INTERNATIONAL SCIENCE FICTION

PROTOTYPING CONFERENCE

2018

SciFi-It'2018

DESIGNING YOUR FUTURE
WITH
SCIENCE FICTION

EDITED BY

Philippe Geril

APRIL 18-19, 2018

NOVOTEL, BRUGES

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SCIENCE FICTION PROTOTYPING CONFERENCE 2018

Preface

Dear Participants,

It is a great pleasure to welcome you to this year's SciFi It, the second International Science Fiction prototyping conference, which is being held at the Novotel Brugge Centrum in the beautiful city of Bruges, the 18th and 19th April 2018. This conference is one of the few and quite unique in looking at "what if" designs and technology out there on the event horizon of research, and how these can become real objects and tools within our human living space.

As our particular event horizon is Science Fiction, participants are most keen to learn from your specific approaches how each of you covered this transition of ideas and objects from science fiction into useful science fact tools.

This year's event hosts four excellent keynote speakers, namely Professor Christian-Andreas Schumann, from the Westsächsische Hochschule Zwickau, who will talk about the "Smart Education Prototyping for Digital Transformation and Industry 4.0." program. Secondly we have, Richárd Révész, from the Budapest University of Technology and Economics, whose talk will focus on car design for the "Blade Runner 2049 Vehicles". Thirdly we have, David Wortley, from Coventry University who will talk about the "Transfer to Immortality a Virtual Alternative to the Singularity". And last but not least, Piet Kommers, Professor of UNESCO Learning Technologies, who will talk about "Identity in the Mediated Network Society".

Finally, we would like to express our gratitude to all persons who have contributed to this event: firstly, to those who have submitted papers, and will present them over the next couple of days; to the programme committee who have reviewed papers, and contributed to organising this event.

We hope that you will have a great time in Bruges, in the real present and in the medieval VR experience at the Historium, that your will enjoy the very special social programme, and will find the conference interesting and inspiring.

Bruges, April 2018

Philippe Geril
ETI
SciFi It General Conference Chair

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SMART EDUCATION PROTOTYPING FOR DIGITAL TRANSFORMATION AND INDUSTRY 4.0

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KEYWORDS
digitization, digital transformation, smart education prototyping, education 4.0, smart learning worlds.

ABSTRACT

The ongoing digitization and the increasing number of technological solutions for nearly every aspect of our modern society is influencing the way we live and work. In order to be able to develop and apply smart systems of the future, the education and training of professionals, especially in higher education, has to be reoriented methodically, technologically and contentually. General transformations are specified by digital transformations and Industry 4.0 is accompanied by Working Worlds 4.0 and Education 4.0. The knowledge spiral is turning ever faster between the priorities of research and teaching creating more and more (smart) data and information in an increasingly complex world of development and application. Complexity forces to transdisciplinary and interdisciplinary ways of working and holistic views. The challenge is to react and act with smart approaches in education using new technologies for changing the living environment as well as the lifelong learning. One of the currently most important priorities is the design of smart learning worlds for digital transformation in general and cyber physical systems as kernel of the Industry 4.0 concepts in particular. Smart education prototyping for digital transformation and industry 4.0 is one of the key approaches to the future viability of social systems. What should be the focus now, and in the future, is outlined methodically, technologically and contentually and will be explained by selected examples.

INTRODUCTION

Smartness is a characteristic that is posited positively in many ways. It expresses that intelligence is present or an appearance seems intelligent; one is smart, clever or amusing. In view of the overwhelming flood of information, the hardly manageable data explosion, the omnipresent communication flows and the constant influence of the media, the question arises, how to respond to these influences and challenges by appropriate education in a smart way. Digital transformations intensify these scenarios, but also offer the opportunity to design education systems and processes in such a way that the new conditions are not only a burden, but also an opportunity for better education and thus better living conditions. Smart education also means that data, information, communication and media in all social, professional and personal areas are intelligently used to generate more quality of life, better career opportunities and more personal happiness.

If the new developments, technologies, methods and processes, sometimes with a negative touch in social discourse, are understood as an opportunity, fear and rejection turn into curiosity and joy at the new. Smartness in education also means positive thinking through intelligent approaches, fun in learning through motivational processes and enthusiasm for new things through interaction with smart systems. Knowledge acquisition and knowledge application should be motivating and fun. This requires smart prototypes for education in the context of digital transformations. In particular, the massive changes triggered by Industry 4.0 and the associated wave of digitization and automation require a high degree of smartness in order to motivate people across generations not only to see the risks, but above all the opportunities and to prepare themselves through education to use the new intelligently.

IMPACT OF DIGITALIZATION ON OUR LIFE

Humans and their social relationships have always been subject to permanent change. Most people hope that they can live in stable and happy conditions. The constant change, however, dissolves the stability again and again, to which one reacts in order to generate a re-balanced state. The associated cardinal question it is not better to take the constant transformations for granted in order to be able to shape them in a proactive way and at least partially control them. Transformations in general, as well as the digital transformation, would then become balanced transformations.

Digitization, like communication and globalization, is a fact that is simply there or created and with which people live. It is part of human development. Since digitization is still a relatively new phenomenon, its mass application and dissemination causes not only euphoria but also scepticism, as it is with everything new, not yet completely explored and unknown. Suddenly, people realize that in each of their relationships, contacts, actions, etc. they are confronted with digital or digitized systems, processes and functions. They are no longer able to perform the simplest basic functions of their lives without relying on digital services. Those who refuse to accept this phenomenon are gradually isolating themselves in their social environment.

Not only our way of life and our quality of life depend on digital services, but also the survival of humans and humanity. Thus, if temporarily stable conditions are broken up by digital changes in order to allow room for further developments and innovations, then transformations must be actively influenced by active monitoring and intelligent conclusions in order to achieve a new balanced state at an advanced stage of development in the long term. The impact of digitization on our lives affects social, economic and ecological aspects that can lead to a sustainable improvement in our lives through balanced transformations. The prerequisite for this is a corresponding level of education, which should be increased further and further in order not only to react smartly, but also to control and manage transformations and upheavals in a smart way.

DIGITALIZATION BY TRANSFORMATION AND SYSTEM DEVELOPMENT

The digital interconnection of billions of devices is today's most dynamic opportunity. The enabling key technology is the Internet as an open and independent network for worldwide communication and data transfer. A single technology platform uniquely combines complexity, global reach, and novelty. After being opened up for a broad application, it is also referred to as the Internet of Things. (Burkitt 2014)

However, the centralization of many personal data on centralized servers is increasingly proving to be a problem counteracted by increased decentralization, which is developing the so-called Internet of People. A variety of new technologies and, like block chains or quantum computers to name only two striking examples, will push further evolutionary as well as disruptive changes.

With all the hype, it should not be ignored that digitization and all the technologies and methods associated with it are also a continuation of human cognitive processes. They rely on the proven and are therefore simply innovations. All new approaches are based on systems and their transformations. Their design and development has already been analysed, described and modelled in a variety of contexts in other applications. Digitalization is therefore not an independent form of further development, but rather technology embedded in the general environment, which acts as an enabler and catalyst for greater development dynamics. It is therefore important to combine transformations and system developments with the possibilities of digitization. Although the new services generated by digitization in all areas of society are extremely diverse, one of the key tasks remains to create products that provide industrial performance and value creation as one of the main bases for digitization and digital transformation.

Therefore, the digitization and automation of industrial processes for the production of material and immaterial products remains one of the core tasks in the field of digital transformations. They are reflected in the approaches of Industry 4.0 or Industrial Internet Consortium and, interestingly enough, can only be realized by three to four highly developed global research and industrial zones in cooperation and in competition. It should also be noted that it is precisely in these high-tech and industrial locations that a large part of the existential foundations of life are generated in an understanding of today's standard of living. This circumstance will have a massive influence on further digitization through transformations, also with regard to smart education.

CHALLENGES FOR EDUCATION AND TRAINING

To understand the challenges that education and training are faced today and in the future, it is not sufficient just to talk about the breadth and depth of education profiles or the complexity of education. Rather, an understanding should be developed on how complex educational systems are developed, both methodologically and in terms of content, in a constant transformation process and in a dialectical context. The high degree of complexity results from the multitude of topics and the variety of their relations as well as the permanent temporal, methodological and content-related change. In order to meet the dynamics of development and continuous expansion of systems and system views in reality, methods and content in education are constantly being adapted. Usually, this is very active behaviour. However, it would rather be necessary to proactively explore ways in which knowledge about medium to long-term challenges can be transferred in the coming years.

If this approach is placed in the context of digitization, it becomes clear that something new has to be synthesized from the thesis and the antithesis. So new (digital) methods and at the same time digitised content have to be embedded in previous forms of teaching and learning. Designing digitization methodically, didactically and content-related is not the real challenge. The challenge is rather to place them in a meaningful context with the existing, in order to be able to decide which previous contents are negligible with the objective of creating space for new study contents. In addition, there is always the question, which methods are suitable for best communicating both classical, consolidated knowledge and new aspects of digitization.

Useful are procedural models that follow the proven methods of scientific work. Since digitization and digital transformation are derived primarily from the social context or can be seen in it, a procedure from the general to the specific offers itself. Based on the consideration of society, life, work and work environments, conclusions can be drawn about educational requirements for the digital transformation in order to present them in concrete cycles and models of globalized, lifelong and digitized learning. The consequences for special educational profiles can then be deduced as well as impulses for the concrete development of educational offers. It is important to recognize that digitization has a massive influence on both methods and content of future education. (Gallenkämper et al. 2018)

SMART LEARNING WORLDS

In the future, it will not suffice to embed digitisation in education only as an eye-catcher or in a selective way in terms of method and content. The variety of generalising and specializing educational areas is overlaid by different levels of digitization of individual education modules or educational clusters. Basically, it only reflects the diversity of application areas, which should be influenced by evermore individually acquired knowledge and competences. The human being must always acquire new knowledge and new skills in a personal process in order to be able to successfully influence the reality. For educational-economic reasons, the balance of general, collectively conveyed knowledge and special, individually acquired competences must be optimised. Contentwise and methodically determined education modular systems are created in order to allow both larger groups and individuals to access existing knowledge effectively and efficiently.

Learning worlds are generated, which are extremely complex due to the variety of existing method and content building blocks as well as their manifold combinations for the access of the teachers, coaches and learners. These learning worlds become smart when every individual, whether in a group or individually, is offered the learning path in a short time that best meets their knowledge needs while taking into account their specific learning, professional or life situation. Smart also means to use the fantastic possibilities of digital methods, procedures and means to enrich the content towards smarter systems as well as to provide a smart didactics as a basis for knowledge acquisition and knowledge transfer processes. Smarter learning worlds learning itself in order to optimally design the individual and collective knowledge spiral and competence development in symbiosis with the learner. Ideally, intelligent services for smart users will be offered on an intelligent platform in the digital future.

Latest technologies are constantly being examined and smartly embedded in their relevance for increasing the intelligence of education systems as well as their relevance for increasing limited educational content. The biggest challenge is to find and combine exactly those of the variety of classical and digitized methods and contents that are optimal for the learning success. Since this question also concerns psychological, psychological and social aspects of the current state of the individual or a group of individuals in the learning process, educational systems must be smart enough to recognize these facets and respond accordingly, to act better in a forward-looking manner and to connect individuals if necessary.

OUTLOOK FOR THE FURTHER DEVELOPMENT

The central question will also be in the future, which knowledge and which competencies will be relevant with regard to the forecast of the further development. The ever-growing knowledge also raises the issue, which basics still have to be taught and which parts should be eliminated or substituted by new knowledge. A constantly changing mix of knowledge objects, knowledge relations and competences will be generated repeatedly. The basis for this is the continuous adaptation of teaching and learning content, study forms and formats, methodology and didactics, organization and leadership with respect to individual learning types and types of teachers, educational prerequisites and social status, learning motivation and learning abilities, taking into account mediality, interactivity, accessibility, modality, space and time, etc. In addition to contentual, methodological and economic aspects, questions of learning motivation and learning psychology will increasingly be tapped in order not only to be striking, but really profound to respond to the learners' needs as an individual and / or as a social structure of a learning group.

It is not a question of whether but rather how the gulf of execution and the gulf of evaluation can be bridged by the use of new forms of teaching and learning. The demand for more smartness in the prototypical design of future education systems is directly linked to digitization and digital transformation, which is why, in addition to the learning-driven view, the technology mainstreams are directly relevant. Education as a service, education on demand, and micro-services and micro-creditation are directly linked to digital services today. All of this has to be embedded in lifelong learning processes and linked to individual learning pathways that are always more targeted. Virtuality, adaptability, responsiveness, balancing, accessibility, semanticity, servicing are terms that are related to future technologies, methods, content, models, concepts and approaches. The overarching theme will be the ability to interoperate all educational objects and subjects of education in open digital learning worlds beyond simple networking and integration.

SUMMARY

Digitization, especially in the form of digital transformations and applications such as IoT and Industry 4.0, is forcing education systems to have more of their own smartness to cope with ever-increasing demands. In the prototyping processes for new educational offerings in this context, more emphasis is placed on intelligent planning, development and implementation. Actions of digital systems are increasingly interlinked with human activities. Human and machine enter a symbiosis that requires completely different ways of thinking and educational strategies. The paper outlines the complexity of the task and should promote and stimulate the discussion on the development of new, smart learning environments.

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Blade Runner 2049 Vehicles

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KEYWORDS
Blade Runner, Spinner, Vehicle, Flying Car, Movie Production, Motion Picture, Film, Sci-Fi, Design

ABSTRACT

The 2-times Academy Awards winner sequel of the classic neo-noir sci-fi features a wide range of vehicles, those have been actually built and are functional to various extent.
The technology may be fake, but design had to be real. How to design real vehicles for a non-existing world?

INTRODUCTION

Every design process starts with research to define a concept as a foundation for the design. However, in a movie production the context is being developed in parallel: the whole world may be designed simultaneously. The task is quite exciting and challenging as well. This unique experience is described in the followings from the perspective of a crew member.
(The main paragraphs follow the steps of a design process.)

PHASE 1: RESEARCH

Normally the context is so obvious that the most challenging part of the job is to think outside the box. Look at commercial products: they probably have some competitor on the market, use case scenarios can be mapped easily, tons of data is available (or can be mined), so it is mostly about filtering and getting rid of the preconceptions.
Now, when the you are about to design for is a science fiction movie, you need to buckle up. The context you need to explore and digest into a concept mostly does not exist.
If it would have been a Star Wars movie, there would be 6 movies, several animated films, books and cartoons, even some LEGOs to start with. Star Trek has plenty of series. These universes has pretty solid outlines.
But what do you have with Blade Runner? One movie, some background photos and few vehicles, and all of those date back 30 years ago in the cinematic timeline and in reality as well. The context can be explored through the tiny hole of a camera aperture which is barely lagging a lifetime.
For the main vehicles concept artist provided us some visual guidance. These range from the excellently detailed and already approved concept art (actually I would call it concept design) of George Hull that only needs to be prototyped, through photoshop enhanced hand sketches like Victor Martinez's dashing concept art, to bare sketches or even nothing.

Image 1: Luv's Spinner by George Hull

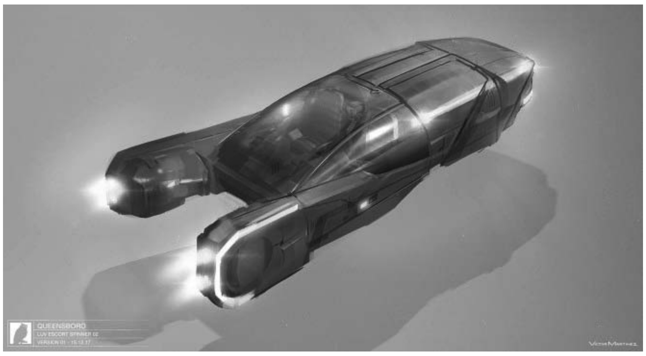

Image 2: Escort Spinner by Victor Martinez

Any other concept art that is available now about non-vehicle related things was unavailable for us at this phase. Some were simply non-existing and created later for marketing purposes, others were, well, secret. Yes, secret. Highly appreciated movie productions apply extreme measures of secrecy, resulting that even the crew has restricted access to background materials: we only had access to concept art that shows a vehicle.
When looking for other information sources, it also gets obvious that the vehicles are *used* in the movie. There are scenes where they are in action, interact with other objects or characters, so these will also guide the design.
Fun fact: I have never read the script. My principal was allowed to read it: he was locked up in a room without windows, he had to leave his phone outside and was not allowed to take notes by any means.
So we knew that the Escort Spinner (see Image 2) will land *somewhere* and a character codenamed at that time "*Bill*" will be dragged onto the rear seats. That is all.

PHASE 2: CONCEPT

Lacking solid foundation the strategy was to fail fast. Failure is demonized by our society, but failing is the fastest (and hardest) way to learn, and we were desperately in need to figure out ASAP what will work in this cinematic universe, and what will not. So we started to sketch. Sketch by hand, create sketchy 3D models, create a lot of them to present it to the decision makers and get feedback. This exploration was kind of conceptualization blurred with research. After all, the Production Designer and the Director decides how this movie will look like, so we also needed to research their minds.

Concept artists prefer to showcase quality renders (including me), but to present the whole concept development process I will make an exception. For the background vehicles we selected several characteristic existing cars to be customized for the movie. As an example, Dennis Gassner really liked the Trabant 601s among the others, so we made created some really fast and dirty sketches to explore their potential.

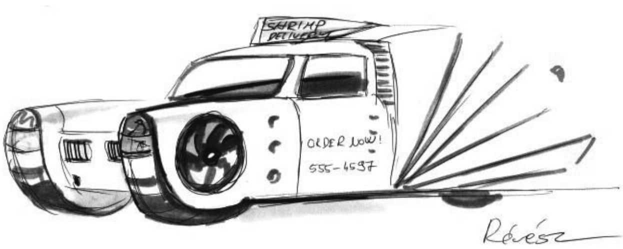

Image 3: Trabant Based Background Vehicle
Ideation Sketch

The sketches those were awarded with a nod we started to develop into renderings. Below you can observe steps of the concept art development (there were 26 renders created in total only for the "Trabi").

Image 4: "Trabi" Early Stage Concept Art
- Based on Peter Popken's Render –

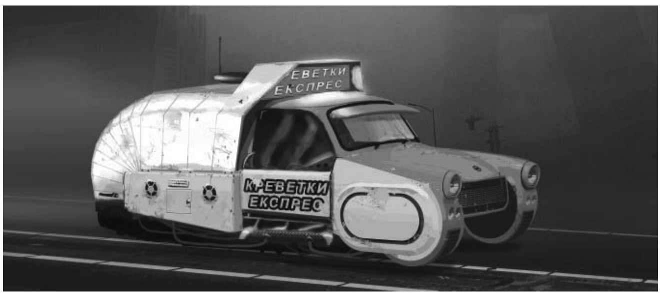

Image 5: "Trabi" Concept Art in Development

Image 6: "Trabi" Concept Art – a More Subtle Approach

Image 7: "Trabi" Final Concept Art

For most of the background vehicles it was nearly enough to start manufacturing them, as the base vehicle defined most of the design.

Image 8: Beetle Background Vehicle Concept Art

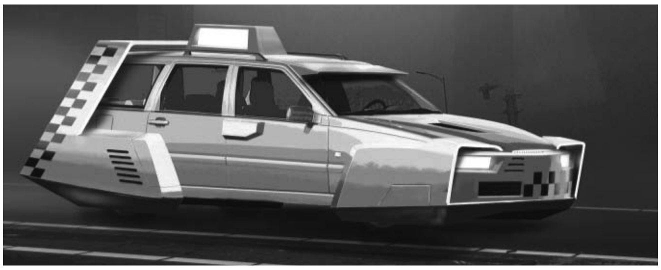

Image 9: Volvo Based "Taxi" Concept Art

Image 10: Renault 5 based Background Vehicle Concept Art
by Peter Popken
Mariette's Car

PHASE 3: DESIGN

There were 5 different spinners designed and built for the movie. I will go through on one in detail and give some glimpse on the others. This will be the Escort Spinner for 2 reasons: first, this is my design so have all the details to present it and also have all the materials to do so, and second: this is my design so I am biased.
So, as soon as the feeling of a concept is right a lot of things start to emerge. Sizes and proportions started to roughly outline so we were ready to define them.

Size and proportions

One of the thumb rules was when these vehicles are using the roads, they need to fit for obvious reasons: in this fantasy world these are practical vehicles. Also when we want to move them between shooting locations we don't want to make our life complicated, they need to fit on the trailers. Yes, prosaic as that.
Other straight forward requirement is as they are used by humans (or "replicants", but designvise they are pretty much the same), they need to fit in.
For such considerations we started to sketch on top of existing vehicles for each of the spinners. As the Escort Spinner's size reference the BMW 7 Series sedan (2010) was used.

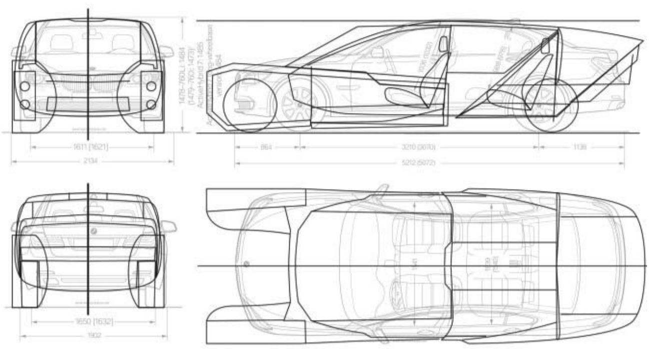

Image 12: Outlines of the Escort Spinner

By this way it was verified that this size and these proportions will be convenient. The 3D modelling phase started with blocking out the volumes of the vehicle with some form details which is defined by the concept art (see Image 2: Escort Spinner by Victor Martinez).

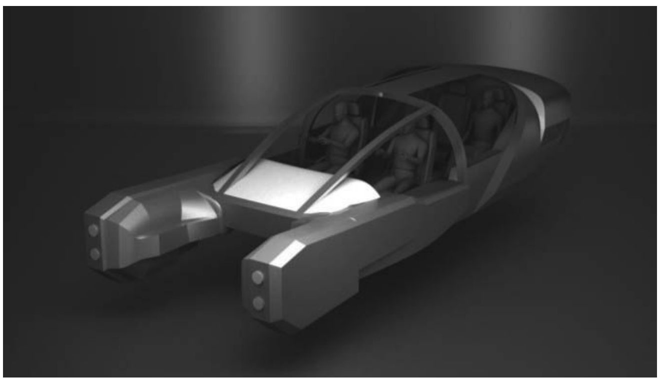

Image 13: Building Blocks of Escort Spinner

This very rough model already served as a good base to inspect which forms are working in 3D as well and where is design space for improvement. Focusing on these areas several versions were sketched and 3 selected versions were built in 3D.

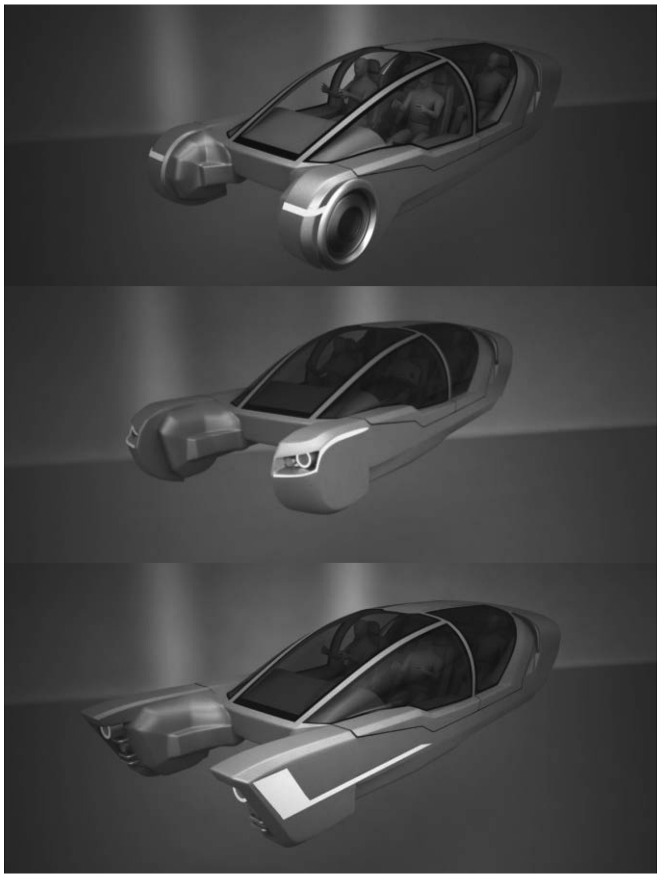

Image 14: Design Proposals for the Front of the Spinner

Propulsion system

Next step is to make this vehicle mobile. The only reference to the spinner hover and propulsion technology available is probably fan art. However it is reasonable enough to work with it.

Image 15: Spinner Hover and Propulsion Technology (Unknown Artist)

The conclusion is that it needs some engine compartment (check), thrusters to hover drive forward, and some air inlets are also logical to provide the thrusters air.

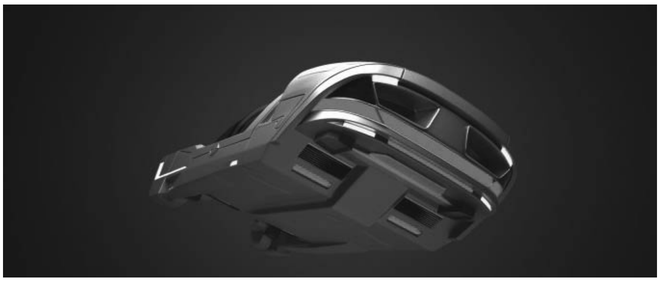

Image 16: Escort Spinner's Thrusters

The spinner has 2 thrusters at the front and 2 at the back for hovering, and 2 larger one at the back to for propulsion.

Landing gears, landing legs

These also need to land sometimes. For the Escort Spinner rear landing gears/legs opening there were 8 versions generated and evaluated.

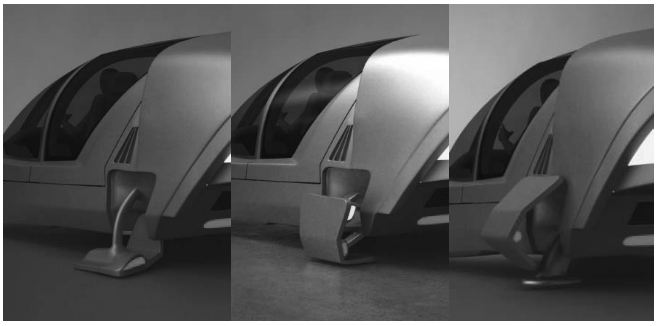

Image 17: Some Landing Leg Configurations

(The spinner of Officer K got landing gears, however. It has a three-wheeler configuration with swiveling rear wheel. There was a fully driveable spinner built for the movie: it was turning corners and driven by an electric engine.)

Doors

To ride these vehicles people (or replicants) needs to get in first. Door opening configurations were defined by the concept arts, however, making the doors open without interfering with the body and keep tight division lines when they are closed is a specialization at automotive engineering field. This gullwing plus scissor door configuration should also avoid interference with each other, and we also had to preserve space for the opening mechanisms as well: it was opening and closing on a button push via pneumatics. These spectacular doors demanded some serious consideration.

Image 18: Spectacular Door Configuration Demands Attention

Interior

Further human interaction is the actually riding or driving/flying the vehicle. As the Escort Spinner had no closeup shootings on the interior so its design is a bit rough: time is the most precious resource in the movie industry so you should allocate it where you really need. It is a composite of other spinner's parts and some unique panels. The manufactured spinner got similar steering wheel to Luv's Spinner.

Image 19: The Interior Needed to be Good Enough to Sell the Story, but Get Away with Minimal Effort

Image 20: This is the Closest Picture We got in the Movie of the Interior

The K's Spinner interior was a totally different story. It had several concept arts to define it, Mike Hill, an extraordinary talented 3D artist dedicated to design it, he was closely working together with Zsolt Tárnok who designed the exterior, and Dennis Gassner supervised and directed the whole process with particular attention. Syd Mead's Spinner was a true sci-fi icon, this spinner had to be a worthy successor. It is all practical in every detail, human interaction and ergonomics are infused into a puritan but also futuristic interior design.

Image 21: K’s Spinner Interior
Design: Mike Hill
Render: Zsolt Tárnok

Structure

As these vehicles were actually built and moved, the inertia of their structure always needed to be considered. K’s Spinner was driving. The Escort Spinner in the scene it hovers into the building is not CG.

Image 22: Escort Spinner Enters the Penthouse in the Movie

It was on a top of a huge robotic arm rolling on a rail, so it was actually making those moves on the set while shooting.

Image 23: This is How it Looked like During the Tests

However, with the bubble top it needed some rigid structure, like a handy cabrio, not to bend under its own weight or twist by its momentum while dynamically yanked around by a 6 degree of freedom massive robotic arm.

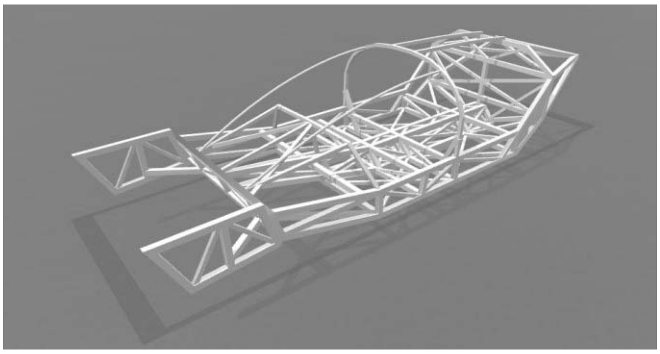

Image 24: Frame Design of the Escort Spinner

The rigidity was achieved by structural design. The futuristic bubble top was supported by space frame lower area.
For all the spinners it was a crucial requirement that they need to withstand the forces those are awakening during the shootings.
But there was an extraordinary one: the Wallace Limo.
This was a real beast. To determine its size we have used 1:1 side views printed out and taped to a hangar wall. It was comparable to a bus in every dimension, with detachable side solids to make it transportable: its assembled width exceeded 4 meters/13 feet.

Image 25: Wallace Limo Size Examination with Paul Inglis, Supervising Art Director

With the huge gullwing doors and bubble top it was a real challenge to create an underlying structure that is rigid enough but also as lightweight as possible. Its own weight significant alone, but the main forces were expected during the crash landing onto the seawall after the spinner chase scene, as it was partially shot in real.

Image 26: Some Part of this Crash Landing Scene were Shot for Real

Obviously it was a controlled stunt, but it needed to be hard enough to sell the story. Moreover, after that 5 tons of water were dumped on it. Repeatedly.

Image 27: Wallace Limo Under Repetitive Stress Test in the Movie

In the light of that, the robotic arm's forces look gentle. To withstand the these stresses, at some of the hardest stunts the door's frame was fixed to the main frame, becoming integral part of the spaceframe.

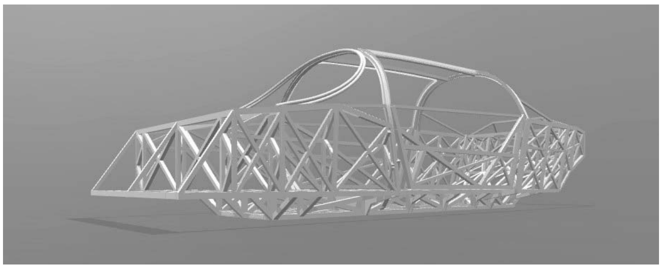

Image 28: Spaceframe Design of the Enormous Wallace Limo

These frame designs were created in the software the exterior and the interior. No calculations were made, and as polymodelling software are not suitable for tasks like this, but we are industrial design engineers so it was an educated guess. Its aim was to create a design space for the SFX team where they can work. Naturally it was properly engineered later, it will referred in the followings.

PHASE 4: DEVELOPMENT

Watertight sealings and wipers

Image 29: Officer K (Ryan Gosling) Driving His Spinner in the Rainy LA

The rain is a so permanent motive in the movie (inherited from its predecessor) that wipers watertight sealings at the doors' gap was one of the first thing to be designed during the development phase. The design was similar to the car's door sealing or wiper, some actual car parts were used.

Image 30: Close Up on The Escort Spinner's Door Sealings and Wiper Design

This urgency was due to the importance of not to leak during the closeup shots, or referring again to the Wallace Limo's crash landing scene, it gets clear it was something to be well executed. It was so important that it was already mentioned by Paul Inglis at our very first meeting.

Detail design

"The devil is in the details." This phrase is extremely true in the movie industry. The previously described steps, when implemented on a high level makes the design credible, but the details make it look real.

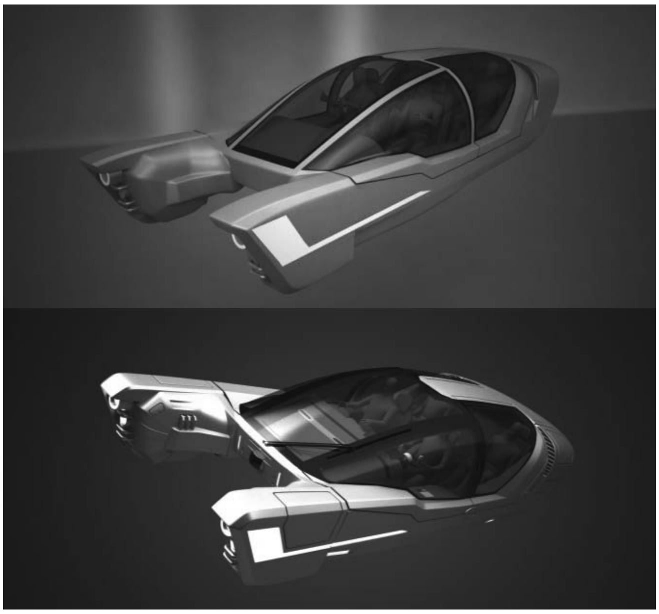

Image 31: Importance of the Details

Above the very first render of the Escort Spinner and one of the last renders underneath. Exactly 3 months passed between the 2. Parting lines, air inlets and outlets, position indicator lamps, dome in the middle for radar and camera systems, air registers behind the windshield, some further hints of interior, door handle summoning the iconic Police Spinner 44, the previously mentioned window wiper, well-defined character lines and edges, and some effort in lighting, material and composition makes the difference.

The level of the details did not stop at the geometry. For the graphics of the movie there was a dedicated graphic design team. All we needed to do is provide them the references, where should be and what kind of graphics on the vehicles.

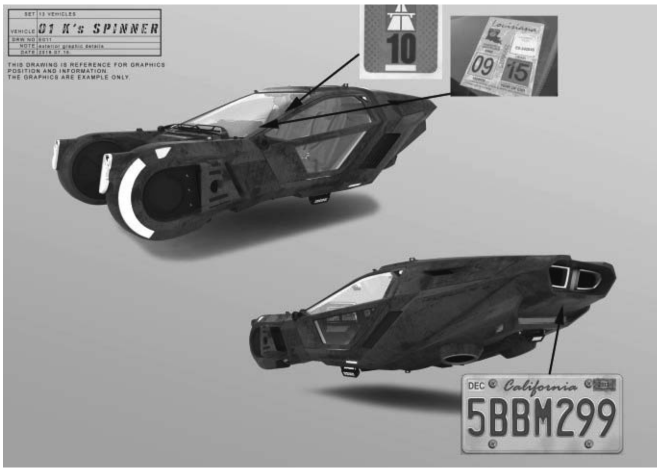

Image 32: Reference for Graphics on the K's Spinner

This was quite subtle for the spinners, but some background vehicles suffered real sticker tsunami.

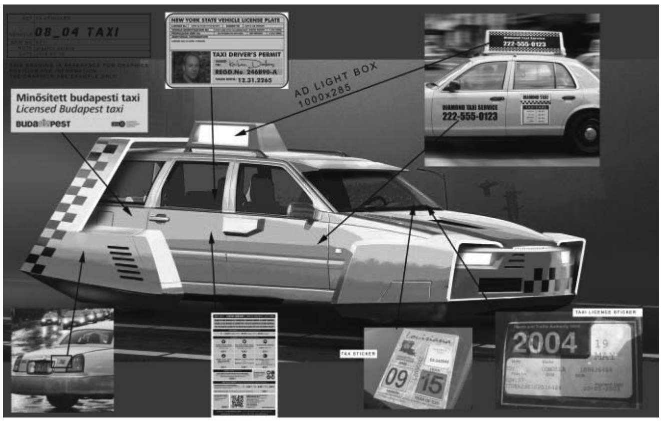

Image 33: Reference for Graphics on the Taxi

PHASE 5: DOCUMENTATION

Documentation sometimes feels like heavy and useless paperwork. However, when designing a movie every designer and art director works parallelly in an extremely limited time window, so it is essential for everyone to be on the same page. Moreover, for the manufacturer there is literally one shot to create the vehicles, there is no place for mistakes, so proper documentation is indispensable.
It is also a factor to consider that everyone is extremely busy with doing what they are doing, so demanding their attention when it is unnecessary is a no-go. This requires strict discipline from everyone to issue a drawing when it is really the final version, and issue them to only those who are really affected.
All the vehicles got a drawing with the main views and bounding box dimensions, several exterior and interior renderings and the spinners documentation included 3D models for the manufacturers, SFX and VFX departments.

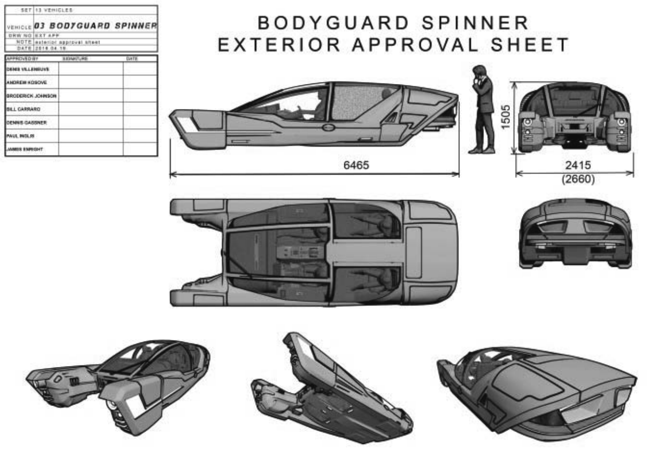

Image 34: Escort Spinner's Documentation

PHASE 6: PROTOTYPE

Every each set gets their own to scale models, there are professional modelers hired just for this purpose in every movie production. Props are small assets so they can be prototyped even several times to get them right.
Vehicles these special are rare in movies, so there was no really best practice for prototyping.
At the early design phases we used aluminum profiles and foam rubbers to block out the volume the spinners would in reality. Later on when the manufacturer got the early 3D models they 3D printed it and sent to the studio to evaluate it. Some of the spinners were printed by us on our FDM 3D printer.

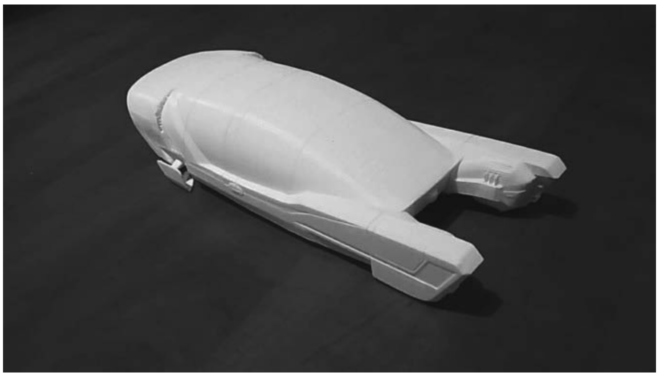

Image 35: Escort Spinner 1:24 Model

The background vehicles, well, they are all prototypes. They were built on existing vehicles, so we had pretty good idea how they would look like without any intermediate steps. Except for the snow sweeper appeared in the teasing trailer already, that was huge. It was meant to be huge, but still, it is completely different to have it paper actually see it. And to be honest, there was simply no time to mess with them.

PHASE 7: ENGINEERING

SFX department was in charge and responsible for all the mechanical engineering related issues. All the frame design proposals were created with consultations with them. They have redesigned them in engineering software, evaluated and

developed it optimizing for stiffness and lightness. They consulted the results with us and it was done. This was a pretty seamless process.
However, it is common that the aesthetic requirements conflict with engineering requirements. It is not a farfetched guess that every each SFX team had experience working with art directors who were great artists, but they had no technical sense. With our engineering background it was just much easier to work together, so they were articulately happy to work with us. Even if we were facing them with challenging tasks, we all knew what we were asking for was feasible. They were always up for some challenging tasks, and also very welcoming, so we were also happy to generally work with them and comply with their requests.

PHASE 8: PRODUCTION

Regarding the spinners the process started in England where the workshop with the technology was given to produce such huge parts on large scale. At a point where the tricky schedule required, they were shipped to Hungary to be finished up here in English – Hungarian coproduction. There were 7 full life-size interior-exterior spinners (so called "heroes") required to be built. As mentioned earlier there was a fully driveable K's Spinner created, and all of them was practical to an extent, so all available hands were needed to fabricate this level and quantity of vehicles.
There were about 15 practical (self-propelling) background vehicles manufactured all here in Hungary, distributed to 6 workshops. Just scheduling the meetings with these was a task alone.

EXPOSURE ON THE SCREEN

In the end, after having a glimpse on all of the preproduction work, it is time to evaluate the true results, what made it to the movie.
Without the need for completeness, see how well – and how long – did the previously mentioned vehicles on the screen. As a warm up, take some background vehicles.

Image 36: Biggest Moment of the "Wacaro" Street Cleaner in the Movie.

The "Wacaro" Street Cleaner appears several times for a few seconds in the movie making it one of the most exposed background vehicles. Still, all of its details only revealed in a YouTube feature video where Adam Savage takes the viewer to a set tour (find the link between the Web References).

Image 37: Detailed Review of the "Wacaro" Street Cleaner in "Adam Savage's Set Tour of the Blade Runner Universe!" Titled YouTube Feature Video

Image 38: Beetle and Taxi Appears on the Screen for a Few Seconds. The Trabi Hides on the Far Left.

There was even a whole bus fully revamped for the movie. I have watched it twice in cinema knowing it was there – I was organizing its transport to the set and helping with its light system setup on the set – , and I still missed it twice.

Image 39: There is a Bus on this Frame

But there were even spinners which got exiguous focus as well. On the very first image of this document Luv's Spinner is shown. In the movie you need to actually search for its spot. It was physically built, interior and exterior, there were some shootings with the interior scenes, but these never made it to the movie, only the CG versions.

Image 40: Luv (Sylvia Hoeks) Driving her Spinner (Cutout of an Image from George Hull's Website)

Image 41: Luv's CG Spinner Deploys its Drone

Image 42: Luv's CG Spinner Deploys its Drone from Another Point of View. The Whole Event Takes Moments.

Image 43: The Spinner also Appears in the Blade Runner 2049 Replicant Pursuit VR Experience

There was an intermediate Police Spinner developed for Deckard, or as the script was referring to him, "Bill". The concept behind it was that during the elapsed 30 years the Police Spinner in the '82 movie has gradually evolved into the Peugeot Spinner used by Officer K. In this timeframe Deckard acquires a Spinner that is newer than the legendary Police Spinner 44, but way older than the K's Spinner. So it was designed.

Image 44: Deckard's Intermediate Spinner "Accidentally" Wears the Same Identification Number 44

It was not enough to design its exterior. It got blown up, when its structure and some of its interior got exposed. So its underlying structure in its damaged form with the burnt out interior needed to be designed.

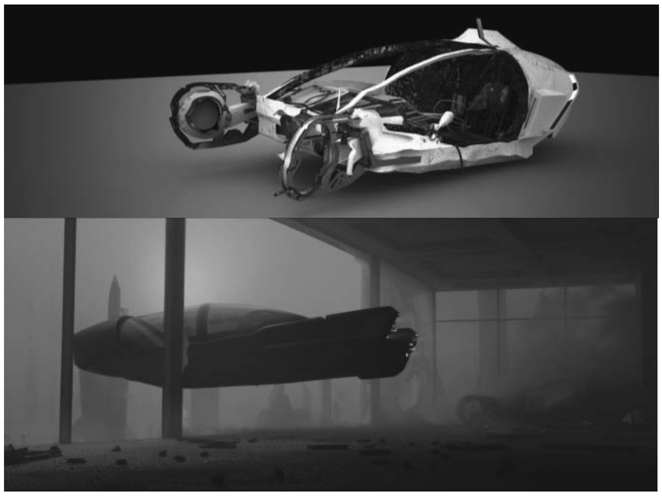

Image 45: Wreckage of Deckard's Spinner

Compared to these the Escort Spinner received a lot of attention. In the scene on the previous image it reveals itself in a showing off manner. In the followings we see it with the doors open, and even get some interior close-ups (see image 20 in the chapter PHASE 3: DESIGN).

Image 46: Escort Spinner with All Doors Open

Furthermore, we get a glimpse of its back later when K raids the convoy, and two of them are getting destroyed by him. It was even exhibited alongside the K's Spinner at Oculus Connect 4.

Image 47: Escort Spinners Destroyed During the Raid

Image 48: Escort Spinner Exhibited at OC4
(picture by Hugo Barra)

Of course its presence was nothing compared to K's Spinner.

Image 49: K's Spinner Exhibited at OC4
(picture by The Verge)

Nonetheless, I still could have bear more of it on the screen. One thing I felt sorry for left out of the movie was its actual ability to drive and steer. Only one shot shows it in rolling mode, and it just goes in a straight line.

Image 50: K Parks his Spinner in a Straight Line

CONCLUSION

This paper is about the vehicles, but the story is not. These vehicles were mere assets of a higher level artwork, the Blade Runner 2049 movie itself, and that as whole is true masterpiece as is shown by numerous awards.
Some of the background vehicles we have been working on for months appear on the screen for a few seconds or get lost due to the focus of the events. They are background vehicles, that was exactly their purpose.
I think I could never get enough screen time of the spinners. These vehicles were designed for a non-existing reality, still, they spectacularly support the story, become integral part of the Blade Runner Universe, and I really hope the world sees them as a proper way to pay tribute to Syd Mead's legendary Police Spinner.

I am grateful that I had a chance to put my name on such a crew list.

ACKNOWLEDGEMENTS

I would like to express my gratitude first of all to my mentor and friend, Zsolt Tárnok. He trusted me to delegate an enormous amount of work in this project which allowed me to gain incredible level and quantity of skills and credits. He testifies excellence in both professional and personal manners, so I am happy that I was given the opportunity to work with him.
I am more than happy to meet and work with the Art Department crew, working with those design professionals was one of the most inspiring time of my life.
I am also a lucky man as I had a chance to work with those excellent professionals I could not even enumerate, but luckily the crew list does it for me.
I would also like to say many thanks to the workshops and their crew who made our designs real.
However, I let the most important person to the end: my gorgeous wife, Dalma. Movie industry is one of the most demanding ones and I could have never performed at this level without a strong hinterland, her continuous support.

DISCLAIMER

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BIOGRAPHY

RICHARD RÉVÉSZ is a Hungarian automotive designer attended to the TU Budapest (BME), where he studied Industrial Design Engineering and obtained his Master degree 2015. His thesis project consultant was Zsolt Tárnok. His interest in alternative energy technologies made him land first at a high-tech start-up company. He left them when Zsolt Tárnok offered him to join to the crew of the Blade Runner 2049 movie production. After working on two Hollywood feature films (Robin Hood premiers in 2018) he turned to extended reality applications and works now as automotive VR/AR experience designer at Accenture.

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Transfer to Immortality
A Scenario for Sustainable Society beyond "The Singularity"

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KEYWORDS
Singularity, Immortality, Virtual Worlds, Artificial Intelligence, Avatars.

ABSTRACT

Transfer to Immortality is a discussion paper reflecting on the challenges arising from increased longevity and environmental sustainability. It explores the increasingly realistic potential phenomenon of "The Singularity", postulated by Ray Kurzweil, in which the blending of humans and robots could extend human life indefinitely. If such a scenario became a reality, one of the possible alternatives to immortal physical hybrid humans would be to digitally extract individual human memories and characteristics and use them to create an avatar "clone" capable of independent life in a virtual world. This paper outlines such a scenario and its potential consequences for the future of humanity.

INTRODUCTION

The impact of pervasive disruptive technologies on society is profound and challenging. These exponentially emerging technologies have brought about rapid developments in the quality of life for millions of people, have helped to bring about the eradication of many diseases that were primary causes of death in the 20th century and continue to extend life expectancies in the developed world. Today, most of the causes of ill-health and death such as cancer, cardiovascular disease and diabetes are in some way related to lifestyles. Citizens with previously life threatening medical conditions are kept alive through medical interventions that were previously unavailable.

At the same time as technology is rapidly building our understanding of and ability to combat disease and mortality, it is also helping to remove or diminish our daily physical and cognitive challenges through almost instant, ubiquitous access to information and services. In this way, on the one hand technology is helping us to live longer and combat disease but on the other hand it is contributing to the sedentary and hedonistic lifestyles that are responsible for conditions such as obesity, diabetes, cardiovascular disease and sexually transmitted diseases. Today, this paradoxical combination of threatening lifestyle related medical conditions and the use of technology to potentially extend lifespans indefinitely has created a scenario in which public health services which have previously been taken for granted are becoming unsustainable. Medical and care services are struggling to cope with medical conditions that are arguably both caused by and could be managed by disruptive technologies.

Extrapolating this scenario to 2045 when the baby boomer generation are reaching their 100th year, how can society and technology co-evolve to create a sustainable future in which human beings living on a planet with finite resources have the potential to become immortal?

IN THE YEAR 2045

The year is 2045 and Ray Kurzweil's predictions of the "Singularity" in which a blend of humanity and technology can extend human life indefinitely has become a reality. Developments in biomedical technologies have led to embedded devices in human bodies to monitor and manage health are now commonplace and lifestyle related conditions which were the major cause of death in the early 21st century have been all but eradicated. Technology mediated human to human and human to machine relationships have revolutionised the social and economic models that have sustained society for centuries. Almost every action and thought is captured in the ubiquitous internet of things, data warehoused and analysed to help citizens effortlessly and intuitively manage their lives. Developments in communications technologies, embedded sensors and virtual reality have made it possible to share thoughts and feelings across continents with millions of citizens, creating a form of reality television that would have been unthinkable just 30 years before. Children born into the world each have a unique internet address to help identify, collect and store the whole of life's experiences. Mankind has achieved the potential for immortality but at a massive price..

THE LIFE OF BRIAN

Brian Spinks is approaching his 100th birthday in 2045. As his birthday grew closer, he reflected on how different his life was to that of his parents and how fortunate he was to have been born just after the end of the Second World War. His father had died of a stroke in 1992 at the age of 69, having endured several years of ill health and his mother had passed away in 2012 at the age of 86, dying alone in a care home suffering from dementia. Brian reflected on his good fortune at being fit and healthy at the age of 99. To Brian, his late parents were immortal in his memory and their influence would live on through him but now humanity faced a different challenge.

Developments in environmental technologies had solved many of the problems of the early 21st century. Clean energy was now a reality and global warming and pollution were distant memories. Human understanding of nutrition and agricultural technologies had solved many of the starvation and poverty problems that had been predicted to eradicate mankind. Agreements had even been reached on a form of universal income for all adult citizens to compensate for the massive loss of traditional jobs that had resulted from developments in robotics and artificial intelligence.

The human race had evolved to create a paradise world in which all human needs could be met virtually on demand. Despite all this, the world was unsettled. Restrictions had been placed on the number of children that could be born and raised in a family but overcrowding and the loss of the green spaces and open countryside that Brian had so loved as a child made Brian unhappy. Citizens across the globe, especially those who had been born in the pre-digital era, reflected on the prospects of immortality and the future of humanity and recognised that humans were not designed for the prospect of immortality.

Brian did not want to die but he wanted future generations to have the chance to grow and develop in the kind of world he had enjoyed as a child and so he volunteered for a new initiative that the Global Authorities had initiated called "Transfer to Immortality" (TTI). Brian saw this initiative as his chance to help sustain the future for coming generations whilst giving himself a new challenge in a brave, new virtual world.

Technologies that had evolved in the 21st century were able to access all Brian's stored memories and experiences and transfer them to a virtual character or avatar with all of Brian's personality attributes. The "Transfer to Immortality" scheme involved Brian effectively re-living his life in a space of 24 hours in a special "holodeck" chamber. He imagined it would be like having his whole life flash before his eyes as if it would have been in death. The TTI scheme allowed others to share in this experience through the virtual reality technologies commonplace in 2045 with the most advanced systems using embedded neuro-sensors to allow "viewers" to share exactly the same feelings and emotions that Brian had felt as his life was re-played.

When his 100th birthday came, Brian entered the holodeck chamber and settled down on the couch whilst the technicians connected the headset and prepared for the TTI. He drank a special compound to help him relax and free his mind for the experience. The following 24 hours were like a dream in which he experienced his early life as a baby, felt the warmth of his mother's arms and heard the laughter of his grand-parents. He could smell the London underground when his grand-parents had taken him to a circus at Harringay when he was a young boy and he cried as he once again stood at the hospital gates when his father broke the news of Grandma's death.

At the exact moment when Brian's experiences became synchronised with the actual date and time, he entered a new world which seemed indistinguishable from the world he had just left but he knew that he was better off than those he had left behind. For Brian and the physical world he had planned to leave, there was a mysterious conclusion. It was a matter of uncertainty, at the precise moment of transfer, as to whether the process had been successful. Was Brian technically dead in a physical sense to be reborn as a virtual clone or would technical and/or human interventions interfere with his plans?

PROTECTING THE FUTURE OF HUMANITY

The "Life of Brian" scenario raises many scientific and ethical issues. The science fiction of today is rapidly becoming the science fact of tomorrow. There are many respected scientists and academics who have very serious concenrs about the impact of disruptive digital technologies on society. The holy grail of immortality has been a persistent theme in human literature but, as often depicted in "Vampire" movies, the notion of en eternal life brings with it a miserable existence.

The question is whether the cycle of life and death should be an essential part of what makes us human. In many aspects, if one considers that human beings throughout history have continued to influence the world long after death through their writings, passed on memories and genetic heritage, modern digital technologies have the abilty to store human life events indefinitely and, by implication, have created virtual immortality for everyone.

It may yet be that human beings have an inbuilt "self-destruct" button so that, whether as a direct result of human intervention or indirectly by natural disasters, we may protect the future of humanity by partially destroying or seriously damaging the civilization we have created.

Mapping Science Fiction onto Reality

EVOLUTION OF THE SCIENCE FICTION WRITER'S CAPACITY TO IMAGINE THE FUTURE

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KEYWORDS

cognition, future, imagination, innovation, science fiction

ABSTRACT

Drawing upon a body of research on the evolution of creativity, this paper proposes a theory of how, when, and why the forward-thinking story-telling abilities of humans evolved, culminating in the visionary abilities of science fiction writers. The ability to recursively chain thoughts together evolved approximately two million years ago. Language abilities, and the ability to shift between different modes of thought, evolved approximately 100,000 years ago. Science fiction dates to at least the second Century AD. It is suggested that well before this time, but after 100,000 years ago, and concurrent with the evolution of a division of labour between creators and imitators, there arose a division of labour between past, present, and future thinkers. Agent-based model research suggests there are social benefits to the evolution of individual differences in creativity such that there is a balance between novelty-generating creators and continuity-perpetuating imitators. A balance between individuals focused on the past, present, and future would be expected to yield similar adaptive benefits.

INTRODUCTION

Science fiction writers possess an often uncanny ability to envision the future before it happens, particularly with respect to technological advances. Drawing upon research in psychology, anthropology, archaeology, and agent-based modeling, this paper offers a theory of how these abilities evolved. First, we look at two key cognitive transitions that have been proposed to underlie the uniquely creative abilities of humans. Next, we examine evidence that individual differences in creativity are adaptive at the level of the social group. Third, I argue that, using analogous reasoning, we could expect individual differences in the proclivity to focus one's thoughts along the spectrum from past, to present, to future, should also be adaptive at the level of the social group.

THE EVOLUTION OF HUMAN CREATIVITY

We now outline a body of research on the evolution of creativity that will form the scaffold for the rest of this paper. We will examine how, when, and why the forward-thinking story-telling abilities of humans evolved, culminating in the visionary abilities of science fiction writers.

Recursive Recall and the Chaining of Thoughts

How did the capacity for human creativity evolve in the first place? Let us first consider how the mind acquired the capacity to modify thoughts and ideas by thinking about them in the context of other thoughts and ideas that are similar, that is, in the same local cluster. Merlin Donald (1991) suggested that the enlarged cranial capacity of our *Homo erectus* ancestors 1.7 million years ago enabled them to voluntarily retrieve and modify memories independent of environmental cues (sometimes referred to as 'autocuing'), a capacity he referred to as *self-triggered recall and rehearsal,* and which ushered forth a transition to a new mode of cognitive functioning. Thus, while *Homo habilis* was limited to the "here and now", *Homo erectus* could *chain* memories, thoughts, and actions into more complex ones, and progressively modify them, thereby gaining new perspectives on past or possible events, and even mime or re-enact them for others. The notion of self-triggered recall bears some resemblance to Hauser et al.'s (2002) idea that what distinguishes human cognition from that of other species is the capacity for recursion, and to Penn, Holyoak, and Povinelli's (2008) concept of *relational reinterpretation*, the ability to reinterpret higher order relations between perceptual relations.

Donald's proposal has been shown to be consistent with the structure and dynamics of associative memory (Gabora 2000, 2010, 2017). Neurons are sensitive to primitive stimulus attributes or 'microfeatures', such as sounds of a particular pitch or lines of a particular orientation. Experiences encoded in memory are *distributed* across cell assemblies of neurons, and each neuron participates in the encoding of many experiences. Memory is also *content-addressable:* similar stimuli activate overlapping distributions of neurons. With larger brains, experiences could be encoded in more detail, enabling a transition from coarse-grained to fine-grained memory. Fine-grained memory enabled concepts and ideas to be encoded in more detail; that is, there were more ways in which distributed sets of microfeatures could overlap. Greater overlap enabled more routes for self-triggered recall, and this paved the way for streams of abstract thought. Thoughts and actions could now be reprocessed, allowing for not just the generation of progressively refined tools but the emergence of local clusters of mutually consistent ideas that helped orient ones relationship to ones world (Gabora 1999; Gabora and Aerts 2009; Gabora and Steel 2017). This in turn paved the way for a primitive form of storytelling, although it was limited to mime and gesture, as complex language had not yet evolved.

In short, it is suggested that the onset of creative cultural evolution, including a capacity for simple mime and gesture based storytelling, was made possible by the onset of the capacity for one thought to trigger another, leading to the chaining and progressive modification of thoughts and actions. However, due the sparseness of the pre-modern archaeological record, it is difficult to experimentally test hypotheses about how the creative abilities underlying cultural transitions evolved. Although methods for analyzing archaeological remains are becoming increasingly sophisticated, they cannot always distinguish amongst different theories.

Some attribute the archaeological changes seen at this time to social factors. One suggestion is that it reflects enhanced family bonding and a more focused style of concentration, which was enhanced by controlled use of fire by at least 400,000 years ago (Foley & Gamble, 2009). Wiessner (2014) proposes that fire not only enabled the preparation of healthier food, but by providing light after dark, facilitated playful and imaginative forms of social bonding. Others emphasize an extrication from biologically based to culturally based kinship networks (Leaf & Read, 2012). I suggest that these social explanations are essentially correct, but that they derive from cognitive changes, which affected not just social interactions but interactions with other aspects of human life as well.

Agent-based Model of Chaining

Agent-based modeling is a computational methodology in which artificial agents can be used to represent interacting individuals. It enables us to address questions about the workings of collectives such as societies. It is particularly valuable for answering questions of this sort which lie at the interface between anthropology and psychology, owing to the difficulty of experimentally manipulating a variable, such as the average amount by which one invention differs from its predecessor and observing its impact on cumulative culture over time.

EVOC (for EVOlution of Culture) is a computational modeling of cultural evolution that consists of neural network based agents that invent new actions and imitate actions performed by neighbors (Gabora 1995, 2008b). The assemblage of ideas changes over time not because some replicate at the expense of others, as in natural selection, but through inventive and social processes. Agents can learn generalizations concerning what kinds of actions are useful, or have a high 'fitness', with respect to a particular goal, and use this acquired knowledge to modify ideas for actions before transmitting them to other agents. A model such as EVOC is a vast simplification, and results obtained with it may or may not have direct bearing on complex human societies, but it allows us to vary one parameter while holding others constant and thereby test hypotheses that could otherwise not be tested. It provides new ways of thinking about and understand what is going on.

The hypothesis that cultural evolution was made possible by the onset of the capacity for one thought to trigger another was tested in EVOC by comparing runs in which agents were limited to single-step actions to runs in which they could chain ideas together to generate multi-step actions (Gabora, Chia, and Firouzi, 2013; Gabora and Smith, submitted). Pseudocode of the 'without chaining' algorithm is as follows:

```
Each iteration
  For each agent
    Obtain new action through invention or imitation
    If new action is fitter than current action
      Executes new action
    Else continue to execute current action
```

Pseudocode of the 'with chaining' algorithm is as follows:

```
Each iteration
  For each agent
    Obtain new action through invention or imitation
    Obtain a second new action--referred to as 'sub-action'--through
  invention or imitation
      While sub-action meets criterion
        Incorporate new sub-action into action
    If new action is fitter than current action
      Executes new action
    Else continue to execute current action
```

Thus with chaining turned on agents could generate actions that consisted of ever-longer and more complex sequences of actions. An example of a 'criterion' that was used to determine whether a given sub-action would be added was that it had to be symmetrical to the previous sub-action (e.g., if the previous sub-action involved forward movement of one particular limb, the next sub-action had to involve forward movement of the corresponding limb).

Chaining increases the mean fitness and diversity of cultural outputs across the artificial society (Gabora, Chia, and Firouzi, 2013; Gabora & Smith, submitted). While chaining and no-chaining runs both converged on optimal actions, without chaining this set was static, but with chaining it was in constant flux as ever-fitter actions were found. While without chaining there was a ceiling on mean fitness of actions, with chaining there was no such ceiling, and chaining also enhanced the effectiveness of the ability to learn trends. These findings supported the hypothesis that the ability to chain ideas together can transform a culturally static society into one characterized by open-ended novelty.

Contextual Focus and Language

To recap so far: it is suggested the evolution of the capacity for science fiction, and storytelling more generally, had its roots 1.7 million years ago in the onset of the capacity to chain thoughts and actions together and thereby string events into narratives. However, the only means of sharing such narratives with others was to express them through mime, i.e., act them out. Thus, the earliest forms of storytelling are thought to be oral, in conjunction with gestures and expressions (Banks-Wallace 2002). It was possible to think about an idea in relation to other closely related ideas and thereby forge clusters of mutually consistent ideas, which allowed for a narrow kind of creativity, limited to minor adaptations of existing ideas. However, the mind was not integrated, nor truly creative, until it could forge connections between seemingly disparate ideas as in the formation of analogies.

The Middle-Upper Paleolithic has been referred to as the birth of art, science, and religion, and the 'big bang' of human creativity (Mithen 1998). Although the timing, location, and abruptness of this shift has been the subject of extensive debate (e.g., McBrearty and Brooks 2000), it is evident that something took place around this time. The question is: what caused it?

One proposal is that it was due to the onset in the Middle/Upper Paleolithic of *contextual focus* (CF): the ability to shift between different modes of thought—an explicit *analytic mode* conducive to logical problem solving, and an implicit *associative mode* conducive to insight and breaking out of a rut (Gabora 2003). CF differs from dual processing theories in that dual processing theories generally attribute abstract, hypothetical thinking solely to the more recently evolved "deliberate" mode (e.g., Evans, 2003), while according to the CF hypothesis abstract, hypothetical thinking is possible in either mode but it differs character in the two modes (imaginative flights of fancy versus logically constructed arguments) (Sowden, Pringle, and Gabora 2014). CF thus paved the way for integration of different domains of knowledge (Mithen 1998).

It has been proposed that CF was made possible by mutation of the FOXP2 gene, which is known to have undergone human-specific mutations in the Paleolithic era (Chrusch and Gabora 2014; Gabora & Smith, submitted). FOXP2, once thought to be the "language gene", is not uniquely associated with language. The idea is that, in its modern form, FOXP2 enabled fine-tuning of the neurological mechanisms underlying the capacity to shift between processing modes by varying the size of the activated region of memory.

CF may appear to be inconsistent with Mithen's (1998) suggestion that the integration of previously-compartmentalized intelligence modules–enabled cognitive fluidity: the capacity to combine concepts and adapt ideas to new contexts, and thereby explore, map, and transform conceptual spaces across different knowledge systems. Similarly, Fauconnier and Turner (2002) attribute cultural changes at this time to the benefit of cognitive fluidity for the capacity to draw and understand analogies. The CF proposal is consistent with these explanations but goes beyond them by showing how conceptual fluidity arises naturally as a function of the capacity to tailor how fluid or rigid one's thinking is to the situation one is in.

Agent-based Model of Contextual Focus

The hypothesis that the onset of CF brought about a second cognitive transition underlying the human capacity to evolve complex culture was also tested with EVOC (Gabora, Chia, and Firouzi 2013; Gabora and Smith submitted). When the fitness of an agent's outputs was low it temporarily shifted to a more divergent mode by increasing α: the degree to which a newly invented idea deviates from the idea on which it was based. Pseudocode of the 'with chaining + CF' algorithm is as follows:

```
Each iteration
   If fitness function changed
      Then increase rate of conceptual change
      Else small decrease in rate of conceptual change
   For each agent
      Obtain new action through invention or imitation
      Obtain a second new action--referred to as 'sub-action'--through
   invention or imitation
         While sub-action meets criterion
            Incorporate new sub-action into action
      If new action is fitter than current action
         Executes new action
      Else continue to execute current action
```

By increasing the rate of conceptual change if the fitness function (e.g., the environment, or problem to be solved) changed, the invention process was more radical, resulting in a bigger leap through the space of possibilities. By slowly increasing the rate of conceptual change if the fitness function had not changed, the invention process was more conservative, i.e., more likely to retain proven-effective elements while exploring minor deviations.

CF was implemented two different ways, referred to as CF1 and CF2. The analytic mode works identically in CF1 and CF2. In CF1 the divergent mode operates by exploring the space of possibilities at random. In CF2 it operates by exploring the space of possibilities more conservatively, capitalizing on learned associations.

CF alone without chaining had little effect, which is consistent with the hypothesis that it evolved, and secured adaptive benefit, only after chaining was well established. When CF was implemented in agents already capable of chaining, mean fitness of actions across the society increased, as hypothesized, and CF was particularly effective when the fitness function changed, which supported its hypothesized utility in breaking out of a rut and adapting to new or changing environments. Using an entirely different computational architecture, CF was similarly shown to enhance the art-making abilities of a computational creativity program geared at generating portraits with painterly qualities (DiPaola and Gabora, 2009; Gabora and DiPaola, 2012).

The evolution of the capacity for CF enabled or ancestors to control their thought processes—effectively tailor them to the task at hand—examining their inner and outer worlds from not just different perspectives but at different hierarchical levels (e.g., from detailed to 'big picture'). This enabled them to connect seemingly unrelated aspects of their lives into a more integrated understanding of their world, and it enabled the evolution of complex language. Thus, it made it possible to go from expressing stories by acting them out to *telling* stories. In addition to being part of religious rituals, some archaeologists believe rock art, and tattooing may have served as a form of storytelling in ancient cultures (Kaeppler 1988; Lewis-Williams et al. 1982).

Storytelling is something that, to some degree, we are all capable of; however, not all of us are equally interested in, nor good at, telling stories. I suggest that some other hurdles had to be crossed in the transition to a storytelling species, and in particular, a species that generates science fiction.

INDIVIDUAL DIFFERENCES IN CREATIVITY

Although creativity is encouraged in the abstract it is often discouraged in educational and workplace settings, suggesting that there may be corrective forces at work in society that temper the novelty-generating effects of creativity with the continuity-promoting effects of imitation and ritual (Gabora and Tseng 2017). Such corrective forces might be expected to exert a stronger impact on those who show less creative potential, thereby giving rise to a different degrees and kinds of creativity. Indeed, there *are* pronounced individual differences in creativity, not just in terms of domain of application but also in terms of degree and scope (Chen, Himsel, Kasof, Greenberger and Dmitrieva 2006. Wolfradt and Pretz 2001; Woodman and Schoenfeldt 1989).

Using the above-mentioned agent-based model of cultural evolution (EVOC), we investigated the idea that tempering the novelty-generating effects of creativity with the novelty-preserving effects of imitation is beneficial for society (Gabora and Tseng 2014a,b, 2017; Leijnen & Gabora 2009). Although the model is vastly simpler than real societies it enabled us to manipulate the ratio of creators to imitators and the degree to which creators are creative in a controlled manner and observe the result.

In a first experiment, we systematically introduced individual differences in creativity, and observed a trade-off between the ratio of creators to imitators and how creative the creators were. Because a proportion of individuals benefit from creativity without being creative themselves by imitating creators, the rate of cultural evolution increases when the novelty-generating effects of creativity are tempered with the novelty-preserving effects of imitation. If there were few creators they could afford to be more creative, and vice versa; if there were many their creativity had to be restrained to exert the same global benefit for the society. Excess creativity was detrimental because creators invested in unproven ideas at the expense of propagating proven ones.

We also obtained evidence that society can benefit by rewarding and punishing creativity on the basis of creative success. In a second experiment, we tested the hypothesis that society as a whole benefits if individuals adjust how creative they are in accordance with the fitness of their creative outputs. I refer to this as *social regulation* because could be mediated by social cues such as praise and/or criticism from peers, family, or teachers, but it is also possible that it involves individual differences in the ability to detect or respond to such cues, or individuals' own assessments of the worth of their ideas, or some combination of these. In the *social regulation* condition of our simulation, each agent regulated its invention-to-imitation ratio as a function of the fitness of its cultural outputs; thus, effective creators created more, and ineffective creators created less. With social regulation, the agents segregated into creators and imitators, and the mean fitness of outputs was temporarily higher. We hypothesized that the temporary nature of the effect was attributable to a ceiling on output fitness.

This in turn led to the hypothesis explored in a third experiment, which explored the conditions under which the benefits of social regulation of creativity are long-term. In keeping with the research discussed earlier suggesting that onset of the capacity for chaining was a pivotal transition in the evolution of human creativity, this third experiment made the space of possible outputs open-ended by giving agents the capacity to chain simple outputs into arbitrarily complex ones. This meant that fitter outputs were always possible, and thus the space of possibilities was in theory unlimited. With social regulation *and* the capacity for chained outputs, the agents once again segregated into creators and imitators, and the mean fitness of their outputs was higher. However, as hypothesized, the effect of social regulation was no longer temporary; it could indeed be sustained indefinitely. We did not test the effect of adding the capacity for contextual focus in this particular set of experiments, but our previous results suggest that it would have magnified the effect of social regulation to increase the mean fitness of cultural outputs further still.

Together, these experiments provide evidence that individual differences in creativity are of not just temporary but ongoing adaptive benefit to society, that these benefits can be that they could come about and be maintained due to social regulation mechanisms. Although further investigation is needed to establish the relevance of these results to real societies, they are a step forward to understanding the underlying mechanisms that enable societies to balance novelty with continuity.

It is difficult to pinpoint when the capacity for a division of labour between creators and imitators across societies could have arisen. What we can say is that it was after the 'big bang of human creativity in the Paleolithic. In any case, with the arrival of the internet, individual differences in the expression of creativity has exploded, with respect to both degree and domain. For any particular topic, every community seems to have *someone* who is an expert on it, and conversely, everyone seems to be an expert on *something*.

PAST, PRESENT, AND FUTURE THINKING AS A FORM OF INDIVIDUAL DIFFERENCES

We have examined evidence that individual differences in the balance between novelty-generating creators and continuity-perpetuating imitators may have adaptive benefits for society at large. This suggests that there may have group selection pressure to preserve and perhaps amplify individual differences in creativity over time. Let us take now this line of reasoning one step further.

A balance between individuals focused on the past, present, and future would be expected to yield similar adaptive benefits. Those who are focused on the here and now would be more apt to detect the presence of predators or food items, signs of illness or weather changes, and so forth. Those who are focused on the past would be better able to provide a stabilizing sense of continuity, and to make use of past lessons to avoid repeating mistakes. Finally, those who are focused on the future would help society prepare for effects to come, and think in terms of not just short-term benefits but long-term goals. Ostensibly, a society that consisted of individuals along the spectrum from past to future might argue more, because their points of view will not always be in sync. But nevertheless it is easy to see why such a society would be more successful.

Thus, it is suggested that well before the earliest known works that could be called science fiction in second Century AD, but after 100,000 years ago, and concurrent with the evolution of a division of labour between creators and imitators discussed above, there arose a division of labour between past, present, and future thinkers, as illustrated schematically in Figure 1. The eye in the middle represents someone who naturally focuses on, and thinks most clearly about, the present. The eye on the left represents someone who naturally focuses on, and thinks most clearly about, the past. The eye on the right represents someone who naturally focuses on, and thinks most clearly about, the future.

Most people are probably of the sort that they focus on, and think most clearly about, the present. They are *capable* of thinking about the past and the future, but this is not the natural comfort zone or 'attractor state' for their thoughts; for them both the past and the future are much hazier than what is going on now.

Archaeologists, historians, writers of historical fiction, and so forth, are more likely to focus on, and think most clearly about, the past. They tend to view the present and future in terms of how it is rooted in what has come before.

Futurists, inventors, and writers of science fiction, are more likely to focus on, and think most clearly about, the future. It is not that they cannot or do not think about the past or present but, that they tend to view the past and present as seeds for speculation and prediction about what has yet to pass. Thus, it is proposed that the evolution of individual differences in the extent to which we focus along the spectrum from past to present to future paved the way for the fantastical stories of future events and far-off worlds that we now enjoy.

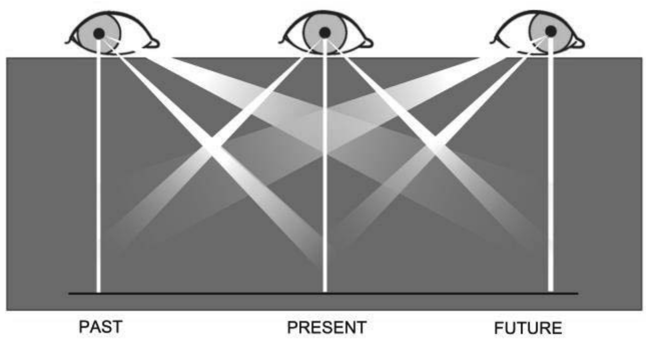

Figure 1. Schematic Depiction of Individual Differences in Tendency to Dwell on Past, Present, and Future

As with the evolution of individual differences in creativity, it is difficult to pinpoint when the capacity for a division of labour between creators and imitators across societies could have arisen. What we can say is that it was after the 'big bang of human creativity in the but before the earliest known works that could be called science fiction in the second Century AD.

THE BIRTH OF SCIENCE FICTION

Science fiction, which dates to at least the second Century AD, is a genre of speculative fiction that typically deals with imaginative concepts such as futuristic science and technology, parallel universes, extraterrestrial life, and travel through time and space, sometimes at faster than light speeds.

As such, more than other forms of storytelling, it would attract and rely upon individuals whose thought processes lean toward thinking about the future.

IMPLICATIONS FOR PRODUCT DEVELOPMENT

The prototyping of new technological developments derived from science fiction is 'proof of concept' of the phenomenon of cross-domain creativity, a phenomenon wherein inspiration for a creative work comes from a domain that is different from the creative output (as in when a song inspires a painting). For reasons outlined elsewhere (Gabora, 2013), this phenomenon provides a 'litmus test' for a feasible theory cultural evolution; more specifically, it is incompatible with a Darwinian or Selectionist framework but compatible with a framework based on self-organization and communal exchange.

Those who turn the visionary breakthroughs gleaned by the science fiction writer into working prototypes are of course limited to the tools and materials of the present day. This process makes extensive use of chaining (to think about product ideas from different perspectives and refine them over time) as well as CF (to shift from a big picture perspective to a detailed perspective, and to break out of a rut when needed).

The transition from insight as part of a science fiction narrative to actual product on the shelf occurs through a set of stages. The incentive to build these prototypes can stimulate visionary (future oriented) thinking about methods of producing the needed tools and materials. This in turn can hasten the process that can lead to working prototypes. These prototypes must be refined to meet such (present-day) constraints as affordability and ease of use as well as provide a sense of continuity with more familiar (past) technologies, and a sense of being on the cutting edge (of the future). In this way, the actual emergence of the science fiction writer's visionary ideas into our lives requires a convergence of past, present, and future thinking.

CONCLUSION

The 'divide and conquer' strategy is well-known to Mother Nature, and it has previously been suggested that its effectiveness can account for individual differences in human creativity. Using a similar argument, this paper suggested that individual differences in the tendency to focus one's thoughts on the past, present, or future, became magnified over time. This in turn paved the way for forward-thinking science fiction writers and their often uncanny powers to envision technological advances before they become reality.

FUTURE RESEARCH

This account, though built on an extensive foundation of research in psychology, anthropology, archaeology, and agent-based modeling, is at this point speculative. In future agent-based model work we will investigate the extent to which a division of labour into past, present, and future focused modes of cognition exists and is in fact beneficial to a social group. If so, this would provide tentative support for the hypothesis that individual differences in the tendency to focus one's thoughts on the past, present, or future, became magnified over time yielding benefits for societies. This in turn would provide further support for the hypothesis that such differences led to the rich treasure trove of science fiction that has inspired us for generations and will continue to inspire us for generations to come.

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BIOGRAPHY

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Applied Technology

IMMERSIMED: A FUTURE-PROOF IMMERSIVE PLATFORM FOR MEDICAL TRAINING

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Virtual Reality, Augmented Reality, Medical Education, Simulation Training.

ABSTRACT

This work presents our vision and work-in-progress on a new platform for immersive virtual and augmented reality training. ImmersiMed is aimed at medical educational and professional institutions for educating nurses, doctors and other medical personnel. ImmersiMed is created with multi-platform support and extensibility in mind. By creating consistent experiences across different platforms and applications ImmersiMed intends to increase simulation availability. Furthermore, it is expected to improve quality of training and prepare students better for more advanced tasks and boost confidence in their abilities. Tools for educators are being provided so new scenarios can be added without intervention of costly content creators or programmers. We address the future of ImmersiMed and discuss how its AR applications will ease the transition from virtual training environments to the real world. We also show many other opportunities the platform has to offer to improve and lower medical training and simulation costs.

INTRODUCTION

While the term Virtual Reality (VR) was coined in the 1980's, its concepts had been fueling sci-fi literature and movies for decades. Nowadays, VR refers to a computer generated virtual environments (VE) in which users are being immersed using VR devices such as Head Mounted displays (HMD) and intuitive, motion sensing input devices. The goal of VR applications is to create an experience in which the user feels immersed and present in that VE. The focus of VR interactions thus remains in the digital environment.

Augmented Reality (AR) differs from VR as it uses the real environment but enhances the experience by adding an interactive overlay onto it. Therefore, AR applications usually focus on real world tasks. The virtual and physical environment layers are blended in such a way that an immersive, interactive environment is experienced.

VR and AR are no longer just about video games and research. Over the last few years, big players in the tech industry such as Facebook (Oculus Rift), Google (Glasses, Cardboard, Daydream), Samsung (Gear), Microsoft (HoloLens) and HTC (Vive) have invested in the future of VR and AR. The technology has since evolved dramatically, providing high-fidelity experiences at affordable prices. They are thus no longer Sci-fi vision but are a commercial reality and are on the verge of being adopted in every other industry, as well.

Training is one of the earliest use cases for VR and AR. Especially VR, which allows for practicing dangerous, complex, uncommon or expensive tasks in a risk-free environment. From a learner's point, the possibilities are unlimited, as trainees can perform 'hands on' tasks in a controlled and safe environment. Trainees can afford to make mistakes and learn from it in the VR setup where there is literally no risk at all. A comprehensive publication of the benefits of VR training can be found in (Gupta et al. 2008) Although these benefits are numerous, a gap between the simulation and the real world remains.

As AR is a more recent technology, its advantages have not been studied in such a general way, however some studies do point out that many of the benefits that VR brings to training also hold true for AR (Barzom et al. 2016; Khor et al. 2016; Ma et al. 2016; Kamphuis 2014). Some AR applications have shown the potential of AR. Perhaps, it might be able to bridge that gap between achieving a skill in a virtual training context and the actual competence in the real world.

One of the fields that has been adopting VR for training and simulation since its early days is healthcare (Jones 2015). Over the past couple of decades, VR and simulation technology has been implemented in healthcare training and education. Surgery simulators have been invaluable for physician training. However, these tools have historically come at a considerable cost and students often only have limited access to these simulators. Furthermore, most of these setups were only designed to focus on specific procedures, scenarios or situations, mostly aimed at surgeon training. New real-time visualization platforms, such as smartphones, are now becoming ubiquitous and their power is nearing that of desktop computers. This has been pushing VR and AR technologies and is making it cheap and available to everyone. Studies have shown that the VR and AR training of medical students and residents improves students' knowledge base and in evaluating their performance (Okuda et al. 2009). Students perceive simulation-based education as ''an opportunity to learn new skills in a safe environment.'' (Weller et al. 2004). Use of VR training at the start of medical training has also been

shown to improve understanding of basic concepts of medical science, such as pharmacology and physiology, presumably because these simulated experiences help students to understand abstract concepts of basic science that are difficult to perceive with regular discourse (Rosen et al 2009).
Apart from the understanding aspects, there is also an important confidence aspect. There has always been a strong mental connection between performance and seeing oneself as being successful. Visualizing yourself on the ladder of success certainly helps you boost your confidence level. And that's one of the reasons VR and AR simulations are a successful technology for training. The more medical students train and succeed in a virtual situation, the more confident they will be once they enter real-life situations. More and better training will improve quality of care and lower the risk of medical mistakes.
The healthcare industry lies at the intersection of high-tech, medical knowledge and legal policy. Medical knowledge doubles every six to eight years and new innovations in medical procedures pop up every day. Healthcare practitioners have an obligation to keep their knowledge and skillset up-to-date. Medical professional training and proficiency are a huge part of health care costs and many hospitals and educational institutions lack availability of tools and/or time to keep up with all new developments. Due to the high cost, training is often limited to pure medical knowledge. We believe a blend of AR and VR can solve these issues. As reported earlier, many tools for both VR and AR already exist in the field of medical training. However, they are mostly complex expensive and focused on fixed procedures and scenarios. The largest group of medical personnel consists of nurses, a group which we believe has been overlooked by most VR application developers and researchers. Furthermore, their technical knowledge on how to adapt VR/AR applications is mostly non-existing.

IMMERSIMED

In this work we present our vision and work-in-progress on the ImmersiMed platform. ImmersiMed is a combined VR/AR platform aimed at educational and medical institutions for training, nurses, doctors and other medical personnel. It envisions being an easy to use platform for training all kinds of procedures from navigating through the hospital to highly specialized surgical procedures. By allowing different setups, ranging from highly specialized setups, to commercially available computer-HMD combinations, down to downloadable mobile apps that users can run on their smartphones at home ImmersiMed will be tailorable to every budget and situation. Combining multiple setups based on the same platform will improve the learning experience by increasing the amount of time a student can train. Furthermore, the experience across these platforms will remain much more consistent than if separate applications were to be used. Highly advanced simulator setups, that might be available at the institution, will never be available for every student at all times. The mobile apps, that can deliver similar experiences, can be available on every student's smartphone, allowing them to practice whenever, wherever. Training programs could also work their way up by letting students learn the basic knowledge and procedures at home on their smartphone apps, then move on to more available computer-HMD setups at the institution and finally do a simulation on the sparsely available high-end simulator. This would save valuable time and costs on these expensive simulators.
However good these expensive high-end simulators can be, a gap will still remain between virtual and real experiences with real patients. We strongly believe, AR apllications will be able to bridge that gap, so we aim researching this as well.
Another important aspect of the ImmersiMed platform is flexibility. ImmersiMed will provide educators and even students with the opportunity to create new scenarios and procedures which could be scenarios for all or for specific setups only. Finally, ImmersiMed incorporates user feedback, directly in the virtual/augmented environment and indirectly after the session. Depending on their level of skill the instructor or the student themselves, could determine when and how much feedback he wants. In all setups, this feedback could also be set up as an evaluation tool to check student's progress and skill level and might be stored permanently or exported.

CURRENT STATUS

System Overview

ImmersiMed and its first set of applications have been developed using the Unity multi-purpose cross-platform game engine. Unity was chosen for its flexibility and cross-platform capabilities, as it supports building to 27 different platforms. This will be crucial for future releases, especially those running on mobile devices. Also, Unity has a plugin supporting OpenVR, a standard which encourages a common baseline experience for VR users. It is an SDK developed by Valve and supports most VR HMDs and motion controllers. For future AR setups and mobile apps, Unity allows for AR development and supports most popular AR headsets, amongst others the Microsoft HoloLens. It has been proven to be a very reliable engine for AR applications for all major platforms and allows for cross platform development as well.
Our first set of applications, which will be described in the next section, focus on a computer-HMD VR setup. We use a standard VR-enabled desktop computer combined with a HTC Vive HMD. We allow the user to interact with the VE using the standard Vive controllers. Since we implement all VR components using the OpenVR plugin, switching or adding motion controllers or changing the HMD would require very little effort.
The reasons we initiated the projecton on this setup before moving on to the other platforms include:

1. it will require the most resources (computational, graphical and complex user interactions),
2. it will require the highest level of graphical detail,
3. it was the first platform requested by the Department of HealthCare, at the Karel de Grote University College,

which will be our main partner in the future testing and development of the ImmersiMed platform.

Internally, we use an XML-based file format to describe scenarios, including patient details, available medications and equipment, tasks the student should perform and so on. A user-friendly tool that allows nursing teachers or trainers to edit and create new scenarios was also developed. It uses the same Unity modules and codebase that were used to create the applications. More details will be described in the next section where we discuss the current status.

Current Functionality and Applications

Currently, the ImmersiMed applications are aimed at training nursing students in routine tasks and providing them with feedback on how well they performed. The implemented tasks were identified by a team of instructors from the Bachelor in Nursing program at the Karel de Grote University College. They identified the priorities of the routine tasks based on the importance of the task, set out against the lack of training possibilities in the current curriculum. From this prioritized set we, in close collaboration with the instructions, selected a set of tasks that would create a complete overall training experience, focusing on the tasks which had the highest priority outcome.
In this first stage they were developed for the computer-HMD setup, but with the other platforms in mind.

These routine tasks include:

1. navigating through and interact with a virtual hospital environment. The subject can walk through the hallways, enter patient rooms, medical supply rooms, open, close doors, etc (Figures 1).
2. Finding, identifying patients (Figure 2) and reading their medical charts containing history, allergies, etc. (Figure 3).
3. Finding and reading instructions on the required medical treatments, prescriptions.
4. retrieving necessary medical equipment and machines from store rooms and computer-controlled medication cabinets, also known as secured unit-based cabinets (UBCS) (Figure 4). Our system is based on the Vanas computer controlled medical cabinet system which is the most prevalent in Belgian Hospitals.
5. preparing medical equipment (syringes, needles, etc.) and medications such as dosage, collecting extra aids for administrating medicines (a cup of water, etc.). (Figure 5).
6. looking up medication information in the official professional drug and medications databases.
7. Administrating medications to the patient according to professional guidelines (Figure 6).

Figure 1: Navigating through the Medical Institution's hallway, to get to a patient's room

Figure 2: A Patient's Room including a Pregnant Famele Patient. The Patient can be Identified by Scanning a Code on the Wristband

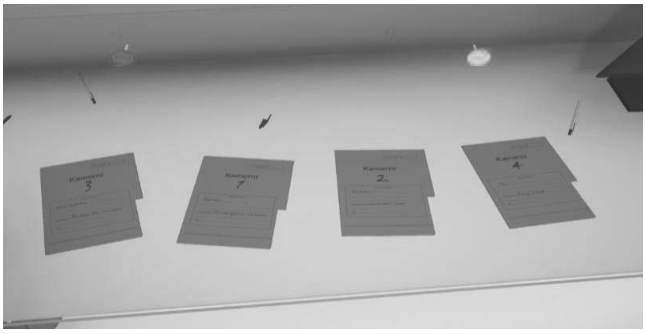

Figure 3: A collection of Virtual Patient Charts located at the department's central Desk

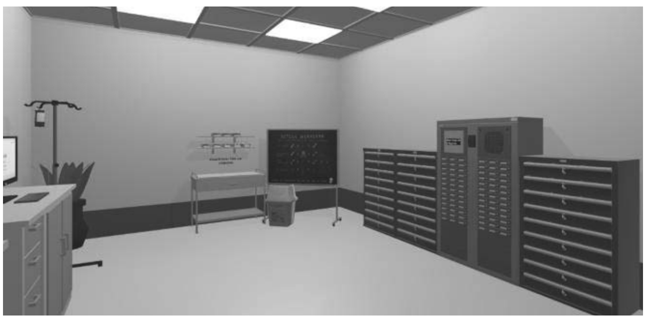

Figure 4: Room with Secured Medical UBCS for Retrieving Medications and Medical Equipment

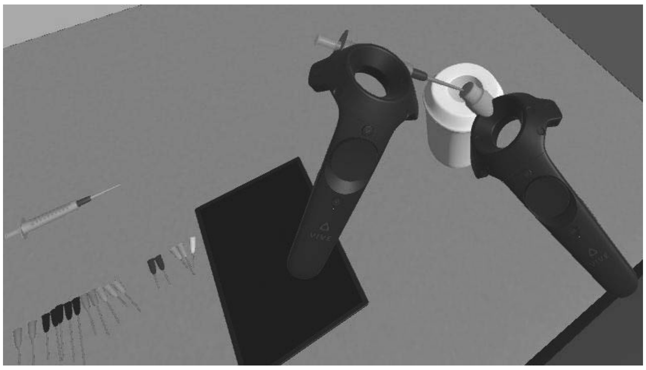

Figure 5: Drawing Up Medication from a Vial after Selecting the Correct Syringe and Type of Hypodermic Needle

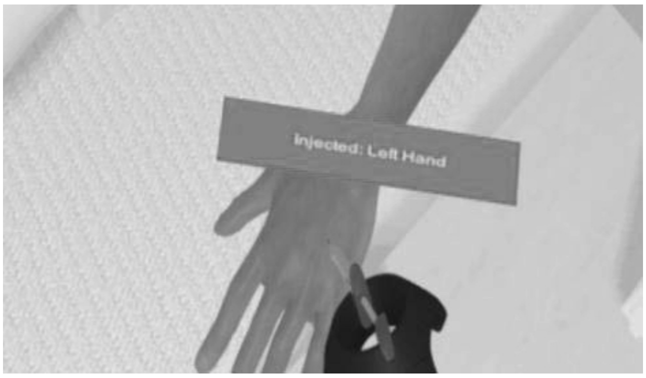

Figure 6: Administrating Medications with Direct Feedback Enabled

Instructors, on the other end, are provided with two simple tools. The first tool is a simple, easy-to-use form-based scenario creation tools which allows them to:
create new scenarios by:

1. creating new patienta with a history and type (adult, child, male, female, pregnant, senior, etc.)
2. adding new medications and tools, describing their form (pill, flask, etc.).
3. Setting up the entire UBCS contents, the medication, tools and security level can be set up per drawer, multiple cabinets can be set up.
4. Describe the entire scenario:
   i. select the patient that needs treatment
   ii. select the right medication
   iii. select the right way and details of how to administer the medication (using the correct tools and doseage).

Part of the interface is shown in Figure 7.

Figure 7: Adding a new Patient in the Scenario Creator Tool.

The second tool provided to instructors, allows them to check a student's progress by viewing the results after the session has ended. This progress is, for now, kept in a simple text-based file logging every timed action. An example of a very short session is shown in Figure 8. This feedback is an extra addition to the feedback that can be given while the student is training in VR. It could easily be exported to a database or grading tool if necessary.
So, in contrast to most VR applications for medical education our current applications do not aim to simulate complex surgical tasks, train for diagnosing patients or learn anatomy. Instead we focus on routine nursing tasks and performing them in the correct order and in compliance with the healthcare procedures.
A first set of trials, comparing different interaction methods for navigation, preparing and administrating medications and different forms of feedback has already been carried out in close collaboration with the Department of Health Care at the Karel de Grote University College, Belgium. Its conclusions are now being grouped and the different techniques are now being implemented and combined into the next release. This release, along with the first version of a smartphone app, will be used to train students starting the Bachelor in Nursing program at the Karel de Grote University College in 2018-2019.

```
New Session:
1/23/2018 11:44:07 PM: User scanned badge and accessed the VANAS UI
1/23/2018 11:44:14 PM: User selected patient Ludwig Vermeiren
1/23/2018 11:44:18 PM: User is selecting another medicine
1/23/2018 11:44:23 PM: User selected medicine Insuline - 100units
1/23/2018 11:45:29 PM: User filled syringe with a Bottle_Piritramide liquid
1/23/2018 11:46:12 PM: User succesfully injected medicine into Left Hand
--------------------------------------------------
```

Figure 8: Part of a Log File for the Instructor

FUTURE DEVELOPMENTS

The next phase in the ImmersiMed project will be to create mobile training applications that mimic our computer-HMD setup. This will allow nursing students to practice the same skills, when and wherever and let them learn at their own pace. Of course, the level-of-detail will not be the same, and interaction with the VE on the mobile app will not be as sophisticated as within our VR setup. However, by working on the same platform, using the same codebase, graphical elements and scenarios, we intend to achieve a consistent experience across all our applications. Apart from allowing for more hours of practice, the combination of having a mobile app and a more advanced setup, also has the merit of letting students try, learn and experience certain scenarios at home, prior to engaging in more advanced lessons using the scarcely available advanced setup. This is expected to increase the quality of training on the more detailed aspects of the simulation and increase students' confidence in the routines and procedures they are trying to master. Of course, these results will have to be confirmed in future research.

Another future development will be more detailed instructor feedback. Currently, instructor feedback is limited to be shown directly in the HMD application and a simple text-based logging of student's actions, as described in the previous section. An instructor can follow the entire simulation on a separate screen, and can thus see the student's every action, when he is there. By enlarging the amount of tracked data, nursing teachers should be able to check which students have been training and how well they have developed their skills, both at home and in the advanced simulator, even when not around. This information could also be used to show student's progress as well, for both instructor and student. This e.g. by showing statistics on how correct, fast procedures were performed, the number of mistakes made, over time. Also, it could be used to allow to check whether students prepared themselves well enough to take part in advanced setup trainings etc...

The next phase of ImmersiMed applications for students will start AR development. AR smartphone and high-end AR device applications will be developed to help students bridge that gap between achieving a skill in a virtual training context and the actual competence in a real-world hospital. This could be realized by showing them the steps of procedures, visualize how medications should be prepared, warn them in case of mistakes, etc. Another way we expect our AR applications to bridge that gap is by letting students train in real medical environments, with real medical equipment, but on virtual patients.

In a parallel path, next to the student-focused applications, we intend to develop AR tools for medical staff in general aiming at reducing mistakes. We can take all the elements of the student focused AR applications, and extend them with facial recognition, scanning tools to scan patient id tags, couple them to hospital medical tracking systems, patient chart databases and so on realizing a system reducing medical errors. As high-end AR device prices will start to drop in the very near future, equipping every healthcare worker with such a tool is no longer just a sci-fi scenario, in contrast, it is a plausible near-future reality.

Finally, one of our future realizations will include storing all medications preparation tracking data. Preparing medications is one of the most important tasks of the nursing staff. However, it is error-prone and takes up quite a percentage of nurses' time. As the shortage of trained medical staff is increasing in most western regions, we need to optimize their workload. By collecting all motion controller data, we could train a robots or other devices to prepare medications for patients, taking over these tasks from human nurses, creating more time for tasks which robots will not be able to do in the short term. This part of ImmersiMed will be developed in conjunction with the Op3Mech research group at the University of Antwerp.

Other future ImmersiMed opportunities include: a remote AR medical assistance app that let's untrained bystanders get instructions from emergency services, remote controlled nurse robots for highly contagious patients, and many more.

The technical challenges in these future developments are numerous and addressing them all would be beyond the scope of this paper. The most urgent ones we face include:

1. creating a consistent experience across mobile and more advanced setups. This will be met by developing on a single platform and codebase wherever possible. Unity Allows for cross-platform development and 3D models can be designed in different levels of detail. Code for selecting the models at startup, depending on the computing/graphical capabilities of the device will realize the optimal result for every device.
2. develop interactions for mobile and AR platforms with limited motion controller systems. As we want our smartphone apps to be available to students at all time, we also want to keep the burden of adding, buying, configuring extra peripherals to a minimum. Interactions in AR have already been studied and many techniques exist. Most of them use computer vision-based gesture recognition (Haria 2017), a field of research that has received a lot of attention and has progressed enormously over the past decade. Most AR devices and smartphones are equipped with cameras nowadays, so this opens up a lot of possibilities to allow for a whole range of controller-free interactions. Gaze control (Nillson 2007) is another intuitive and more lightweight way of interacting in AR.
3. allowing for new graphical and technical elements to be included for new scenarios. To tackle this issue, we intend to use the asset bundle component that is included in Unity, exactly with this in mind. Of course, this could result in the fact that our XML description of scenarios will have to be expanded to also incorporate new assets. Another option would be to develop a simple, easy-to-use visual scene editor that would allow nursing teachers to create their own VE and scenario, all in one tool. This would generate the XML containing a VE description, interactions and the scenario and tasks that the student would have to carry out. In future versions we might also let the instructor create scenarios by performing tasks themselves and record his choices and actions. This to make it even more intuitive for the instructors.

Most of solutions are currently under development will be tested in the next phase of the ImmersiMed project, in close collaboration with the Bachelor in Nursing program at the Karel de Grote University College.

CONCLUSIONS

In this work we present our vision and work-in-progress on the ImmersiMed platform. ImmersiMed is a combined VR/AR platform aimed at educational and medical institutions for training, nurses, doctors and other medical personnel. ImmersiMed and its applications are being developed on top of the Unity multi-platform engine. All developments are done with extensibility, future applications and hardware evolutions in mind. By creating consistent experiences across different VR and AR we intend to increase simulation availability, improve quality of training and enhance student's preparations for more advanced tasks and boost their confidence. We presented the first set of ImmersiMed applications aimed at training nursing students in routine tasks and providing them with feedback on how well they performed. Tools for educators provide the possibility to create new scenarios without intervention of expensive content creators or programmers. Finally, we discussed the future options of ImmersiMed and suggest how its AR applications will ease the transition from virtual training environments to the real world and show many other opportunities the platform offers to improve and lower medical training and simulation costs. Proving our assumptions will be part of further research.

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AR GUIDE FOR A ROBOT DESIGN KIT

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KEYWORDS

Augmented Reality, Accented Visualization, Robot, Design Kit, Decision making support

ABSTRACT

This paper presents the results of implementation of AR based interactive guide for a robot design kit. AR software solution can be deployed on a tablet or AR goggles and used by children to make the process of finding the small pieces of robot easy and comfortable. Examples are given for Abilix robot creative brick series, using tablets or Epson Moverio goggles as AR devices. There is proposed a new algorithm that improves image recognition considering the features of the identified components and the results of its implementation, testing and practical use. In addition to this it is proposed to implement the principles of accented visualization and eye tracking to adapt the logic of contextual data visualization to the user's behavior. One of the critical benefits of the proposed approach is its possibility to function in real time. Out of a set of 74 various objects there were successfully identified up to 66 items, that gives 89 % of algorithm efficiency.

INTRODUCTION

Modern robot design kits provide powerful capabilities of developing various constructions with programmable behaviour starting from elementary to advanced levels of complexity. These design kit have high perspective to be used for education purpose to train a child's creative, analytic, and practical abilities. Due to this fact they are widely implemented to educational process at middle schools.

In order to improve the efficiency of robot design kids and make their use even more attractive for students it is proposed to use them together with the modern technologies of Augmented Reality. Various AR devices like goggles, head mounted displays or widely spread tablets provide overlaid information additive or masking the real environment that can be informative at the stage of robot details search and identification.

First experiments and practical use of AR devices at schools have proven high potential of their application and interest demonstrated by students. Using the goggles or tablets can help them to find the required design kit components and units and aline the time spent by different persons to make equal constrictions, which is helpful for effective work in group. In addition to this AR technology is interesting for students by itself and gives new ideas of robot design and programming.

Technical challenges of implementation of AR use as a part of AR guide for robot design kit are concerned with low performance and quality of image recognition algorithms capable of functioning in real time. In this paper there is proposed an algorithm that helps solving this issue.

STATE OF THE ART

The problem of AR implementation for interactive user guides has been risen and discussed in (Ivaschenko, 2017). There was proposed a solution based on accented visualization, tracking and control over the user's focus in order to reduce possible deviations and increase the performance of AR guide. These papers also includes some modern research overview this area. This paper describes the going on progress of this solution development is based on it and continues it with application in education.

Still it should be noted that modern AR technologies (Kreven, 2007, Navab, 2004) are tailored with adaptive user interfaces (UI) (Julier, 2003, Rusev, 2014). AR devices need to present the adequate information required at a certain stages of user story with no redundant data and maximum attraction to important items. Development of AR based solutions should consider these requirements and provide adaptive user interfaces.

AR based UI differs from the usual UI of personal computers. Additional data and control elements can be placed and presented in all accessible space, in 3D with no limitations of screens or panel size. This data is overlapping the real objects and can hide some of them and use the others for docking. In case of presenting textual information it should appear in the focus of the user to make it readable with no disturb. These problems remain open for most of practical applications of AR and are solved by adapting the UI to concrete user cases.

The possibilities of AR as a ubiquitous user interface to the real world are discussed in (Schmalstieg, 2005, Lee, 2012, Singh, 2013). User Interfaces are usually designed with the focus on maximizing usability and user experience. The goal of user interface design is to make the user's interaction as simple and efficient as possible, in terms of accomplishing user goals.

Therefore AR faces the usability challenges, such as the potential for overloading users with too much information and making it difficult for them to determine a relevant action.

However, AR exacerbates some of these problems because multiple types of augmentation are possible at once, and proactive apps run the risk of overwhelming users.

PROBLEM STATEMENT

Research results described in this paper were achieved for Abilix robot (creative brick series, see http://www.abilix.com), robot example is presented in Fig. 1. One can see a variety of details; some of them close in appearance. There is a possibility to design various models of robots using the same principles of components functioning. It should be noted that the proposed solution does not depend on the type of construction kit and can be used as a part of a universal user guide. Tablet or Epson Moverio goggles were used as an AR device.

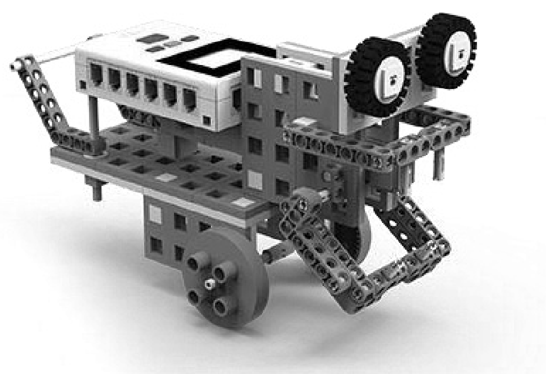


Figure 1: Abilix Robot Example

The problem of AR implementation was concerned with stable and reliable recognition and identification of the objects in view. For example, one of the main challenges of AR user guides is a necessity to identify the object that is required at the current moment, attract the user's attention and give complete and comprehensive annotation. To provide such features the technology should be capable of processing substantial number of images in real time.

AR based solution was dedicated to support the process of finding small pieces (details) easy and comfortable. There was developed special software (see Fig. 2) that can identify the components using a combination of existing image recognition techniques.

Software functionality includes the following features:

- scene object identification based on image analysis;
- contextual description of the object in view;
- search and highlighting of the object required;
- operating scenario processing, tracking, and control;
- complex devices analysis including components identification by partial view and assemble tips generating;
- user attention identification and contextual add-ons generating according to the principles of accented visualization.

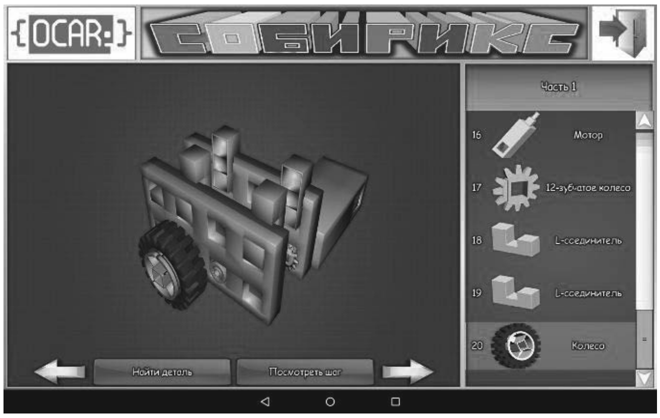


Figure 2: Robot Design Navigator

Despite the variety of shapes of the details most of them can be identified using the same approach. Some components look similar; some differ only in size or color. In addition to this AR device should be capable of identification of overlapped details with the lack of required visual data. To overcome this difficulty and increase the efficiency of AR interactive user guide there was developed a new approach base on accented visualization considering the current context.

IDENTIFICATION ALGORITHM

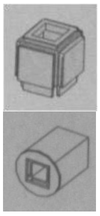
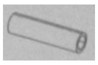
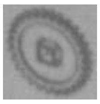
To provide adequate and stable identification of the robot components with a complex shape there was developed an algorithm based on a combination of standard technologies of image analysis and neural network based pattern recognition. Methods of identification of components that have a simple form or consist of elements with a simple shape were taken from free sources and modified for the required quality and performance.

The proposed identification algorithm includes the following steps:

- outer contour is identified for each object;
- the contour is drawn around the rectangle with the smallest possible area;
- the ratio of the length and width of the rectangle is calculated, which must correspond to the analogous value at the contour of the expected part;
- a grid of dots is applied to the rectangle;
- a map is drawn, describing which points are inside the contour (belong to a figure), and which are not;
- the compiled map is compared with a pre-prepared map;
- in case of coincidence, the parts are identified.

Based on the results of comparative analysis of the components' types the algorithm was extended by heuristics considering the features of the items processed. These extensions are presented in Table 1.

Table 1: Identification Features for Selected Components

Typical Detail	Example	Identification result	Identification algorithm
Cubes, bolts, con-nectors		Successfully identified on a contrast field. Still shapes of one type can be mixed (e.g. half cube slope cube)	A mesh (grid) is put over the object to identify specific shapes
Hubs, wheels and tires		Successfully identified on a contrast field	Find a round contour, in the center of which there should be located a square or round contour of a certain size
Tubes		Successfully identified on a contrast field	Find a rectangular with a specified proportion of length and width
Gears		Successfully identified on a contrast field. Identification quality depend on size and distance	Find a contour close to a circular shape, the number of convexities of such a contour must correspond to a specific number, inside the contour there must be a square contour of a certain size
Sensors		Successfully identified (including various types of sensors)	Recognition is performed by comparing the key points of the picture to the detail with the image from the camera.
Slab		Identified in case the shape is not overlapped by any other object and is located on a contrast field.	Find rectangular contour with a specified length and width ratio. Specific number of contours of inner shapes is identified and counted (they must be located in a strictly defined order).

One can see that despite the quality of source picture, no colors, and a comparatively big number of objects in view and partial overlapping the requested object was identified and outlined. The proposed algorithm is illustrated by Fig. 3.

AR device shows the mesh that overlays the corresponding component and its name that has been identified and presented as a hint.

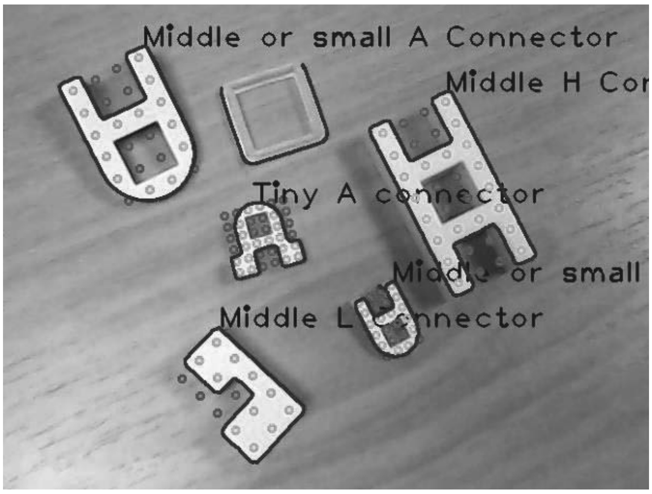


Figure 3: Design Kit Components Identification

Identification result is presented in Fig. 4.

In order to provide the required performance in addition to the described algorithm there was implemented an approach of accented visualization. User's focus coordination was introduced and based on analysis of the design process. The system tracks user attention and adapts additional data according to the current context and need.

Figure 4: Identification Algorithm Result

User's focus is captured in the form of event chains and compared with typical scenarios. Context is a set of concepts that describe the current situation and background that determines the decision. Focus is a concrete object processed at a certain moment. Such fragmentation allows introducing a control loop, where the correct focus is generated according to context in real time.

ANALYSIS AND TESTS

The example of AR guide for a robot design kit in use is presented in Fig. 5. To provide standard design scenarios the AR interactive guide generates virtual entities with context driven data at the moments when the viewer's attention needs to be attracted to certain objects. To support the design of new constructions additional data is given for selected items to support their proper use.

Robot design kit contains a number of sensors, and the AR guide provides description for them to support student finding better utilization. Such approach allows identification possible gaps in viewer's perception, if no required attention is given to certain scene objects at necessary times.

This information is captured in the form of rules in knowledge base linked to specified types of scene objects and steps of operating scenarios. As a result the scenarios are supplied by virtual entities (textual items, marks or highlights) that attract user's attention to the required scene objects when needed. To capture the corresponding pattern and adapt the system according to the user's preferences there can be used special eye tracking systems that determine and monitor eyes' movement using the front camera.

As an example, there is implemented functionality to simulate the robot over the specified marker. The user can utilise such a feature to observe the robot virtual model and study it from various views using the AR device camera. This opportunity can help constructing the resulting robot model.

Figure 5: Example of Robot 3D Reconstruction using AR

The proposed algorithm was implemented as a part of AR software solution that can be used for education purpose and as a platform for interactive user guides. The resulting product is currently probated in a number of schools and universities. After the probation complete the number of robot models will be increased and new educational technologies will be added.

Testing included a series of experiments carried out for a number of various components. Out of a set of 74 various objects there were successfully identified up to 66 items, that gives 89 % of algorithm efficiency.

Experimental testing procedure was done using the following way. Each robot detail was located over the contrast base surface under the soft light. The camera was located perpendicular to the detail surface and at the required distance. As a result of checking of 74 robot details in 100 % there were determined 66 details, which corresponds to the specified above efficiency.

The summary is given in Table 2.

Table 2: Identification Quality Results

Construction	Number of identified unique details (fragments)	Total number of successfully identified details
1. Helicopter	13/15 = 87%	79/82 = 96%
2. Windlass	13/14 = 93%	19/20 = 95%
3. Centrifuge	16/19 = 84%	41/45 = 91%
4. Traffic light	7/8 = 88%	9/10 = 90%
5. Magnetic secret key	9/12 = 75%	29/37 = 78%
6. Carrier belt	13/19 = 68%	28/35 = 80%
7. Rotating workbench	9/13 = 69%	50/58 = 86%
8. Blender	15/21 = 71%	35/43 = 81%
9. Washing machine	16/22 = 73%	73/80 = 91%
10. Strong light scanner	10/16 = 63%	37/44 = 84%
11. ATM	18/22 = 82%	59/64 = 92%
12. Auto-lathe	15/22 = 68%	105/116 = 91%
13. Auto-door	20/25 = 80%	51/57 = 89%
14. Elevator	26/32 = 81%	98/107 = 92%
15. Auto-car	22/25 = 88%	70/78 = 90%
16. Industrial robot	24/34 = 71%	186/205 = 91%
17. Mechanical arm	24/31 = 77%	136/156 = 87%
18. NC machine	18/22 = 82%	168/179 = 94%

AR devices with low cost processors powered by Android average performance rate of typical details identification is up to 10 FPS, marker identification is 8 FPS and representation of 3D model over the identified marker is 20 FPS.

Future work is concerned with extending the number of details and robots identified and implementing the concept of accented visualization to adapt the identification algorithms and increase their efficiency. As a part of this solution there is proposed an idea of eye tracking subsystem implementation to adapt the logic of contextual data visualization to the user's behavior. Tobii solution can be used as a possible tool for this purpose.

Different users have various behavior patterns: some prefer to get maximum information in view, others try to reduce non essential data leaving bare minimum, which is really important. To capture the corresponding pattern and adapt the system according to the user's preferences there can be used special eye tracking systems that determine and monitor eyes' movement using the front camera.

CONCLUSION

Implementation of AR based guides has high potential in education, especially in the areas concerned with creativity and technology. AR guides for robot design kits can considerably reduce time needed to search the required components and learning their capabilities and features of application. AR improves the usability of Robot design kits, improves the efficiency of work in groups, and attracts additional interest of potential users. One of the benefits of the proposed approach is its possibility to function in real time on mobile devices.

Technical challenges of AR implementation are concerned with better robot components identification using various image recognition algorithms and adaptive technologies of accented visualization. The results of research presented in this paper prove the possibility to cover high range and number of real robot components. This research might be interesting for the developers of robot design kits and school teachers who are interested in application of these technologies as a part of educational process.

Future work is concerned with analysis of AR using in practice and considering the human factor, usability and possible constraints.

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Approaches for the Combination of Additive Manufacturing and 3D-Measurement

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ABSTRACT

The combination of additive manufacturing and 3D-measurement holds large potentials for process integrated quality control and furthermore can increase the possibilities for the utilization of 3D printers. After an introduction, this paper will give an overview on the theoretical background of these two technologies, while the subsequent chapter will be used to describe possible technological approaches for process integrated quality control and reverse engineering, based on the theoretical background given. The last chapter will give a conclusion and an outlook for future research.

INTRODUCTION

The ongoing digitization has been the foundation for many modern technologies, which have become viable solutions for the industrial sector within the last years. These new technological developments and the associated possibilities will lead to sustainable changes in industrial manufacturing and additionally hold great potential for designing future manufacturing processes. Widely known examples for these technologies are additive manufacturing, interoperability, artificial intelligence, augmented and virtual reality, big data (analytics) or the Internet of Things.
While each of these technologies is a powerful tool on their own, their capabilities can be further increased by combining them with other technologies. An example for this will be presented in this paper, by combining additive manufacturing, which allows the production of objects with a high degree of geometric flexibility as well as the economically feasible production of individual goods at a batch size of one, and three-dimensional measurement technologies, which allow the generation of three-dimensional representations of physical objects and with this, for example improved quality control and automated fault detection.

THEORETICAL BACKGROUND
3D-Measurement

The use of and the demand for three-dimensional data is increasing in nearly all business areas of modern corporations, due to the changing requirements associated with the progressing digitization. Gathering three-dimensional information of a physical object can be achieved by two approaches, which have specific applications: contact (mechanical/tactile) and non-contact (optical/x-ray tomography) measurement.
While tactile measurement systems allow to gather very accurate information on the objects roughness, they are usually not suited for a swift generation of three-dimensional data, as this technology requires the sensor to move along the whole object to generate a complete digital and three-dimensional representation of its surface (Christoph and Neumann 2013).
Due to this constraint, optical measurement systems have shown their advantages in comparison to their tactile counterparts. Especially photogrammetry-based optical 3D-measurement systems have found use in a growing number of practical applications (Bösemann 2003, Bösemann 2016). These systems offer a reliable technology with the advantage of generating three-dimensional point clouds within short times of less than 30 seconds and accuracies of up to 40 micrometer (Schumann et al. 2015).
Optical measurement systems, which consist of a number of modules containing stereo-cameras and a projector, allow a high degree of flexibility, due to their modular structure. This allows to integrate them into production processes and thus makes an automated quality control possible (Schumann et al. 2013; Schumann et al. 2015; Baum et al. 2017).
These optical measurement systems use the concepts of structured light and photogrammetry. A number of different structured light patterns are projected onto the object by the projector, where a picture of each pattern is taken by the stereo cameras. The light patterns appear distorted from the cameras positions, an effect that is caused by the objects surface. The resulting pictures are used to digitally reconstruct the objects surface as a three dimensional point cloud, by using photogrammetric algorithms (Chen et al. 2000; Peng and Gupta 2007; Salvi et al. 2010).
Optical measurement systems, as well as their tactile counterparts have one major disadvantage, they are only able to measure an objects surface, but are unable to measure cavities and internal structures within the object. This is something that, if destruction free testing is required, can only be achieved by x-ray tomography, which is harder to integrate into production processes as its use requires radiation shielding (Christoph and Neumann 2012).
The result of all three-dimensional measurement processes are three-dimensional point clouds, which can be used for a number of tasks:

- Documentation: point clouds allow a more accurate representation of the measured object than classical measurement protocols
- Quality control: the measurement data can be compared to CAD reference models If this comparison shows deviations, then the measured work piece is faulty (Baum et al. 2017).
- Identification of products: this is also based on a comparison between the measurement data and CAD reference models to identify, which kind of product has been scanned (Klein et al 2015; Schumann 2017).
- Reverse Engineering/Replication: the point clouds can be used to digitally and physically reconstruct an object based on the previously measured sample

Additive Manufacturing

While it has been mostly used for the production of prototypes in the past, additive manufacturing has recently made its way into industrial use for individual parts and for small and medium series productions (Bechthold et al. 2015; Woensel et al. 2015; Richter et al. 2016).
The term additive manufacturing covers a multitude of different technologies, which can be distinguished by the materials used and the way these are processed. A number of examples are given in Table 1. All of these technologies are characterized by the additive way the manufacturing process is carried out. Additive in this context means that layer by layer of material is added to the work piece. They also have in common, that digital product representations, built for example with CAD-solutions or taken from point clouds, can be manufactured directly from the existing digital dataset. This means that expensive and product specific tools, which are required for other manufacturing technologies, are unnecessary. It also implies that production will no longer depend on specific machines and could instead be carried out with additive manufacturing devices everywhere on the world (Chen et al. 2015).

Table 1: Selected Additive Manufacturing Technologies, based on (Bechthold et al. 2015; Dudek and Zagórski 2017)

Technology	Function	Materials
Vat Polymerization	Photopolymers are hardened by (UV-) light beam	Epoxide Resin, Elastomers, Plastics
Binder Jetting	Powder-based material is combined via the use of binder	Starch, Plaster, Ceramics, Sand, Metal
Material Jetting	Drops of build material are deposited and hardened	Plastics
Material Extrusion	Wire-shaped material is melted and applied layer-wise	ABS, PLA, Metal
Sheet Lamination	Flat layers are stacked and combined with glue; topmost layer is cut according to shape	Paper, Thin metal sheets
Powder Bed Fusion	A laser or other energy source is used to melt powders	Plastics, Metal

In order to additively manufacture an object from a digital representation, the dataset has to be prepared for the manufacturing process by converting it into a fitting data type, whereas STL has become the quasi-standard for additive manufacturing. If information has been lost due to this conversion, for example through missing points or triangulation mistakes, then the model has to be repaired.
The next step towards the physical manufacturing process is the digital construction of support structures, which might be required to transfer a model with complex shapes into a physical structure. The most important step is the division of the model and the support structures into different layers of manufacturing technology specific thickness in the slicing process. In the following hatching process, hollow spaces which can be caused by the conversion to an STL file, have to be filled, to receive solid structures. Once the data has been prepared, the layer-wise manufacturing of the product can begin. The required steps for the additive manufacturing of a physical object from a dataset are shown in Figure 1.

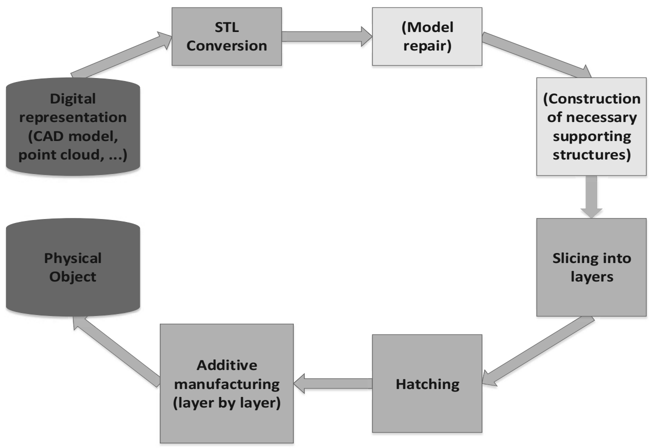

Figure 1: Dataset Preparation on the way from Digital Representation to Physical Object

TECHNOLOGICAL APPROACHES: COMBINING ADDITIVE MANUFACTURING AND 3D-MEASUREMENT

The three-dimensional point clouds, gathered by 3D-Measurement systems can be used for a number of tasks, as previously mentioned. Especially a process integrated quality control and reverse engineering/replication are suited for a combination with additive manufacturing. Two possible combinations will be described more in depth.

Quality Control

Product quality has become an important criterion; as faulty parts can be a substantial cost factor. That's why companies strive to be able to control the quality of every product. While additive manufacturing produces parts directly based on the digital product representation, there are still possibilities for faults. These may for example be caused by defects or wrong calibration of a laser beam, clogging of a nozzle or thermal stress effects caused by melting processes.

Especially machine and material costs for additive manufacturing are high, thus faulty work pieces may result in high losses that could be prevented by process integrated quality control.

3D-Measurement systems can be utilized in different parts of the production process. The finished product can be scanned and the resulting point cloud can be compared to the associated dataset. If deviations are detected, then the work piece is faulty and the printer should be checked for faulty configurations or defects. While this allows the detection of problems in the manufacturing process by the possible utilization of different 3D-measurement technologies, it would still result in a loss of production time and material, as the fault would only be detected after the process is finished.

Modular optical measurement systems can be integrated into the process and thus can be used to monitor the manufacturing process either in real-time or layer by layer. The real time process monitoring appears to be more challenging here as it would require further synchronization with the printer's machine code to detect deviations.

The layer-wise control would allow a comparison with the sliced STL-file, so that deviations could be detected fairly easy and the manufacturing process could be stopped, to prevent the waste of material and production time.

Reverse Engineering/Replicator

The point clouds gathered by 3D-Measurement can be used as a base to reconstruct or replicate the object. However, tactile or optical measurement systems are only suited for objects that do not have any internal structures, as they only can gather data from the objects surface. Complex objects would also require manual reworking, as the measurement system might miss features.

A promising solution to this is the application of x-ray/computer tomography, as the utilized x-rays allow to take pictures of the objects internal structures. The pictures can then be transferred into a point cloud, just like it can be done with the data gathered by other 3D-measurement systems.

While x-ray tomography is a relatively slow measurement solution, the way it operates could be utilized for the replication of measured objects via additive manufacturing. The acquired pictures contain the objects structure for a layer with a defined thickness. These can be transformed into a point cloud, which then could be converted into STL-based machine code. This would enable the printer to produce this specific layer, while the measurement system could gather data for the next layer. Depending on the speed of the scanning and printing processes this could allow the replication of objects in quasi-real time.

CONCLUSION

In this paper two possibilities for the combination of additive manufacturing and 3D-measurement systems have been presented. Both combinations have great potential for the increased practical use of additive manufacturing, as quality control will remain an important subject, while the possibility to replicate objects in quasi-real time adds an interesting new application field.

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HUMAN INTELLIGENCE, AMBIDEXTERITY AND AI: REFLECTIONS ON A DATA COGNIFICATION CASE STUDY IN AN UNDERWATER SCENARIO

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Human intelligence, AI, Computational ambidexterity, Neural networks, Underwater exploration

ABSTRACT

We present an experimental study with three concurrent goals: a) to link AI-driven processes with some fundamental theoretical assumptions of management theory; b) to challenge the current assumption that modern synthetic intelligences might be easily "human-comparable"; c) to present the results a neural net has returned that was trained with real data from an underwater exploration scenario, with implications on the kind of the nature of this synthetic intelligence.

INTRODUCTION

The 2016 report of the Stanford Committee of the so called One Hundred Year Study on Artificial Intelligence (Stone et al., 2016) concluded that there is no reason to fear the evolution in the field, as the evidence of its positive impact in many industries and application is clear, and will be even more clear in the near future. The proper framing of the current situation is deemed key to face the different decisions that governments, institutions, and firms are called to make on many grounds; from regulation to value building propositions. The OECD Next Production Revolution Report released in June 2017 (OECD, 2017) presents, instead, more skeptical conclusions, based on the analysis of a broader set of technological trajectories and country level productivity data. Those concerns about future scenarios with structural changes in employment opportunities, as well as the distribution of the value generated by new technologies, are also presented in the June 2017 discussion paper of the McKinsey Global Institute (MGI, 2017). Within this context, in this paper, we try to contribute to this growing debate by moving from a macro environmental perspective to a more micro level one, reflecting on the relationships between the evolution in AI and the concept of human bounded rationality. While most of the current attention is dedicated to the evolution/adaptation of current business models and paradigms to the changing conditions of the technological AI space, little or no attention is paid to their theoretical foundations and the extent to which they will remain valid or not. As a similar debate is in its infant stage in the AI community, we joined forces coming from different perspectives to present a preliminary application to the notion of ambidexterity which is central for many theories in the different fields of management and to test it in a real setting with a neural network trained to find optimal routes in an underwater exploration scenario. In the remainder of this paper, we will first provide the theoretical framework within which our reflections on the nature of the intelligence that neural nets exhibit make sense, and then we will illustrate and discuss the experimental results we have obtained with our net trained on the case of interest.

NEURAL NETWORKS AND THEIR EVOLUTION

A discussion on the intersection between management studies and AI should start from the history of the most recent advancements in the field of neural networks. Neural networks are computational systems based on the idea to replicate how the human brain works. Indeed, neural networks have been around for decades, proposing a simple learning mechanism that could fit to any source of data, through layers of perceptrons (or neurons) that first performed weighted averaging of their inputs, and then accommodated the complexity of non-linearities with sigmoids or rectified-linear curves. Such simple systems could be trained to fit a given input set to its desirable output, serving various supervised regression and classification tasks (Rosenblatt, 1958). Though this can sound technically spectacular, the concept did not boom before, as they were not able to provide a sufficiently competitive performance against traditional classification algorithms. Consequently, neural networks have long been forgotten by the scientific community and confined to a niche. Only a few researchers persisted along that original line, yielding innovative results that finally revitalized the most prominent concepts behind neural networks. A burden of papers during the early 2000s showed how to apply successfully a neural network to learn in essentially any assigned task (Schmidhuber, 2015). Disruptive factors of these advancements included: the presence of several network layers, hence the term deep learning (Silver et al., 2016); the growing amount of digital data on which training activities can be performed; the availability of massive computational resources under the typical form of networks of computers, equipped with graphic processing units (GPUs); and smart optimization algorithms, exploiting effective initializations and gradual stochastic gradient learning. Yet, the real problem behind all these empirical successes is that they have been achieved almost without a theoretical understanding of the underlying mathematical paradigm, while the optimization technique employed in the learning process is non-convex and even considered intractable from an abstract viewpoint. Nonetheless, the use of that kind of intelligent machines took off, initially starting with written character recognition and rapidly moving to more complex tasks, such as image and speech recognition and natural language processing, finally resulting into an attempt to apply it to practically anything that could be cast as a supervised learning task. Consequently, a common deduction about the evolution of this field is that it will run along a pathway, accelerating towards a super synthetic intelligence outperforming human capabilities in almost all tasks that need to be tackled using some form of intelligent reasoning. One of the motivations we are writing this paper is to argue over this simplistic forecast, in the firm conviction that alternative forms of synthetic intelligences could emerge at the end of this path which will be not easily "human-comparable".

CHALLENGES FOR MANAGEMENT PRIMES

Any link between management and AI leads to the seminal work of Herbert Simon (Simon, 1955) and his notion of bounded rationality, which has been key to advance research in decision making and to offer a basis for different theoretical developments in strategy, organization studies, innovation studies, entrepreneurship studies, to name only a few. Simon's premises are clear and challenge the fundamental assumption of neo-classical economics according to which market equilibria are reached thanks to a set of perfectly rational agents able to properly discriminate among alternatives on the basis of a complete information set. Simon's boundedly rational individuals remain intentionally rational, as they engage in problem solving activities with a clear goal in mind, but are computationally limited and have limited access to information. Both limitations are faced by a sequential approach to problem solving based on information processing activities involving symbolic classification and manipulation, where heuristics are developed to reduce problem complexity to a manageable level. Within this framework, intuition is itself a form of bounded rationality, as it represents the output of a problem-solving process where the solution is selected on the basis of its fit with previous experience. Problem solving therefore relies on memories which catalogue past actions and choices and offer a quick set of alternatives, again aimed at reducing complexity. The evolution of AI approaches as described above, coupled with the increased computational efficiency of modern computers and the shrinking costs of their components, are presented as a unique opportunity to overcome information processing limitations. Yet, the problem of information access remains. Data sources might or not be in an accessible format, might or not be free to access, might or not be clearly identified if the problem itself is ill-structured or complex. Borrowing on Fiori's review (2011), we focus here on three specific aspects. Dealing with an incomplete information set might not just depend on computational limitations, but on individual preferences, which, according to March (1978), are all but coherent, stable, exogenous and unambiguous. Indeed, they emerge through the decision-making process and the related experiences, and are socially embedded as they depend on our interaction with different contexts and communities. The outcome is therefore not defined as a rational evaluation of alternatives bounded by information processing limitations, but rather by an unstable preference set on the fit between alternatives and multiple identities. Therefore, how and where we develop our problem-solving skills become relevant to understand how we make decisions and choose among alternatives. The relevance of experience and contextual knowledge, however, could itself be subjected to a symbolic representation, which is at the core of the information processing foundation of bounded rationality, provided that they can be codified. Nelson and Winter (1982) elaboration of Polanyi notion of tacit knowledge (Polanyi, 1958) challenges this possibility reaching a different conclusion. The distinction between codified and uncodified knowledge rests upon the assumption that, given the appropriate amount of time and resources, all the knowledge could be codified and transferred. And yet, individuals develop skills, as well as organization develop routines, that remain tacit neither for a deliberate choice, nor for a lack of resources, but for the combination of our inherent limited capability to fully articulate decision-making processes and the key role of experience. Further, even when skills and routines can be properly described and codified, there is always an experiential component that remains tacit and not transferable without replicating the experience. And when the experience itself cannot be replicated, due to time or contextual limitations, even investing on the replication of experiences cannot make tacit knowledge explicit. Tacit knowledge and its relevance in understanding individual and organizational behavior therefore strengthen the notion of bounded rationality, but moves it beyond a pure information processing view and provides an anchor to the framing of experience and its context-related components. It also helps better understanding similarities and differences on when and if different agents react intuitively or not, and on the outputs of their decision and their degree of uniqueness. And yet, it leaves the determinants of tacitness in a "black box" which only recently has been explored within behavioral approaches launched by the seminal work of Kahneman and Tversky (1979). Not only are our decisions heavily dependent on tacit knowledge, but they are also inherently biased even when we think that we can properly describe them and how we chose them. Intuitive vs. structured problem solving approaches rely on different neurological resources (De Martino et al., 2006). The former are faster, require less effort, are driven by emotions and feelings, are superficially associative often mistaking co-occurrence with causality, can be processed in parallel. The latter, on the contrary, require more efforts and time, are disciplined by rules, need to be processed serially and are therefore slower. Our main structural limitation is that more often than not we are unable to leverage on their complementarity and when conflicting alternatives emerge intuition prevails over structured problem solving. And worst, we might either be unaware of this dominance or pretend ex post that it was our intentional and rational choice among the alternatives available. The misfit between alternatives and choices is therefore the consequence of a wide set of behavioral biases.

A Focus on Ambidexterity

A key concept which we propose as directly related to the evolution of the notion of bounded rationality and neural networks is ambidexterity, defined as the ability to pursue both exploration and exploitation (March, 1991). The explorative dimension is related to search, variance reduction, discovery and experimentation, whereas exploitation deals with efficiency, variance reduction, selection, and implementation. Over the last two decades, a number of researches conducted in different contexts have shown that companies thrive when their managers embrace and manage trade-offs and tensions (Gibson & Birkinshaw, 2004). Scholars have adopted two perspectives with respect to organizational ambidexterity. The first models ambidexterity as an optimal point on a continuum (O'Really & Tushman, 2004 & 2013). Firms should therefore achieve and maintain a proper balance between exploration and exploitation-related activities to survive and prosper (Simsek et al., 2009; Raisch et al., 2009). Too much focus on the exploitation of current capabilities and activities, at the expenses of exploration of new trajectories and ideas, will determine the emergence of organizational inertia, with consequences on the ability of a company to adapt to changes in the environment (Levinthal & March, 1993). On the other hand, an excessive focus on exploration may lead to the underdevelopment of the newly proposed ideas, replaced before the exploitation of their full potential (Levinthal & March, 1993). Firms can resolve the potential trade-offs between these activities (Tushman & O'Reilly, 1996) in several ways. First, they can dedicate different units within the organization to the process of search and the process of consolidation (Duncan, 1976). This is called 'structural ambidexterity'. By putting in place "dual structures" arrangements, with dedicated business units - or groups within business units - focused on efficiency, and others focused on innovation (Duncan, 1976), organizations configure each unit to the specific needs of its task environment (Lawrence & Lorsch, 1967). Contextual ambidexterity may complement dual structures and strategies by enabling shared values that support coordination. The second perspective sees explorative and exploitative activities as independent. To increase the benefits of ambidexterity, firms should therefore maximize both exploration and exploitation (Cao et al., 2009). High efficiency in current activities and wide capturing of new opportunities can jointly prevent organizational inertia and the negative effects of path dependence (Junni et al., 2013; Simsek et al., 2009). To simultaneously achieve alignment and adaptability within a single business unit, firms should build a context that encourages individuals to make their own judgments as to how best divide their time and energies between the conflicting demands for alignment and adaptability. Successful business units are able to simultaneously develop these capacities by aligning themselves around adaptability.

CHALLENGING AI FOR AMBIDEXTERITY

All that said, emerging research questions are:

- How modern neural nets-based decision support systems fit to the managerial context we have described?
- Do they help to overcome the limits of human ambidexterity?
- Is their intelligence either exploitative or explorative or a mixture of both?

To provide a response to these questions, we conducted an experiment training a neural net with real data taken from an underwater scenario. In particular, we focused on data concerning an underwater fiber optic cable installation case. Such kind of operation requires an a priori in-depth analysis of the seabed. This process consists of two main phases. In the first one, a vessel inspects the seabed, using appropriate instrumentations, to obtain a grid of sampled points. For each georeferenced point, relevant information is searched about depth and soil typology. In the second phase, starting from those data, a team of geologists defines an optimal route for a specific cable installation. This route is the final output of the analysis process and the geologists provide it to the crew of the vessel that will then install the cable. Needless to say, the accuracy of the analysis has a great impact on the cable installation process. The ability of geologists to take into account all the available data, recognizing patterns and regularity, allows them to identify an "optimal" route to be followed by the vessel.

Case Study

To conduct our experiment, we were helped by a major company in the field that provided us with real georeferenced data of a part of a seabed they had collected, along with the final optimal routes chosen by their team of geologists. Starting from all these data, we have trained a neural network, with the aim of allowing it to individuate an optimal route from a given starting point to a final destination within the marine area of interest. To the aim of this work, we used a neural net as those proposed in typical path finding problems (Graham et al. 2004; Kindermann et al. 1996; Kim et al. 2002). After the training phase, we carried out a testing phase, where our net was required to individuate a route in the same underwater scenario on which it was trained. Finally, we contrasted the route individuated by our net against that that was suggested by the geologists of the company that provided the data. In the remainder of this paper we will discuss the results we have obtained with our experiments.

Data Description

We first describe the dataset on which our net was trained, as consisting of:

- Coordinates of each given seabed point;
- Soil type for each given point;
- The optimal routes as proposed by the geologists.

As to the points of the seabed, the coordinates x, y were provided as a mapping of the correspondent latitude and longitude values into a Cartesian plane. The z value, instead, is the depth of the sea in that point. Each point was mapped at a distance of 10mt from the other. Summing up: the x value varied from 0 to 117183mt, while the y one from 0 to 71160mt. The total amount of points comprised in the dataset was 2.302.913. Further, eleven soil typologies, such as fine sediment, rock, depression and so on … characterized the points in the dataset. This information was obtained during the seabed inspection, mainly by taking sonar pictures. Subsequently, a group of geologists interpreted those images and assigned to each point of an area a soil typology. Notably, points existed in the dataset whose type was not classified, due to the lack of sufficient information. Finally, optimal routes were provided in the dataset, as suggested by geologists, under the form of a polygonal line with its set of vertexes and corresponding coordinates (x, y) in the space of interest. It is also worth noticing that while geologists insisted to pass to us information concerning the procedure/strategy they used to take routing decisions in correspondence to seabed points of a given type, we did not inject those rules into our system, so as to let our neural net free to infer rules only form the data. Hence, so far, we do not actually know any of the technical strategies geologists adopt to deal with seabed points of a specific type.

Methodology

As anticipated, the goal here was to find a feasible route that interconnects a starting point with a final destination in an underwater scenario, where each given point has a specific soil characteristic. A route may be seen as a sequence of subsequent points with their coordinates (x, y). Our neural network was hence trained to learn, at each given point along the route, which was the next one. Given a point (with its coordinates), eight different directions (movements) are possible that make the route advance toward the next selected point and can be seen as a combination of the three following attributes: forward/backward; right/left, diagonal/straight. A class was defined for each possible movement, as shown in Table 1, allowing the neural net to perform as a simple classifier that, given a position in a grid, learns the next movement to do to advance of one step in that grid.

5	6	7
4	x,y	0
3	2	1

Table 1. Possible movements

As usual, before starting to train the neural network, a data preparation phase was needed in order to clean, aggregate and normalize the data that was actually very time-consuming. For the sake of conciseness, we omit all the details regarding this phase, while we remind to our readers that the dataset we exploited to train, and then test, the network was that of a specific portion of an African seabed, whose name and real coordinates we are not allowed to disclose. Experiments were conducted with this dataset, and its optimal route as suggested by geologists, that consisted in an initial training of the net and then in its testing, in order to evaluate its performances. As clear from the context, the optimization parameters were the distance from destination of each point along the route and the soil typology of that point and of its neighbors. Different experiments were carried out by varying the number of neighbors to be considered for each point along the route, as well as some training parameters, such as the number of epochs and learning rates. In each experiment, as much as the 2/3 of the dataset was used for the training phase, while 1/3 was left for use in the testing phase. As a metric useful to evaluate the neural network performances, the “area under the curve” parameter was used, computed as both a micro and a macro average. As an anticipation of the results we will describe in the next Section, Figure 1 below provides the ROC values as a figure of merit describing how well the eight different movements were learnt by the net. As seen from the Figure, almost all the movements were well learnt by the net, with the only exception of movements 5 and 6, due to the very specific shape of the route under examination that will be disclosed in the next Section.

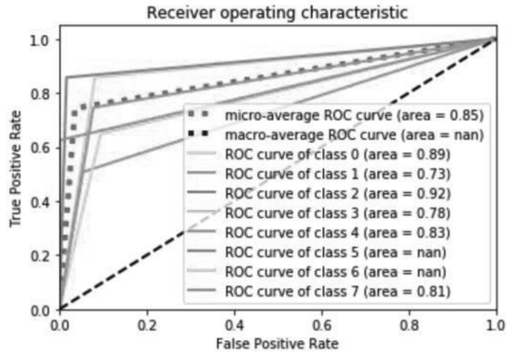

Figure 1. Movements: ROC values

Results

We begin this section by emphasizing that the final goal of our study is to try to contrast the routes that our trained net has computed against those suggested by geologists. To the aim of this comparison, we adopted two different metrics. The first one computes the average distance between points of the two alternative routes, and exploits the Needleman-Wunsch algorithm to align different, yet comparable, points of the two alternative routes. To have an additional quantitative measure of the difference between the two routes, we have also computed the value of the ratio of the length of the route computed by our net and the length of the route suggested by the team of geologists. Notably, in the very first testing experiment we conducted, after the corresponding training phase, a surprising result emerged. Figure 2 shows this gratifying result, depicting the two routes that were suggested by the geologists (red one, approx. 204km long) and by our trained neural net (blue one), respectively. The average distance between the points of the two routes is only 417m, while the total length of the blue route is just 1,01 times longer than the length of the red one.

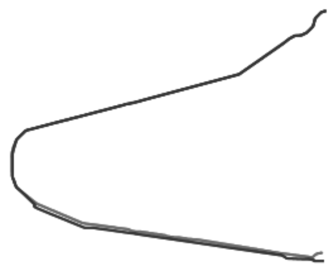

Figure 2. Route comparison (Test #1): Geologists (red) vs. Neural network (blue)

Nonetheless, what did not comfort us in this first experiment was the fact that at a given point the two routes begin to differentiate, while the two routes were almost identical before reaching that specific point. We hence trained again our net, randomly varying the 2/3 of the points to be used for training, as well as the initial weights and parameters of the network. After this further training phases, we repeated several times our tests and found evidence that it often occurred that the routes computed by the trained net deviated from the trajectories suggested by geologists, without even reaching the destination, as emphasized in the three cases of Figure 3 below. Surprised by this type of result, we then run an additional experiment to understand if the particular shape of that route, that almost resembles a curve, could be the cause for our net to be deceived. A possible reason behind these divergences could in fact reasonably be that the neural net erroneously classified some points along the route as it is comprised of two very different parts: the first one with a shape that goes from right to left, and the second one that goes in the opposite direction. In the light of such considerations, we hence decided to split the route and the corresponding dataset into two different parts; and then to try to train and test our net only on one of those two parts: specifically, the second one. The results shown in Figure 4 rejected our first simplistic hypothesis. As clear from the Figure, there exist again situations where the route computed by the trained net diverges from the optimal trajectory as defined by geologists.

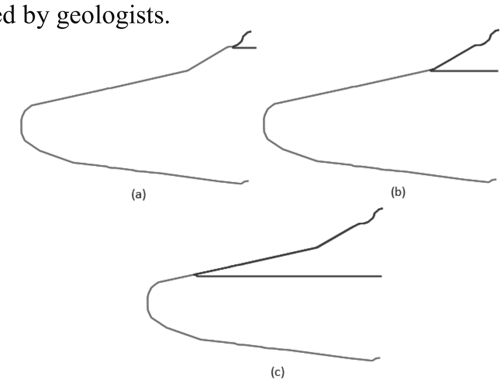

Figure 3. Route comparison (subsequent tests): Geologists (red) vs. Neural network (blue)

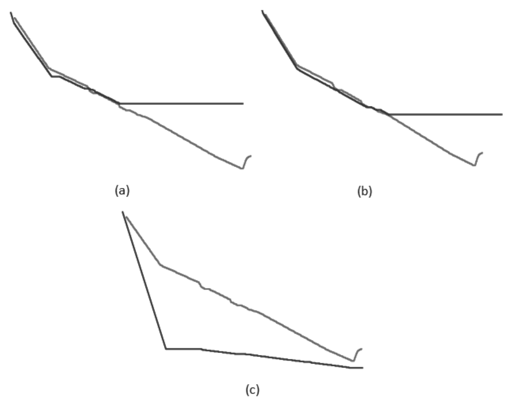

Figure 4. Half of the route: Geologists (red) vs. Neural network (blue)

At that point, we took the decision to examine, within the dataset we were provided with, the characteristics of the points where the differentiation of the two trajectories took place, for each and any of the experiments that had exhibited this behavior. Not surprisingly, this analysis revealed to us that whenever the blue route differentiated from the red one, the neural net had taken a decision in the presence of a point whose soil characteristics were not known, and the corresponding information was lacking or simply incomplete in the dataset on which the net was trained. In other words, as long as the net is required to classify points whose characteristics are known, it performs its tasks correctly and efficiently. Yet, as often as it has to perform in the presence of unknown or uncertain information, it dramatically fails. Summing up, as far as ambidexterity is concerned, an intriguing result emerged from our experiments: our net seemed to exhibit a pure exploitative behavior. As soon as it runs into a point, whose characteristics are not known, it diverges from the optimal trajectory, without even achieving a result. It performs very well, instead, all the times that it is asked to take a decision on points (situations) on which it has been trained "correctly". To have a final confirmation of our hypothesis, and also to provide a contribution towards the design of an intelligent system able to discover optimal routes in the underwater scenario of interest, we developed and additional experiment where one specific constraint was added during the training phase. Specifically: to generate a route, the net can utilize only points whose soil type is known. Further, we added to the knowledge of our net the following simple backtracking mechanism that the net has to exploit, to deal with situations where a point with unknown characteristics is encountered. If such unfortunate situation occurs, the net removes that point from the route and goes back to the previous point in the route, trying to follow an alternative direction until a new admissible point is found. With these modifications, we run several other final experiments, of which some three results are shown in Figure 5 below. Not surprisingly, the trained net is now always able to suggest a plausible route from the initial point to the destination. Nonetheless, this good result comes with the drawback that these computed routes can be often much longer than those proposed by geologists. Consider for example the routes depicted in Figure 5. While the average distances between the blue and the red ones is as low as 158m, 161m and 149m, respectively, the ratio of their lengths (blues/reds) is as much as 4.98, 4.52 and 5.71, respectively. It should also be noted that this increment in the length is essentially due to the backtrack mechanism and that this negative effect could be smoothed out by employing a more sophisticated algorithm that takes into account the now well-known problem of points whose soil type characteristics are not given.

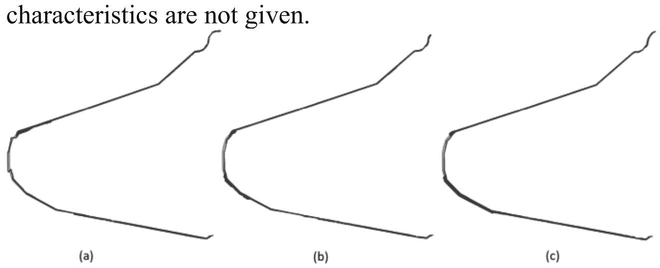

Figure 5. Route comparison (final tests): Geologists (red) vs. Neural network (blue)

CONCLUSIONS

Even though this should be still considered as a preliminary work, we have provided an initial contribution towards the direction of understanding the nature of the intelligence with which modern AI (based on neural networks) reasons and takes decisions. Our experiments with a neural network trained on data describing a given seabed have revealed that our net is not yet able to take reasonable decisions in the lack of a complete information, thus suggesting that it is not currently able to purse exploration. Instead, if constraints are added during the training phase and an explicit piece of knowledge is injected (the backtrack algorithm), the net seems to perform rather well, at least on an exploitative dimension. Further reflections are in order to discuss the extent to which these two kinds of intelligence (i.e., human and synthetic) can cooperate in the light of the obtained results, in this specific case of interest or in similar ones (Ferretti et al., 2016; Palazzi et al., 2004; Prandi et al. 2017; Roccetti et al., 2017a; Roccetti et al., 2017b; Roccetti et al., 2007).

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