gives freedom to the modelling. The same problem can be modelled in several ways in BOCBPN using the best fitting combination. The downside of this freedom is that the final model must be verified with care.

REGULATION OF G-PROTEIN

The regulation of G-protein is modelled with BOCBPN. In the inactive state, the α subunit is bound to GDP in a complex with β and γ (Alberts, et al., 2002). The hormone binding induces an interaction of the receptor with the G-protein, stimulating the release of GDP and the exchange of GTP. The activated GTP-bound α subunit and βγ complex then dissociate from the receptor and interact with their targets. The activity of the α subunit is terminated by hydrolysis of the bound GTP, and the inactive GDP-bound α subunit then reassociates with the βγ complex (Alberts, et al., 2002).

In this example and for sake of clarity and simplicity the regulation as a switching mechanism (Tarihi, 2009).

Capture the Roles with CRC cards: Since the switching is kept in mind for this example, the main roles are the Activator and Activated.

Use PE for ordering the steps: The PE for the CRC cards is shown in Figure 3.

Activator	
- (hormone binding; conformation) +	-

Activated	
- (conformation; release GDP and exchange GTP; inactivate)+	- Activator

Figure 3: The CRC cards and PEs for G-protein regulation (Tarihi, 2009).

Convert each CRC card into proper PN: The PE in the previous section translate into Figure 4. Because of the cycle, the PNs are enclosed in circles.

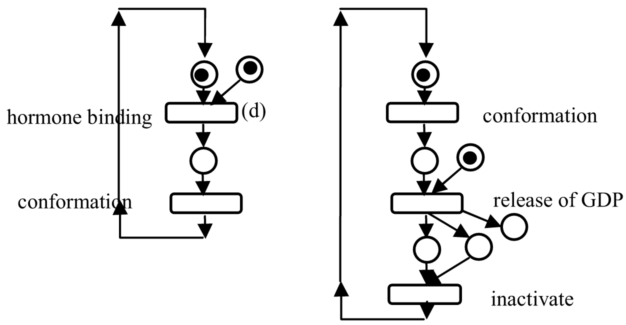

Figure 4: Shows the equivalent PN to PE using discrete notation. The Activator is on the left and the Activated is on the right. Note the delay on the hormone binding step indicating the time needed for the binding to take place. The delay

can be used on any of the steps. This time is confined only to one step (Tarihi, 2009).

Add collaborations: The responsibility of the conformation change in the Activated requires the collaboration of the Activator, thus this must be added as a shared place between them (Figure 5).

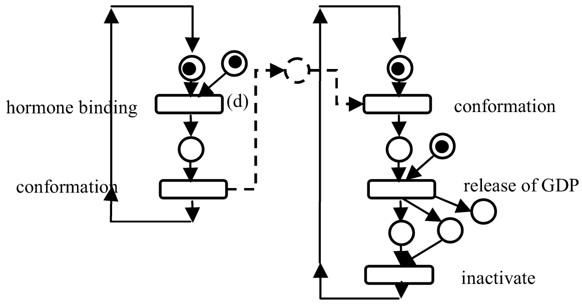

Figure 5: Show collaboration added to G-protein regulation. Note that for clarity the additional arcs and place are shown in dashed style (Tarihi, 2009).

Verify the model and simulate: The verification can be done manually. BOCBPN allows for the verification to occur in several steps: CRC cards can be checked independently, which will verify the concepts in the environment. Next for each object, the corresponding PN can be checked individually in order to check whether the responsibilities can be carried out correctly or not. Finally the PN can be checked by taking the collaborations into view, which is the final step in the verification. All these steps hold for the regulation of G-protein. For simulation, the BOCBPN can be simulated via available tools. Since the example is fairly simple, the simulation can be carried manually, which shows the correctness of the model.

DISCUSSION

There have been many PNs around in the bioinformatics, each has some capabilities for modelling. In this section the proposed PN will be compared in terms of its capabilities with HFPN, as one of the most general and powerful PNs in modelling. The HFPN like BOCBPN has taken many capabilities of other PNs (Tarihi, 2009).

Table 1: A Comparison Between BOCPN and HFPN (Tarihi, 2009)

	COBCPN	HFPN
Continuous Places/Transition	Yes	Yes
Timing	Yes, simple delays	Yes (as function or extensions like HTPN(Troncale, et al., 2006))
Probability	Yes	Yes, but implicit(as function on arc)

As shown in Table1, the capabilities expressed in BOCBPN can be achieved with HFPN, but there is one fundamental difference which is the OO nature of BOCBPN. HFPN is not OO (Mutsano, 2003), while BOCBPN is based on CRC cards and roles. Moreover, the latter has a clear conceptual view of the modelling environment via the CRC cards, and the PN can be viewed as the realization of the conceptual role-based model (Tarihi, 2009). This can both be very useful to Software Engineering or Computer Science researchers, and can potentially have a larger audience (Tarihi, 2009).

CONCLUSION

The proposed PN, can be a useful PN for modelling in bioinformatics for both bioinformatists and Computer Scientists. It uses the simple concept of CRC cards and this makes it simple to use and capable for the intended users.

FUTUREWORK

Creating tools for supporting automation in using BOCBPN is the main topic for the future work. Via good tools, we hope to attract researchers to use BOCBPN and as the applications increase, new opportunities will arise for us to expand BOCBPN's modeling capabilities.
Also, we think because of the real-time nature of the cell environment, BOCBPN might be useful as an engineering modeling tool in Real-time systems.

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BIOGRAPHY

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A Novel Approach using Hybrid Artificial Neural Networks for Prediction of TBM Performance and Disaster Risk in Complex Geological Environments

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KEYWORDS

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ABSTRACT

Due to complex geological conditions in tunneling, TBM performance prediction with risk response is highly recommended, mostly affected by conditional environments of the following: geological formation, methane explosion, landside, geological disaster, rock mass, rock property, and fractured rock mass. This study presents a novel approach using Hybrid Artificial Neural Networks for prediction of TBM performance and reduction of disaster risk in uncertain geological environments. The proposed approach is essential to predict the TBM performance, together with warning disaster risks in terms of real-time evaluation for the planning tunnel projects. In the mechanisms of this approach, all data series including uncertain values have considered through an artificial network in complex underground conditions such as rock mass, geology, lithography, and disaster in tunnel projects. The proposed approach has tested data series from tunnel projects in Japan and Asian countries. To validate the significance of the findings and show added valuable parameters of the proposed approach, the results are compared with conventional statistical methods in terms of TBM performance evaluation. In simulation results, these results are useful for engineers and technicians to predict TBM performance and reduce disaster risk in the tunneling project construction.

INTRODUCTION

In industry computer and tunnel engineering, tunneling in difficult geological conditions is one of the most challenging tasks in tunnel engineering. In recent years, Tunnel Boring Machine (TBM) techniques have been used widespread applications in tunnel constructions, which reduce overall development costs (M. and Anagnostou 2010). Geotropical condition and TBM utilization performance are essential to establish schedules and cost analysis for any tunnel project. Prediction of the TBM utilization performance, especially in long-term projects, has become very important, considering the machine parameters and ground conditions. In particular, geological effects and operational states of TBM machine performance prediction are closely related to predict TBM performance. Most methods (M. and Anagnostou 2010, Hamidi J. and J. 2010) are currently concerned with a simple function of TBM prediction performance instead of risk response. When focusing on the prediction of TBM performance, researchers have not investigated in both TBM performance and risk disaster prediction since uncertain conditions are not concurrently combined in these approaches. For a good example of tunneling projects from Higashimurayama district and Huyiki town in Japan (Copur M. and Bilgin 2012), a methane explosion occurred in June 28, 1978 in mudstone tunnels of Higashimurayama district, was occurred in accident for nine workers died and two people injured. To conclude this points, the lack of these approaches' performance and disaster risk prediction in real-time, leads to new problems in geological grounds since a TBM is used in a place from the beginning project may occur by disaster risks. In addition, with more accurate predictive TBM performance and better forecasting of risk response, accurate planning and cost estimation is significant for the project construction.

This study presents a new approach using Hybrid Artificial Neural Networks for prediction of TBM performance and reduction of disaster risks in complex geological conditions. The proposed approach is essential to evaluate the TBM performance and disaster risk for the planning and management of tunneling. The novelty of the proposed model in performance prediction with reducing disaster risks are possibly to take into account the ground conditions specially geological behavior while including the complexity of machine operational parameters. To validate the proposed approach‘s performance, the simulation results are validated with data series in projects and compared with conventional statistical methods in terms of penetration rate. In addition, the proposed approach has been tested in experiments using various data series from tunnel projects through case studies in Japan and Asian countries for improvement of the effectiveness in this model performance and reduction for tunneling disaster risks.

RESEARCH BACKGROUNDS

Tunnel owners and their engineers need to make realistic estimation of TBM performance as a basis for project planning, choice of tunneling methods and scheduling. TBM performance prediction is crucial for contractors when selecting equipment and tendering, as mistakes or misjudgment can have serious consequences both for their profit and for the overall success of the project Zhang K. and X.Lai (2010).
A Penetration Rate (PR) M. and Anagnostou (2010) is the ratio of actual distance drilled to the time involved in continuous drilling and support errection is dependent closely on the speed of cutter head it represents the penetration speed of boring machine cutter into rock with boring and express as millimeter per rotary of cutter head (mm/rotary) or meter per hour (m/h).
In real-wold problems, there are many potential sources of geological and geotechnical risks in TBM tunneling which should be taken into account while decision-making for TBM selection. The possibility of encountering hard and abrasive rock, gassy and sticky ground, fault zones, squeezing mixed face, and high water inflow should be highlight risks. The encountered geological conditions required TBM operation to change frequently from hard rock to soft, and dry to wet are possible to occur risks when TBM excavated. Risks in tunneling categorised into two components: Amount of damage $\boldsymbol{D}$ and possibility of risk occurrence $\boldsymbol{W}$, as calculated by $\boldsymbol{R} = \boldsymbol{W} \times \boldsymbol{D}$.
Hybrid Artificial Neural Networks (ANN) including in Self-organizing Maps (SOM) (Kohonen 1995) and Neural Networks (NN) (Du 2010) have emerged as new tools for analyzing uncertain geological problems. These techniques allow generalizing from a pattern in data series with supervisor and unsupervised training.

PROPOSED APPROACH

The proposed model for TBM utilization and performance prediction in complex underground conditions is depicted, as shown in Figure 1.
The components of the proposed model can be described as follows:

1. Data series and refined parameters: Data and necessary parameters are refined to the needs of TBM performance.

2. Knowledge Base: The database consists of data series and fuzzy rules needed to calculated in real-time. All consequent data series and rules can be retrieved from the existent knowledge and updated new rules to the Knowledge Base.

3. Hybrid Artificial Neural Networks: an integration of fuzzy reasoning evaluation with SOM and NN to optimize TBM utilization and prediction performance.

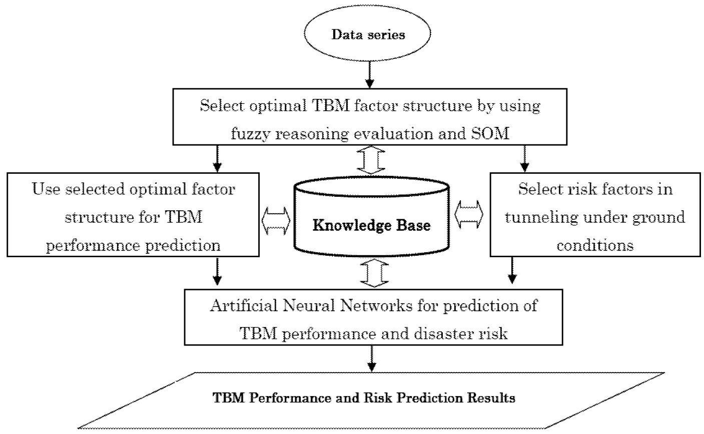

Figure 1: Overview of the proposed system

Steps of mechanisms of the proposed approach are described as follows:
Step 1. Select parameters by influencing to TBM performance and risk . To optimise significant parameters of the TBM, we apply fuzzy reasoning evaluation model, together with expert preferences by SOM visualization. The map shows groups of these parameters influencing the TBM utilization and performance.
Step 1.1. Use selected factors for optimal TBM performance prediction and risk. Data series including geometry conditions, rock properties, and TBM operational parameters consider from the TBM in tunnel projects.
Step 1.2. Normalise data sets for preparation of clean data and update in to the Knowledge Base. To predict a TBM performance and utilization based on an evaluation of quantitative factors, quantitative factors consist of data series weights obtained from a TBM tunneling to normalize these weights in interval values in the range [0,1]. To set the quantitative weighting for the TBM we apply a Sigmoid function.
Step 2. Apply fuzzy reasoning to adjust factors influencing to TBM performance and uncertain risk. Uncertain complex underground conditions change according the parameters so rules consider an environmental conditions in tunneling.
Step 3. Use Artificial Neural Networks (NN) and SOM with fuzzy reasoning for training data sets. Unsupervised and supervised of the NNs and SOM training is to predict TBM performance and uncertain risk in tunneling.
Step 4. Update rules in Knowledge Base and screen results To adapt with new situations in complex underground conditions in tunneling the proposed system updates new rules and uses existent rules in the

Knowledge Base.

Step 5. Experimental results in simulations to validate the method. To refine the model and validate the system performance, system results are compared with other statistic methods in terms of TBM performance and risk response.

HYBRID ARTIFICIAL NEURAL NETWORKS AND DATA PROCESS

Regarding the Step 1 and 5 above, this section aims to describe mechanisms of data process using Hybrid Artificial Neural Networks integrated with fuzzy reasoning evaluation model, to predict TBM utilization and prediction.

Fuzzy Reasoning Evaluation model for optimal parameters under uncertain conditions

This section provides tunneling engineers with a fuzzy reasoning evaluation model to choose a particular assessment system depending on available input data sets. In TBM of Enzan Kobou‘s projects in experiments, all parameters are independent, consisting of hundred parameters. However, some of parameters are strongly corrected in terms of TBM performance evaluation.

Qualitative factors are getting from the TBM, evaluated by experts and expert preferences are rated within a five point 1: very satisfy, 0.75: most satisfy, 0.5: neutral, 0.25: little satisfy, 0: not satisfy. Fuzzy reasoning can be described in fuzzy sets, such that the membership of an element ranges over the unit interval value 0,1. Fuzzy proposition is a concept of fuzzy logics, allowing input-output relationships via fuzzy IF-THEN rules and representing expert reasoning in terms of TBM factor evaluation. We use logical rule expressions and inference that encapsulate common preferences among group members under uncertain values of the machine in tunneling environments.

Let $C^S = \{C_1^S, C_2^S, ..., C_n^S\}$ be a set of machines in tunnel project S, where n is the numbers of machines in tunnel project S. Let $f^S = \{f_1^S, f_2^S, ..., f_l^S\}$ be a set of qualitative factors in TBM using in tunnel project S, where l is the number of qualitative factors. Factor f_j^S is evaluated by expert preference so that each factor has a different significant factor degree. Let $I^{C^S} = \{I_1^{C^S}, I_2^{C^S}, ..., I_l^{C^S}\}$ be a set of factor weight states of a TBM. Let $R^{f_j} = \{R_1^{f_j}, R_2^{f_j}, ..., R_m^{f_j}\}$ be a set of fuzzy rules, where m is the number of fuzzy rules. These fuzzy rules represent by the tunneling environment and TBM parameters of the *j-th* factor f_j^S affected by $R_i^{f_j}$ to evaluate a machine based on expert preferences.

Let R_i^0 and $R_i^{f_j}$ be defined by $\mu_{R_i}^0$ and $\mu_{R_i}^{f_j}$ initial-stage and environmental-sage fuzzy membership values, respectively. A form of rules can be presented as follows:

IF $R_1^{f_j}$ AND $R_2^{f_j}$ AND...AND $R_m^{f_j}$
THEN Update weights in $I_j^{C^S}$ of the Knowledge Base.

where m is the number of fuzzy rules assigned by expert preferences and the fuzzy membership values are defined in Table 1.

Table 1: Expert scale representing by fuzzy weights

ID No	$\mu_{R_i}^{f_j}$	Expert scale
1	1	strongly agree
2	0.75	agree
3	0.5	almost agree
4	0.25	almost oppose
5	0	oppose

Note that $0 < \mu_{R_i}^{f_j} < 1$ means fuzzy membership values evaluated by expert preferences of $R_i^{f_j}$ updated its status in I_j^S with severity $\mu_{R_i}^{f_j}$ fuzzy membership values.

In the inference process, fuzzy rules represent by the underground tunneling conditions of the factor f_j affected by $R_i^{f_j}\,(i = 1, ..., m)$ to evaluate machine C_i^S based on expert preferences. The weight $w_{C_i}^j$ is expressed by Eq.1.

$$w_{C_i}^j = \mu_{R_i}^0 \otimes \mu_{R_i}^{f_j} \tag{1}$$

where $\otimes$ is a *t-norm* operator.

Hence, $I_j^{S*} = w_{C_i}^j$ is the membership value of factor f_j^S that use to evaluate machine C_i^S in the Knowledge Base.

Unsupervised Learning using Self-organizing Maps integrated with Fuzzy Reasoning Evaluation model for disaster risk forecasting

Let $\Gamma = \{\Gamma_1, \Gamma_2, ..., \Gamma_n\}$ be a set of disaster degree, where n is the numbers of degree scales in uncertain tunneling environments. Suppose that $D^S = \{D_1^S, D_2^S, ..., D_m^S\}$ be a set of disaster symposiums in tunnel project S, where m is the numbers of disaster symposiums. For example, popular disaster symposiums are in the following of tunneling: fire, compressed air explosion, methane gas explosion, defective workmanship, flood, and landside.

To predict disaster risk in tunneling, disaster symposiums distance $P_{D_i \to D_j}^S$ is represented by g_{ij}^t, calculated from disaster symposiums attribute distance v_{ij}^t, affected by fuzzy rules as evaluated by expert e_i^S at iteration t and the disaster TBM attribute distance weight $w_{\xi j}^t$ of the disaster symposium.

Rule *t*: **IF** *TBM tunneling Conditions B* **AND** *Other disaster risk conditions* **THEN** Calculating disaster risks with an aggregation of affected factors' weights, as expressed by Eq.2.

$$g_{ij}^{t+1} = g_{ij}^{t} + \Gamma_i^S(\| \frac{1}{T} \sum_{\xi=1}^{T} w_{\xi j}^t - v_{ij}^t \|) \qquad (2)$$

where T is the numbers of disaster symposiums in a tunneling project.

Supervised Learning using Neural Networks integrated with Fuzzy Reasoning Evaluation model for TBM performance prediction

Let $X = \{X_1, X_2, ..., X_n\}$ be a set of input factors, where n is the numbers of input factors in a machine. Let $y = \{y_1, y_2, ..., y_n\}$ be a set of output factors, where n is the numbers of output factors in a machine.
The Neural Networks (NN) topology of the proposed model consists of three layers (*m:v:d*), where m is the numbers of input variables, v represents neurons in the hidden layers, and d is an output variable.

EXPERIMENTS IN CASE STUDIES

In experiments, the proposed system has been tested in case studies of tunneling projects in Japan and Australia for the period of 2010-2011. Steps of the proposed system were carried out in the experiments as follows: 1) Data series getting from TBM were clean and normalized in interval values [0,1]; 2) These data sets were visualized by SOM integrated with fuzzy reasoning evaluation model, together with expert preferences, to select influencing factors in terms of TBM utilization and prediction; 3) Optimal factors including input and output parameters were placed in the NN structure to predict Penetration Rate (PR); 4) Experimental results were compared with an actual statistic evaluation in terms of TBM performance prediction.
In experiments, senior experts from tunnel projects of Enzan Koubo company were responded surveys with TBM factors in international projects. With expert preferences in evaluation of Penetration Rate (PR), the system result showed significant factors influencing to PR, as shown in Figure 2.
In the NN structure, there were 10 factors used in input pasterns and PR was the output parameter. The NN topology was tested in tunnel projects with real-world data sets. To establish an optimal NN that can be used for predicting PR in terms of TBM utilization and prediction, the model needs to design for training and testing with data series. In NN topology, during the learning phase of these experiments, the decrease of the error as a function of time is controlled for both training set and testing set in order to avoid data overfilling. To overcome this, the data set was randomly separated into types of data: the training set about 83% for generating the model and the testing set 17% for checking the generation capability of the model. In simulation results, the proposed system can be viewed in various

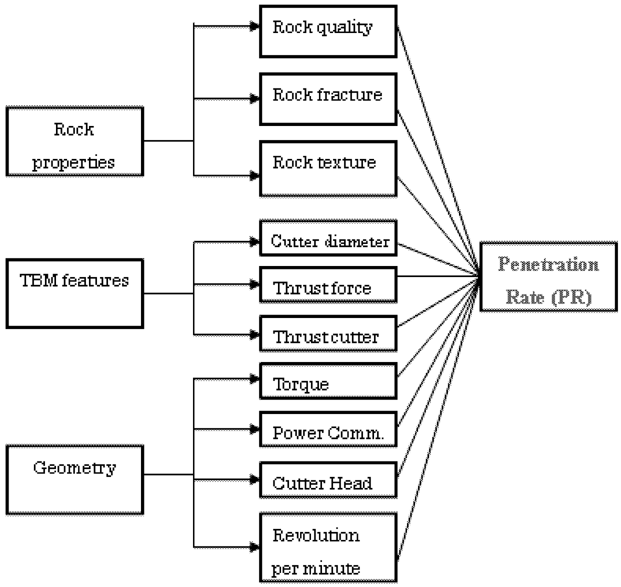

Figure 2: Factors influencing to penetration rate of TBM performance

dimensions for prediction pattern of PR in data series, as depicted simulated results in Figure 3.

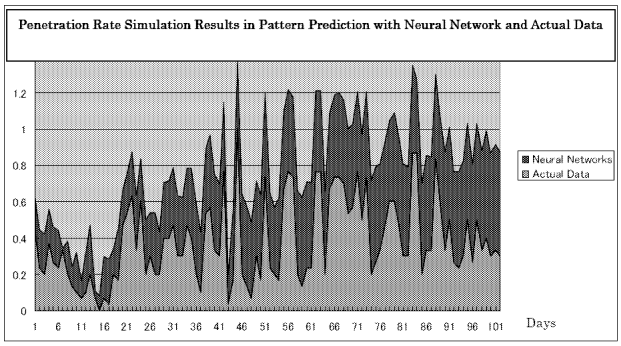

Figure 3: Pattern Simulation Results of Penetration Rates using NNs with actual data sets

When running the proposed system, we have tested data sets influencing to gas explosion, compressed air explosion, and land side. Figure 4 shows simulation results of disaster risks based on the time lines in tunneling.

RESULT DISCUSSIONS

The proposed system performed and tested in Enzan Koubo tunnel projects in Japan and Australia. In simulation results, it is confirmed that ANN has successfully used for predicting surface settlements and rock mass in the projects. To evaluate model performance in terms of PR the proposed approach has been estimated by using the NN of Root Mean Square Error (RMSE). The

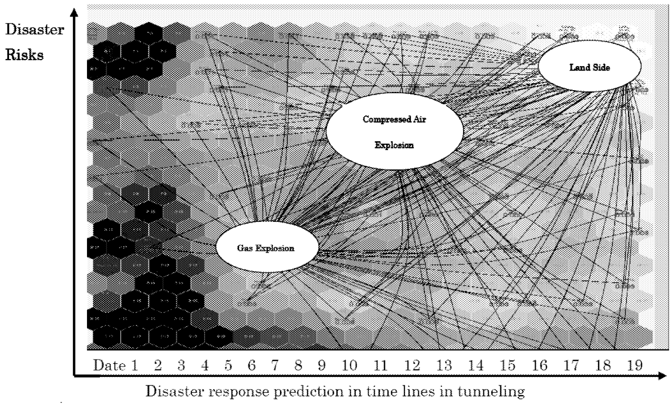

Figure 4: Disaster response in simulation results

definition of RMSE used to predict PR is expressed by

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(O_i - V_i)^2}{M}} \quad (3)$$

where M is the number of patterns in the testing set, O is the output, which presents predicted value by the NN and V is an actual value measured in the tunnel projects.
To assess the generalization capability of the proposed model, a static approach was developed, mostly based on conventional TBM performance in tunneling estimation of data series. The static approach was calculated from TBM data series in the past so its performance was predicted in short-term prediction within few segments of tunneling projects. As compared with the static model, the proposed model was performed the same data sets under the same underground conditions. As can be seen in Table 2, the RMSE indicates that the proposed approach performs better than statistic's model in terms of PR prediction.

Table 2: Comparison by RMSE of the approaches

Project location	**Approaches**	
	Statistic Approach *Avg.Training* \ *Testing*	Proposed Approach *Avg.Training* \ *Testing*
Japan	1.22 \ 2.01	0.28 \ 1.01
Australia	1.32 \ 2.32	0.32 \ 1.31
Asian countries	1.28 \ 2.12	0.25 \ 1.34
Avg.RMSE	1.27 \ 2.15	0.28 \ 1.22

The experimental results consistently show that the proposed approach performs better than the conventional statistic model's. In experimental results, we have also figured out that fractures in the rock mass have a major impact on TBM performance in geological conditions in tunneling. A reasonable estimate of the time to excavate the tunnel length and the cost of excavation become deciding factors for the prevailing geological conditions of the ground along the tunnel.

CONCLUSIONS AND FUTURE WORKS

In this paper we have presented a novel approach to enable the improvement for capability of the TBM performance prediction and reduction of tunneling disaster risk. The proposed approach is predicated on real-time data sets in tunnel projects under uncertainty in underground conditions; such conditions can be driven by complex TBM and geological factors. The proposed system provides an effective basis upon which the dynamic and sophisticated tunneling conditions which projects can be managed and planned. The experimental results in simulation results demonstrate that the proposed approach is capable of predicting TBM performance and disaster risk.

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Hybrid Intelligent Decision Support System Model for Simulation of Disaster and Weather Forecasting

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KEYWORDS

AI in simulation, Self-Organizing Map, Disaster Risk, Weather Forecasting, Decision Support Systems

ABSTRACT

A large number of disaster-related DSS models have been developed as part of disaster management activities involved with decision making that can handle a single model of disaster situations. Limitations of these current approaches include that they are applied in specific disaster areas with only a single function. In addition, these approaches have not aggregated expert sensibilities and preferences, weather consequences and environmental phenomena, together with real-time data sets. This paper presents a new framework integrated by DSS, called Hybrid Intelligent Decision Support Systems for disaster management by aggregating multiple expert decisions, aiming for the appropriate decision and reducing risk pre and post disasters. This framework can be used to forecast in disaster and weather in complex geological environments of a tunneling construction.

INTRODUCTION

In recent years, scientists and researchers have investigated conventional DSS models for particular individual disaster categories, one of the basic solutions in disaster decision support system in theory and practice. A large number of disaster-related DSS models have been developed as part of disaster management activities involved with decision making that can handle a single model of disaster situations. Limitations of these current approaches include that they are applied in specific disaster areas (Petrez and Cabrerizo 2010, Amir H. K. and J. 2011). All major managing disaster activities are required for decision-making needs under uncertainty. In recent years, scientists and researchers have investigated conventional Decision Support System (DSS) models for particular individual disaster categories, one of the basic solutions in disaster decision support system in theory and practice.

The purpose of this proposed research is to solve the existing problems by encompassing all aspects of disaster and weather forecast for responding to pre and post managing disaster activities, such as prevention, hazard preparedness assessment, vulnerability analysis, disaster risks, mitigation plans, emergency responses, resettlement issues and recovery in managing disaster activities. The main contribution in the proposed research is to present a new framework integrated by DSS, called Hybrid Intelligent Decision Support Systems for disaster management by aggregating multiple expert decisions, aiming for the appropriate decision and reducing risk pre and post disasters. The motivation of the proposed study is to dynamically integrate dynamic DSS models based on various disaster management issues, aiming for the best decisions in complex disaster situations. In the mechanisms of the proposed approach, Self Organizing Maps integrated with fuzzy reasoning to aggregate expert sensibilities and preferences, ecological consequences and environmental phenomena, together with real-time data sets. As compared with conventional weather disaster management, we can combine multiple DSS models for solving complex situations of weather disaster in nature.

To confirm the model's performance, the proposed approach has been tested and performed well in simulation results, through disaster data sets. The experiments in simulations show that the new approach, applying Hybrid Intelligent DSS improves the capability of quantitative prediction as well as dynamic disaster evaluation.

PROPOSED APPROACH

The proposed framework using Hybrid DSS for weather disaster forecasting and system architecture is shown in Figure 1 and 2.

The components of this framework can be described as follows:

1. Data series and expert preferences are considered in real-time under uncertain disaster environments.
2. DSS techniques and SOM integrated with fuzzy reasoning are main process in the proposed framework.
3. This framework is expected to forecast pre disaster, post disaster and disaster in complex situations.

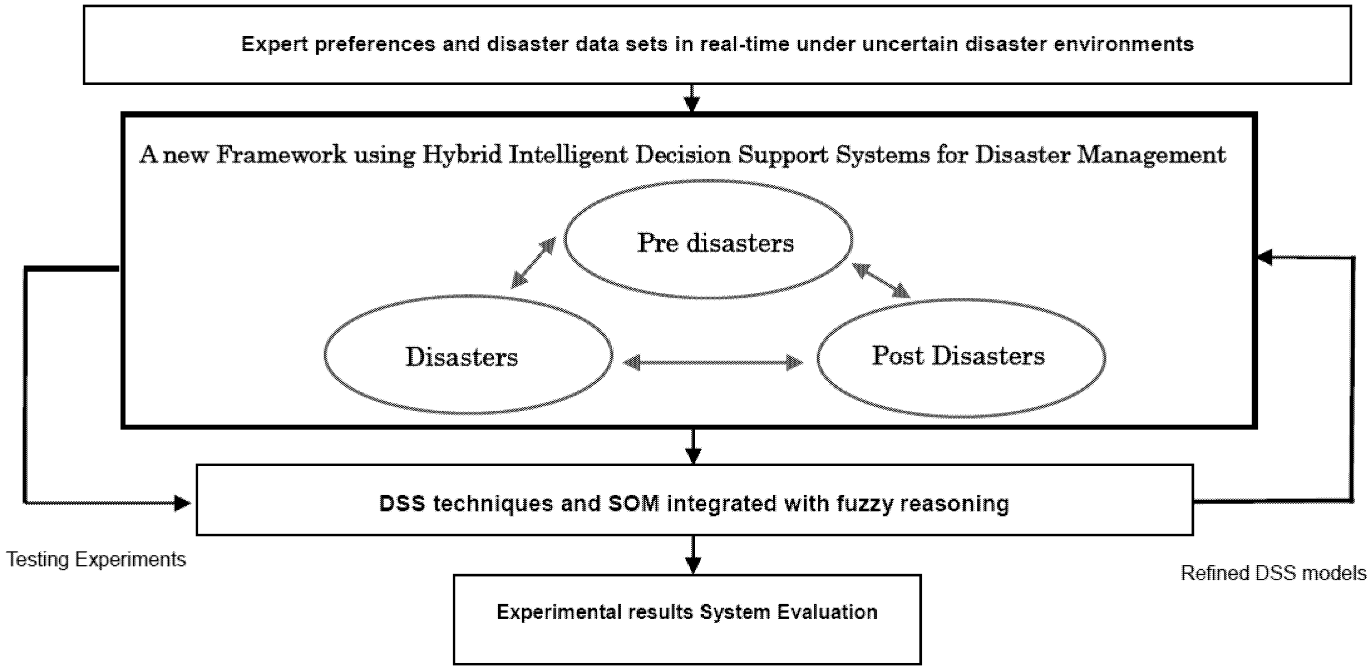

Figure 1: Framework using Hybrid Intelligent DSS for Weather Disaster Forecasting

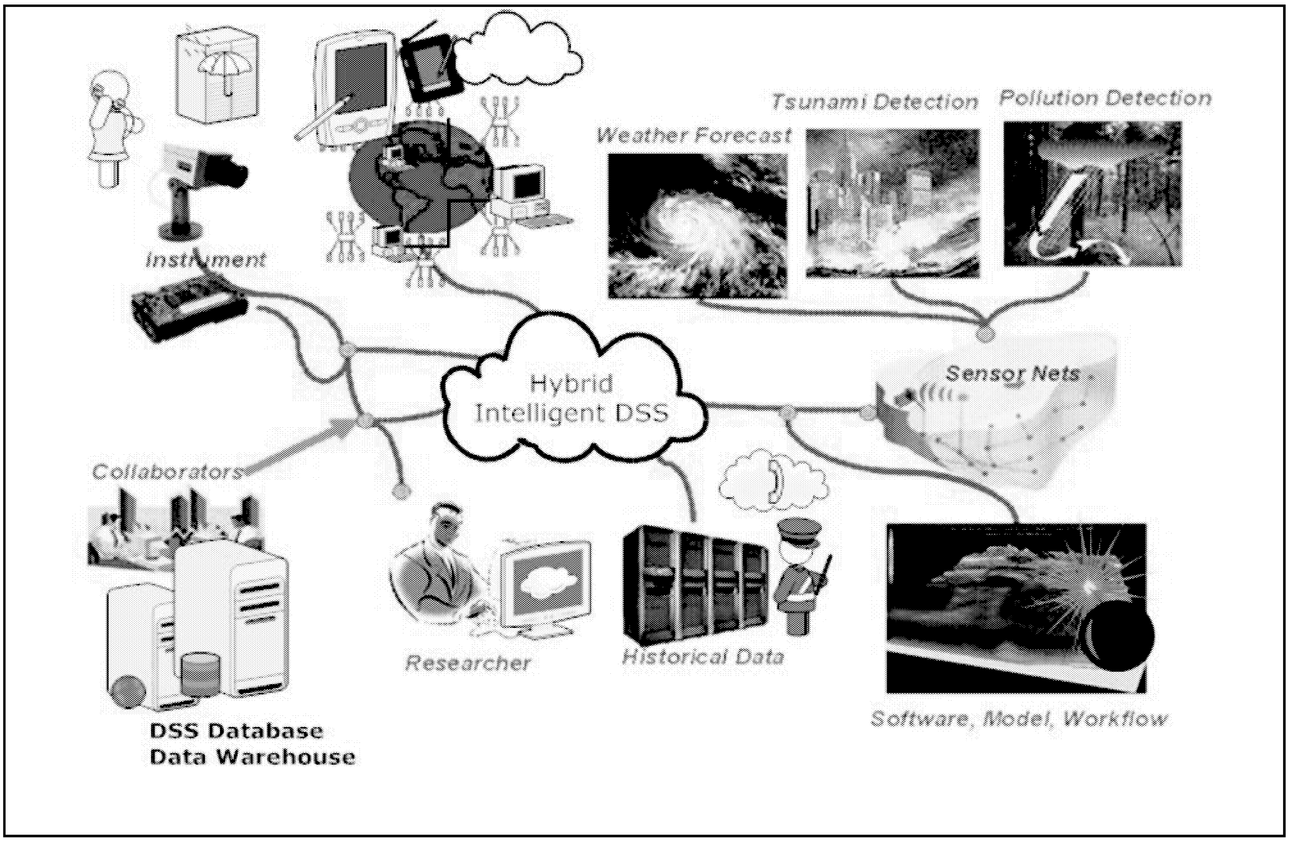

Figure 2: The proposed system architecture of Hybrid Intelligent DSS

Mechanisms of the proposed framework using Unsupervised Learning using Self-organizing Maps integrated with Fuzzy Reasoning Evaluation model for disaster risk forecasting

Let $\Gamma = \{\Gamma_1, \Gamma_2, ..., \Gamma_n\}$ be a set of disaster degree, where n is the numbers of degree scales in uncertain tunneling environments. Suppose that $D^S = \{D_1^S, D_2^S, ..., D_m^S\}$ be a set of disaster symposiums in stage S, where m is the numbers of disaster symposiums. For example, popular disaster symposiums are in the following of tunneling geological features: raining, typhoon, compressed air pressure, and flood..,etc.
To predict disaster forecasting in stage S, disaster symposiums distance $P^S_{D_i \rightarrow D_j}$ is represented by g^t_{ij}, calculated from disaster symposiums attribute distance v^t_{ij}, affected by fuzzy rules as evaluated by expert e^S_i at iteration t and the disaster attribute distance weight $w^t_{\xi j}$ of the disaster symposium.
Rule *t*: **IF** *Weather Conditions B* **AND** *Other disaster conditions* **THEN** Calculating disaster symposiums with an aggregation of affected factors' weights, as expressed by Eq.1.

$$g^{t+1}_{ij} = g^t_{ij} + \Gamma^S_i(\parallel \frac{1}{T}\sum_{\xi=1}^{T} w^t_{\xi j} - v^t_{ij} \parallel) \qquad (1)$$

where T is the numbers of disaster symposiums in a tunneling construction side.

RESULT DISCUSSIONS

In experiments, we have tested with real-data sets obtained from conventional weather systems from tunneling projects in rural areas. In simulation results, the experimental results show that all weather consequences and environmental phenomena are quantified in the system in the rand of uncertain fuzzy weight [0,1]. Based on these weights, the proposed system uses to visualize weathers and disasters dealing uncertain conditions in weather environments. The proposed system provides dynamic evaluation in terms of managing disaster activities. For each iteration time, we aggregate clustering weights with a simulation result as shown in Figure 3. The simulation result is shown in a weather forecasting and dynamic evaluation.
In simulation results with various data sets of weather, one of the primary tasks of the model forecasting is to perform model integration which consists of combining existing DSS models and components. It involves tasks such produce effective decision making in disaster management that can also easily maintain adaptiveness, special consideration is given to the modular approach for the development of decision support systems for disaster and weather forecast. This model attempts to support a complex decision making process in a disaster forecasting and management environment by providing the

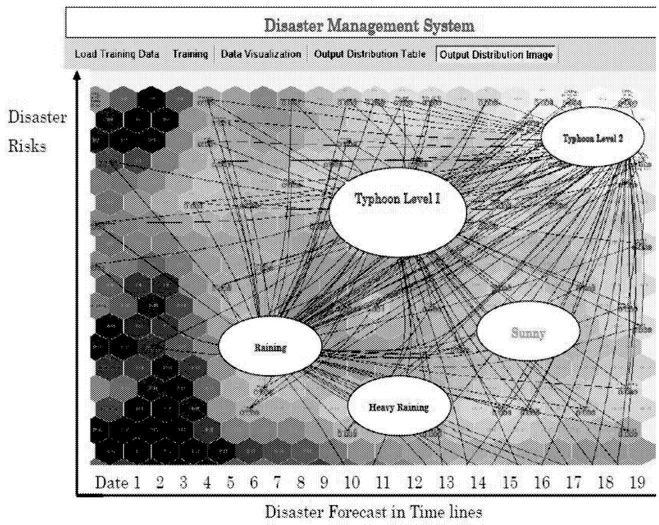

Figure 3: A sample result of combined multiple weight calculation for disaster and weather forecasting

ability to select modular subroutines to make a dynamic model.

CONCLUSIONS AND FUTURE WORKS

In this paper we have presented a new framework for disaster and weather forecasting. This methods can combined both expert preferences and sensibilities with intangible and tangible information in real-time. In further work, the proposed model can be extended for solving all significant natural signals, intangible-disaster events and ecological-phenomena consequences are quantified by using fuzzy random variables, fuzzy cognitive map, and *Kansei* evaluation in the proposed system, together with learning behavior data set sequences to forecast/plan response disaster emergencies.

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LATE PAPER

KNOWLEDGE PRODUCTION AND SURVEILLANCE IN GAME COMMUNITIES THE PRACTICE OF THEORYCRAFTING

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ABSTRACT

The aim of my paper is to investigate theorycrafting, a cultural practice of gaming communities, to contribute to conceptual debates and the dynamics of participation in this specific field. Theorycrafting describes a process of reverse engineering, a process of extracting design "blue prints" to understand a technology better, whose design is not accessible. This paper tries to investigate which understanding of theory and science is central in the practice of theorycrafting. Theorycrafting can be understood as the desire of players to gain control over the game and share this knowledge with other players. The production of knowledge for the community leads to tools that are used to improve the playing skills but can also be described as tools for surveillance.

INTRUDUCTION

Control and agency are relevant topics discussed in this article. The community investigated here are theorycrafting communities and observations made in the Massive Multiplayer Online Role-Playing Games (MMORPG) *Ragnarok*, *World of Warcraft* and *Aion*. The term theorycrafting is used to refer to data analyses made by players of MMORPG as an important means to control the game and to improve their own gameplay. As for most games the underlying algorithms are not accessible to the players, they develop hypotheses based on their playing experience.

THEORYCRAFTING

The term theorycrafting has been coined by players of the MMORPG *Starcraft* as a result of ongoing debates among players about gaming strategies. Theorycrafting has been applied to all MMORPGs on the market. The analyses based on players' experiences and testing of strategies in the game world has not only led to a vivid discussion but also to the application of mathematical formulas to gain an insight into the underlying game mechanics and algorithms. The algorithmic basis of games and the abstract rules hidden behind the visual representation of the game worlds is made visible in the way theorycrafters engage with the game. Glas (2010, 121) calls this "hyperproductive demystification". Glas (2010, 150) shows that "play moves away from fictional and social play practices to a more 'bare bones' approach where play engages the inner, instrumental core of the game's design." Theorycrafters increase the cognitive skills, abstraction and understanding of mathematical formulas, generalization, collective problem-solving, as well as the use of online networks. The approach to games theorycrafters develop can be described as scientification of gameplay.

SCIENTIFICATION OF GAMEPLAY

Scientification of gameplay refers to a positivist approach to science based on quantitative methods. There is a dominant trend as described in Paul (2011) to prioritize quantitative data and rely on statistics. It is interesting to observe how theorycrafters "like science" and engage with the game in a different way than most players would do. Theorycrafting has been described as a meta-gaming activity. Players collect data to analyze them outside the game and engage in discussion about their results. Theorycrafters set up experiments in the game and thereby in a controllable environment, they collect data over an extended period of time, analyze the log files stored while playing after their experiments and apply quantitative methods to the data collected. Theorycrafters develop a better understanding of the game they play but also knowledge about methods as data mining, experimental set ups, the analysis of data and generalizations based on them. Thereby they improve their research skills. Theorycrafting is one practice that shows an engagement with data as part of a leisure activity. Theorycrafters implicitly understand science as finding "the truth" behind the game and develop formula for a truthful and correct understanding of the game mechanics. A critical approach to science and the methods used is lacking.

Do we follow Aristotle's distinction between *episteme*, *techne* and *phronesis* we can observe a difference in the practice of theorycrafting and the discourse about this practice followed by theorycrafters. Knowledge is understood here as *techne* and a practice. It is understood as context-dependent as the results change with every minor change of the game and are therefore variable. However the results are presented as *episteme*, as scientific knowledge, invariable in space and time by choosing mathematical formulas to generalize the findings. *Episteme* has also been translated as theory or scientific knowledge. This translation emphasizes certainty. Conducting experiments as theorycrafters do could be understood as *techne* and craft. The concept *theorycrafting* includes both aspects already. The formula developed by theorycrafters are presented as results based on analytic rationality and are used to develop successful strategies for playing. Theorycrafters are aware of this distinction as they reflect on it when being asked why they publish these results on forums and thereby make them accessible and usable for everyone. The answer, why they share the information and not keep it to themselves to have an advantage in game, is that the knowledge about the formulas does not already mean that a player has the skills to apply them. The *episteme* is made accessible but the *techne* has to be developed individually. *Techne* and *phronesis* are closely related as *phronesis* refers to transferability of knowledge. Following Flyvbjerg and his discussion of the third approach to knowledge, *phronesis*, we can discuss the effect theorycrafting has on the community. *Phronesis* concerns values and involves judgement. Aristotle describes it as a guide for practitioners to make choices and support problem-solving. He understands phronesis as the most important of all three approaches to knowledge production as it feeds into practice. The transferability is relevant here as well as specific, context-dependent knowledge.

TECHNE

Techne is not only a specific understanding of knowledge related to practice but can also be translated as craft or art. The practice used here is reverse engineering, which is based on data mining. The data are collected through experiments made in the game environment. The log files of the game provide data for the analysis of theorycrafters. The knowledge collected through those experiments and the analysis of a huge set of data enable a better understanding of the game mechanics and as a result of are used for customization of the player's strategies. Players engaging in theorycraft use the game as a laboratory. One experiment made by a Korean theorycrafter in the game *Aion* was conducted 950.000 times with a minor variation. Dependent on the goal of the theorycrafters variables are changed slightly as for example stats, the use of equipment and weapons. After the description of the experiment and after its results had been translated to English by the theorycrafting community, French players partly repeated the experiments to verify the results and to take the changes in the game into consideration after a new patch had been released. Small groups on English European servers also tested equipment in game to see whether those calculations are correct. The log files had been analyzed and compared. Outside the game and based on the collection of data theorycrafters generalize their results, develop mathematical formulas and make them accessible to the gaming community. The data collected are used to formulate hypotheses how the game world works. As Mortensen (2008: 220) puts it:

> mastering the game is not submitting to the game: it is to know it so well that the game no longer controls the player.

Theorycrafting is one option to control the game. The information provided by theorycrafters helps players in their decision-making processes.

PHRONESIS

As the knowledge gained is made available to the player community on forums, wikis and YouTube videos (game guides, suggestions how to develop a game character) it is distributed for and used by other players as well. Those guides and suggestions are discussed and in case that other experiments show different results those guides are modified. The assumptions are further tested through empirical studies in the games to try out strategies, change the game character's skills and equipment. The knowledge published in those guides and videos has become obligatory for players in high-level guilds. Belonging to a high-level guild does not only mean to play the game regularly but also to keep track of material published about the game and those results from theorycrafting. As MMORPGs are updated regularly this knowledge is considered necessary for skillful gameplay. Paul (2011) states that "theorycraft is a productive discourse that reshapes play [...] Theorycraft extends play and centres gamers, rather than developers, as authorities in a discussion" how the game works. The results from theorycrafting are taken as binding and necessary for the decision of a player how to develop the own character, which skills and equipment to choose. As Paul clearly shows, this changes playing. Playing the game is not anymore about having choices how to play but about making the right choice. The guides and discussions published have the function to teach other players with less expertise how to play the game "correctly".

> Unlike the live role-playing and dice rolling that happens in a traditional RPG, videogames like *WoW* are ultimately inflexible and rule-governed. The intent of theorycraft is to divine these rules and present them as math equations. Once the right answers are attained, there is no need for or possibility of a saving roll, the discourse surrounding *WoW* shifts from a focus on fun or options to figuring out which choice is 'right'. (Paul 2011)

The effect is that not only control over the own gameplay is gained but furthermore the gameplay and choices of those, who want to reach the end-game content are streamlined.

CONTROL

Control and streamlining can be observed when high-level guilds recruit new members. The character's equipment and the player's experience in MMORPGs in general is evaluated. The player's choice of specific equipment is used to judge his/her knowledge about the game. Based on the information given someone is invited for a trial time with the guild or rejected immediately. Games as *World of Warcraft* and *Aion* offer searchable databases about the players' statistics. Those databases collect and update information about the character's stat, equipment, skills developed as well as engagement in player vs. player activities and guild information. As Medler (2011) shows, these data "are indicative of how players focus on their personal game personas and the connection they create between other players". In *Aion* as well as in *WoW* this information is provided by the official game site. Data are based on the last game session of a player and are recorded and updated by telemetric software built into the game. These data provided focus heavily on achievements and status of a player but not on skills as cooperation, communication skills and reliability of a player. The effect of those databases is that even when a player applies to join a group whose players he or she does not know yet to fulfill a task or finish a quest, the group can decide to check the database and see whether the player is eligible to play with the group or not. This check up on a player only happens when players do not know each other as in most cases groups rather consist of people who played together beforehand and know they can rely on each other. The skills to play the game are not only visible in the equipment a player has. Being known on a server and having a good reputation as a friendly, supportive and skillful player is more important than stats. As the player's personality or skills are not quantifiable some players criticize the heavy use of those databases by the community. As players notice "this is a slippery slope" between on one hand giving players more control and on the other hand creating elitism and challenges between players.

SURVEILLANCE/SOUSVAILLANCE

Taylor (2006) as well as Glas (2010) point out that players use tools developed by theorycrafters for both surveillance as well as sousveillance. *Sousveillance* is a term coined by Mann, Nolan, and Wellman (2003) to describe instances in which people watch those above them. This term can be applied here as well as the community considers the high-level players as being "above" in a hierarchy consisting of level, skills and knowledge. As players know that other players are watching and judging their gameplay and equipment they try to adapt to the expectations of the community. Those setting up the rules, the high-level players and theorycrafters, are also aware of being watched by other players. Thereby sousveillance is at stake here as much as surveillance. The term "participatory surveillance" (Taylor 2006) highlights the ambiguous effect theorycrafting has on the community. It offers control and agency to the players but at the same time asks for subjugation under this knowledge if players want to reach the end game content and be accepted by high-level guilds. This has the effect of mainstreaming the players. The question then who is in control can be answered: it is partly the game developers who provide the software to play with based on underlying rules the player has to become familiar with and adapt to and it is partly the player community itself. Based on the desire to control the game instead of being controlled by it they develop game guides, suggestions for strategies and add-ons, which in the end mainstream and thereby control the player community using them.

CONCLUSION

Theorycrafting as a scientification of gameplay is an approach to playing MMORPGs based in a pro-gamer community. Players, who want to understand the game mechanics and use their knowledge to optimize their gameplay are those who engage in theorycrafting and apply the results. It is interesting to observe, which understanding of science is relevant here. Even though theorycrafting is understood as a craft and *techne* and not as a scientific theory or *episteme*, the results are presented in mathematical formulas that give the impression of rationality, truth and reliability. The presentation of formulas and their application in game as if they are based on a verified theory supports the authority of the theorycrafting community and can be understood as part of a discourse to improve control and power. Theorycrafters are perceived by the gaming communities as those being in control of the game and therefore receive a high reputation. For many players theorycrafting has changed gameplay in MMORPGs from a casual entertaining activity to finding the optimal solution. It has led to gain control over the game but also over the gaming community. Even though theorycrafters are perceived by other gamers as the authority a complete de-mystification of the underlying algorithms is hindered by the game developers who do not engage in the theorycrafters discussions and do not offer a proof for the hypotheses formulated. The final control is still in the developers hands.

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