# INTERNATIONAL SCIENCE FICTION

# PROTOTYPING CONFERENCE

# 2017

# SciFi-It'2017

## DESIGNING YOUR FUTURE WITH SCIENCE FICTION

**EDITED BY**

**Helena Barbas**

**APRIL 10-11, 2017**

**NOVOTEL, BRUGES**

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# SCIENCE FICTION PROTOTYPING CONFERENCE 2017

# Preface

Dear Participants,

It is a great honour to welcome you to SciFi It, a surely avant-garde and quite ambitious first International Science Fiction prototyping conference, held at the Novotel Brugge Centrum, in the beautiful city of Bruges, the 10th and 11th April 2017.

We are welcoming your presentations encompassing the proposed motto - Designing your Future with Science Fiction – and most keen to learn from your specific approaches how each covered this transition of ideas and objects from science fiction into useful science fact tools for our future present daily lives.

Inspired by what used to be classified as science-fiction, this new science-fact is being explored in business and technological development using data trends in order to create a pragmatic visionary present for users and consumers. And we are very enthusiastic to host two excellent keynote speakers, namely Professor Geert De Cubber, from the Royal Military Academy of Belgium, specialist in robotics for high risk applications, who will talk about the successful use of search and rescue drones in real dangerous missions and life-saving operations; and Vincent Nys, CEO of NewFusion, a Flemish Digital Media Agency - focusing on digital media experiences and offering technological pioneering business solutions - who will elucidate how true innovation can exist and be the reality of the digital age;. Also, we are happy that the program is supplemented with a tutorial - Programming ZORA for a hospital environment – by Hannes Laverge, explaining how to program the Zora robot for daily use in healthcare environments.

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; to EUROSIS for the opportunity to be involved in such a pioneering conference as this one and, of course, and above all, to Philippe Geril whose vision has made all this science fiction a possible fact.

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 2017

Helena Barbas
CICS.Nova – FCSH-UNL
SciFi It General Conference Chair

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# SCIENTIFIC PROGRAMME

# SCI-FI DESIGN PROTOTYPING

# DIEGETIC PROTOTYPES - TO WARE OR VAPOURWARE PASSING THROUGH SOLUTIONISM AND PALEO-FUTURE

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**KEYWORDS**
Design Fiction; Digital Humanities; Interactive Fiction; Internet of Things; Literary Theory; Narratology; Human-computer interaction; Smart Houses.

**ABSTRACT**

The object of this paper is to discuss the concept(s) of Design Fiction(s), and to elaborate a critical re-definition of the terms from Literary Theory and Narratology's stand-points. By so doing, it aims to propose a clarification of the types of objects frameable by Design Fiction (DF), and shorten the gap between the latter and Interactive Fiction (IF), IoT (Internet of Things) fictions and AR (Augmented Reality) whenever these practices are being used to tell stories. Smart-houses will be used as an example of successful DF narratives.

**INTRODUCTION**

Design Fiction (DF) is the name given to a new discipline, or methodology, or practice, that deals with speculative design, critical design, objects' prototyping, scenarios, future worlds, and storytelling processes.

The exercise of DF is much older than its designation. Being scattered geographically, and through several scientific or artistic areas, the recent theoretical interest in this discipline suffers from such a variety of scopes. The word Fiction in its name relates it to older Literary practices, and asks for a deeper characterization than the ones offered so far.

So, the concept(s) of Design Fiction(s) will be discussed to clarify the path towards a more critical re-definition of the terms from other than Punk aesthetics – namely resorting to Literary Theory and Narratology.

This discussion will start with the collation of the state-of-the-art connotations, their improvements and shortcomings. Then it will propose a distinction of the species of objects which have been the theme of DF at a double level – of concept and utility. The resulting ontology might contribute to fashion a common ground for a better understanding of the cross-field communication between Interactive Fiction (IF), IoT (Internet of Things) fictions and AR (Augmented Reality) whenever these practices are being used to tell stories. Finally, and more than futuristic worlds or cities, it is in the imagined hi-tech houses of the future – as successful narratives – that can be found the objects/elements that came to constitute the basics of DF.

**DESIGN FICTION(S) – STATE-OF-THE-ART**

The current version has an historical hue associated with DF practitioners: Bruce Sterling (2005); Julian Bleecker (Nokia/Near Future Lab 2009) in response to Paul Dourish and Genevieve Bell (2014). David A. Kirby (2009), from cinema, contributed with «*diegetic prototypes*» and stating that these: «*have a major rhetorical advantage over true prototypes: In the diegesis these techniques exist as 'real' objects that function properly and that people use*» – here, *people* should be replaced with the term *characters* – informing/confirming that «*stories matter*». Joshua Tanenbaum (2008-2014) keeping an open and updated discussion in *Quora* favors the diegetic approach (https://www.quora.com/What-is-design-fiction).

Aspiring to "Defining a definitive definition" Lindley & Coulton (2013:210), from Media Theory, focus on the flexibility of the terms, the concept of diegesis and advance their proposal: «*So a design fiction is (1) something that creates a story world, (2) has something being prototyped within that story world, (3) does so to create a discursive space. Although this definition appears straightforward, complexity arrives when we consider what 'something' may be – and we believe it is this complexity that is circumvented in discourses that characterize design fiction as 'up for grabs' or 'open to different interpretations*». They expand their personal interpretations up to the study of scientific abstracts and papers as DF.

Derek Hales (2013:1) presenting the first volume of *Digital Creativity* uses the plural: «*It is an attempt to grapple with the notion of Design Fictions and considers this a 'speculative turn' within contemporary design practice. It presents Design Fictions as a 'cluster of problems', delineating their 'multidimensionality' to suggest that DFs: 'create a discursive space within which new forms of cultural artefact (futures) might emerge'.»;* he does not proceed to explain the terms, returning instead to Bruce Sterling's definitions. Hales carries on speculating about possible consequences, considering: «*design fictions as a methodology*» (2013:2) a futurology, or interesting to Media Philosophers.

Also in 2013 Charles Beckett writes a blog entry – "How to think about the future - Design Fiction, Science Fiction and Literary Criticism" – the assessment nearest to (traditional) Literary Criticism, but sideslips into Science-fiction landscapes.

James Langdon (2015) founder of "A School for Design Fiction" affirms: «*I see design essentially as a storytelling*

*process, in the sense that I understand all human artefacts to be implicated in telling the story of the universe*». His motivation is to: «*present an alternative understanding of design fiction. In my practice I have never been concerned with anticipating or implying particular futures through design.*». His work is illustrated on a book/bible for the *Eastside Projects Annual* 2014-15 (http://jameslangdon.net).

Joseph Lindley (April 2015) summarizes that DF has the potential for a multi-dimensional relationship with research: «*It may be used as a method for simultaneously producing knowledge and insights that pertain to design fiction practice, as well as other domains (research through design fiction)*»; also: «*it may be used as a research method as part of a contextual search supporting some other design practice (research for design fiction)*»; finally: «*design fiction may itself be the subject of an objective inquiry (research into design fiction).*».

Blythe et al (2016) return to Sterling's and previous definitions to retain the notion of diegesis, more useful to their practice of Human-Computer Interaction (HCI): «*The notion of diegesis helps distinguish design fiction from practices like scenario and persona development in HCI.*» (2016:4970). The scope of this paper regarding 'serious silliness' relates to smart cities. And he contributes with a synonym «*critical design*»: «*In HCI the production of conceptual designs, images and fictions, which question and challenge existing technologies, was developed by Tony Dunne and Fiona Raby in a series of fascinating and ground breaking series of works they called critical design*» (2016: 4970); the authors became known as Dunne & Raby (http://www.dunneandraby.co.uk/) and one of the objects mentioned – *Compass Table* (with inlaid compass needles that twitch in response to electromagnetic fields produced by electronic devices placed on its surface) ended up sold as art. (http://www.dunneandraby.co.uk/content/books/90/0)

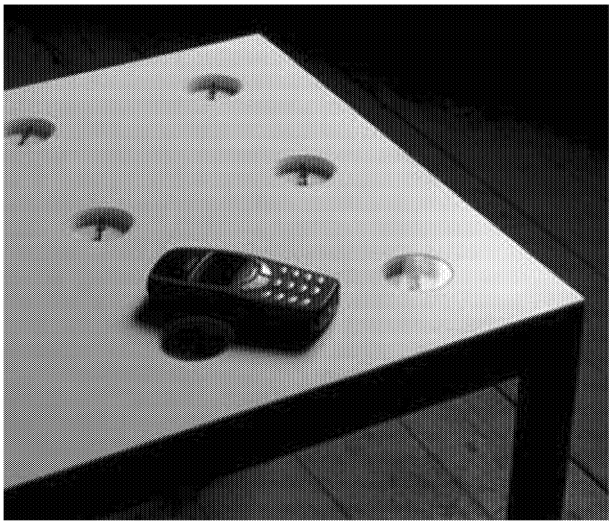


Figure 1: Compass Table 2002 - White Corian, Instrument Glass, 25 Compass Needles (750x750x350 mm)

Coulton & Lindley (2016) discuss the creation of a DF world in gaming context: «*it follows that constructing a reality fit for, and familiar to, that audience would be a pragmatic approach.*». Two points seem important – one when they try to explain the concept of Fiction inside DF: «*A common point of confusion in design fiction discourse is the precise relevance of the word 'fiction'. This is because the prototypes inside the design fiction are, by definition, 'not real' and they are therefore fictional. However, that is not what the word fiction, in 'design fiction', is referring to. Design fiction is named such because the designs are diegetic prototypes, or prototypes that only exist or make sense from the inside of a fictional world. So the use of the word 'fiction' is actually referring to the prototyping medium, not the prototypes themselves.*» (2016:6) – a fallacy, because the word diegesis means fiction, and there are works self-called 'design fiction' existing in the real world. And the second point is the association with vaporware: «*As discussed in this paper, although vaporware and design fictions are produced with differing intentions, there are many parallels between them.*» (2016:7) – the paper starts with the definition of 'vaporware': «*Vaporware is a term commonly used to describe software and hardware that is announced, sometimes marketed, but is never actually produced [1]*» (2016:1).

Still in 2016 Coulton & al. write another paper addressing the issue of 'suspension of belief': «*the term 'design fiction' has generated considerable interest as a future-focused method of research through design whose aim is to suspend disbelief about change by depicting prototypes inside diegesis, or 'story worlds'. Plausibility is one of the key qualities often associated with suspension of disbelief, a quality encoded within the artefacts created as design fictions suspend disbelief about change by depicting prototypes inside diegesis, or 'story worlds'*». In the end, they imply that DF is deliberately ambiguous and deceptive, and could be ethically dangerous.

Blyth & Encinas (2016) attempt a literary framing up but from the HCI usage perspective. Discussing Hales' taxonomy they say that: «*it also considers the different forms design fiction can take – narratives, short stories, sketches, images, films but also objects and semi-working prototypes.*». The conclusion of DF malleability comes from the fact that it: «*can take the form of the media in which it is presented.*» (2016:348). Under the topic "Magic and Wonder Tales" they sustain: «*Literature, like dreaming, is, at a fundamental level, concerned with wish fulfilment*» analogous to wonder tales – as proposed by the subsequently summoned Margareth Atwood. At this point – comparing Literature to dreaming – jumps to South-American «*magic-realism*» admitting that: «*Here miracles happen almost without comment and certainly without any scientistic explanation. Magic realism describes wonders without recourse to any rationalist accounting*» (2016:349). The amount of misconceptions cannot be ignored: first, Literature is NOT like dreaming – everybody dreams, not everybody writes a novel, and not all dreams are about wish fulfillment (Freud *dixit*).

The characteristic of Literature is the ability to create the worlds it pleases with, or without, any scientistic explanation – see *Tristram Shandy* of Laurence Sterne; *Jacques et son Maître* de Diderot. The authors end quoting Atwood, the science-fiction writer: «*Atwood places speculative fiction, science fiction as well as sword and sorcery under a single umbrella of "wonder tale".*» (2016:347). It should be added that this single umbrella is, in fact, Literature.

In the interim, Bruce Sterling continues giving his lectures (October 2015; Jan. 2016; October 2016) emphasizing and repeating his ideas: «*Design Fiction is neither Design, nor Fiction: it is diegesis*» and that it implies «*the deliberate use of diegetic prototypes to suspend disbelief about change*». He proposes his Venn diagram of possible DF objects:

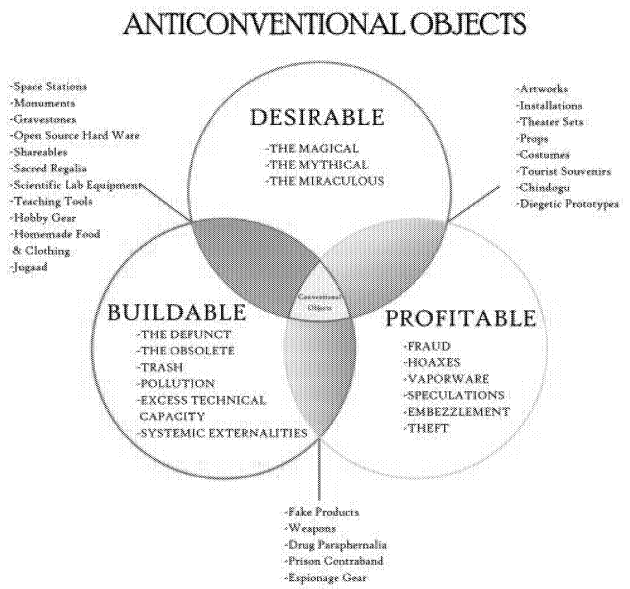



Figure 2: Anticonventional Objects 2013 – Bruce Sterling

In 2004, at SIGGRAPH, Los Angeles, August 2004, «*Subject: Viridian Note 00422: The Spime*» - Bruce Sterling elaborated on the several types of objects adequate for different historical times: «*These classes of objects are called, in order of their historical appearance, Artifacts, Machines, Products, and Gizmos./ The lines between Artifacts, Machines, Products and Gizmos aren't mechanical. They're historical. The differences between them are found in the material cultures they make possible. The kind of society they produce, and the kind of human being that is necessary to make them and use them*». So: «*Artifacts are made and used by hunter-gatherers and subsistence farmers.*»; «*Machines are made and used by customers, in an industrial society.*»; «*Products are made and used by consumers, in a military-industrial complex.*»; «*While Gizmos are made and used by end-users, in whatever today is – a "New World Disorder", a "Terrorism-Entertainment Complex," our own brief interregnum.*»; «*Blobjects tend to be a subset of the class of Gizmos.*». He defines a classic Gizmo: «*it's a cellphone, a web browser, an SMS platform, an MMS platform, a really bad camera, and an abysmal typewriter, plus a notepad, a sketchpad, a calendar, a diary, a clock, a music player, and an education system with its own onboard tutorial that nobody ever reads.*». And he continues: «*But that is not the end of the story. Because the next stage is coming on fast. The next stage is an object that does not exist yet. It needs a noun, so that we can think about it. We can call it a "Spime,"* [space-time] *which is a neologism for an imaginary object that is still speculative. A Spime also has a kind of person who makes it and uses it, and that kind of person is somebody called a "Wrangler". At the moment, you are end-using Gizmos. My thesis here, my prophesy to you, is that, pretty soon, you will be wrangling Spimes.*». Then he explains: «*The most important thing to know about Spimes is that they are precisely located in space and time. They have histories. They are recorded, tracked, inventoried, and always associated with a story. Spimes have identities, they are protagonists of a documented process. They are searchable, like Google. You can think of Spimes as being auto-Googling objects.*». All this evolves into a long *Spimes* dominated dystopia.

The most part of the theories expended about DF come from their practitioners. This means that, for one, we do have first-hand information about DF, by the other that each of them is defending their own 'manifesto'. So, to try and unclutter the fields and propose a formulation of this fictional practice from a narratological/rhetorical/literary perspective, it is necessary to start by recovering the core linguistic definitions.

## DESIGN FICTION – BACK TO BASICS

The terms Design Fiction refer to an object (be it a *Gizmo* or a *Spime*), design and fiction.

Concerning the word object, noun per the *OED* it means: «*a thing that can be seen and touched, but is not alive*», from the late Middle English via the medieval Latin *objectum*. It has synonyms: device, gadget, instrument, tool, machine, an appliance, equipment, and apparatus.

Design has its origin in Late Middle English, as a verb with the sense 'to designate', from Latin *designare*, reinforced by French «*designer*»; the noun arrives via French from Italian. Presently it has the sense of: «*A plan or drawing produced to show the look and function or workings of a building, garment, or other object before it is made*»; «*The art or action of conceiving of and producing a plan or drawing of something before it is made.*»; «*a decorative pattern*»; «*purpose or planning that exists behind an action, fact, or object*». Design is the creation of a plan or convention for the construction of an object. The words «some-*thing*» or «*object*» come up synonymously; a second association is invention, allied with creativity.

Fiction means: «*Literature in the form of prose, especially novels, that describes imaginary events and people.*»; «*Something that is invented or untrue*». Usually fiction goes de par with «*narrative*»: «*The practice or art of telling stories*».

So, in its etymological core, DF is a novel way of telling stories that, initially, departed from Science-fiction because the first examples and practitioners of this art came from the universe of Punk or Sci-fi – both sub-genres or modalities of Literature as a larger discipline.

## LITERARY FEATURES OF DESIGN FICTION

If «*diegetic prototypes*» are the objects inside a story or a film (Sterling, Hale) they are truly fictional – this means that they are mimetic and only exist inside the diegesis (be this in whatever media – book, film, game, IF, IoT). They will function properly, or not, in accordance with the will and intent of the narrator/drama manager/author.

These objects will always work (or not) because they are governed by the so-called narrative-pact, an implicit contract established between any author and the reader-spectator-recipient, by which both accept the rules of the fictional universe at stake.

In traditional stories this pact is inaugurated by the incipit «*once upon a time*». A formula announcing the «*poetic license*» long and lastly theorized – from Aristotle, Horace, Boileau, to Pope. In English criticism reinforced by S. T. Coleridge: «*In this idea originated the plan of the LYRICAL BALLADS; in which it was agreed, that my endeavours should be directed to persons and characters supernatural, or at least romantic; yet so as to transfer from our inward nature a human interest and a semblance of truth sufficient to procure for these shadows of imagination that willing suspension of disbelief for the moment, which constitutes poetic faith.*» (Lyrical Ballads, Chap. XIV).

This pact/suspension of disbelief goes de par with the concept of verisimilitude – and the lack of the later affects the former.

Moreover, as above said, the worlds in which these objects inhabit – be it in books' or cinema, IF's, IoT's or DF's – are all fictional: do not exist beyond their media. The difference in these universes comes from the epochal time they portray: past (historical), present, or future (Science-fiction).

All these premises are subject to the concept of plausibility. Plausibility is Aristotle's verisimilitude concept (Aristoteles *Poetics*, 1460 b 13): «*What is convincing though impossible should always be preferred to what is possible and unconvincing. Stories should not be made up of inexplicable details;[...] Since the poet represents life, as a painter does or any other maker of likenesses, he must always represent one of three things—either things as they were or are; or things as they are said and seem to be; or things as they should be*».

This plausibility/verisimilitude has evolved through the Latin concept of *decorum* – decorum designates the appropriateness of style to the subject – and the French concept of *bienséance(s)* – ethical and social rules of a period, of a society. In literary terms, it is the quality of a work that complies with the laws of the genre, the requirements of the subject, the characters and their language appropriateness, the dominant taste of an era. If the DF works are internally coherent – respect the rules the author proposes for his creation – the work is plausible.

On the other hand, ethical issues should not be considered as they have been expelled from aesthetics since/by Kant. Consequently, the works should be evaluated by the quality of their narratives in context and co-text.

In literary and linguistic terms, context is the allusion to the real world (the referents, lexicon and grammar needed for any interpretation); co-text relates to the fictional/narrative universe. In alien/utopias, futuristic narratives or Sci-fi, although the second demands some referents to the former in order not to become completely illegible (i. e. some of Tolkien experiences) there is an estrangement relatively to the first. When the world pictured belongs to any kind of other space, or time, the risk of – a posteriori – loose its plausibility is very high, and can only be appraised when the depicted future becomes a present.

## AN ONTOLOGY FOR OBJECTS-OBJECTS

At a first level, the natural life course of any common object derives from its necessity or utility (to solve an imaginary or real problem), and will follow a pattern: a) concept/ design (ideation/ creation); b) prototyping/ construction (sketch/ modelling); c) manufacturing (the making of goods or wares by manual labor or by machinery, especially on a large scale).

At a second level it should be addressed how the objects are going to be used:

1) if the concept is right the object has the chance to become a useful and successful artefact, turns into ware. As with the 1930's illustration of a «proto-eyephone-o-matic», acceptable ancestor of a smartphone:



Figure 3: Proto-eyephone-o-matic 1930

2) if the concept is wrong (due to any reason, imputable to the source or destination) the object can die/disappear, even if it went through all the other sequences of its natural life (including sales promotion) and becomes vaporware. As the mechanism below, assuring «*three million volts electrons*» to kill «*organisms that causes decay without affecting the food itself*»:




Figure 4: "Lightning" strikes your steak 1950

Another example could be the AvroCar, by Jack Frost, presently at the National Museum of the U. S. Air Force in Dayton, Ohio. Frost was hired by Avro Canada aviation in 1958. He supervised a team of researchers who called themselves the Special Projects Group (SPG). They conceived the two passenger Avrocar as part of a secret U.S. military project, directly inspired by Sci-fi UFO's. It actually functioned with top speed of 35 miles/hour, a range of 80 miles, and it could rise 3 feet above ground before it stopped working definitely:




Figure 5: AvroCar VZ-9 1956-1961 – Jack Frost

3) if the concept or the utility are wrong, it enters the spectrum of solutionism (to solve a problem that does not exist). Per Michael Dobbins (2009:182), the disconnection between problem and solution, is: «*always likely to be an issue, became exaggerated in the culture and practice of modernism in city design and planning, where problems were "dumbed down" to meet the solutions offered*». But it can also be met in unexpected appliances:




Figure 6: Portable air conditioner 1956 – Jeff McNabb

4) if the concept is premeditatedly wrong, and the utility subverted it becomes *Chindōgu* (http://www.chindogu.com). The objects must exist and they must solve one problem while creating a larger one. Like the practice in "The uncomfortable project", KK studio, and Katerina Kamprani's objects (2014-ongoing): «*The goal is to re-design useful objects making them uncomfortable but usable and maintain the semiotics of the original item*» (http://www.kkstudio.gr):




Figure 7: Waterfall teapot 2015 - Katerina Kamprani

At a third level, if any of the above items are superseded by the aesthetic quality or narrative intention endowed by the author/performer, the object becomes art.

IF, IoT and DF – all can choose to tell stories with/through their objects. The intention (lack of use and utility) makes them different from commodities.

Summarizing: diegetic prototypes can become ware (+concept +making +utility); vaporware (+concept -making +utility); solutionist (-concept +making –utility); chindogu (+/-concept +making -utility). Independently, and as said before, if the aesthetic quality surpasses all these features it becomes art.

Whenever the objects inhabit a future imagined world they belong to the Science-fiction universe. There, they have to be plausible, endorse the referents to the respective story's time and space. Some, in the long run, become a forecast of the future, DF – like the "Newspad" in *2001:Space Odyssey*.

There is a nuance comparatively to Paleo-futurism (invented by the Nazis in 1941), synonymous with Retro-Futurism, more often a direct prediction of the future by people of the past. The most outstanding illustration is Nicola Tesla (1919). In 1926 he gave an interview to *Collier's Weekly* in which he predicted objects remarkably like portable television, referring that this technology would be used to watch the war unfold: «*just as though we were present*». In Tesla's *My Inventions: The Autobiography*... he lists objects from the future, small portable instruments, much like the mobile phone, and says: «*We shall be able to witness the inauguration of a president, the playing of a world's series baseball game, the havoc of an earthquake, or a battle just as though we were present*».

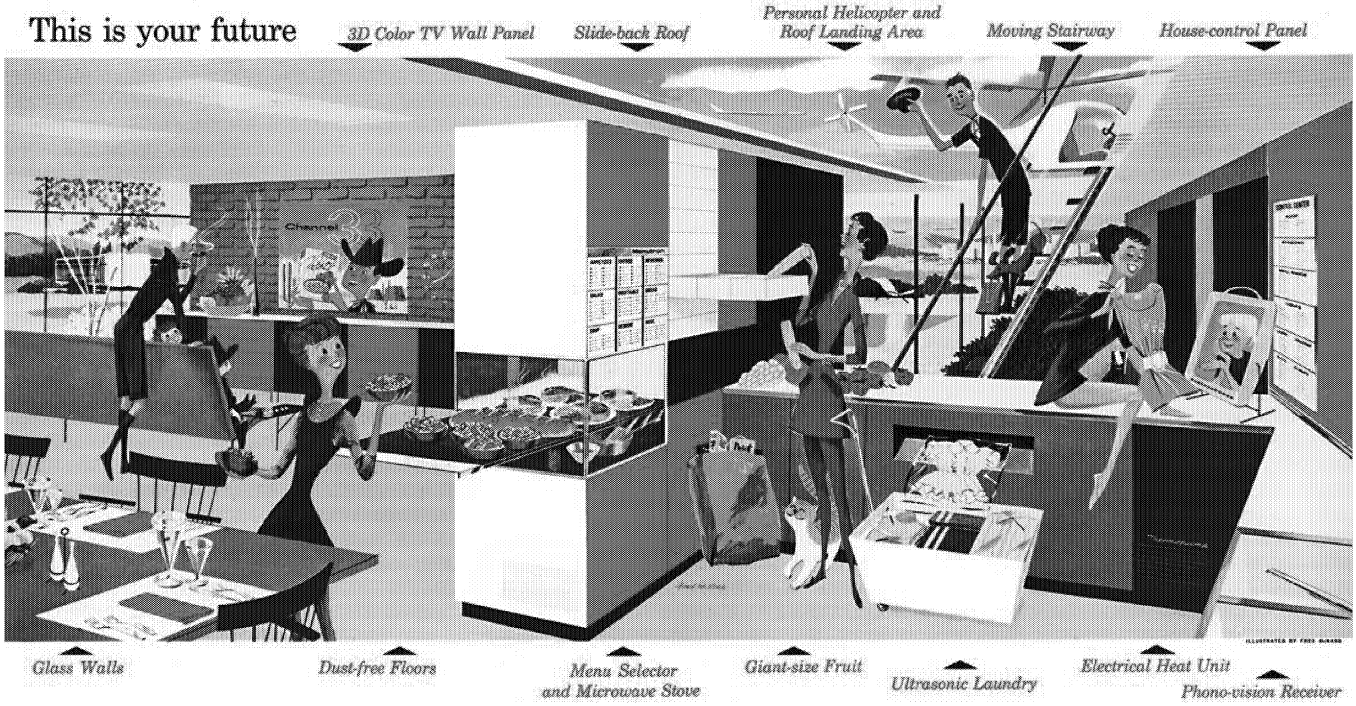



Figure 8: House of the future 1965 - Fred McNabb

## HI-TECH HOUSES – SUCCESSFUL NARRATIVES

More than futuristic worlds or cities, the smart-houses of the future can exhibit the objects/elements that came to constitute the basis of DF. The problems to be solved are utilitarian – initially coming from essential surviving issues: a roof, some clothes. When the basic needs are fulfilled, it can elaborate over them – their concepts can be enriched.

As common thematic IF, IoT, or DF ground there is the hi-tech house, with new appliances, weather protection, or developments for other normal human activities – living, eating, working, studying.

In 1956, the magazine *American Weekly* (1911-1960) devoted a whole issue to the «*fascinating facts about the way you'll soon be living*» in 1965, illustrated by Fred McNabb (http://www.bpib.com/illustra2/various2.htm). Sixty some years later it is possible to see what went beyond the expectations, and what fell short. From this "House of the Future" to be materialized in 1965, some items became reality – like the Phono-vision Receiver – the current tablet. The remnant, although not offending verisimilitude, nor becoming comical, are still far away like «*dust-free floors*», or «*ultrasonic laundry*».

Other previsions for homes of the future are not so accurate as the bove like the "Monsanto plastic home", a Disneyland attraction between 1957-1967. In 1967 Walter Cronkite presents a forecast for a "State of the Art Home in 2001", a completely controlled environment via a switchboard. The main concern is comfort. Most of these smart homes are built and sponsored by industry manufacturers that want to promote their appliances.

A Belgian experience, "Living Tomorrow" (2010) focuses on intelligent touch devices, a wc mirror giving the morning news. The "Honda Smart Home" (2015), zero-net energy, is more an excuse to housing electrical cars, and the newer eco-friendly and greener concerns.

"Casa Jasmina" is an Italian pilot project (2015) started with the collaboration and presence of Bruce Sterling. It rents rooms to potential users, who must identify, imagine, their needs. Other examples could be listed, but the pitch is much the same: the homes of the future will have robots that can greet you when you get home and appliances that you control with your voice (beware of pharyngitis).

Two of the recurrent worries are the quality of the air and floor cleaning. A glimpse into smart technology gadgets – already available – show that (still) try to propose solutions to the 50's problems. The "Denso Vacuum Cleaner Shoes" (2017) prototype was developed as part of a biannual company competition allowing employees to «*foster their creative and innovative design concepts*». The "Ecology Shoes" hide apparatus inside each over-sized sole, to hoover the floor while walking. Each step powers the motor, charging the batteries, leaving the new concern to empty the dust boxes in the shoes.



Figure 9: Denso Vacuum Cleaner Shoes - 2017

In general, the creations for the last 150 years have been a human strive for freedom and communication, to be able to control time and space. The inventions that have affected most people around the world for everyday living are electricity, radio, the car, the telephone, television, but mainly the computer and the ability to communicate through Internet. Lots of other inventions have made life easier, like faster transports, new medicine, new appliances.

All these areas can be found represented in DF, as well as Literature, or storytelling by any other media than the book. These suggest other ways of living, alternative worlds and lives prospects. Forecasting is part of the human need to extrapolate the present into the future, also effective in arts and sciences.

## CONCLUSION

There is a similarity between IF, IoT, AR and DF – all these practices are some form of digital fiction, that can choose to tell stories with/through their objects.

They would all lose something of their aesthetics, content, structural form and meaning if they were removed from the digital medium. In them the reader/user has a main role in constructing the narrative, either by interacting with the story world, or their characters' avatars.

The specificity lies in the objects themselves – the concept and intention that presided to their creation makes them different from commodities. Whenever the things inhabit a future world they belong to the Science-fiction universe. Here, they must be plausible referents to the period of the respective story. Some, with time, become a forecast of the future, DF, and DF being different from Paleo/retro-futurism, the direct estimate of the future by persons of the past.

Diegetic prototypes are, on their onset, DF. They can become ware, vaporware, solutionist, or chindogu. Independently, if the aesthetic quality supersedes all the other features they become art.

The authors of DF consider themselves futurists, creating ideas that are not in/of the universe we live in, but that applies also to the traditional literary authors.

The aesthetical and critical discourse to address these new creative practices is in the making. Creativity and originality can be evaluated through old-fashioned ways and help to provide a common ground for understanding in this cross-field communication.

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In 2011 she received the (2nd.) SANTANDER Award for the Internationalization of the F.C.S.H. Scientific Production 2010, and in 2015 the «Best paper Award» for *Cloud Computing and (new) mobile storytelling in the Internet of Things*, presented at EUROMEDIA'2015, I.S.T., Lisbon, Portugal.

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# INTERACTIVE TRANSMEDIA vs. VORONOI DIAGRAM EXPRESSIONS

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Digital Humanities , Interactive Television, Transmedia, Storytelling, Voronoi Diagram

**ABSTRACT**

Combining the concepts of classic narrative and transmedia, we will show, as Jenkins argues, that Digital Technology and non-linear narratives can be represented through the Voronoi Diagram. Starting from this premise, we will present the transmedia product prototype *The Portal* – prepared for interactive tv – questioning whether it retains transmedia narrative characteristics and geometric computational representationally.

**INTRODUCTION**

The present moment of media's change can be defined by the overlapping of diversified layers and by the interconnectivity of the media, contrasting with the previous model which supposes that new media would replace old media (Jenkins, 2011).

Transmedia narrative asserts itself in a paradigm characterized by the convergence of mass media and digital media properties. It operates in a media ecosystem in which the digital has preponderance, determining the form, production, diffusion and reception of cultural products. This led Manovich (2001) to defend the computer as metamedia with unique properties, allowing it to represent the contents in accordance with a new logic. Previous media struggled against bi-directional communication, and fostering the sharing of emotional space; while digital media offers individual access to interactive media, promoting and sharing cognitive space (Manovich, 2001).

Jenkins (2006) condemns the 1990's criticism that prophesied old media extinction. This was based on a prejudice which classified old media as passive, in opposition to the interactivity of new media. Some authors argued that the digital age would kill mass culture instead of transforming it. Jenkins (2006) rejects the mediation of the old media's condemnation by new media. He proposes the concepts of media and cultural convergence underlining the cooperation paradigm of the new media ecosystem.

The specific convergence of some media is emphasized. The cultural convergence between television and computer focuses on the (linear and non-linear) narrative issue, as it prefigures a reorganization and reconfiguration of television narrative into new logical functional terms. It is the proposed articulation between television and the computer that allowed to personalize the television (Parks, 2003).

Television has proved to be a particularly fertile medium in the field of media convergence analysis. It has been adapting itself to new configurations that befit the new media ecosystem. The latter is characterized by convergence, translated into addition of interactive and collaborative properties in their models of representation.

Simultaneously, as proposed by Jenkins, and concerning circulation concerns, television is one of the central medium in terms of contents convergence and transmedia narratives. This lets us guessing what may the near future be, concerning this medium and what role it will play in the new digital technologies paradigm.

**DOUBLE CONVERGENCES**

Transmediation is one of the most visible facets of convergence. It applies its properties to narrative construction beyond intertextuality or remediation, establishing a dialogue at textual level. Convergence institutes a culture of dialogue between meanings, incorporating form, content, production, consumption, life and media.

The concept of transmedia narrative is operationalized in the universe of media convergence. It is understood as a flow of contents crossing different and multiple platforms in the field of cultural industries. It also operates in the context of audience's migratory behavior, wishing to be in almost everywhere having all kind of entertainment experiences (Jenkins, 2006).

Cultural convergence is defined top down (business decisions) and bottom up (decisions and choices made by users, usually teenagers). It mirrors the conglomerates of cultural industries' desire to expand in the different media, and it mirrors the consumers' desire to have the contents of the media they want, when they want it and in the format they want (Jenkins, 2006).

This content expansion and circulation is operationalized by the active participation of the consumers (Jenkins, 2006). At the same time, it represents the digital technological transformation of a new cultural consumption logic: spectators became participants (Jenkins, 2006).

In association with digital technology, convergence of media and, even more, convergence of cultural contents, can also be operationalized by digital technology applications. However, it takes place in the consumer's brain: each individual

constructs his/her own mythology from the bits, and fragments, of information they then process (Jenkins, 2006). In the digital age, the collective intelligence power (Lévy, 2007) is opposed to the mass media power.

## TRANSMEDIA NARRATIVE

### The ecosystem

In 2003, Jenkins presented the term transmedia narrative developing it in 2006. Up till then, from 1980 to 1990, the concepts and thinkers did not agree. In 1991, Marsha Kinder had already introduced the transmediation notion; in 1997, Janet Murray backed the term hyperserial to express fragmented narrative structures in a multiplicity of media; in 2001, Peter Hill used, also in the same sense, the term superfiction. Multiple authors analysis' revealed that transmedia narratives have specific properties and patterns, that manifest themselves in operationalization strategies' (Jenkins, 2006; Askwith and Gray, 2008; Dena, 2009; Smith, 2009; Ruppel, 2012).

Transmedia narrative represents a process in which elements of a fiction are scattered, systematically, across platforms with the purpose of creating an entertainment unified experience (Jenkins, 2007). Our lives are built around stories we tell each other. These stories represent our understanding of the world, of the people with whom we interact. When we connect what we learn with each of these episodic narratives, there are life lessons that guide how we should behave and live within our far-reaching society. Today's digital technology allows us to share incredible visual and interactive experiences. However, no transmedia narrative can work without a guiding script informing all the related creative decisions that shape every aspect of storytelling: characters, context, story worlds, the protagonist's journey – as already postulated by traditional narrative regarding the hero's journey (Campbell, 1949). All these elements are commanded by the narrative and, in turn, influence what kind of platform is going to be chosen by different audiences, i.e., what kind of technologies will be used.

The transmedia's narrative beauty has been able to create an ecosystem fully developed by the narrative itself. Once in flow, it is its users that look for, and find, different experiences between them, in different platforms. Access can be made through different entrance doors, that is, each medium being an access door, chosen by the operator and in accordance with each individual ease towards the media being used.

### From spectator to participant

Transmedia storytelling is based on fictional worlds that support multiple and interrelated characters and story arches (developed by users), encouraging an encyclopedic impulse both in creator and user. That is, transmedia narrative works constantly expanding, independently or beyond our own will, because it summons the user as participant or co-creator (Jenkins, 2007). Consequently, it is different from traditional narrative (linear and closed) that, in the end, allows the grasp of a story's total meaning (Jenkins, 2007) and condemns the individual (user) to a spectator's passivity.

In opposition, transmedia narrative triggers and enlarges its content through all or to one of the following functions: backstory, story worlds map, other characters' perspectives, increased audience involvement, user summoning to participation in narrative construction; thus the passive viewer becomes an active participant (Jenkins, 2011).

This storytelling participative characteristic leads many authors to argue that interactivity is transmedia core.

By interactivity it is meant the vast territory of different relationships fans can establish within a transmedia narrative. This can happen through different ways: gathering information to try to grasp the meaning of the story; to try to reach a game level, overcoming obstacles or different fans' performances (from fan fiction to cosplay). All these possibilities, not present in traditional linear narrative, appear in transmedia narrative because it summons the user to participate, being less dependent on the producers' content design choices (Jenkins, 2011).

This underlies the difference between continuity and multiplicity. Transmedia demands a high degree of creative coordination and control to ensure that all story pieces are coherent, and consistent, within the world(s) of each co-created narrative (Jenkins, 2011).

### From adaptation to expansion

Transmedia narrative has its roots in film and television. It retains the seriality of contents. It creates a story over time in a process of chunking and dispersal (breaking and dividing the story by several interconnected media). These processes are operationalized by creating cliffhangers, in order to motivate the user to return back to the story.

In traditional linear narrative seriality occurs within the same text; in transmedia narrative it happens at each story arch (Jenkins, 2011), hence it is fundamental to distinguish adaptation from expansion.

Theory of Adaptation is based on the interchangeability of a text and its conservation in new forms (O'Donnell, 2000). Adaptation is also considered typical at the initial stages of digital media because they had not yet found a proper aesthetic language (Holtzman, 1998). Therefore remediation is referred to as an apparent adaptation: a medium is incorporated and represented in another medium (Bolter & Grusin, 2000), sustaining that not all adaptation is necessarily remediation (Hutcheon, 2006).

Theory of Adaption arose from the relation cinema/ literature (Woolf, 2008) and progressed within two axis, opposing fidelity and intertextuality (Stam, 2005). This approach summons Kristeva's (1974) and Genette's (1982) intertextuality concepts, together with the dialogism concept (Bakhtin, 2006). Jenkins argues that switching a text to a new medium is a mere recodification, transmedia narrative presupposes text's expansion (Jekins, 2011). In conclusion, adaptation takes the story from one medium and reproduces it in another; expansion adds something new to the existing story when moving it from one medium to another.

Expansion summons the additive comprehension (coined by Neil Young), every degree each text achieves in our understanding of the story (Jenkins, 2011).

**Anatomy of transmedia narrative**

Transmedia narrative presupposes the representation of a fragmented and modular narrative, that can be extended by multiple platforms, regulated by continuity among the different compositions. I.e., the same narrative expands through a plurality of media limited only by (traditional) narrative criteria. For additive comprehension each story arch (that each participant inaugurates in each different media) has unique narrative elements. Based on reconfiguration processes operated by new media, the transmedia narrative maintains criteria of cohesion and canon, not abandoning the diegetic coherence. What distinguishes it from the traditional narrative is the fact that it is not linear and uses the classes of modularity, navigability and database. It is up to the participant (no longer a spectator) to decide when he accesses each composition, identical to what already happened with hypertext, gaming or virtual reality.

Whether traditional or transmedia narrative is always maintained by a model of causality existing in every human communication act, in the way we represent, interpret, and understand the world around us. Morphological narrative models, identified by Aristotle (2008) as organic, emphasize the plot and dramatic unity; the diegetic pact; verisimilitude and a law of totality supported by the causality principle. In the so-called classical theatrical cycle, linear traditional narrative was established in a dramatic crescendo represented by Euclidean Geometry (Figure: 1). From an incident (Field, 2005), causality operated a dramaturgical progression divided into three acts, conducive to a climax and to the result or resolution (story closed end), the audience being of spectators and not participants.

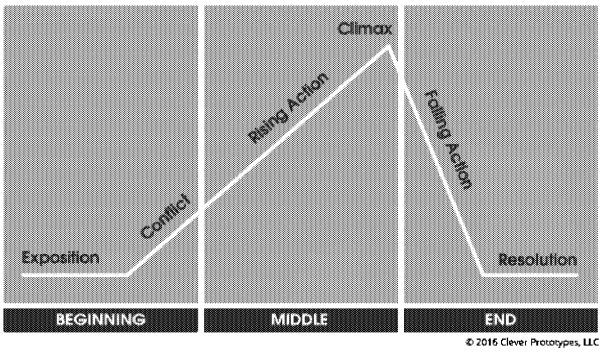



Figure 1: Euclidean dramatic narrative

The fundamentals of nonlinear narratology persisted somewhat unchanged in the new digital media and convergence paradigm.

The new systems break with linearity, forcing it to reconfigure the very concept of narrative. Umberto Eco (1993) highlighted the uncertainty of the communicational process, interpretation and decoding underlying any text. I.e., anchored in semiotics, Eco states that author, text and reader are discursive strategies, so the reader assumes the role of cooperator in the construction of the meaning of the text. Released from the author's tyranny, and the narrative linearity due to the concepts of hypertext (Kristeva, 1974) and of palimpsest (Genette, 1982), the narrative is open to the Rhizome's idea (Deleuze and Guattari, 1987).

Rhizome is a botanical term designating a class of stems, representing a structure unfettered by hierarchies (Figure: 2). Applied to classic narrative, it represents the hypertextual model. Nuclear elements of the narrative can be accessed in any order, and it's association is freed from the author's organizational models.

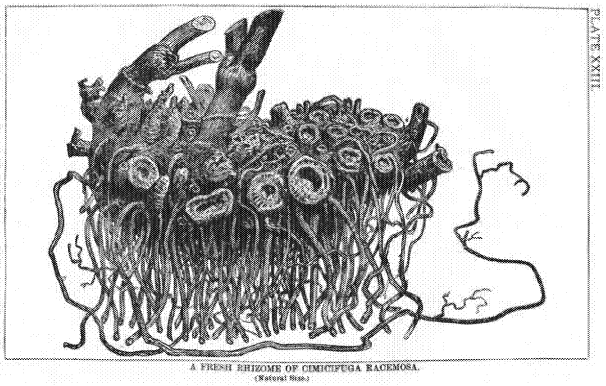



Figure 2: Rizoma's representation

Born with the digital age, media convergence and postmodernity (Lyotard, 1975), transmedia narratives are characterized by not using the usual narratological features, combining game, with linear and multi-linear.

The participants elevate the transmedia narratives to an unspecified zone. It escapes the linear causality of closed end; presents itself in an area of nomadism that appears to survive in apparent chaos. Jenkins considers this chaos only apparent, because it resembles the computational geometry represented by the Voronoi diagram (Figure: 3) - the seed sites, or seeds, personifying the participants in transmedia narratives.

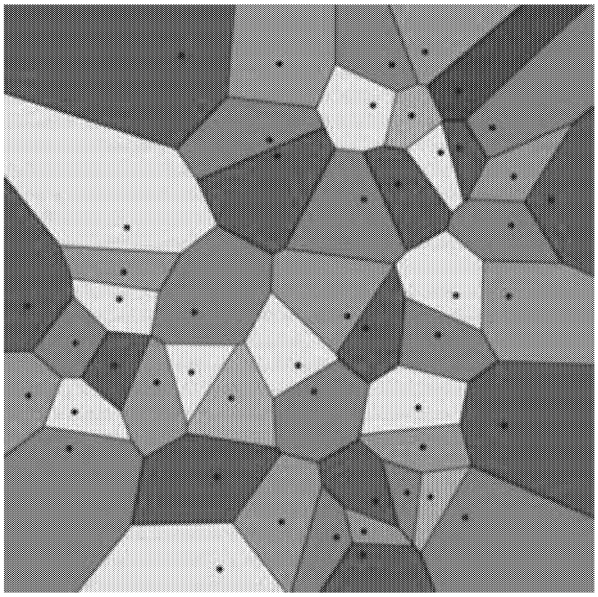


Figure 3: Voronoi's diagram of a random set of points in the plane (all points are contained in the image)

Similar to the spots in the Voronoi diagram, each participant is equidistant from the global narrative. Each participant is co-creator of the story he shares. Participative dispersion is so apparent as the ones in the patterns of nature that the Voronoi diagram represents (Figures: 4-6).

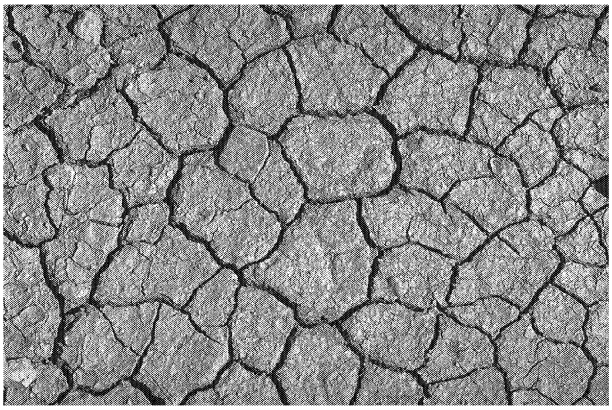


Figure 4: Dry earth (Voronoi diagram)

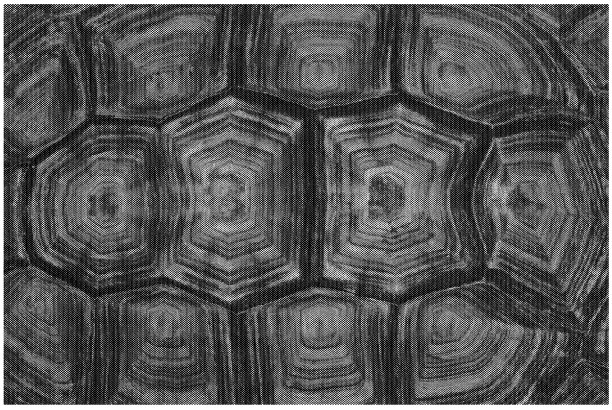


Figure 5: Tortoise shell (Voronoi diagram)

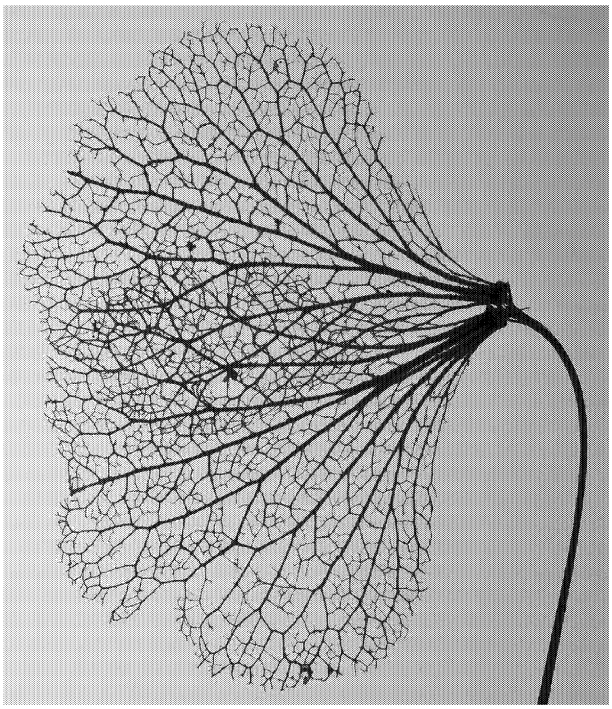


Figure 6: Hydrangea leaf (Voronoi diagram)

Instead of individual participation producing disharmony, it leads to beauty and pure art. In this Benjamin's aura concept (Benjamin, 2006) is recognized as lost in the age of technical reproducibility.

Paradoxically, the era of digital technology gives back to narrative its place as art, replicating Nature's Big Narrative structures (Lyotard 1975), representing a technological artistic form that could emulate a tree (Figure: 7).

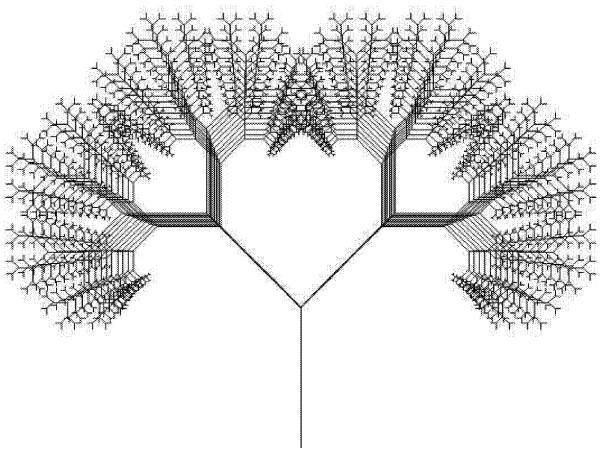


Figure 7: Tree structure for transmedia narrative

**Where transmedia narrative meets game**

Digital media created an ecosystem that shows the convergence and ubiquity interweaved into narrative.

Murray (1997) argues that the reader becomes a player; in digital narrative, the reader makes decisions with and as the author. The digital media author has new modes for telling stories. Jull (2004) adds that the time of the story (time of the speech) has been replaced by the time of the play (time of the events). Jenkins (2004) prefers to keep a more narrativist approach arguing that many games narrate, but not all of the games do so. Though he recognizes that game brings back to transmedia narrative an important factor: the thrill of winning, the fight not to lose, that underlie game logic. Transmedia narrative takes over from the game universe an important postulation: immersion.

**Transmedia as a four-level narrative**

Transmedia storytelling is based on four narration levels: the first one - «*here is the story*» - belongs to any medium of transmission; the second: «*what am I hearing*» is the audience's engagement with the raconteur via the social media of transmission; the third: «*this is my world and be welcome*» is when/where the audience can participate; the fourth: «*take the world*» the audience takes on the story world and begins to create fan fiction, as story ambassador.

According to Jenkins (2007) transmedia narratives have the following characteristics: a) they abandon traditional stories' linear structure and place themselves in the non-linear; b) the viewer abandons his passive role becoming a participant, and

being co-author of story archs developed from the story worlds resultant from the main story; c) the story archs are constructs of each participant that, at each moment, can choose the narrative's entrance door.

Transmedia crosses several of the old media (consider *Matrix* analyzed by Jenkins in: comics, television, movies, games, online social networks, and forums formats. What characterizes transmedia is that it proposes a tale no longer to be heard, but instead invites to an assault of its world, and to building a never-ending story.

**PORTAL – TRANSMEDIA NARRATIVE**
**© Helena Barbas & Vanda de Sousa**

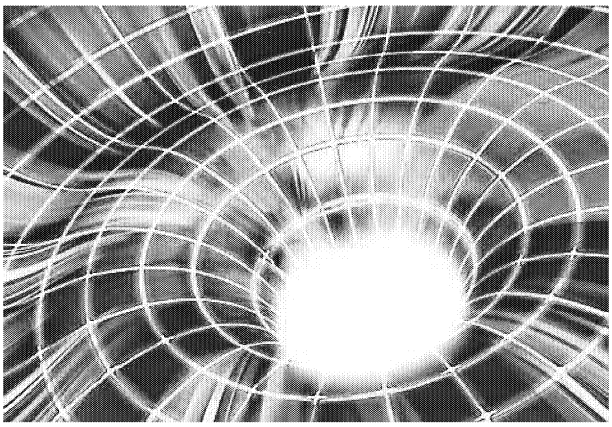


Figure 8: Portal

Portal is a 12 episode (10 minutes each) of a multi-stream project for an interactive TV transmedia narrative with a dedicated website. Each episode obeys to a specific line of action in some circumstances unknown to the characters themselves.

The goal of the project was to find a new format of narrative fiction, proposing a different way for consuming new audiovisual formats that included on-line games motivation, and crossing over from linear to non-linear narrative.

Each episode has a full action cycle. All the characters are protagonists inaugurating each episode with a new proposal. The plot progresses simultaneously and in accordance with each character space, breaking the canon of the classical line. In the dramatic intrigues, each conflict offers three entrance doors: Yes-No-Maybe.

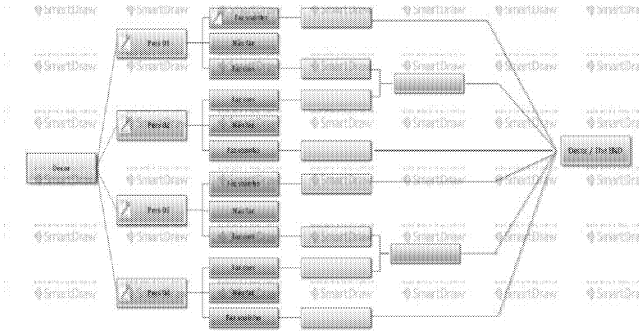


Figure 9: Portal plot structure

The previous structure can be reproduced with other diverse contents. In the present case, the storyline intended to recreate the reality show format. The story inspiration came from Voltaire's *Candide, ou L'Optimisme*, and Dr. Pangloss (teacher of metaphysico-theologo-cosmolonigology) motto and leitmotiv: *« ...there is no effect without a cause; and, that in this best of all possible worlds...»*.

The characters inhabit a technological world, and the chances are ruled by the watchful eye of two geeks (N and M) who govern the odds via Social Media Networks through their mobile phones.

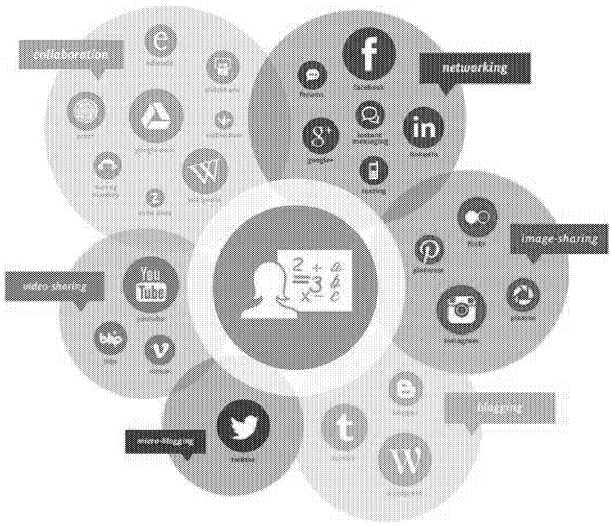



Figure 10: Portal - Social media networks

The other two characters (J and C) are confronted with a spiral of disagreements that dramatically distances them and drives them against each other.

The power of the password will allow them to live jealously or happily ever after, until the next episode.

## CONCLUSION

The Portal prototype was elaborated from empirical experience, by tentative and error, trying to solve each of the problems that were arising in April 2016. A posteriori, it was confronted with Jenkins theorization about digital technology and non-linear narratives, enriched with the Voronoi Diagram representation.

As an interactive tv script and transmedia narrative, the Portal project proved to have all the charateristics which are in demand, as well as geometric computational representation of the aforementioned.

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# ENHANCING INNOVATION PROCESSES BY DISRUPTIVE TECHNOLOGIES

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**KEYWORDS**
Virtual Reality, 360 degree cameras, Design Thinking, Virtual Creativity, Innovation process

**ABSTRACT**

This paper proposes a Virtual Design Thinking (VDT) model to improve innovation management in the product creation process (PCP) by implementation of disruptive technologies. Tasks of innovation management such as the idea generation are supported by conventional creativity methods. The aim of this paper is to show that innovative technologies such as Virtual Reality (VR) and Additive Manufacturing (AM) have potentials to improve early stages of the product creation process. Design Thinking (DT) provides aspects for integrating technologies in innovation management. Results of a preliminary study show that the technology gains a high user acceptance in innovation management process.

## INTRODUCTION

The PCP is influenced by mega trends: globalization, demographic change and digitalization. To challenge these influences SMEs have to be strengthened by innovative processes and technologies. (BMBF 2016)
Generating innovative product ideas is a key factor to achieve unique selling propositions. Nowadays, workshops and expert interviews including conventional creativity methods are used for the idea generation for designing future products. These methods have the disadvantage that all participants have to be at the same place to generate ideas with a high grade of innovation. However, the number of virtual project teams developing product ideas from different places steadily increases (Lipnack and Stamps 1997). Challenges for virtual teams are the choice of suitable tools, limited information channels, motivational, cultural and linguistic aspects (Albers et al. 2015).
Disruptive technologies such as Virtual and Mixed Reality (MR) are only used in late phases of PCP yet (Gräßler and Taplick 2015). For example, (virtual) design reviews and investigations of ergonomics are state of the art in producing companies. Still, both VR and MR provide possibilities to support innovation processes and by:

- Real-time collaborative work in virtual spaces
- Enhancing creativity by fictional content
- Implementation of flexible work forms such as home office in companies

One specific innovation process being suitable to implement disruptive technologies is Design Thinking (Gräßler and Taplick 2016). This process includes the early usage of prototypes and provides the possibility to generate product ideas in an agile engineering context. To combine DT and disruptive technologies, an analysis of the DT process steps (Empathize, Define, Ideate, Prototyping and Testing) is necessary to use advantages of VR, MR and AM.

## STATE OF THE ART

### Innovative technologies

VR is a disruptive technology standing before the breakthrough in industries (Deloitte 2016b). Actually, the technology is used in areas such as entertainment and gaming. But there are also use cases in industries. Especially OEMs in automotive and aerospace use Virtual Reality for design reviews and marketing.
Studies of Deloitte and KPMG have identified several applications of Virtual Reality (especially Head Mounted Displays (HMD)) in B2B. Applications in fields such as training, design or production are well known and investigated in several projects. The application field being interesting for interaction from human to human is conferencing and collaboration. Deloitte mentions the reduction of costs for travelling, higher flexibility and efficiency of processes as reasons to use Virtual Reality in communication and interaction. (Deloitte2016a)
Use cases by VR & AR for business and benefits of the usage of these in collaboration are emphasized by another study. The replacement of conventional communication and interaction tools by Virtual Reality gives the opportunity to interact in a more intuitive way for example by natural gestures and voice control. (Deloitte2016b)
Increasing potential of Virtual and Augmented Reality in companies is outlined in a study by KPMG: Dynamic growth of the market for VR/AR application, which provides different use cases in all phases of value chains is predicted. Analysis of use cases across the value chain show applications in research, development, production, logistics and a strong focus on marketing and sales (52% of identified use cases), but also use cases in management and administration (7% of identified use cases) with the sub point collaboration and virtual meetings. (KPMG2016)
Regarding projects, first approaches are to create more intuitive communication and interaction forms. There are few providers of virtual collaboration platforms such as AltspaceVR and vTime focusing the consumer sector. Users of AltspaceVR have possibilities to interact with each other with different games or streaming video contents (AltspaceVR). The platform vTime includes virtual environments of exotic places such as outer space (vTime).

Additive Manufacturing (AM) is used in different application areas and describes generative manufacturing processes including layerwise production of a part. AM can be divided in Rapid Prototyping, Rapid Tooling, Rapid Repair and Direct Manufacturing. First applications of the AM technology took place in the area of Rapid Prototyping: the creation of parts, which represent specific properties of a final product or a component. AM usage in prototyping can shorten the product development process and make it more flexible. Rapid Tooling is the production of tools or parts thereof. Rapid Repair describes the addition of material, which has been lost by, for instance, wear or abrasion. Direct Manufacturing is the production of end use parts by layerwise production technologies in small numbers (Lachmayer and Lippert 16).

### Design Thinking

DT is an approach to generate innovative ideas. However, it does not exist a standardized definition for DT. Brown describes it as interdisciplinary approach, which needs designer´s sensitivity, the identification of user´s needs and the technological feasibility (Brown 2008).
Kelly and Kelly define it as "a way of finding human needs and creating new solutions using the tools and mindset of design practitioners" (Kelly and Kelly 2013). Brenner et al. describe the meaning of DT by three different aspects (Brenner and Übernickel 2016):

- Mindset
- Process
- Toolbox

**Mindset:** The mindset consists of several basic principles being important to internalize DT. "Innovation is made by humans for humans" is one of most central principles, which focuses the user centered perspective of idea generation. The combination of convergent and divergent thinking is another point to span a maximal innovation space with conventional and far-fetched ideas. "Fail often and early" characterizes the meaning of many trials in the beginning of development. Another point, which differs DT strongly from other approaches is the creation of many prototypes which have to be validated by users. It is important to integrate users early into idea generation process. The iterative character of DT can be described by the principle: "Design never ends". A previous design has to be revised many times. (Brenner and Übernickel 2016)
**Process:** DT is characterized by two processes: micro and macro process. The macro process describes the whole process to solve problems and tasks with DT. Within the micro process has to be run through several times. The micro process deals with the definition of problems, followed by identification of user needs and the conception of an ideal solution. Finally, a prototype (different types such as paper or software) of this solution are created which have to be tested by users.
The macro process can be depicted by several prototype creations. The first steps include the research of fundamentals and information, followed by a critical function and a "Dark Horse" prototype to span the innovation space. The "Dark Horse" prototype includes far-fetched ideas, which does not take known constraints into account. After the diverging steps, the prototypes are focused on the solution of the basic problems by functional and "X-is finished" prototypes. (Brenner and Übernickel 2016)

**Toolbox**: To carry out a DT project several tools are necessary to support the processes.
Brenner et al. identified seven elementary methods and tools for DT approaches. One of them is a Stakeholder Map to focus the different interest groups. In the center of interest groups are users who solve problems user-centeredly. Empathy Maps support the process with analyses of interviews in a structured way to gain user specific needs. The usage of the 5-Whys method helps to analyze the problem and creates a deeper understanding. The methods are not limited to five usages of the questions. The AEIOU method constrains the structure of problems by the categories: "Activities", "Environment", "Interactions", "Objects" and "Users". Personas are used to structure behaviors and abilities of interest groups by fictive user profiles. The observation of users is another possibility to identify needs, especially hidden ones. The last identified tool by Brenner et al. is the storytelling, which simplifies the display of problems and the usage of solutions in everyday life. (Brenner and Übernickel 2016)

### Creativity methods

The basis for the development of innovative product ideas is creativity being the ability to create something new (Mumford 2013). Several creativity techniques such as brainstorming and 6-3-5 method are used in workshops to create an ideal atmosphere of creativity in the team. These approaches are only suitable for workshops taking place at one location. The interaction of team members from different places can hardly be supported by conventional creativity techniques.

## VIRTUAL DESIGN THINKING

### Aim of the research

The aim of Virtual Design Thinking (VDT) is to increase the possibilities of DT process by innovative technologies. The most important reason to implement innovative technologies in a conventional innovation process is to increase quantity and quality of ideas for innovation. For the fulfillment of this aim, modern information and communication technologies (ICT) provide several advantages. The usage of ICT in early stages of the product creation process leads to a faster digitalization of ideas. These ideas and information can be documented in product lifecycle management (PLM) systems and are thus directly available for following steps. The early digitalization of information is important for objective and repeatable investigations. VR and MR can be used for visualization of information and data. Another advantage of ICT is the location independency. The location of a project team member does not matter if he or she has the necessary ICT infrastructure. Resulting from this, it is not necessary to meet in a special location. This is an important advantage for global operating companies with locations all over the world. With the early digitalization of innovative ideas, it is possible to easily connect them with other data. Connection between innovative ideas and suitable information therefore does not depend on the competence of few employees.
The complete process chain from innovative ideas to first tested prototypes can be shortened by ICT. The digital information of innovative ideas can directly be used to create prototypes. A direct interconnection with simulation tools leads to the reduction of physical prototypes. To enhance creativity with VR or MR technologies, it is necessary to adapt

creativity techniques to virtual spaces for an intuitive interaction between project team members.

**Model concept**

The proposed concept of VDT (illustrated in figure 1 is based on conventional DT process steps (Empathize, Define, Ideate, Prototyping and Testing). The iterative process (see figure 2) has the aim to generate solutions and ideas in short time. Disruptive technologies such as 360° video systems, VR, MR simulation software and Additive Manufacturing support all steps from Empathize to Testing. The following section describes the connections and benefits between separate process steps and ICT. It describes also technical barrier at the moment which have to be investigated.

**Empathize:** The aim of this step is to understand the task or problem and to find necessary information. This step is important because only a correct comprehension and a high amount of necessary information guarantee to fulfill the requirements of the solution.

In cases of an optimization of a product, it makes sense to observe the handling with the product by users. One conventional way to investigate the handling is the real observation of a person while using the product. Disadvantages of this method are the documentation and dectection of information. Team members can only concentrate on specific aspects. The simultaneous tasks of detection and documentation is difficult to fulfill for humans. Another possibility is the conventional video documentation of product usage.

It is much easier to document necessary information by repeated watching the video. A disadvantage of this method is the limitation of perspectives. A video shows only one perspective. Only the creation of videos with different perspectives offers the possibility to include all necessary information. The next logical step to record the whole environment while product handling is the usage of 360 degree camera systems which includes camera lenses in different directions to create a visualization of the whole environment with all possible perspectives. 360 degree cameras are mobile systems which enable recording of every important situation for the investigated task or problem. The recording system can be coupled with a cloud to investigate the created video content in a short time.

The video content can be analyzed using a Head Mounted Display (HMD) by every team member. In this step of the process, the 3D video content can be watched repeatly. To document information a notepad application has to be implemented with a direct output for the PLM system. The results of the first DT step are 360 degree video content and digitally documented information being identified in the videos. For a collaborative working from different places, it is necessary to integrate project teams in a real-time 360 degree video stream. To realize a 360 degree live stream to investigate problem positions, a high Internet bandwidth is necessary. Intel presented a 4K-360 degree video with the possibility of movement within the video on fair CES2017. It streams 60 pictures per second and a size of three gigabyte per pictures. This leads to a bandwidth of 180 gigabyte per second (VRODO 2017). Actually used standards are not suitable to realize a collaborative movement and interaction in a 360 degree video stream.

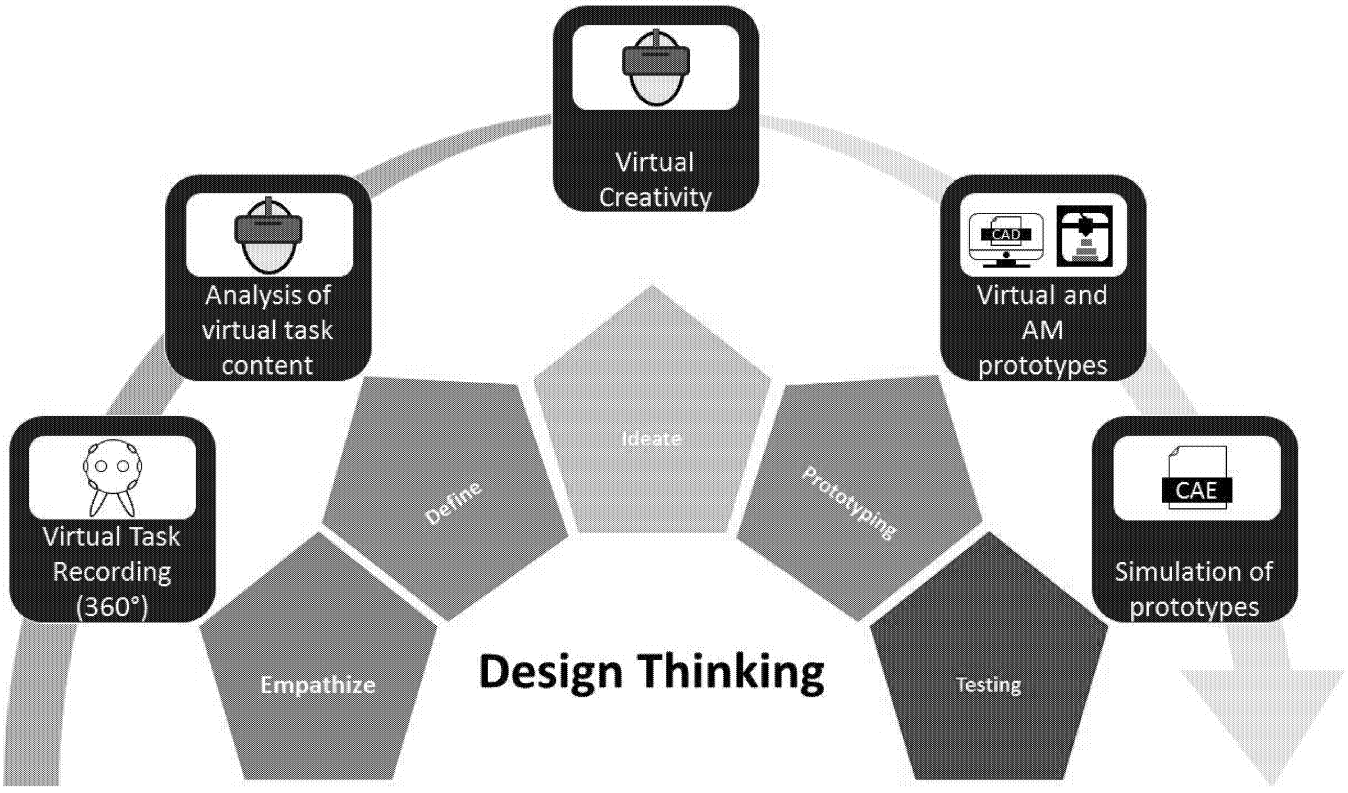



Figure 1: Concept of Virtual Design Thinking

**Define:** This step has the aim to interconnect the found information and create a user´s point of view for the product design. A conventional way to fulfill this task is to collect information and structure them on a whiteboard. A discussion of all team members helps to find relations between information. The VR technology provides a more visual way to investigate the relations. To realize this step with ICT technology it is necessary to develop a virtual collaboration platform. One of the most important tasks in this step is the discussion within the team to identify the relations and the user´s point of view. This is only possible if all team members work in the same virtual environment simulataneously. The usage of a virtual platform superseedes the location of all team members at a single place. The virtual platform needs to have specific tools for intuitive interaction and communication of team members. Another important aspect is the need of analysis tools to structure the visualized information and focus the important ones to create the user´s point of view. Similarly to the first step the structured information and user´s point of view have to be documented by an output interface.

**Ideate:** In this step, the project team create ideas to solve the task. In a conventional DT process, classical creativity techniques such as brainstorming or Five W´s are used. For a virtual team with different locations these techniques are not adequate and have to be adapted to use it in a collaborative virtual environment. Another way is the development of new creativity techniques being adequate for implementation in VR.

One example is the stimulus imaging method. In this method, pictures are used with different topics and contents. Participants should generate ideas by associations with these pictures. One possible adaption of this creativity technique is the usage of pictures in a video chat for participants with different locations. The implementation of VR provides a suitable improvement of this technique. VR can increase the imagination and immersion of a participant by an experience in a virtual environment. This fact follows to the development of the stimulus environment method. Analogly to the conventional method participants create ideas with associations to the visual content. But the stimulus environment method does not use pictures as visual content, but virtual environments. Participants have a 360 degrees view in this virtual world. Furthermore users can move and change positions in this environment. Another feature is the interaction with objects in the virtual world. These new features provide more possibilities and points of view to enhance creativity. A higher quantity of ideas leads at the end to a higher quality of the selected idea. The collaborative experience of a project team in these virtual environments encourages the quantity of ideas by various discussions about the visual content. The communication and interactions between project team members have to be clear and intuitive. Furthermore, documentation tools for ideas based on voice control or intuitive user interfaces have to be implemented for an early digitalization of ideas.

**Prototyping:** The prototyping of ideas gives the possibility of early validating. The type of prototypes can vary depending on the point of time within development. In DT processes early iteration steps are described by paper based prototypes (sketches, scenarios,…). Following prototypes can be virtual or physical results. Innovative technologies provide in this process alternatives to present and test ideas. The usage of polygon based modeling or Computer Aided Design (CAD) software is an adequate possibility to create first incomplete prototypes. The grade of detail increases with following iteration cycles. With existing virtual prototypes, it is possible to manufacture physical prototypes using AM. An important aspect is the right decision for the type of prototype.

**Testing:** Validating prototypes is an important step to gain new information for the further development of a solution. The testing environment depends on the kind of prototype. Developed virtual prototypes can be tested by Computer Aided Engineering (CAE) software to proof for example mechanical (static or dynamic) properties. Physically manufactured prototypes can be tested by mechanical, thermal or other types of testing machines to identify property constraints. For an improvement in the next iterative cycle, the quantitative data have to be saved in the PLM system. For a new qualitative observation, physical tests or simulations can be recorded with a 360 degree camera to investigate it in the first step Empathize of the next DT cycle.

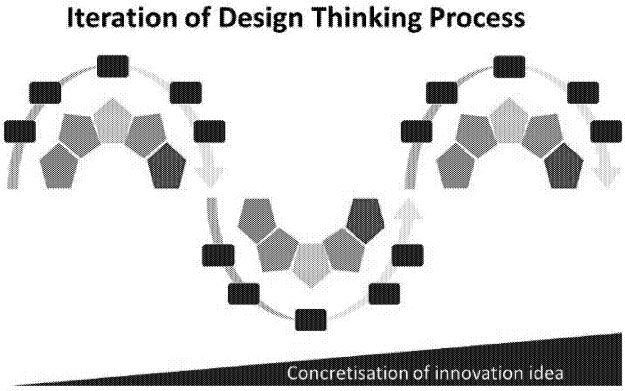



Figure 2: Iterative cycles of VDT

**Preliminary Study of a virtual creativity method**

The first investigations include the Virtual Creativity step of the Virtual Design Thinking process. Since being creative is the most important task to create innovative ideas for products and services, the influence on creativity by virtual environments has to be investigated firstly to create a basis for the whole VDT process.

The experimental approach includes six Virtual Reality environments which differ by three VR/MR influence factors (see figure 4). The influence factors immersion, interaction and movement/mobility are combined and varied in the virtual creativity environments. To investigate the impact of these VR/MR influence factors on creativity, the virtual creativity environments are validated by students of mechanical and industrial engineering of Paderborn University. 67 students of the master course "Innovation and Development Management" participated in the experiment.

For the technical implementation a computer with a high performance graphics card, display, interaction and tracking systems are needed. The used HMD HTC Vive combines a display, interaction and tracking system. Two integrated lenses and OLED displays generates a field of view of 110 degrees and a resolution of 2160 x 1200. The HTC Vive offers controllers to interact with the virtual environment. A specific feature of the HMD is the room scaling tracking function generated by two external tracking sensors being connected with sensors of the HMD. This function gives the possibility

to move in an area of 15 x 15 feet. To run the HTC Vive a computer with a Geforce GTX970 is used.
For the experiment, a specific task which have to be solved was defined. The task for the participants was to generate an automatized device to transport meals in a restaurant. Participants were asked to create a high number of possible solutions. All students were split in groups of two participants. The first one wore the HMD and saw three virtual creativity environments with different variations of the influence factors in succession. The participant had six minutes in every environment to generate ideas. The second participant supported the partner who wore the HMD by documenting the ideas and conversating to improve ideas. After the first three virtual creativity environments the participants changed the roles. The participant who wore the HMD in this session saw three other environment comparable with the three creativity environments of the first participant.
For the assessment of the virtual creativity environments, three questionnaires were answered by participants. The timeline of figure 3 shows the points in time of the three questionnaires. The first one was answered before the experiment and includes questions being relevant to assess the favourite type of information (visual, auditive, textual,…). Other questions focus the experience with creativity techniques and Virtual and Mixed Reality technologies. The second questionnaire was answered directly after the experiment. It contains questions to assess the method, the specific generated virtual creativity environments and the usability of technology. The last questionnaire was answered one week after the experiment to get specific feedback of the method and virtual creativity environments. The six created virtual creativity environments differ by the influence factors movement/mobility, interaction and immersion being illustrated in figure 4.
The classification of virtual creativity environments in relation to the three influence factors is displayed in figure 5.
The first two enviroments are only influenced by the factor immersion and show a Christmas tree in a town and an airport on an island nearby a beach.
Both environments are based on 360 degree pictures which did not allow movement and interaction. The participant has only one view point to generate ideas.
The third environment presents a laboratory including a CAVE (Cave Automatic Virtual Environment), 3D printing systems and assembly robots. The environment was created with the development software "Destinations" of STEAM and a 3D polygon modeling software. The visualization of this environment (polygon based 3D objects) is less realistic than the 360 degree pictures.

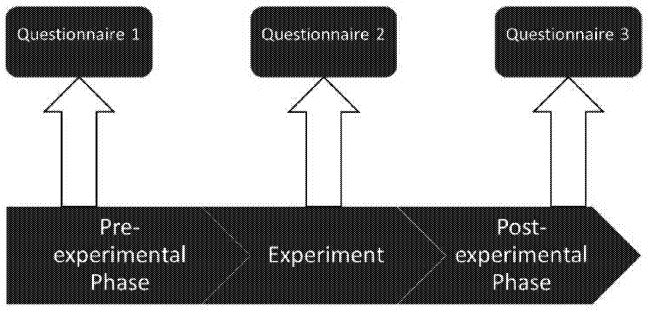


Figure 3: Timeline for questionnaires

The psychedelic environment provides possibilities to teleport and move such as in the Laboratory environment. Additonally to the third one the user is able to interact with several objects in this environment. For example there are baseballs on a table which can be picked up and thrown on boxes of the can throwing stand. Another interacting possibility is the scaling of objects by picking them with both controllers and stretch them.
The fifth environment includes a natural green landscape with stone ruins. The environment is realistic because of the combination of 360 degree pictures, included created 3D objects and specific animations (for example a bird flys around).

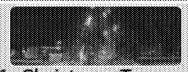
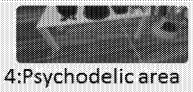
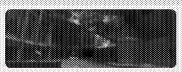
| Enviroment | Participant | Movement | Interaction | Immersion |
|---|---|---|---|---|
|  1: Christmas Tree | 1 | No movement ➔ 1 view point | No interaction | 360° picture |
|  2: Airport | 2 | No movement ➔ 1 view point | No interaction | 360° picture |
|  3: Laboratory | 1 | Movement ➔ Infinite view points | No interaction | Self generated 3D area |
|  4:Psychodelic area | 2 | Movement ➔ Infinite view points | Interaction ➔ Movement of objects | Self generated 3D area |
|  5: Ruins | 2 | Movement ➔ Infinite view points | No interaction | 360° picture supplemented by 3D objects |
|  6: Spanish patio | 1 | Movement ➔ Infinite view points | Interaction ➔ Movement of objects | 360° picture supplemented by 3D objects |

Figure 4: Generated virtual creativity environments for the experiment

It is possible to move and teleport in the environment. Interactions with objects is not possible. The last virtual creativity environment is a Spanish patio. Similar to the fifth environment it is a combination of 360 degree pictures and several 3D modeled objects which can be included by a user interface of "Destinations". Movement, teleport and interaction with the 3D modeled objects is also possible. The last environment depicts the highest grade of the influence factors immersion, interaction and movement.

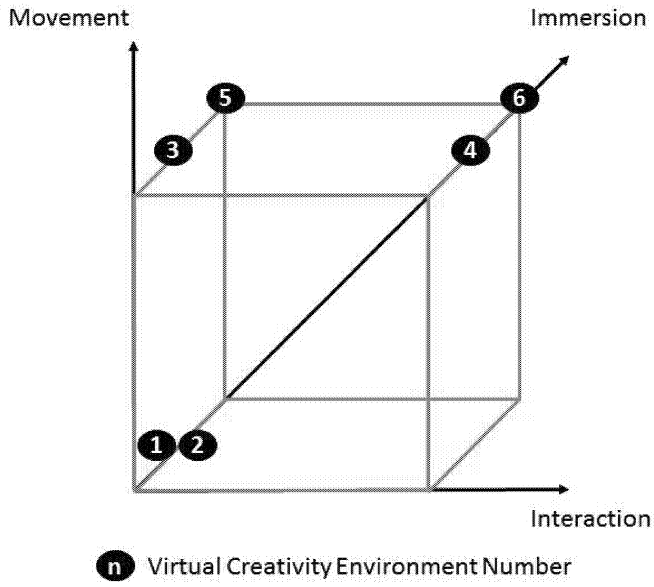



Figure 5: Influence factors in virtual creativity environments

Participant 1 had to create ideas in context to the predetermined task in environment 1, 3 and 6. Participant 2 used environment 2, 4 and 5.
The aim of the experiment is to show that Virtual Reality technology provides the possibility to work creatively and to generate a high number of solutions and ideas.

**Results of preliminary study**

The first questionnaire gives an overview of the students experience with VR. Most students (65,2%) had only theoretically knowledge in context of VR by articles, pictures and videos. Only 24,2% had used a VR/MR application. The rest of participants have non previous knowledge about VR and no student had ever program a VR/MR application. Another question addresses the experience with creativity techniques such as 6-3-5 method or brainstorming. 66,7% of the participants use creativity techniques sometimes. 22,7 % never use such techniques and 10,6% use them often. The participants have theoretical know how of VR/MR technology and know several creativity techniques. Additionally they know partially how to use them. The last section of the first questionnaire deals with personal characteristics about intercultural experience, own creativity and preferred type of information. Most participants have intercultural experience by vacations (59,1%) or already lived in other countries (15,2%). Many participants consider themselves partly creative (63,6%). Most participants receive information in a visual form such as videos or pictures (72,7%). Other adequate media are textial documents (54,5%). Auditive input of information is not assessed well by participants (16,7%).
The results of the preferred type of information show that visual forms are the best possibility to present information. This fact inplies that VR/MR can be an adequate technology to receive stimuli and information to create innovative ideas.
After the experiment of Virtual Creativity, participants had to answer the second questionnaire. The first section dealt with fun factors of method and VR technology. Almost every participant had fun to use VR technology (95,45%). The majority (77,3%) had also fun by working with creativity method in VR. The novelty of technology is the most important reason to have fun with this kind of method and technology. Most of the participants never used a HMD before. When VR/MR technology will become a mass market media this fun factor will decrease.
The following section includes the assessment of environments in context of creativity, immersion and interaction. One question dealt with influences of mobility and movement in the virtual environments on creativity and idea generation. The majority of participants (figure 6) assess the mobility by teleporting and moving positively. The mobility in a virtual world provides the possibility to see all aspects of an area in different kind of ways. The contemplation of different view points leads to the generation of new stimuli being important for a high number of ideas and creativity.

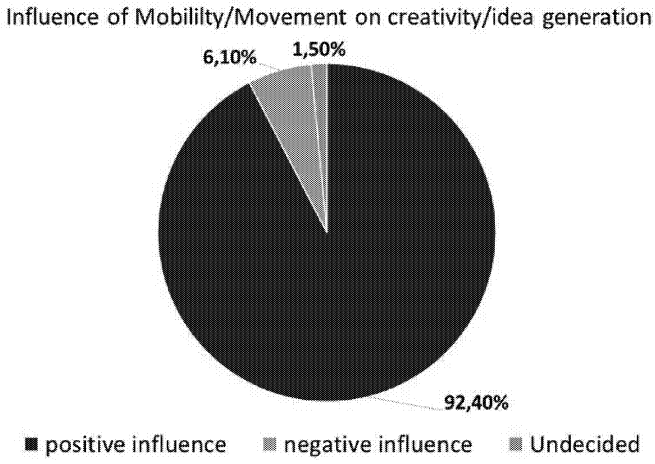



Figure 6: Influence of mobility on creativity

Complementary to the previous question the next one included the influence of interaction on creativity and idea generation. The result of this question are not so obvious. 60,6% of participants think that interaction has a positive influence on creativity and idea generation. One reason of this result could be the distraction which appears by acting with objects in the virtual environment. These activities distract the user from the focus of the actual task. But persons being able to multi tasking can possibly create an added value by a parallel activity in the virtual environment. Another interesting aspect of the second questionnaire is the correlation between immersion and creativity. Figure 7 includes the participants´ subjective feeling of the environment´s immersion. The assessment values have a range from 1 (very low immersion) to 4 (very high immersion). Overall, all environments were positively evaluated (>50% for high (3) and very high (4) immersion).

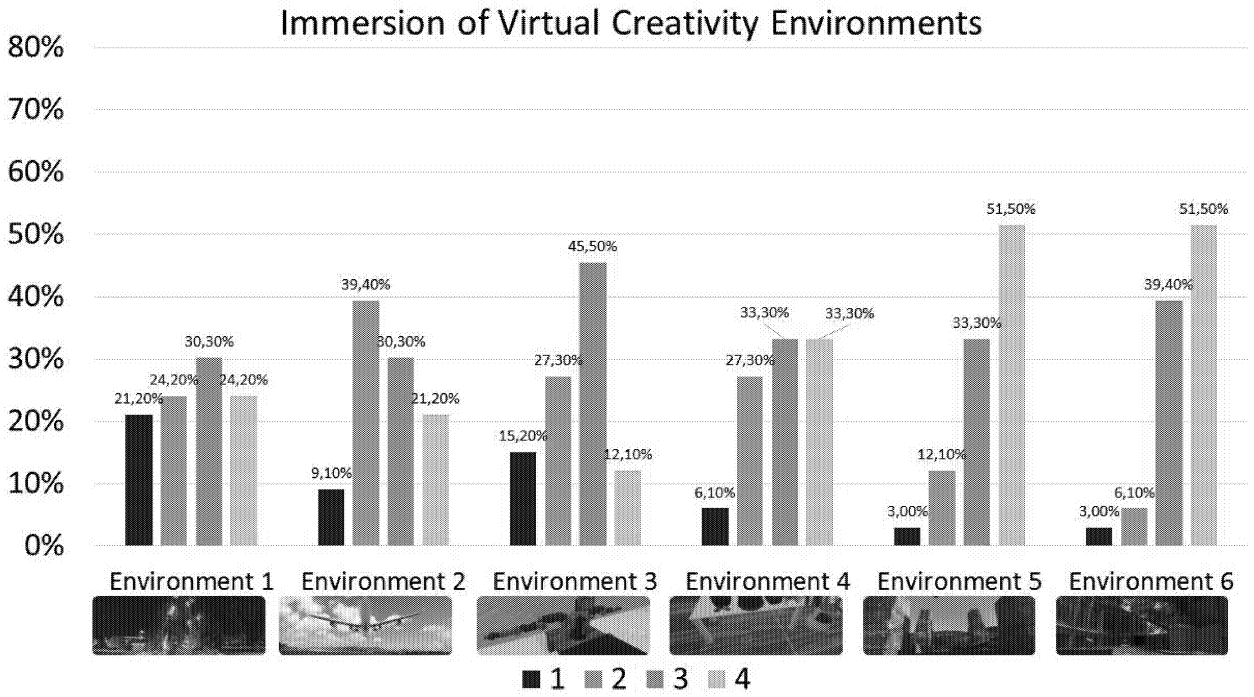



Figure 7: Immersion of environments

The environments 5 and 6 which were created by a combination of 360 degree pictures for the background and 3D modeled objects for the foreground are evaluated as most immersive in comparison to other environments (>80% for high (3) and very high (4) immersion). To investigate the influence of immersion on creativity, the participant´s assessments for the influence of creativity by every environment were collected (Figure 8). The values of all environments differ intensively. In combination with the results of assessing the immersion (figure 7), environments with the highest values for immersion (5 and 6) have low values for creativity (especially 5). Focussing environment 3, it is noticeable that the Laboratory environment is best assessed in context of creativity. The immersion of environment 3 has only an average value. The combination of both statistics leads to the hypothesis that immersion has a negligible influence on creativity in a virtual environment. There must be other influence factors being important for creativity in virtual environments. One possibility is a topic related content for the environment which have to be adapted for every tasks. The task of this experiment was focused on transport solutions of meals in a restaurant. The best assessed environment including robots, and other technical systems could be more suitable for a technical task. These theses have to be validated in further studies.

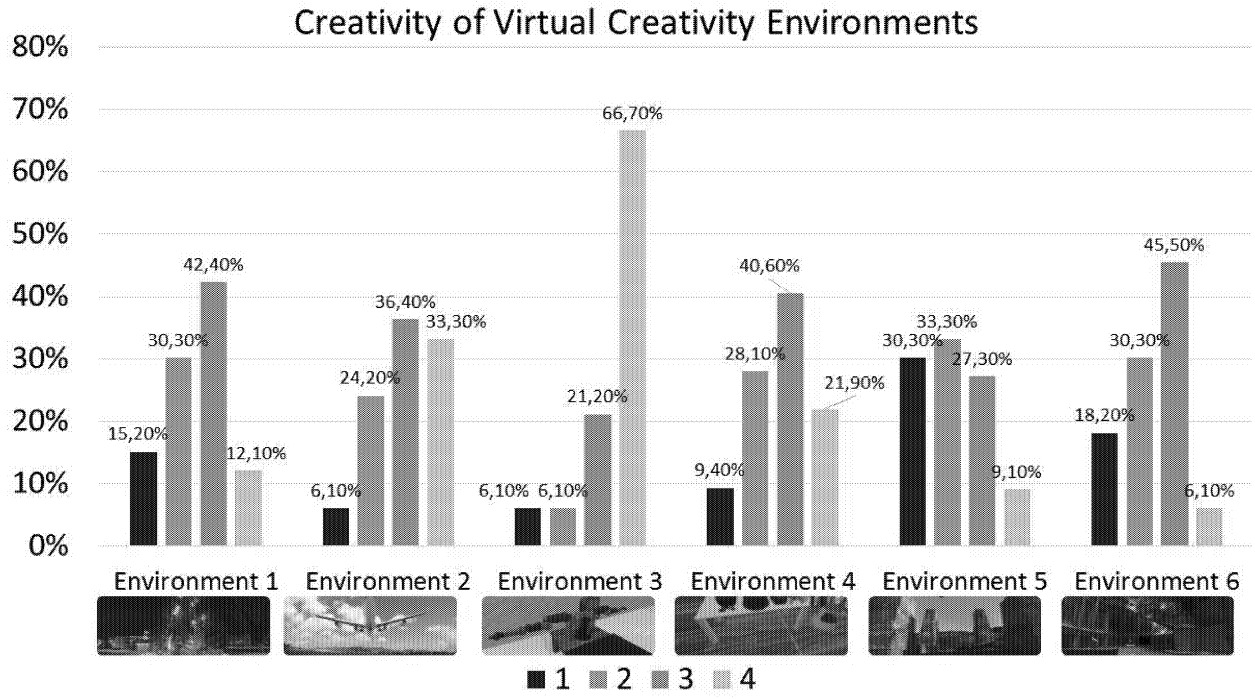



Figure 8: Assessment of environments for creativity

## CONCLUSION AND OUTLOOK

The presented Virtual Design Thinking model demonstrates possibilities to integrate innovative technologies such as VR, MR, simulation software and AM in steps of an innovation process. The first step for realization of this model was an experiment focusing the influence of factors such as immersion, interaction and mobility in Virtual Reality on creativity. The experiment results lead to five hypotheses:

- Mobility (Teleporting, Moving) in VR has a positive influence on creativity and idea generation.
- Interaction (picking up and handling of 3D objects) in VR has a positive influence on creativity and idea generation for persons with multi-tasking abilities.
- Interaction in VR has a negative influence on creativity and idea generation for persons without multi-tasking abilities. Interaction can distract the user from the focus of the actual task.
- Immersion in VR does not have a high influence on creativity and idea generation. The grade of computer graphics plays no role for creativity.
- There are other factors influencing creativity and idea generation. Topic related content in a VR environment could increase creativity.

The first qualitative results of Virtual Creativity experiment disclosed that there are several to be fullfilled for an application in remote team environments in industrial practice:

- Identification of influence factors in VR for creativity
- Methodical and technical improvement of VR creativity methods
- IT-infrastructure for real-time VR collaboration
- Validation in laboratory and industrial projects

For an examination of the VDT, the creation of demonstrators for all DT steps is necessary. Subsequently the demonstrators have to be validated by possible users. The first step will be the usage in a laboratory environment. A following step will be the usage in representive pilot projects in companies.

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## BIOGRAPHIES

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Dr.-Ing. Jens Pottebaum, is senior researcher at the chair for Product Creation. He studied mechanical engineering and computer science and received the doctor's degree for his research on the ‚Optimisation of application oriented learning by knowledge identification' in 2011. He is experienced in European collaborative research.

# DESIGNING YOUR FUTURE WITH SCIENCE FICTION: FROM SHOPPING MALL TO TAILORED SHOPPING EXPERIENCE

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**KEYWORDS**

Science fiction prototypes Retail Shopping, Creative writing, Prototyping

**ABSTRACT**

This paper builds upon an extended body of work that employs Science Fiction Prototypes to explore the potential of technology innovation to improve community living. The case study drawn upon in this paper explores one community's aspirations to reinvigorate a struggling high street and turn it into a vibrant and community friendly retail shopping experience. In particular, we explore whether the desirable future visions expressed by workshop participants from the community are 'realistic', 'futuristic' or simply 'fantasy'. To assess their discussions we comparatively consider the extent to which leading-edge technology developments are ready for commercial retail implementation and whether they can meet the expectations of personal and community imaginings that can be inspired by Science Fiction Prototyping (SFP). Our assessment reveals that - in many instances - non-specialist creative narratives are in fact already under technical development.

## INTRODUCTION

The digital economy has brought many changes to the retail experience. All the advantages of digital technology have been applied to making retail shopping online the equivalent or better than the experience of the high street. This attention has made cheap delivery, free returns, instantly comparable prices and greater levels of variety and competition the expected minimum level of retail service. In contrast, the high street experience has struggled to keep up. Challenged by congested transport networks, car parking charges, high ground rental rates, restrictive planning policies and a choice of goods limited by physical storage space many UK high street feel increasingly abandoned. An increase in the number of "retail parks" outside city and town centres and of one-stop superstores has further pulled consumers away from using the high street. The New Economics Foundation (2002) reported that between 1995 and 2000, the UK lost 30,000 local outlets that amounted to about one fifth of the nation's corner shops, post offices, grocers, high street banks and pubs. The report also predicted a further 25,000 were expect to close by 2005.

To consider the current situation of physical retailing we pick up the thread of community participation in planning in combination with the impact and meaning of the decline in the UK high street. Our data collection method is based upon the use of science fiction prototyping to encourage community participation. The resultant narratives that are generated within workshops are then examined to identify the ways in which technologies can be applied to the problem of UK high street regeneration and physical retail innovation. Our examination then assesses the maturity of the technologies discussed in each of the science fiction prototypes on a range of criteria drawn from existing technology maturity and readiness models. Ultimately this assessment enables the positioning of SFPs in a continuum from the immediately possible through to long-term visions on the very cusp of current plausibility.

## SCIENCE FICTION PROTOTYPING

In this paper the 'prototype' of science fiction prototyping is used consciously and in distinction from 'scenario'. Scenarios are stories that describe the context and impact of a future event. There is evidence to suggest that the ease with which a scenario can be imagined or constructed, or the plausibility of a scenario, upwardly biases general belief that the depicted event can occur (Glaska 2014). The scenario is a specific set of predictions placed within a future world that could occur while also actively encouraging its realisation.

The prototype, in contrast and somewhat more idealistically, expresses a 'hope' that is an approximation for a desired future. In this way the prototype is less constrained than a scenario in being able to advocate for long-term visionary change. Predictions presented *in situ* within either a dystopian or utopian future will generally be flawed. Arguably, ''a revolutionary technology defies predictions'' or, as Clarke (1945) famously claimed, it becomes indistinguishable from magic. Predictions of the "unthinkable" are often ridiculed, by those who assume and adopt descriptive paradigms of futures. This conflict is explained in this paper with the understanding that descriptive models exist at the operational level of a near-present future that is the result of evolutionary change that can only be recognised retrospectively in an historical context. Taken together the perspectives of the prototype, scenario and model present different stages of technological maturity and readiness - with prototypes representing the most distant future and least mature development (see Table 1 below).

*Table 1: Prototype/Scenario/Model (ProSM) Technology Recognition Table based on previous readiness and maturity models, Prototype > 20, Scenario > 15, Model > 10, Process <= 10.*

| | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|
| Acceptance<br><br>"It is currently" | Unknown speculative technology | Of limited under-standing commerci ally, available in a R&D context | In commercial use in a specific sector | In commercial use in a variety of sectors, specialist private use | Used in niches known but not widely used in household situations | Widespre and a commonl used, household |
| Affect<br><br>"The affect is best described as..." | Innovating | Improving | Integrating | Investing | Initiating | Inaction |
| Transformati ve Impact<br><br>"It has the capability to be..." | Completely transformati ve, changes common everyday practices | Clustered transforma tion, regionally, sub-cultur ally, etc | Limited transformatio n, evolves existing processes or practices | Potentially transformative, requires other changes for further impact | Of little application | None, unl |
| Substitutive impact<br><br>"It has the capacity to ..." | Be a complete substitution for an existing product or practice | Largely substitute existing products or practice, will eventually overcome an existing product or practice | Offer shared, substitutes sometimes in a range of situations | Create specific substitution, used as a replacement in well defined situations | Be a preference substitution, used on the basis of personal preference rather than for any clear advantage | Is not a substitute existing p or proces imitation |
| Experiential impact<br><br>"It has the ability to..." | Widely create completely new forms of experiences or actions | Become a widespread new form of experienc e or action | Offer limited creation of new experiences or actions with specific locations or sectors | To create new experience or action but requires other innovations to occur | To create transitory or imagined experiences | No new experienc created |

*The High Street in the UK*

There has been much recognition of the UK high street's slow decline and of the impact on communities. Several initiatives have emerged to save the situation. One of the most high profile of these initiatives was the Portas Review (2011) which was allocated £1.2m of public funding to revitalise the town centres of the UK. This project, however, was highly problematic and poorly received. One reason voiced by critics was that Portas tried to recreate the high street of the past, rather than reinventing a new high street informed by digital and connected societies and representative of their communities (Butler 2013). The Portas project revealed the failure of often well-intended regeneration work to engage the communities most impacted by high street failure. There are many reasons why local residents are often excluded from planning and redevelopment projects but most often planners and project leaders simply do not know how to effectively engage with these key stakeholders. Lay people (residents) do not speak the language of local government and planning departments and do not recognise the mechanisms through which they can respond. The result is that residents are left feeling disenfranchised, excluded and often with community spaces or high streets that do not meet their needs or expectations.

Irrespective of this lack of consumer engagement, increasingly the retail experience has embraced the full potential of social media and digital innovations across a variety of geographical locations. For example, developments in the area of interactive and unconventional screens (BBC n.d.), virtual mirrors, playful interactions (Jones 2011) and free wifi connections are now all part of the integrated experience of digitally mediated shopping. Current examples of these developments can be found in such platforms as justbought.it and the interactions available with a global community through channels such as Instagram and the hashtag '#shallIbuyit?'. These immersive experiences are distinct moves away from the 'traditional' shopping experience. Change in the high street is also underway in ways that blend traditional and new ways of shopping. While these developments show examples of the digital working with the physical it does not represent a reinvention of retail that pushes the boundaries of the possible.

## CREATIVE PROTOTYPING

The empirical data for this study was collected at a collaborative workshop entitled 'Creative

Prototyping the Future High Street'. In order to gather the appropriate data associated with a Science Fiction Prototyping method we adopted Petersen's (2007) approach so as to develop concepts of city logistics with its stakeholders. Petersen (2007) argues that this process allows all participants "with new knowledge to be applied in their daily fields of work" (p.616). The aim of the workshop was to apply innovative and creative methods to bring together and promote discussion amongst a variety of stakeholders about the shape and form of a future high street. The purpose of utilising creative methods was to act as a bridge that could span the complexity of discussing an observable situation with a diverse range of stakeholders who all operate with a set of preconceptions and specific knowledge that shapes their existing understanding.

The workshop was aimed at a wide range of participants and included members of community groups, academics, retailers, digital evangelists, high street shoppers and members of the local council. Participation in the workshop was through an open invitation disseminated via active social media accounts on the most common channels. We also directly approached individuals to ensure a diverse knowledge base about the high street. These contacts were drawn from the personal and professional contacts of the research team. We also invited local councillors, community groups and retail organisations in order to provide a fair representation of commercial and government stakeholders. The workshop took place in July 2014 at MediaCityUK, Salford based in the Northwest of England and a total of fourteen external participants contributed to the discussions. An independent facilitator as well as members of the research team led the workshop.

The workshop began by introducing 'Science Fiction Prototyping' to the participants after which they set about applying this method by creating characters, events and stories that assisted in expressing their vision of a future high street. Participants worked in small teams to support each other and to extend and co-create their ideas. Collaborative working uncovered new insights through new combinations of experience and knowledge. Co-working also enabled participants to feel confident to act upon shared knowledge and embed additional insight into their stories. The stories and ideas were then shared amongst the whole group and potential outcomes of these factors were discussed, consolidating and actualising these ideas into longer and more complete narratives. Stories and ideas were captured as summary transcripts from each participant's recitation of their story, reinforcing the plurality of stakeholders in the planning process. The researchers led a discussion with the participants about the ideas and rationale behind their creations throughout the SFP process. This data was captured with video and photographs and provided an additional layer of understanding regarding the features of a future 'smart' high street that the participants wanted.

## ANALYSIS

The data collected at the workshop was analysed with particular reference to how community imaginings provided an insight into stakeholder aspirations as well as their fears of an imagined future high street and physical retail shopping experience. Stakeholder perspectives on the integration of technologies in future cities were also captured. The willingness for all participants to exchange, listen and respond was a bolstered by the initial act of collectively listening to their ideas and as a result of their inputs were being captured. Table 2 offers a succinct overview of the storylines and imaginings drawn from the workshop participants.

*Table 2. Emergent themes and illustrative data from the stories written at the SFP workshop.*

| Overarching Theme | Illustrative Data | Technologies |
|---|---|---|
| Identity | Smartcard: stores personal details for payment, delivery, consumer profiles, downloads personalised offers before leaving home, home delivery arranged with one swipe.<br>Range of characters in stories (ages 18 - 70; majority women; some have disabilities) the imagined high street that is described meets the needs of each. | Smartcard<br>Mobile devices |
| Experience | Plan the day in advance<br>Interactive wall alerts shopper to information about events, locations, activities, updated in real time on the street<br>Smartcard: connects to interactive wall, receives and sends person to person connections "your friend X is nearby"<br>People and family oriented space, music and entertainment opportunities, creative spaces | Interactive wall<br>Smartcard |
| Environment Technology rich | Automated transport system in high street is always on/always available 24/7<br>Personal transport devices<br>Post-Google Glass, LEDs embedded in clothing | Personal public transport<br>Ubiquitous & interactive screens |
| Environment - Technology free | A dead zone – flickering lights, rainy, no cars, public transport, solar energy,<br>Faraday cage in the high street blocks all digital activity and communications<br>A living museum of traditional experiences that people want to visit | Faraday Cage (technology to block technology) |

The full details of the stories developed by the workshop participants cannot be presented in their entirety here. While some were brief - effectively a short story - others continued to develop throughout the day and became increasingly interwoven with each other. The stories included discussions of smart card innovations; interactive screens and surfaces; and technology free zones. The content of these stories enable an exploration as to whether the future visions expressed by the workshop participants are 'realistic', 'futuristic' or 'fantasy'. Workshop participants did not necessarily agree about the specific direction or outcomes of each topic and in some cases even presented varying antithetical positions. The discussion associated with each individual narrative provided an insight into the imagined future high street and whether creative non-specialist narratives are already under technical development.

Utilising insight from the Technology Recognition Table (Table 1) we have then considered the stories as being realistic, offering a model for the near future; futuristic, setting out a scenario for the medium-term future; or fantasy, presenting a prototype of a more distant future.

## CONCLUSION

*Realistic*

The application of technology clearly commanded key importance in all the participants' view of a future and the constitution of a desirable future high street. The suggestions ranged from LEDs being embedded within clothing to computer-controlled vehicles to aid with transport issues. These are concepts that have now significantly developed towards commercial realisation in the subsequent three years since the original workshop. The relationship between the digital and the physical was also an important theme that was observed in the story descriptions at the workshop. Participants expressed a desire to link shops and retail brands of the past to those of the future by the digitising physical space in order to create interactive and digital displays. Participants complemented Etsy.com, which has leverage ecommerce concepts to create a digital craft fair. Participants supported being able to buy items while shopping at physical shops but then having these goods being immediately delivered to their home. This innovation would make the physical shopping experience means less inconvenient (particularly for those with mobility issues or using public transport networks) by avoiding the need to carry around already purchased items. The change also required no new additional technology or innovation but rather brought together existing practices into a new form. In terms of the analysis in Table 1 this is scored as a realistic model of the future (scoring 1,3,3,2,3). The ideas from the SFP workshop demonstrated that participants appreciate the opportunities provided by the application of digital technology but they also have a continued desire for experiences that include tangible aspects of the physical high street.

*Future*

The theme of future planning was also a focus within the workshop discussions. The narratives that were provided around planning most clearly linked realistic expectations and future visions. For example, older participants and those who have looked after older relatives expressed the need for a safe space when navigating the high street including the removal or mitigation of hazards such as tramlines and poor street maintenance. These dangers can be reduced with the application of smart planning techniques for walking routes that accounts for accessibility and mobility as well as distance. Some participants even suggested physically levelling the entire high street in order to allow it be more accessible for all. An argument already realised in some cities with the implementation of shared space streets (Department for Transport, 2011). Personal transport solutions were also given a lot of discussion as a solution to issues of mobility, access and the reduction of motor vehicle traffic.

The high street space itself and how it could be used was given much consideration. Many of the participants expressed a desire for a more "authentic" shopping experience with shops and activities that could not be found elsewhere acting as an enticement. Some suggested that this initiative should being supported by local councils through their commitment to reduced rates and facilitating pop up shops as well as by providing greater flexibility for the development of smaller, more unique businesses. This fundamental innovation in the composition of a high street's offering could potentially open up new opportunities for enterprise, high street shoppers and the economy. The town square was highlighted as a location to blend multiple experiences including an area to be able to meet others, socialise, and be entertained. Participants highlighted how cultural spaces often found with the high street such as libraries, museums and churches could fulfill the role of multifunctional coffee shops and

social spaces by blending current services as well as their respective cultural experiences in order to attract more visitors. Future visions clearly reflected a technologically enabled and immersive customer retail experience. The workshop participants were keen to embrace the full potential of digital innovation across a variety of geographical locations. Future visions - while imaginative - shared close parallels to many contemporary innovations, for example the increasing developments in the areas of interactive and unconventional screens (BBC n.d.), virtual mirrors, playful interactions (Jones 2011) and wifi connections all of which will allow the digital integration of virtual and physical social shopping sites.

Some of the workshop participants also identified the benefits of locking away parts of the physical high street from the intrusions of digital technology - as a type of museum to 20th Century consumerism. Blocking out technology primarily focused on blocking wireless data signals. Viewing part of the high street as a Faraday caged museum held appeal for some participants and was seen as a new potential commercial opportunity. Using Table 1 the Faraday cage high street is revealed as being a scenario (scoring 3,4,3,4,2) of the medium-term future.

*Fantasy*

Beyond the physical shopping experience participants also mentioned other examples of technology that would bring heightened levels of convenience without directly altering the experiential aspects of shopping. These visions tended to be beyond current technological capability. For example there were a number of discussions about improving the use of, and immediate access to, information facilitated by smartcards. The smartcards described in these discussion were of a form and capability that exceeded anything that was, at the time, currently available. Community participants were insistent that an app would not be a suitable analogue and instead described a smartcard that was capable of contextual, transparent and potentially intuitive interaction without direct human input. The information accessible by the card included real-time and totally individualised what's-on guides and a locator for activities. Particular emphasis was placed upon customised interests for the participants and most notably the possibility of updating information - 'on the go' - on the street. The workshop participants went further again by imagining an interactive wall in which the smart cards could connect and present a personalised experience unique to each individual. The Technology Recognition Table (Table 1) points to the type of smartcard that was being imagined in the workshop as a genuine prototype for a more distant future (scoring 5,4,4,3,4)

Other participants observed that existing smartphones were an existing accessible means to connect to environments and retrieve information, but voiced their desire to have a greater connection to high street environment through personal connection points and places to charge and update personal devices. Currently such fully immersive and customised interactions are not available and therefore illustrate some of the limitations of SFPs in future planning processes. Further discussion produced the consensus within the workshop that the imagined smart card should be able to present a single 'easy' one-stop alternative to accessing information via multiple apps and a mobile phone. The smart card would avoid the multiple collections of apps, where a smart card can go directly to the essential and necessary information in an accessible and semi-automated way. A vision, that technology innovators could listen to for future innovations and development.

*The future high street*

Finally, all of the workshop participants expressed a desire to keep the high street as a local experience and expressed alarm at any form of more intensive corporate vision for the high street. The response to these desires are already evidenced in the UK where many of the high street chains attempt to counter community feelings of exclusion by providing some local context or details of local community interests through community billboards, magazines, charity collections and announcements. Participants collectively longed for an authentic experience that reflected a desire for the high street to be unique in its location. These visions are clearly not driven by technology and are expressions of a grassroots resistance to mass consumerism. Some narratives discussed the experiential magic of discovering a place of interest by chance and spoke of the high street as a nostalgic theme park meeting all basic needs and satisfying curiosities at the same time. This fanciful view of the high street could be operationalised with the high street acting as a physical outlet for luxury goods and a hallmark for quality. From the visions and narratives presented at the 'Creative Prototyping the Future High Street' workshop it is clear that science fiction and similar forms of creative writing can help businesses define

their future visions through prototyping. Within this paper we present SFP as being capable of generating alternative future imaginings on a topic. The results will be variously realistic, futuristic and "fantastic" expressions of a writer's extrapolation from the existing present. In particular, we have shown that within SFP the solution to a defined problem can readily bridge all three innovative potentials. The value of fictional narratives are their ability to provide a voice for contemporary experience, as well giving an outlet for envisioning realistic, future and fanciful solutions and innovations that solve recognisable problems. Furthermore in many instances of SFP non-specialist creative narratives are already pre-empting innovations and technical development.

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## BIOGRAPHIES

Dr Gordon Fletcher is an educator, manager, researcher and innovator with an eye for the distinctive, inspirational and new. Gordon is currently the academic unit head of international operations and information management in Salford Business School. Gordon's research broadly focuses on all aspect of Digital Business and Cultures. He has previously published work about conflict in social networks, the concept of thananetworking and the use of science fiction prototyping. Gordon regularly writes for The Conversation on topics relating to digital business including hacked websites, social networks, the Internet of Things and cryptocurrencies.

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Dr. Rachel McLean was recently appointed as Director of Liverpool Screen School at Liverpool John Moores University. She Joined Liverpool John Moores University in 2013 initially as Reader in Digital Marketing and more recently as Associate Dean (Research) for the Faculty of Arts, Professional and Social Studies before being appointed to her current role. Rachel has published nationally and internationally on ICTs and social media in commercial and social contexts and has been awarded research council funding. In October 2014 Rachel became president elect of the UKAIS, the first woman to be elected to this role since UKAIS was founded in the early 1990s.

# AUGMENTED VIRTUAL REALITY

# FIELD OPERATOR'S INTERFACE IN COMPUTER SIMULATOR: VIRTUAL TOURS VS VIRTUAL REALITY

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**KEYWORDS**

Industrial process, computer-based operator training systems, console operator, field operator, operator interface, 3D immersion, virtual tours, panoramic interface

**ABSTRACT**

Requirements as to the field operator interface of computer-based training systems for process unit operators are analyzed. A new approach is suggested to the implementation of a field operator interface using panoramic photography. Functional and psychological characteristics are compared as among legacy 2D, 3D, and panoramic interfaces. Hands-on experience and issues associated with the development and implementation of field operator panoramic interfaces are discussed. Tasks are formulated for future research.

## INTRODUCTION

Computer-based training systems (CBTS) for process operators are both a generally recognized highly efficient tool for operator training and a major global business. As projected by ARC, a highly-reputed consultancy, annual sales of CBTS for chemical-type industry facilities will reach $750 million by 2017 (Operator Training Simulation. 2012).

First and foremost, CBTS is a means to reduce the accident rate and assure safety. In key industries, personnel training is recommended by reputed professional organizations or expressly mandated by law. Nowadays, no major construction or upgrade project at a refinery can do without a computer-based training component. According to (Dozortsev 2009), operator errors produce an average of $0.51 in losses per ton of feedstock oil. A recent analysis based on a forty years' worth of refinery accident statistics indicates losses of $0.52 per ton in 2013 prices.

Indeed, losses through operator errors are huge; in addition to accidents *per se*, such errors result in product quality degradation, unscheduled downtime, environmental damage, and other losses that, at the least, are comparable in their scope to losses from accidents. At the same time, the costs of CBTS, compared to accident losses alone, would pay back if the accident and incident rate is reduced by 6…9% (Dozortsev 2009). Obviously, in economic terms, CBTS is a highly lucrative tool of accident rate reduction.

In all probability, CBTS is the most synthetic technology among modern systems of industrial automation. In addition to highly accurate process models and learning models, such training systems include an information model implemented in user interfaces of training participants, i.e., operators and the instructor. Process control involves two types of operators: console operators (i.e., operators of distributed control systems or DCS) and field operators (who control operations "in the field"). Hereinafter, we refer to them, respectively, as COs and FOs.

As to CO interfaces of CBTS, everything is fundamentally clear. Information that a CO requires for control is fully captured by instruments; it rules out any "real life" images of the facility under control, not to mention kinesthetic stimuli. Technical implementation of CO interfaces relies on emulation or stimulation of a real-life DCS interface. (Stimulation (as opposed to emulation) means the reproduction of a control system's operation using authentic DCS software and hardware). This makes sure that the training environment of process control is fully identical to the conditions of CO work using the DCS. There is much less clarity as regards the FO interfaces.

Traditionally, a standalone FO station would be set up within a CBTS; it is of absolute necessity to make sure that the operator's activities in training are similar to his real-life activities. Indeed, a field operator should not be in possession of information available to the console operator and vice versa (such extraneous information is fraught with so-called "false" skills). However, legacy FO interfaces were schematic, repeating the process topology accepted for the DCS purposes and showing additional equipment "in the field" (Fig. 1). However, an FO does not see behind a computer; he works in a 3D space that takes navigation, orientation, and manipulation of real-life actuators. As a result, the FO was used as a stooge offering his remarks to the leading actor, while FO's own training was highly ineffective.

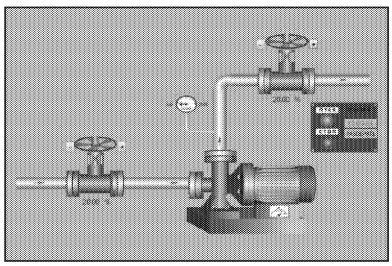


Figure 1: Example of a legacy 2D interface for a field operator

As relevant technical capabilities come to exist, users evince a lot of interest to more advanced FO interfaces. As projected (Operator Training Simulation. 2012), a shift towards such systems would increase their share from 6.4% in 2012 to 7.5% in 2017 (adding $22 million a year) with a compound annual growth rate of 11.2% vs. 7.5% growth in the legacy interface sector.

An obvious idea that arises here involves the use of 3D interfaces (virtual reality; immersive interfaces). A number of writings (Colombo et al. 2013; Dalgarno and Lee 2010; Kluge 2014; Nazir et al. 2013) not as much justify the advantage of 3D interfaces as highlight fundamental unsuitability of 2D interfaces going forward. Other properties of 3D are ignored, even though such issues obviously exist (imperfect reflection of reality, gaming bias, and higher costs). No alternative is considered to a 3D immersion as the future for computer-based training interfaces.

In this paper, the authors will endeavor to:

- analyze strong and weak points of the 3D approach;
- propose and justify an alternative approach to building an FO interface; and
- describe its implementation and the initial practical results of its use.

## SHORTCOMINGS OF LEGACY 2D INTERFACES. EXAMPLES OF 3D APPROACHES

The paper's authors (Colombo et al. 2013) claim that the training paradigm has already shifted from the legacy setup to operator training for decision-making purposes. In this context, the following fundamental faults are found with the legacy approach:

- the set of training scenarios in legacy CBTS setups is limited; one could only operate within such setups based on pre-configured templates. (This claim is disputable: scenarios that are surprising to operators may be generated by training instructors in a largely unlimited scope. It is true, however, that most abnormal situations occurring "in the field" are difficult if not impossible to implement using the legacy approach);
- it is impossible to provide full-fledged training to a FO; his role is secondary compared to the CO;
- it is impossible to substantively simulate industrial emergencies.

One could not but concur with the paper's authors (Nazir et al. 2013) that approaches to training console operators, as opposed to field operators, should differ since the realities wherein they act are different. A CO faces a reality that is global (the entire process unit) although schematic and artificial, the CO perceives it by way of instrument readings. In case of a FO, the reality is local (particular routes, specific vessels, and controls), but authentic and "tangible"; it may be learned using his sensory faculties.

The unrealistic nature of legacy FO interfaces presented in a flat schematic version prevents the operator from transitioning from the level of rational activity to the emotional level; this may not but devalue such training. To that, we may also add a loss of operator motivation (the way it happens in computer games that attract less interest when they become less realistic).

Immersive interfaces are clearly an attractive concept for FO training purposes. While being mindful that immersion is not only inherent with 3D, let us analyze the immersion phenomenon in the context of computer training for operators. According to (Adams 2004), immersion could be:

- tactical, in the context of local operations requiring dexterity. Often it concerns intuitive decisions that do not engage an overall understanding of the task at hand;
- strategic, i.e., more intellectual, associated with resolving mental problems (assessing the situation and choosing the right decision out of numerous alternatives);
- narrative, with a deep dive into the action scenario. K. Brooks (Brooks 2009) identifies three attributes of narrative immersion: time, context, and engagement that must operate together. Here, immersion is assisted by narrative time (where the speed, duration, latency, and rhythm are more flexible compared to presentation-based "physical time"), narrative context (where the recreated space may also differ from physical space), and narrative engagement (where user finds it more important to "deep dive" into the story than monitor a clear sequence of actions).

From the perspective of mechanisms engaged by immersion, the following immersion types are identified (Björk and Holopainen 2006):

- sensory, i.e., the feeling of finding oneself in a 3D environment and being intellectually stimulated thereby;
- spatial, whereby the operator feels the space's dimensions and the distances between objects. Spatial immersion is based on sensory immersion yet also includes intellectual reflection of simulated reality;
- emotional, whereby the operator experiences emotions arising from his/her involvement in the simulated situation;
- psychological, whereby the operator identifies himself/herself with the implicit person in control

of the process. It is broader than emotional immersion, which mostly characterizes operator response to any goings-on within the interface.

Key immersion elements are already present and will find an ever-greater demand in FO training interfaces. Table 1 shows them broken down by dimension (2D/3D) and display type. All interfaces alternatives are interactive (this is an inherent property of operator interfaces). 2*D interfaces* (with animated elements, e.g. bar graphs, dynamic equipment status, etc.) might only be capable of strategic immersion: with luck, the operator might be carried away by the narrative, i.e., resolving a cognitive control objective "in the field". Such are legacy FO interfaces that attract heavy criticism by the users and developers. Interfaces built using *virtual reality (VR)* technologies let the operator dive into tactical operations with the simulated environment and experience his activities on sensory, spatial, emotional, and psychological levels. At the same time, salient features of VR technologies result in a distortion of operator perception; this is fraught with the development of false skills (to be discussed below). In our view, narrative immersion must be restricted whatever the interface type, since FO work does not leave too much room for captivating narrative effects, while the flow of time, context, and engagement must match the relevant real parameters as far as possible.

However attractive the VR approach could be, one ought to note its vulnerabilities that are rarely, if at all, its realism. There are way to improve it, but the comprehensiveness of spatial immersion (and, therefore, of emotional and psychological immersion alike) required for training is impossible, not even for cost considerations but for reasons of limitations inherent in 3D approach itself. There is always a feeling that the reproduced environment is fake.

The above salient feature of VR begets an ever-present psychological feeling of a game situation. Clearly, it boosts operator motivation but also reduces his/her responsibility, which is the basic necessity of real-life operations.

The cost aspect is also important, of course. VR interface accuracy is achieved by incurring huge costs of developing and then supporting relevant systems. According to available estimates, the cost of a full-fledged 3D interface for an FO, covering an entire process unit, is comparable with the cost of CBTS itself, such as the process model, CO interface, and the instructor's workstation. To that, we must add the costs of 3D interface support, since any change of the simulated reality, for the avoidance of false skills, must be reproduced in such interface.

One alternative to such 3D approach involves so-called virtual tours (VT) based on panoramic photography, which is capable of producing a realistic image of multi-element 3D space on a computer screen. Normally, these are spherical panoramas connected by interactive transition links (hotspots). In the course of viewing, one can virtually "move" between such panoramas. Such interface also contains pop-up information windows, explanatory inscriptions, graphic control keys, etc.

Table 1: Immersion elements in various FO interfaces (* limited, ** distortion possible)

| FO interfaces | Dynamic (animation) | Dynamic (recorded images) |
|---|---|---|
| 2D | *Process flow diagrams (with animated elements)*<br>• tactical*<br>• strategic<br>• narrative* | *Virtual tours using panoramic photography*<br>• tactical<br>• strategic<br>• narrative *<br>• sensory *<br>• spatial*<br>• emotional<br>• psychological |
| 3D | *Virtual reality*<br>• tactical<br>• strategic<br>• narrative*<br>• sensory**<br>• spatial**<br>• emotional**<br>• psychological** | |

Nevertheless, a lot of work is being done in the area of VR interfaces; various CBTS manufacturers have their own R&D projects; some of them rely on solutions offered by specialized firms. Fig. 2 shows an example of one such solution.

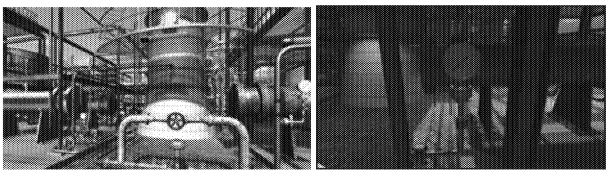


Figure 2: An example of 3D interface by VIRTHUALIS

VT are a highly effective marketing tool that gives the viewer feeling of being there and relies on bright and memorable visual images to convey the fullest possible information regarding a product or service. Such tours are extensively used online in navigation maps. As of now, VT of several hundred cities are already available: one can see sights, visit museums, navigate a strange neighborhood, study road junctions and traffic signs. VT are heavily used in e-manuals: a high-quality illustration of such manual for the International Space Station (ISS) appears on Fig. 3, left (esa.int). At the same time, where the context presents a particular type of reality (inaccessible or unusually lit), as found outside the Space Station, the VR approach works well (Fig. 3, right).

As opposed to the VR approach that is heavily prevalent in both B2B (*Business-to-Business*) and B2C (*Business-to-Consumer*) sectors, VT have hardly any B2B penetration so far. At the same time, there is an application sphere where the requirements applicable to

the interface's psychological similarity and realism prevent the use of VR. FO training, particularly in case of dangerous, abnormal, and emergency situations, clearly falls within such application class.

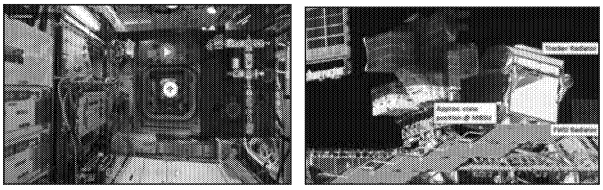


Figure 3: Immersion into ISS work:
a virtual tour of internal sections (left),
VR immersion outside the station (right).

According to a pointed dictum of an executive responsible for personnel training, the last thing an operator using a CBTS needs is a "feeling he has got five more lives". According to the authors, VT is a appropriate tool for FO interface implementation.

## PANORAMIC INTERFACES FOR FIELD OPERATORS

In terms of achieving the immersion effect, a panoramic FO interface has the following features:

- essentially, it is a 3D interface based on 2D representations;
- it is as good as VR in terms of tactical, strategic, and narrative immersion (to the extent such narrative is needed);
- at the same time, a panoramic interface is free of VR's inherent distortions. Even though panoramic reality is incomplete, such incompleteness is "real". It features no abstraction from the context, no gaming attitude, and no resultant reduction in responsibility.

According to feedback, numerous training professionals prefer panoramas to VR. One of them has intuitively sensed the danger of studying a facility through VR before the novice "walks through" such facility using real-life routes. Otherwise, the person may develop a vivid yet false ideation of reality. In case of a panorama, the respondent either does not see such danger at all or deems it an incomparably lesser hazard.

General approaches to creating panoramas have been described repeatedly. Relevant technical nuances fall outside the scope of this paper; therefore, we shall touch them very briefly. In projects we have implemented, a camera takes a series of shots from every point, each shot rotated several degrees to the prior shot around the vertical axis (Fig. 4, top row); if need be, another shot is taken upwards to obtain a closed sphere. Next, using a special software program (quite a number of those are commercially available), the shots are stitched up to from a panorama (Fig. 4, second row). Such panoramas are placed into a tailor-made HMI display editor that configures transitions between various points in the panoramas and incorporates active interface elements linked to the CBTS's mathematical model (Fig. 4, third row). The resultant screen of an FO interface appears on Fig. 4 at the bottom.

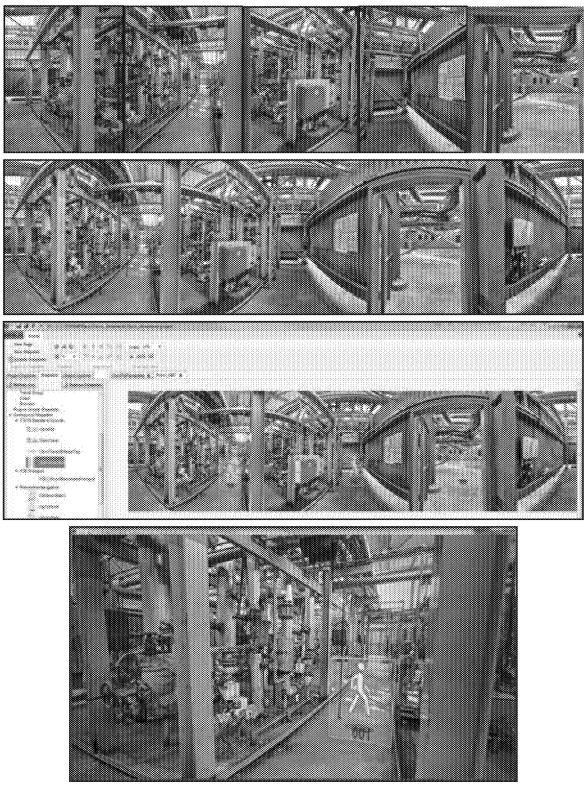


Figure 4: Example of a panoramic interface: photos (top row), panorama (second row), HMI screen editor (third row), operator screen (bottom row)

In organizational terms, panoramic interface development includes the following stages:

- definition of process modeling scope and depth. Considering the purpose of training, various process nodes are modeled to different depth. Accordingly, "in the field" valves and fixtures are modeled in different scopes;
- identification of "onsite" control elements;
- identification of sampling points and points for regular planned inspections by way of preventive maintenance. The operator should be familiar with such points and able to get to them within the interface;
- panoramic photography on site. Panoramas feature two types of spots: transitions and spots with equipment that operator could interact with;
- stitching up photo images into a panorama;
- configuration of transitions between frames;
- linkage of equipment shown on photos with the training system model.

We have already completed and are developing a number of large scale panoramic projects. Let us note initial key observations that stem from this experience. Panoramic interfaces are also nearly always used apart from CBTS to familiarize operators (not just field

operators!) with the equipment and train them in navigation skills. The panoramic interface must be sufficiently complete, reflecting all existing approach ways to equipment. Naturally, this makes the task more difficult yet also opens up new opportunities for using such panoramas.

## CONCLUSION

Initial results of developing and implementing panoramic FO interfaces are encouraging. While incomparably less costly, they are as good as costly 3D interfaces and, on some psychological aspects, better than those. Still, a lot of room is left for further research. Among other things, we note the following:

- a well-justified cognitive model of FO activities is required. It is only on the basis of such model that the scope of FO training objectives and therefore the composition and structure of FO interface could be defined in a methodologically proper manner. As opposed to a console operator (Dozortsev 1999), this topic is largely undeveloped in case of FOs. The few existing results (Kluge 2014) are fragmentary so far;
- a compromise is required in determining the degree of panoramic detailing. It is impossible to photo everything and a narrowing down of potential movement areas cannot be avoided; still, the navigable field should be sufficiently complete;
- algorithms for pre-marking space and configuring a panoramic interface need further elaboration. That would make such development work cheaper and faster;
- suitability, effectiveness, and benefits of panoramic interfaces compared to alternative solutions (2D and VR) may only be validly proven through psychological experiment. Its objects and structure are clear in principle, but its successful performance takes major technical and methodological effort.

The authors expect panoramic FO interfaces to have a big future. Combined with augmented reality technologies, they will soon be capable of displacing both legacy 2D interfaces as well as costly and psychologically vulnerable VR interfaces, both in computer training environment as such and in related tasks of personnel training (facility familiarization and navigation, abnormal situations and emergency response drills, e-textbooks on equipment support and repairs, etc.).

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## BIOGRAPHY

**Victor M. Dozortsev** was educated in Russia and got Ph.D. degree in control engineering in 1987. He received his doctorate (Dr. Sc.) after defending in 1999 the thesis dedicated to design, development and application of operator training simulators. In 1976 - 2005 he worked in the Institute of Control Sciences of Russian Academy of Sciences (Moscow, Russia) as chief of a research group. In 2005 he joined the Russian branch of Honeywell Corp. as Advanced Solutions Leader. His research interests include system analysis, mathematical modeling, advanced process control, cognitive engineering, computer-based training and decision-making support. He has professorship in some technical universities of Moscow.

# ACCENTED VISUALIZATION IN MAINTENANCE AR GUIDES

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**KEYWORDS**

Augmented Reality, Interactive Guide, Accented Visualization, Ontology

**ABSTRACT**

Maintenance and repair informational support remain one of the most promising areas of Augmented Reality practical applications. Despite a variety of solutions available, the problem of efficient data presentation in context to the maintenance engineer operations remains open. In this paper a possible solution of accented visualization is proposed, which is based on context driven data representation considering the combination of time and human factors. Implementation examples are given for maintenance AR tablet introduced for industrial technology support.

## INTRODUCTION

Maintenance support of modern technical devices is a challenging process that requires high professional competence from the operating staff. Considering the complexity of the accessories in most industries the maintenance crew should include engineers of high qualification, especially in case of rugged industrial performance. However not all the members of maintenance crew can correspond these requirements. To cover this gap there are various interactive guides based on implementation of Augmented Reality to support the operating staff with all the information needed.

Such guides can be implemented using innovative technologies of Augmented Reality and special gogglers or tablets. However, practical implementation of those solutions is concerned with a number of problems caused by performance, visibility and layout, informational value and conciseness issues. Information being presented for the maintenance engineer should be useful and clear at a certain moment of time, which makes the process of guide data processing a complex technical problem. To solve this task a new approach based on accented visualization is proposed, which is presented in this paper.

## STATE OF THE ART

In industry world, when a machine comes to a standstill, the problem must be immediately localized, since managers will want to know how long the machine has been down. Long downtimes lead to the reduced availability of equipment and inefficient production bottlenecks, but in order to evaluate the error analysis and repair the defective machinery, the service technician must do a lengthy search for information in various printed manuals.

Increasingly complex installations and repairs require highly qualified staff and readily available data. When a company's own technicians cannot perform the service or maintenance, then it must resort to external resources. This is not only more costly, but it may lengthen repair time, thus further impacting production processes. Industry users need an app that is an extension of the traditional manual and also enhances support by using visual and digital elements; the required data must be in real-time and available on-demand. Therefore, the necessary tools and instructions should be provided directly to the service technicians' work environment, thus making it possible for them to fully concentrate on their tasks. Lastly, the app should make collaborative efforts possible via direct video communication with colleagues and specialists.

Such app is possible using modern Augmented Reality technologies (Krevelen, 2007, Navab, 2004.) tailored with adaptive user interfaces (Julier, 2003.). The user is able to receive visual aids for the quick and reliable repair of both machinery and the manufacturing plant using user interfaces that support each task naturally without distracting. The development and scope of such applications are geared directly to the needs of clients with standardized modules available as well as individually tailored designs.

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. The possibilities of augmented reality (AR) as a ubiquitous user interface to the real world are greatly discussed in (Schmalstieg, 2005). Technological advances, exploding amounts of information, and user receptiveness are fueling augmented reality's (AR) rapid expansion from a novelty concept to potentially the default interface paradigm in coming years. AR is drawing considerable interest not only because it involves novel or "cool" technologies, but also because it promises to help users manage today's information overload (Lee, 2012, Singh, 2013).

AR faces the same core usability challenges as traditional interfaces, 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.

Augmented reality (AR) is an excellent user interface for mobile computing applications (Hollerer, 2004.), because it allows intuitive information browsing of location-referenced information. The main use of a mobile AR device is as an information appliance operated in browsing mode. Applying AR to maintenance tasks could make it possible for users to be trained for those tasks, and actively assisted during their performance, without ever needing to refer to separate paper or electronic technical orders (Ke, 2005). Incorporating instruction and assistance directly within the task domain, and directly referencing the equipment at which the user is looking, could eliminate the current need for personnel to continually switch their focus of attention between the task and its separate documentation.

Maintenance/repair and assembly/procedural tasks serve as natural applications for AR (Henderson, 2009, 2011). We attribute this to a variety of factors. First, these tasks typically demand maximum preservation of a user's focus on a specific area of interest. A second requirement is the need to synthesize additional information, such as delicate and complex sequences, obtuse component identification, and lengthy textual data. This synthesis is, in and of itself, difficult to place directly in the context of the area of interest using classic techniques such as prints, manuals, or laptops. Instead, these approaches at best visually replicate a separate annotated view of the area of interest. Consequently, if the user refers to these kinds of documentation, they temporarily switch focus (context) away from the actual area of interest to pictures and text describing it.

Example of AR in Development, Production and Service (ARVIK) is presented in (Friedrich, 2003). Maintenance and training AR applications in aeronautical domain are greatly presented in (Hincapié, 2011) and (Haritos, 2005). An example of attention modeling using an egocentric camera as the primary interface between the user and the robotic wheelchair is presented in (Li, 2016). Adaptive user interfaces with Augmented Reality based on accented visualization approach may be the application that serves as the pivot point for IoT (Internet-of-Things) adoption because of its proven applicability and readiness for core industrial activities such as quality inspection, work instructions and training. Such technology can strongly connect the physical, digital and human experience.

## ABSTRACT MODEL

Accented visualization concept is based on adaptive construction of virtual content considering not only the current real scene in view, but also the viewer's experience that contain the peculiarities of perception, viewpoint and expected behavior. This is especially actual for maintenance and service data support problem domain as soon as the correct maintenance procedure is required to be carried out by different executors with various education, knowledge and skills in a unified manner.

Let us consider the scene $s_j$, where $j=1..N^s$ is the scene number that contains a number of real objects $w_{i,j}$, $i=1..N_j^w$ and corresponding virtual entities $q_{i,j,l}$, $l=1..N_{i,j}^q$:

$$s_j=\{w_{i,j},q_{i,j,l}\}. \tag{1}$$

The objects are considered independent due to different visualization features in different scenes. Objects can have various visualization in different scenes, but refer to a single entity in real world. These objects are considered to be equal. To describe the equality there is defined a compliance matrix for all the scenes:

$$C(w_{i_1,j_1},w_{i_2,j_2})=\begin{cases}1, & w_{i_1,j_1}\equiv w_{i_2,j_2},\\ 0, & elswise.\end{cases} \tag{2}$$

Viewer's attention at a certain moment of time is given to a number of objects (one or several). Each object focus can be described by the event, presented by the Boolean variable:

$$v_{i,j,k}=v(w_{i,j},t_{i,j,k})\in\{0,1\}. \tag{3}$$

This focus can result or require actions. In this case the sequence of actions can be treated as a scenario. For example, maintenance process for a certain device can be described by a scenario of actions organized by sequence. The process of maintenance is formulated by the standard scenario:

$$c_{j,m}=\{e_{i,j,m,n}\}, \tag{4}$$

where $e_{i,j,m,n}=e(w_{i,j},d_{i,j,m,n},t_{i,j,m,n},\Delta t_{i,j,m,n})\in\{0,1\}$ represents the event of action $d_{i,j,m,n}$ that refers to the object $w_{i,j}$ and has to be done at lap time $t_{i,j,m,n}\pm t_{i,j,m,n}/2$.

Effective maintenance process requires correspondence of $e_{i,j,m,n}$ and $v_{i,j,k}$:

$$M(e_{i_1,j,m,n}\cdot v_{i_2,j,k})=e_{i_1,j,m,n}\cdot v_{i_2,j,k}\cdot[w_{i_1,j_1}\equiv w_{i_2,j_2}]\cdot\\ \cdot[w_{i_1,j_1}\equiv w_{i_2,j_2}]\cdot[t_{i,j,k}=t_{i_1,j,m,n}\pm\Delta t_{i_1,j,m,n}] \tag{5}$$

AR implementation in this case should support maximum correspondence of $v_{i,j,k}$ to $e_{i,j,m,n}$ and result in prompt data contextual visualization according to the current viewer's focus. It can be formalized as generating the set of focus attractors in textual, mark or highlight form:

$$Q_{i,m}=\{q_{i,j,l}\},q_{i,j,l}=q(w_{i,j},t_{i,j,l})\in\{0,1\}, \tag{6}$$

to meet the following objective:

$$I(s_j,c_{j,m})=\sum_{n=1}^{N_{j,m}^c}e_{i,j,m,n}\cdot\\ \cdot\left(1-\left[\sum_{k=1}^{N_j^v}\sum_{l=1}^{N_j^q}\sum_{i=1}^{N_j^w}\left(M(e_{i,j,m,n}\cdot v_{i,j,k})\vee q_{i,j,l}\right)>0\right]\right)=0 \tag{7}$$

This means that in order to provide standard maintenance scenario the AR interactive guide needs to generate virtual entities with context driven data at the moments when the viewer's attention should be attracted to certain objects.

## SOLUTION VISION AND ITS IMPLEMENTATION

The proposed solution is based on users' behavior analysis according to the introduced model. Embedded software with intelligent decision-making support captures the users behavior in the form of event chains and compares them with typical scenarios of maintenance and repair. Analysis is produced at a time frame of standardized procedure using cross-correlation functions. Such analysis allows identification possible gaps in viewer's perception, when no required attention is given to certain scene objects at necessary times. This knowledge is captured in the form of rules in knowledge base linked to specified types of scene objects and steps of maintenance 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.

The proposed approach is illustrated by Fig. 1. There are presented two modules that process knowledge base on user's actions and maintenance scenarios in the form of Ontology, and a couple of modules for decision-making support that produce user's actions analysis and focus attraction. User behavior can also be identified by capturing the head and eyes movement in case the headset or spectacles are used as AR devices.

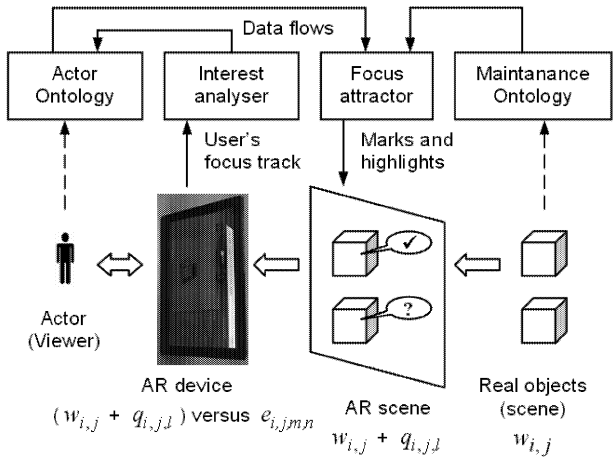



Fig. 1: Accented visualization solution vision

The proposed approach was implemented and tested as part of a network equipment maintenance solution presented in Fig. 2. Tablet with video camera powered by Linux is used as AR device. The following functionality is currently available:

- Scene object identification based on image analysis;
- Contextual description of the object in view;
- Search and highlighting of the object required;
- Maintenance 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 according to the principles of accented visualization.

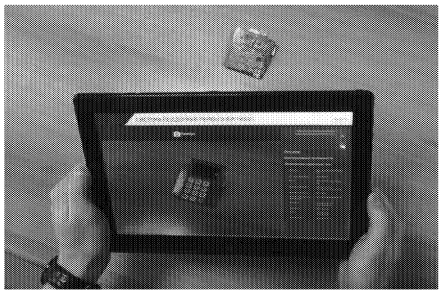


Fig. 2: AR Interactive Guide Implementation

## CONCLUSION

The results of the proposed approach testing and practical use prove the necessity to study and manage the ways of limited but yet effective data representation using AR. The main benefit of accented visualization is personification of AR, which allows minimization of the additional information added to the scene view.

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# APPLICATION OF VIRTUAL AND AUGMENTED REALITY IN AUTOMOTIVE MEASUREMENT PROCESSES

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**KEYWORDS**

Virtual Reality, Augmented Reality, Measurement Services, Automotive, Human-Computer Interaction, Planning and Control

**ABSTRACT**

Measurement processes in the automotive industry are characterized by Computer Aided tools. Increasing cost and quality pressure with a reduced time-to-market necessitates a continuous improvement of processes. In the last decades, Virtual and Augmented Reality technologies become more and more popular. The utilization of those systems in multiple workflows promises improvements and reduced time in product development cycles. In this paper, a vision of the future usage of Virtual and Augmented Reality in automotive measuring processes is described. For that reason, the Augmented and Virtual technologies and the current measuring process are introduced. Four cases for the use of Augmented or Virtual Reality in measuring processes in the automotive industry are identified to give an example for the implementation of those technologies in product development processes. The use cases handle with the determination of sensor positions, the physical application of the sensors, the localization of sensors in case of failure and the visualization of results. Due to the fact that the used technologies are not applicable for this vision nowadays, requirements for future research are identified and explained.

## INTRODUCTION

In spite of sophisticated simulation tools, measurements play an important role in the development of components and vehicles in automotive engineering. Single components are analyzed using test benches and fully equipped vehicles are measured in road tests on proving grounds to ensure product quality and vehicle durability. To enable interoperability in heterogeneous system landscapes, the process was digitized using standard data formats like STEP (Anderl and Trippner 2000) and JT (ISO 10303-203 2011; ISO 10303-214 2010; ISO 14306 2012). Nevertheless, the interface between the virtual and the physical environment lacks of suitable technologies. The transfer of digital information to the physical environment is not practicable and often imprecise. For example, coordinate values or orientations of sensors cannot be used precisely during the physical sensor application without time consuming procedures. In addition, the desired bidirectional dependency between virtual and physical environment requires a continuous adjustment of the 3D CAD model. The digitalization of the measuring process paves the way for the integration of the Augmented Reality (AR) technology, which can improve the interface between the virtual and physical environment. To speed up the process, the Virtual Reality (VR) can be used to start the process before prototypical components are available and to visualize results in a virtual environment. In this paper the digitalization of the measuring process, which is validated in projects of an automobile OEM (Faath et al. 2016), will be enhanced using AR und VR technologies.

## MEASUREMENT SERVICES IN AUTOMOTIVE ENGINEERING

Using the SADT (Ross and Schoman 1977; Marca and McGowan 1987), the digitized process of measurement services in automotive engineering is divided in six main activities (Faath et al. 2016):

1. Order entry
2. Planning of the measurement
3. Physical preparation of components and vehicles
4. Measurement
5. Evaluation
6. Result documentation

During the order entry restrictions and goals are defined. The planned positions and types of sensors are specified. The positions are determined using the 3D CAD model of the component or the full vehicle and can be set in different ways. On the one hand geometrical characteristics like holes, edges or welds are used to identify the desired position of the sensor qualitatively. As a result, the positions are quantified by

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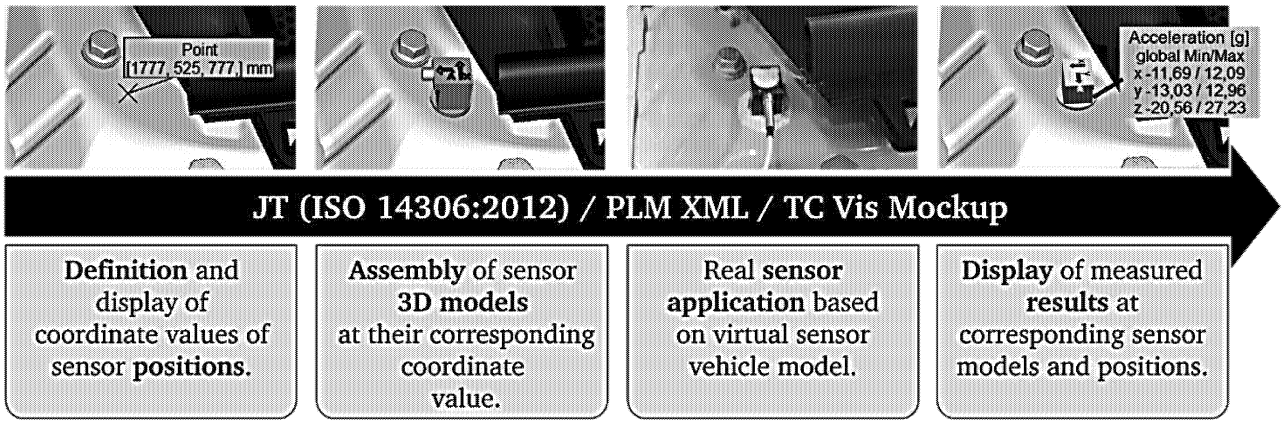



Figure 1: Process of measurement services using format and system backbone (Faath et al. 2015)

their coordinate values. On the other hand, coordinate values can be processed directly if there are for example existing simulation results. The values are displayed in the model using different colors and layers according to the type of sensor. The results of this first activity are the coordinate values of the desired sensor positions. These are displayed at their corresponding position as shown left in Figure 1.

In the second activity the information of the order entry is processed. It defines the sensors and their positions and orientations for the whole measurement process and paves the way for the physical application. Strain gauges, accelerometers and force sensors as well as wheel force sensors are used to measure vehicle dynamics and operating load measurements (Ferry et al. 2002). The associated 3D CAD sensor models are positioned using the coordinate values of the defined sensor positions. The 3D CAD sensor models geometry corresponds to the real sensor dimensions in order to enable a full virtual representation of the 3D CAD model. Missing mounting space and intersections between vehicle components and the sensors can be identified and eliminated by manipulating the sensor positions. To enrich the 3D CAD model with more information, metadata like Product Manufacturing Information (PMI) and important documents, for example application information (cable length, glue, sensor details), are linked to the sensor 3D CAD models. To avoid incorrect positioning of sensors, the created 3D CAD model has to be approved by the customer. The output is a 3D CAD model including sensor models and Metadata managed in a PLM system (Figure 1 second from the left).

The third activity is the preparation of components and vehicles. In this activity the 3D CAD model and its attached metadata are used for the physical application of the defined sensors with high accuracy (Figure 1 second from the right). If a precise translation of the sensor position is required, a Coordinate Measuring Machine (CMM) is used. If there is no accurate transformation necessary, the 3D CAD model will work as foundation for qualitative positioning. The use of the 3D CAD model allows only an approximate correct orientation and processing of information required during the physical application of the sensors. If the components have to be mounted in the vehicle, the 3D CAD model will be used for the correct installation. To transfer results of local sensor accelerations to the global vehicle accelerations, concurrency between sensor axis and vehicle axis is mandatory. To receive an exact accordance between the 3D CAD model and the physical assembly, the sensor positions are measured and adjusted in the 3D CAD model. Furthermore, the real sensor orientations are adjusted in the CAD model as shown right in Figure 1. In addition, in this activity the sensors are connected to the amplifiers using a plan of connections. The output of this third activity is either a component or a functional measuring vehicle which contain all the components, sensors and amplifiers that are intended for the measurement.

The fourth activity is the measurement on test benches or proving grounds. The measurement vehicle is tested on different types of tracks like hill or high speed sections. To simulate the daily stresses, tracks with repeating curbs or potholes are used. Problems occur when sensors malfunction or get loose. Due to the fact, that a measuring vehicle can contain more than hundred sensors, it is difficult to identify the sensor position of the failed signal. In this case the measurement is continued without the failed signals.

The fifth activity is the “evaluation”. Statistical analysis is used to generate results. The most important results are for example minimal and maximal stresses and local as well as global accelerations or relative stress factors (RS). RS factors are used to compare results from different measurements or simulations and to validate the different results regarding to real vehicle road tests.

In activity six the most important measurement results are visualized directly at their corresponding sensor position. Extensive information is linked to the displayed results and can be shown if necessary. Due to the integrated information and results of the measuring processes in the 3D CAD model, downstream processes are able to use the results for iterative optimization processes or to verify simulation results.

## AUGMENTED REALITY AND VIRTUAL REALITY

In the last decades, VR and AR technologies become more and more popular for the usage in industrial environments (Seth et al. 2011). Thereby, VR can be defined as a "multi-dimensional human experience, which is totally or partially computer generated and can be accepted by those experiencing the environment as consistent" (Seidel and Chatelier 1997) while AR systems are characterized by three characteristics (Azuma 1997):

1. The combination of the real and virtual environment
2. The interaction in real time
3. The processing of three dimensions

This enables an improvement of traditional methods in many business areas, e.g. dental industry (Steinmetz et al. 2015 (B)) or product development.

AR Technologies can be categorized in optical see-through and video see-through systems. In an optical see-through system, the user sees the real world through two partial transmissive monitors while the monitors enable an overlay of images that presents virtual objects. The most popular optical see through systems are Microsoft HoloLens, Google Glass and Sony SmartEyeglass Attach. Video see-through systems capture the real world using cameras, overlay the virtual objects in a processing step and show the resulting images on two monitors in front of the eyes. As described in (Azuma 1997), each of the two approaches has its benefits and drawbacks, and the choice depends on the concrete application.

Because AR enables a virtually enhanced look at the real world, the positions of the overlaid objects, as well as the position and orientation of the head-mounted device itself must be determined. To enable the enhanced view, real and virtual objects have to be aligned with respect to each other for producing a realistic illusion of the fusion between the two worlds properly (Barandiaran et al. 2010). The methods for the determination of position and orientation can be categorized into marker-based and markerless techniques. Marker-based approaches use well-known glyph geometries or patterns for computing the position using the characteristics of a (calibrated) camera. In contrast, markerless approaches compare captured images with images of a 3D CAD model in order to determine position and orientation. This approach has the advantages that no marker has to be attached on the component and that more flexible systems are allowed (Barandiaran et al. 2010). There are also other devices, which are able to determine a 3D position, for example a data glove, a 3D Mouse and a Haptic Feedback System. A Haptic Feedback System is a pen-based device, which provides a realistic tactile behaviour during the interaction with the 3D CAD model. If the cursor touches the surface of the 3D CAD model, a force is applied by the haptic feedback system (Steinmetz et al. 2015 (B)). It has also two buttons for triggering custom actions. The device provides the position and orientation of the gimbal in its own coordinate system. This coordinate system must be mapped to the VR or AR coordinate system in order to get a correct alignment.

The usage of 3D CAD models in production systems with AR incorporates an inclusion of CAD data into the viewer system. As described by Caudell and Mizell, sources of expense and errors can be eliminated, if manufacturing workers are able to access digital CAD data directly, when they are using a head-mounted device (Caudell and Mizell 1992). Liverani et al. describe a method for providing information for assembling real components to the user using a video see-through system (Liverani et al. 2004). 2014, Autodesk started integrating Microsoft's HoloLens into the CAD software Fusion 360 (AutoDesk 2017). Gräßler and Taplick give an overview on use cases of VR and AR technologies in product creation processes (Gräßler and Taplick 2015). Many articles in literature describe use cases for the integration of AR in production environments (Choi et al. 2015), but the integration of VR and AR into the measurement process is not covered scientifically yet. Also the usage of the JT format as a neutral data format for the representation of CAD data in VR and AR systems is not yet established.

## CONCEPT FOR THE USE OF AR AND VR IN MEASUREMENT PROCESSES

In this section four use cases of the usage of AR and VR in measurement services are described.

The first use case incorporates the definition of sensor positions during the activity "order entry". Due to the fact, that prototypes are rare and used by multiple downstream processes, the available time of their use is limited. Often the prototypes of the components or the vehicle are not available in the first stages of the measurement process. For that reason, it is necessary to prepare as much as possible before the prototypes are physical available. To reach this goal, 3D CAD models should be loaded from the PDM System and visualized using the VR technology. This paves the way for the execution of the "order entry" without the use of a physical prototype. In the visualized 3D CAD model, the sensor positions can be specified using VR, when there are no coordinate values given and the desired sensor position has to be defined qualitatively. If there are already measured prototypes, which contain cracks, the AR technology will be used to define their coordinate values. The vision is that desired sensor positions can be marked and the corresponding coordinate values are displayed for information and documentation purposes using VR and AR. To enable the interaction with the visualized model, a suitable tracking method as mentioned before has to be used. The use of a haptic feedback system is recommended as shown in Figure 2.

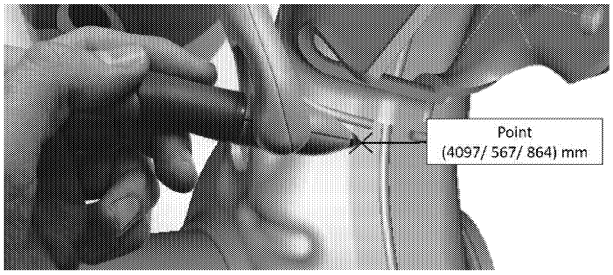



Figure 2: Use case 1 - Definition of sensor positions with AR and Haptic Feedback system

On the one hand the coordinate value of the defined position is provided by the haptic feedback device. On the other hand, the system allows a realistic tactile feeling of the virtual prototype´s surface. The advantage of the VR technology is that the engineer has the possibility to rotate, translate and scale the model, to have a better view of the design area of the desired sensor position.

The second use case is the physical application of the sensors at the defined positions during the activity "Physical preparation of components and vehicles". The current process of positioning and orientating sensors still lacks of precision and is way too complex as well as time consuming. The advantages of the use of AR is that no CMM is required. Using AR the digital sensors are visualized attached to the surface of the physical component or the vehicle in correct position and orientation. This allows that sensors can be easily applied with a high accuracy by aligning the physical sensors to their digital twin as shown in Figure 3. On the left side of Figure 3 the digital twin of the component including the sensor and metadata is shown. On the right side the virtual sensor is visualized at the physical component using AR. As shown, the physical sensor has already been applied precisely aligned to its digital twin.

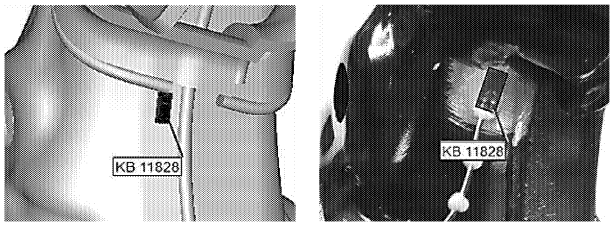



Figure 3: Use case 2 - AR in physical sensor application

To improve usability, the real sensor can be colorized to indicate a correct positioning. The required application information, which is stored as metadata in the 3D CAD model, has to be visualized using the AR device. In addition, individual sensor information will be visualized, if permanent markers related to a sensor database are attached to the sensors. The high level of precision allows that the adjustment between the virtual and the physical environment, which is mandatory in the current process, can be skipped. To realize the precise aligning of the component or vehicle to their digital twin, it has to be tracked by marker-based or markerless approaches as mentioned before. It is recommended that markerless approaches are used, which do not necessitate the previous installation of a marker that is consistent with an intended position in the 3D CAD model.

The third use case is the localization of the sensors during the activity "measurement". As mentioned before, problems occur when the sensors malfunction or get loose. Due to the fact that in measurements many sensors are in operation, it is not efficient to search the sensor which belongs to the failed signal. For that reason, the vision is, that the AR can be used to visualize an arrow that points to the sensor which corresponds to the failed signal.

Use case four is the visualization of measuring results during the activity "result documentation". In current measurement processes, results are visualized in the 3D CAD model. However, the concrete reference to the real component or vehicle is not established. In order to display the most important results at their corresponding real applied sensors, AR is used. In case that further results are desired, these can be visualized additionally. It is conceivable that existing results, for example from simulations or previous measurements, are visualized in order to display all available results for the present components or vehicles. There are different types of result visualization, e.g. curves, colorization, deformation or min/max values. An example of the visualization of results is given in Figure 4. An engine control module (ECM) including the virtual and aligned physical sensor is shown. Relative stress (RS) factors are visualized in two different ways.

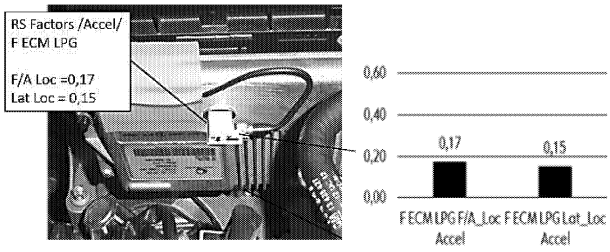



Figure 4: Use case 4 - Virtual visualization of results using AR

Besides the deployment of AR, VR technology provides further benefits, which are then profitable in particular, when the measured prototypes are no longer available. The results can be visualized in the 3D CAD model using VR at any time. It is possible to view hidden measurement points with the abilities of rotation, translation and scaling in detail. Furthermore, single measured components can be integrated virtually in the overall vehicle for visualizing the location of the components and their measurement results in the context of the vehicle. This paves the way for a successive development of a master vehicle result 3D CAD model. In this master model, the related results from different measurements or simulations can be combined, structured and visualized. The vision is, that in context of the term Industrie 4.0, VR is used for collaborative engineering. This enables the

collaboration of development engineers independently from their place of work. Especially in the automotive industry, joint ventures and platform-based vehicles require high level collaboration tools. With the use of VR, engineers are able to interact with the same master model in a virtual environment.

## REQUIREMENTS FOR THE APPLICATION OF THE CONCEPT

As described in the chapter "Augmented Reality", it is not yet possible to load 3D CAD JT files directly in VR and AR systems. The vision is, that the data of product data management systems (PLM systems) can be fetched directly from services (e.g. web services (Steinmetz et al. 2015 (A)), which federate different data repositories, into the VR and AR system.

When the 3D CAD model is loaded, it must be aligned on the current view of the AR system. The position and orientation of the real component has to be determined using a marker-based or a markerless system matching system. A marker-based system uses e.g. glyphs, the glyph has to be attached on the real component at a certain position and orientation. In order to get a correct alignment the position and orientation has to be the same as the one defined in the 3D CAD model. Markerless systems do not require the usage of glyphs, because they compute the position and orientation of the real component using a 3D CAD model. In HALCON, a software library for machine vision, it is possible to load STL models for doing the matching. A drawback is, that the STL model has to be derived from a 3D CAD model prior to the matching. The vision is, that 3D CAD models, like JT, can be loaded directly in software libraries for machine vision.

In order to provide a functionality described in the first use case, the VR and AR system has to be able to recognize the position and orientation, e.g. of a finger which points to the new sensor position. It should be also possible, that the loaded 3D CAD model can be modified by VR or AR system, because the sensor has to be represented in the 3D CAD model using e.g. PMI or labels at a 3D position. Finally, the modified 3D CAD model has to be transmitted to the server in order to save it in the PLM system.

For the fourth use case, the sensor data has to be displayed in the VR and AR system. For this, the data has to be fetched from the database, where the measured data are saved. The approach of using web services that fetch data from several data repositories can be used (Steinmetz et al. 2015 (A)). This service can also be used to get information about the sensors via datasheets of the sensors, if such an information is required by the user of the VR and AR system.

## CONCLUSION

In this paper four use cases for AR and VR during the measurement process in automotive industries are developed. Multiple possibilities of saving time are described. In addition, the use of prototypes for the definition of sensor positions and orientations is reduced. AR or VR is used to define the desired sensor positions and to visualize the designated design area in detail. During the physical application, AR technology facilitates an accurate positioning and orientation of the sensors. An intuitive application by aligning the physical sensor to its digital twin is enabled. In spite of minor error susceptibility, small deviations are displayed by coloring the sensor 3D CAD model. Due to precise positioning and orientating, the 3D CAD model has not to be adjusted subsequently. For result presentation and documentation purposes, results can be visualized at their corresponding sensors and positions using AR or VR. Extensive information can also be visualized if necessary. In the context of Industrie 4.0 the collaboration can be enhanced by the use of a master vehicle result model in a virtual environment. To realize those visions, multiple requirements and research activities are mentioned. At first, the determination of the position and orientation of the component has to be implemented. As mentioned before, the realization using a markerless approach is recommended. In order to visualize the 3D CAD model in a AR/VR system, 3D CAD model data formats like JT has to be loadable in the AR/VR system. Finally, a bidirectional communication of AR/VR system with PLM systems must be established to enable the exchange of product data.

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## BIOGRAPHIES

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# VR
# &
# AR
# INTERFACES

# "VRIFICATION": APPLYING VIRTUAL REALITY TO DIGITAL GAMES

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**KEYWORDS**
Interface, Virtual Reality, VRification, Pure-VR, Former-non-VR, Game Development, Game Design.

**ABSTRACT**

In the following, we discuss the process of applying virtual reality to digital games. We named this process "VRification" and will elaborate on some of its opportunities and issues. Based on a literature survey and professional practice, this work covers several examples of VR games, which were intended as such from the beginning (Job Simulator and Lucky's Tale) and others, which were ported to VR after their initial release (DOOM VR and LizzE). We conclude that, for VR games, it is essential to be optimized for the full potential of targeted interface technologies. Furthermore, porting former-non-VR games to VR can create successful user experiences, when aiming for the same high standard of optimization, especially regarding simulator sickness.

**INTRODUCTION**

Very successful science fiction works like "Snow Crash" (Stephenson 1992), "Rainbows End" (Vinge 2006) and "Ready Player One" (Cline 2011) over several decades illustrated virtual reality's (VR) great potential in socially connecting people. Otherwise physically placed all over the world, VR users could meet in a commonly shared virtual environment. One further aspect of VR, which all three novels have addresses in some way, is gaming and in general play in VR. Relating this to our current society and the significance of gaming and play in it, a need to address this shift from common screen-based digital gaming to VR gaming seems apparent.

Examining the topics and products presented at current gaming and other consumer oriented conferences (e.g. Game Developers Conference, Electronic Entertainment Expo and QuakeCon), VR seems among the top trends. By introducing its head mounted display Oculus Rift, Oculus VR revived VR technology (Rubin 2014). Its affordability and wide developer base has led to an expansion of VR applications. This resulted in applying VR to digital games and other non-entertainment forms of digital applications. A process we have named "VRification", to establish a corresponding vocabulary and thus simplify the further discussion.

**VRIFICATION**

Applications for VRification are separated into two categories: "pure-VR" and "former-non-VR". Pure-VR applications are implemented concepts with VR as the primary user interface in mind, whereas former-non-VR applications were first developed for common interfaces and VR was in some way applied subsequently. This work focuses on VRification of digital games and disregards non-entertainment applications.

VR in its current state in games seems to be heading towards a broad success, as it offers various opportunities. The most obvious advantage is presence (Lang 2014). Lombard and Ditton describe it as the feeling of being in a realistic place

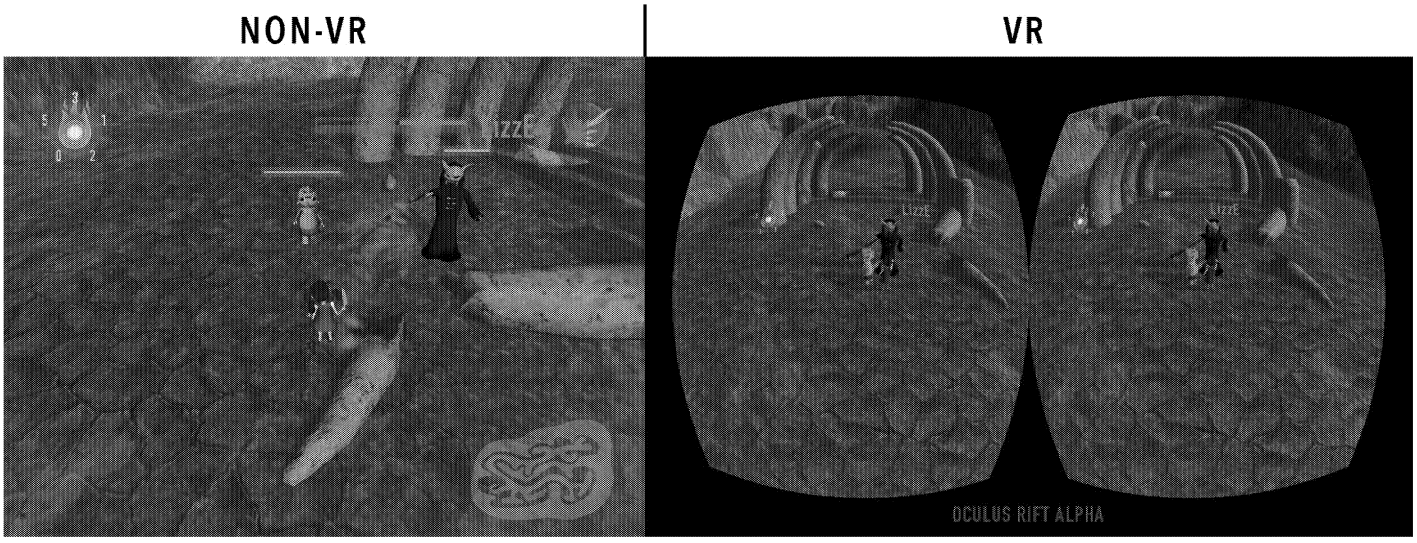



Figure 1: LizzE – And the Light of Dreams, non-VR Mode (left) and VR Mode (right) (FIERY THINGS 2013)

(1997). In other words, when presence is achieved, the user feels literally present in this virtual world and her or his body and mind will react instinctively like in the real world. This effect is particularly heightened by VR and seems intrinsic to its concept (Jerald 2016). It must be noted though, that realism in terms of physical sensual perception, e.g. through high display resolution, low latency, binaural audio, translation of body part movements, haptics, olfaction etc., magnifies the presence effect. The more senses a VR application triggers in a realistic way, the more likely, that the user feels present (Lang 2014).

Economically, VR seems very interesting, as developers can be at the forefront of penetrating a new market. Though unclear how big this market gets, the massive growth of the games market (Livingstone 2014) gives an indication.

**VRification of Pure-VR Games**

Other than that, by offering new interface technologies, VRification in pure-VR games raises a huge amount of game design opportunities.

From the ground up designed for VR, the Job Simulator (Owlchemy Labs 2017) delivers a really successful user experience for example (Stapleton 2016). The user's purpose is to use hand controllers, e.g. HTC Vive, Oculus Touch or PlayStation Move controllers (HTC 2016, Oculus 2016 and PlayStation 2016), to fulfill rather mundane and menial jobs. These include working at an office desk, preparing dishes in a diner, serving at a convenience store and repairing cars in a garage (Stapleton 2016). Though by reducing the visuals and interactive objects to a cartoonish style, lots of humorous and absurd situations evolve. This in combination with some funny robotic dialogues establishes the game's charm. The comic style has another effect, which is the reduction of required performance and thus a higher possible frame rate and less possibility for simulator sickness (Pausch et al. 1992 and Jerald 2016). Furthermore because of the game's rather stationary design no locomotion method is needed, as the user keeps standing on the same spot. This in turn again reduces the possibility for simulator sickness as no vection effect (Riecke and Feuereissen 2012 and Yao 2014) is involved and more complicated teleportation techniques are unnecessary.

Lucky's Tale is another successful VR experience, which was specifically developed for this medium (Playful 2016). Being a cutely illustrated 3rd person game, like Super Mario 64 and Banjo-Kazooie, it needs to overcome certain issues in VR (Hurd and Reiland 2016 and Wiedemann et al. 2016). Though a certain amount of vection is impossible to prevent in this design, the developing studio Playful made some clever decision to reduce the possibility for simulator sickness to a minimum. The reduced usage of user locomotion is mostly aimed away from her or his viewpoint and levels were designed more linearly to avoid too much turning around (Hurd and Bettner 2014, Hurd and Reiland 2016 and Wiedemann et al. 2016). Through these carefully crafted measures and thanks to the charming character of the game, Lucky's Tale is a great example for a 3rd person VR game with an old-school touch (Whitaker 2016).

**VRification of Former-non-VR Games**

In the case of former-non-VR games VRification can provide new angles to common gameplay mechanics and diversify the look and feel.

VRification needs to be handled with care though, as only certain games seem suitable. When the game was not developed for VR from the beginning several issues might arise, like performance setbacks, which are likely to increase latency, which in turn destroys presence and is one of the major causes for nausea. Using less performance intensive billboards instead of complex 3D geometry simply does not work, when using stereoscopic viewing (Holding 2017). Also, former design and hardware interface paradigms might not work as well or not at all. For example, head up displays to show player attributes don't seem to be well accepted by users (Oculus VR 2014). Other more natural, diegetic ways of offering this information might be preferable, e.g. the amount of remaining ammo is displayed directly on the weapon (Oculus VR 2014). Furthermore, the parameters of camera movement (Hurd and Bettner 2014) and the reduction of perceived vection seem very important (Yao 2014) and require more research. Graphical user interfaces like menus need to be designed and navigated completely differently, aiming for an optimized VR experience. Direct object manipulation (e.g. via hand controllers) should be used as much as possible for an increased user satisfaction (Bowman and Hodges 1997). Whereas the indirect Widgets and Panels Pattern should only be used for complex tasks (Jerald 2016) and should be designed for good readability and usability in the context of VR. Mouse and keyboard as input devices finally seem fairly inappropriate, given the number of buttons and being unable to actually see them.

A great VRification example of a former-non-VR game is the DOOM VR demo showed at QuakeCon in late 2016 (ZeniMax Media 2016). In its fourth non-VR iteration, released in early 2016, DOOM had a great impact on first person shooters (FPS) by reviving some of the raw old school trademarks of the genre (Shoemaker 2016). The game is played really fast and the user is practically forced to quickly move into the middle of close combat to succeed (Shoemaker 2016). These are aspects not easily transferable to VR. Moving quickly through virtual space without creating simulator sickness has been a huge challenge so far. There are a plethora of methods handling locomotion based on teleportation, physical motion, room scale tracking (TechTarget 2016) and artificial input devices like common controllers (Reddit 2016). The FPS genre though, lacked an appropriate method, which could deliver a fast pace without creating vection and simulator sickness. The DOOM VR demo seems to have solved this, by implementing a subtly fine-tuned teleportation mechanic (Butterworth 2016). Using one HTC Vive controller to fire at enemies and the other to teleport-dash through space seems to even enhance the experience (Butterworth 2016). Though compared to other teleportation mechanics, DOOM slows down the game to bullet time, when holding the teleport trigger and when released dashes the user in super speed to where she or he was aiming (Butterworth 2016).

**Use Case: VRification of LizzE**

Designing an experience that makes the most of VR, former gameplay paradigms need to be adjusted or completely replaced. For example, in a vrified 3rd person game, the virtual camera(s) looking at a player character is not just a simple viewport into the digital world. By translating and rotating the point of view via the user's head position and rotation, it becomes a dynamic and controllable separate entity. We noticed this effect during the VRification development of LizzE – And the Light of Dreams (LizzE, FIERY THINGS 2013), a multiplatform third-person Hack & Slay game (see Figure 1, Wiedemann 2013).

In the game's non-VR version, the player looks through the screen into the game world and identifies her or himself with the player character, as she or he controls the character's movement and actions. Playing the VR version of the game, the entity split becomes perceptible. Without looking through a viewport and seeing what surrounds the screen, but instead feeling completely encapsulated in the virtual world and in natural control of the camera(s), the player acknowledges her or himself as a distinct entity. Dynamically hovering over the player character, she or he feels more like a god that rather guides the player character than actually identifies with it.

This raises lots of gameplay possibilities, like looking around corners, uncovering for the player character unreachable spaces and objects, but also new kinds of communications and interactions between player, player character, non-player characters (NPCs) and the game world. Interesting questions arise through this, like for example "Why is it, that I can control character XY?", "Am I perceptible to NPCs?" and "Could character XY turn against me at some point?".

On the other hand, LizzE uncovered that a more linear level design might be supportive to a third-person VR game (Hurd and Bettner 2014, Playful 2016 and Wiedemann et al. 2016). Furthermore, a completely different camera behavior is needed to avoid nausea through the reduction of vection. For this matter, in a previous experimental study with an adapted version of LizzE, we explored five different camera behavior modes and tested them with users. An analysis of the resulting data showed that the mode called Buffered Pulling (Wiedemann et al. 2016) seemed to be the most promising one for the game, compared to the other tested modes. In Buffered Pulling mode, the player character can move and turn completely freely in a buffer zone, without manipulating the position or rotation of the user's viewpoint (see Figure 2 and 3). Only when reaching a certain distance will the user's viewpoint get pulled along with the player character (Wiedemann et al. 2016).

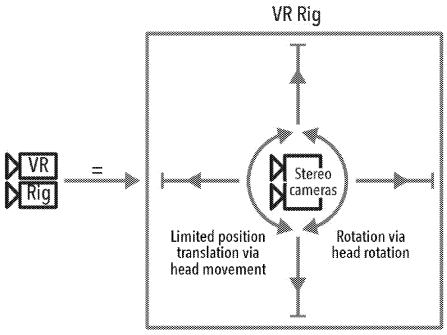



Figure 2: Explanation for VR Rig Symbol (Wiedemann et al. 2016)

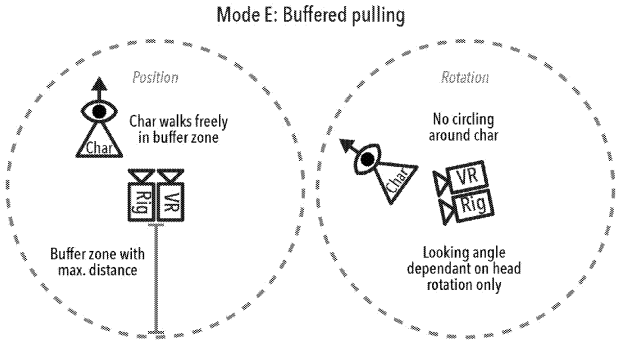



Figure 3: Buffered pulling Camera Behavior Mode Visualization (Wiedemann et al. 2016)

As the game's level design was not structured linearly like in Lucky's Tale for example, exploration in 360 degrees was required and thus the user had to physically turn, when in need of looking in a certain direction. Though this made the experience more like a stand-up or swivel chair one, most users favored this, as their natural movements added to their sense of presence (Wiedemann et al. 2016). Finally Buffered Pulling significantly reduced the vection effect and thus decreased the possibility for simulator sickness.

**CONCLUSION**

Concluding, a glorious and connected world of gaming in VR, like science fiction works of Stephenson, Vinge and Cline have propagated, is not easily established in practical terms. Though similarly inspired visions may already be in the making and definitely on the horizon, it seems questionable that "simply" porting existing games to VR will create good experiences. Addressing stereoscopic 3D vision (one aspect of VR) in game development, the well-known game developer Fish responded similarly: Stereoscopic 3D needs to be at the back of the developer's mind, right from the start, instead of trying to impose it on the game, once its conventional version is finished (Fish 2010). Still, in terms of former-non-VR games, technical challenges of changing existing application aspects have to be weighed against their inherent time-costs, to be adjusted or completely rebuild. We argue that games should be optimized for their technology platform and make use of the corresponding interface options in creative ways to be able to become spot on, well-made user experiences.

The pure-VR examples of this paper have shown great ways of handling VR pitfalls, by including VR in the development process right from the start. The decision to provide stationary jobs and a cartoonish visual style in Job Simulator (Owlchemy Labs 2017), did not require any possibly nausea inducing locomotion mechanic and reduced required computing performance, resulting in high framerates. Lucky's Tale (Playful 2016), on the other hand, implemented a very clever and fine-tuned combination of subtly linear level design and camera behavior. By comparison, vrifying LizzE definitely illustrated the need to specifically develop spot on solutions for problematic fields like camera behavior in VR and our Buffered Pulling mechanic seemed to be a viable solution for a game, in which users can explore in 360 degrees (Wiedemann et al. 2016). Additionally, it also uncovered the entity split and showed the great potential of VR in 3rd person games. In terms of FPS games, the DOOM VR demo finally not only seemed to have "solved" the locomotion issue, but instead simultaneously created a novel and attractive FPS gameplay and feeling.

As such, VRification, even of former-non-VR games, can work (e.g. DOOM, Butterworth 2016 and LizzE, Wiedemann et al. 2016), but only makes sense if the game design also advocates the new interface technologies and special care has been taken concerning the minimization of simulator sickness.

## FUTURE WORK

We argue, that major future research on VRification will be on several topics. Eradicating simulator sickness seems to be one of the most important issues. Taking performant game engines with high framerates and stable tracking for granted, this on the other hand involves identifying and fine tuning new locomotion input paradigms. Correspondingly, camera behaviors need to avoid creating nausea, while fitting the type of game, which should be vrified. Furthermore, we see a great demand in optimizing existing graphical user interfaces for VRification, or even replacing them by using novel paradigms to provide the inherent corresponding meta information to the user instead. This again is very dependent on the type of the game. A common collection of locomotion input paradigms, corresponding camera behaviors and well-working interface designs and mechanics still has to be developed through research and design. Finally, further research seems to be required to check for possible patterns in certain game types or genres, which show better prerequisites to get vrified, or the opposite.

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# ADAPTIVE HUMAN VISUALIZATION IN MEDICAL APPLICATIONS

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**KEYWORDS**

3D anatomy, visualization, medical data, simulation.

**ABSTRACT**

This paper presents a concept for adaptive virtualization of 3D scenes depicting human anatomy based on intelligent analysis of users' actions. The idea of human body simulation, digital prototyping and visualization is common in Science Fiction and inspired by the popular trends in human progress future vision and forthcoming IT technologies. The proposed solution implements control over the load of detail, which allows balancing the target goals of medical data visualization: performance, persistence, perception, and personalization. The example of implementation is given by an interactive computed handbook of anatomic charts.

## INTRODUCTION

Medical data is a major source of human health observation and at the same time a challenging object for visualization. The results of medical diagnostics, treatment and health care can be obtained using different devices that allow capturing and processing the laboratory results, recorded signals (e.g. ECG), pictures (e.g. radiology images), textual data, etc. The process of patient medical state monitoring requires presentation and analysis of a number of medical parameters and their change in time, which makes their visualization a complex technical problem.

Modern information technologies can solve it using graphical interfaces, display panels, visual dashboards, virtual and augmented reality devices and other innovations. Still the problem of effective, clear and obvious visualization of medical data enforces looking for new approaches of 3D visualization in practice. For example, there is a number of IT applications in medical diagnostics and education that require realistic virtualization and visualization of human body parts. 3D models of human body can be used to display the results of medical diagnostics in an informative way and simulate medical treatment like e.g. surgery intervention for better decision-making support.

The idea of human body simulation, digital prototyping and visualization is common in Science Fiction and inspired by the popular trends in human progress future vision and forthcoming IT technologies. Still its implementation in practice is concerned with a challenge to provide both high reality of anatomic 3D scenes together with high performance that allows functioning in real time. In this paper it is proposed to solve this problem by adaptive virtualization of 3D scenes based on intelligent analysis of users' actions.

## STATE OF THE ART

Major modern trends of medical data visualization are widely explored in (Holzinger, 2014, Sturm, 2015). It is noted that the main goal of medical data visualization is to combine several data sets to analyze multiple layers of a biological system at once. The system should interlink all related data sets (e.g., images, text, measured values, scans) and offer visual analytics to support experts. This approach supports the idea of maximum effective visualization of complex medical data for medical professionals instead of automatic decision-making.

This concept gains a foothold and is taken further in (Holzinger, 2016). In this paper there is presented the "human-in-the-loop" approach, according to which the humans (decision makers) are not only involved in pre-processing, by selecting data or features, but actually during the learning phase, directly interacting with the algorithm. The main reason is that in case the set of medical parameters needed for decision-making is big in size and various in type, it becomes problematic to present them in a single picture. Therefore it is proposed to involve the decision maker into the process of data processing and visualization by means of continuous interacting with the system, which helps optimizing the learning behavior of both humans and algorithms.

The idea of deep involvement of actors or subjects in business processes organization and management is studied in S-BPM concept (Fleischmann, 2015), which conceives a process as a collaboration of multiple subjects organized via structured communication.

Consequently medical data should be considered as Big Data (Bessis, 2014). Addressing the multiple-V problem of Big Data analysis and visualization there can be formulated a 4P goals problem of medical data visualization:

- Performance: 3D picture should be processed and visualized in real time using preferably personal or mobile hardware;
- Persistence: separate parts of one picture should correspond to each other with minimum conflicts, caused by data variance, but not data format difference;
- Perception: the picture should be understandable and explicitly interpretable by the user;

- Personalization: the picture should adapt to personal particular aspects of behavior in terms of cognition, knowledge and skills.

Multi-agent technologies (Gorodetskii, 2012) that implement interaction of software and human actors with autonomous behavior using ontology as a knowledge base provide developing the intelligent solutions that meet the specified requirements. The virtual world of 3D scene can be modeled and built as a complex network of continuously running and co-evolving intelligent agents. Such solutions are based on bio-inspired approach (Leitao, 2009) that supports fundamental mechanisms of self-organization and evolution similar to living organisms.

The mentioned above principles should be considered in medical applications that require visualization of a human body. To balance high performance and adequacy of the presented picture the visual scene should adapt to user's behavior considering the human and time factor. The first research results in this area were presented in (Ivaschenko, 2013, 2015, 2016). There should be also mentioned a 3D web-based anatomical visualization tool using virtual reality (VR) technology (Said, 2015).

Within this context the term "adaptation" describes the possibility of scenarios to consider random factor and users' progress and evaluate accordingly. This allows introducing computational complexity optimization. At the early beginning of simulation not all the models with maximum detail are loaded, but only those that are contextually required. Later with user's intervention progress the detailed models are uploaded instead of simple duplicates, which allows simulating more complicated surgery. This logic is described by "Level of detail (LOD)" term, which comes from computer graphics (Glander, 2009, Lemmens, 2011, Biljecki, 2014) and described the process of decreasing the complexity of 3D models representation as it moves away from the viewer or according to other metrics such as object importance, viewpoint-relative speed or position.

## ABSTRACT MODEL OF ADAPTIVE HUMAN VISUALIZATION

In medical applications the human body is represented by 3D models with realistic appearance and possibility to interact with surgery instruments (see Fig. 1). The inner parts of human body are simulated in the scene by soft body models and surgery instruments are simulated by rigid bodies. These models are fashioned with the help of specifically designed shaders and algorithms that simulate jars, liquids and blood.

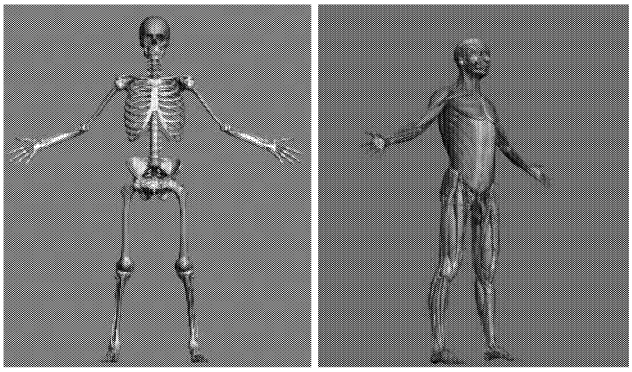


Fig. 1: Anatomic Models of Human Body

In addition to realistic anatomy modeling there is a necessity to simulate the changes of human body parts, breathing, bleeding etc. According to the proposed approach the topology of human body parts is simulated by the 3D scene that contains a combination of 3D models that interact with each other. In order to add dynamics to this model there is proposed an ontological approach based on scenarios description.

To provide adaptive human visualization the model should consider the information about the users behavior captured in the form of actions order and parameters. To reach these goals the simulation scenario must be described using the machine-readable language, so the specialized knowledge base must be created. The knowledge base must contain the information about the simulated objects themselves (behavior aspects of surgery instruments, aircrafts, valves etc.) and the possible interaction aspects between the user and the modeled objects.

Let us consider a 3D *scene* denoted by $z_k$ where $k$ is the identifier of the scene. The scene contains virtual *objects* that we will denote as

$$b_{k,m}, \text{ with } m = 1..N_b(z_k). \quad (1)$$

Every scene object has its 3D visual representation and a set of physical *attributes* which we will denote by

$$a_{k,m,n}, \text{ with } n = 1..N_a(b_{k,m}). \quad (2)$$

Physical attributes are changed during the simulation according to the transformation:

$$\psi_{k,m}(\Delta t) = \psi(\{\{a_{k,m,n}\}, \Delta t\} \rightarrow \{a'_{k,m,n}\}). \quad (3)$$

Now we can define the scene as a set of objects and their attributes:

$$z_k = \{\{b_{k,m}\}, \{a_{k,m,n}\}, \{\psi_{k,m}\}\}. \quad (4)$$

Depending on the boundary values of objects attributes, the scene may be in one of the *states*. We consider the elementary states denoted by $h^0{}_{k,m,w}, w = 1..N_{h^0}(b_{k,m})$ which describe the single object's behavior aspect (i.e. "organ damaged", "organ not damaged") and the composite states de-

noted by $h_{k,m,w}, w=1..N_h(b_{k,m})$ which describe many aspects of object's behavior and are composed from the elementary ones. The superposition of all objects states on the scene is called the scene state and denoted the scene state and is denoted by $s_{k,j}$.

The scene can change its current state during the visualization. The transitions between the scene states will be denoted by:

$$v_{k,j_1,j_2} = v\begin{pmatrix} s_{k,j_1} \to s_{k,j_2}, \\ \{a_{k,m,n}\} \to \{a'_{k,m,n}\} \end{pmatrix}, \quad (5)$$

where $\{a'_{k,m,n}\}$ are the new values of scene objects attributes. The transition between the scene states occurs as a reaction on user actions or as a reaction on some internal event. The same scene state transitions may be triggered by different user actions.

In general, to model the organs behavior realistically the function $\Psi_{k,m}(\Delta t)$ includes the complex transformations requiring much computation power. As an example, to model the realistic behavior of a gallbladder the thickness of it's shell and the non-uniformity of it's internals must be considered. To improve the computational efficiency several different 3d-models may be used instead of a single universal one (considering all real behavior aspects). These models differ in terms of level of detail (LOD) and can be adaptively selected based on the current scene state and events set.

In the rest of this section we propose the extension to out model that allows us to implement such behavior.

The scene object will be denoted as $b_{k,m}, m=1..N_b(z_k)$. Each object can have one or several levels of detail denoted as $\xi$. The attributes set will now be associated with the particular LOD instead of being associated with the body in common. The attributes set associated with the particular LOD will be denoted as:

$$a_{k,m,\xi,n_\xi}, \xi=1..N_\xi(b_{k,m}), n_\xi=1..N_a(b_{k,m},\xi). \quad (6)$$

Current LOD $\xi$ can be changed to the new LOD $\xi'$ in result of emitting events on the scene. This results in attributes set changes. The attributes that belong to the both levels of detail are leaved unchanged. The attributes associated only with the new level of detail are calculated based on the values of the old level of detail attributes set. In common, the transformations set is defined for every object:

$$\varphi_{k,m}(\xi,\xi') = \varphi(\{a_{k,m,\xi,n_\xi} \to a_{k,m,\xi',n_{\xi'}}\}). \quad (7)$$

These transformations map the attributes values of $\xi$ to the attributes values of $\xi'$ after changing the current LOD.

Considering $\xi$ we will rewrite the expression for $\Psi_{k,m}(\Delta t)$:

$$\Psi_{k,m}(\Delta t,\xi) = \Psi(\{\{a_{k,m,\xi,n_\xi}\},\Delta t\} \to \{a'_{k,m,\xi,n_\xi}\}). \quad (8)$$

The expression for scene will be rewritten as:

$$z_k = \{\{b_{k,m}\},\{a_{k,m,\xi,n_\xi}\},\{\Psi_{k,m}\},\{\varphi_{k,m}\}\}. \quad (9)$$

The proposed model extension allows to describe the object's behavior with several levels of detail in a generic way. It also allows to describe the "seamless" transitions between the different LOD's because it defines the transformations between the attributes values on different levels.

We also need to extend the logical part of our model since the objects interactions are described using scenarios. Considering changes introduced to the scene we extend the transition between scene states introducing the transition between level of details:

$$v_{k,j_1,j_2} = v\begin{pmatrix} s_{k,j_1} \to s_{k,j_2} \\ \{a_{k,m,\xi,n_\xi}\} \to \{a'_{k,m,\xi,n_\xi}\} \\ \{\xi_{k,m}\} \to \{\xi'_{k,m}\} \end{pmatrix}. \quad (10)$$

For every LOD of the scene object we have the separate states set described. The states in one of these sets are independent from the states in all other sets, i.e. the state "organ is bleeding" on LOD 1 and the similar state "organ is bleeding" on LOD 2 are completely different states.

The proposed model extension allows to produce more computational efficient educational cases comparing to the original model. As an example, let us consider the simple abstract operational case. In the initial state all organs are in the rest state and are not moving. We do not need to physically simulate such behavior so on the first LOD we can model the objects as a static 3D model. When we touch the organ with an instrument it is deformed and it's parts start to move. We have to use the soft body dynamics to simulate this movement. The static vertices positions of the original static model are translated to the positions of dynamic vertices of the physical tetrahedral grid using $\{\phi_{k,m}\}$ and the first LOD is switched to the second LOD. On this level of details the transformation $\Psi_{k,m}(\Delta t,\xi)$ considers the spring forces between the vertices and models the deformation. But we still do not need to know the internal structure of the organ so it can be modeled only statistically. When we make a cut on the organ we can see it's internals, so we need to use the third LOD, where all internal details are modeled precisely. The positions of soft body vertices are used to initialize the initial values of internal forces in the organ using $\{\phi_{k,m}\}$.

It must be considered that the transitions between LOD's are not always bidirectional. In the example above the transition between the first and the second LOD's is bidirectional, i.e. when the instrument leaves the operational area, the organ will come in the rest state. After that we do not need to simulate the soft body behavior and we can use the first LOD again. Obviously, we need to translate the attribute

values of the second LOD to the attribute values of the first LOD. But when we cut the organ and go to the third LOD we can't return to the second LOD because it results in unrealistic and unexpected behavior.

## HUMAN BODY SIMULATION WITH ADAPTIVE VISUALIZATION

The example of human body 3D visualization is its simulation in computed handbooks of anatomic charts, surgery training suites, intelligent software for surgery decision making support, etc. The project is carried out at Samara State Medical University and results in a unique set of anatomic models of human body parts.

There were designed, developed and conjoined up to 4000 full-size 3D human body visualization model models combined to 12 layers, including the ligaments, intraorganic structures, blood vascular system, innervations system, outflow tracts, lobar and segment structures of internals. There is a possibility of a virtual dissection. Various levels of detail are accessible within a 3D body model in interactive mode. The developed database includes 100 standard pathologies. There is a possibility to compare paired organs, normal and pathological condition, various pathologies. 3D objects selected for comparison are provided with descriptive texts, photos and videos.

The models were designed using real digital volume computer tomography and magnetic resonance tomography images. Some models were developed using 3D-scanner Solutionix Regscan III with prost processing using 3D editor Autodesk 3ds Max and Autodesk Maya. 3D models visualization was implemented using Unity game engine (unity3d.com).

As a result there were worked through a number of atlases addressing different aspects of human anatomy:

- Generic (systemic) anatomy;
- Topographic (regional) anatomy;
- Pathologic anatomy;
- Physiology;
- Histology (microanatomy).

The models of adaptive visualization based on managed load of details were used to implement partial load of 3D scenes and dramatically increase the number of possible visualization options for male/female models, pathologies and specific views. The examples of 3D models and fragments with detailed visualization are presented in Fig. 2 – 4.

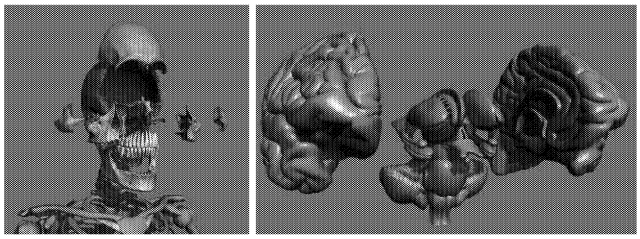


Fig. 2: Head and Brain Details

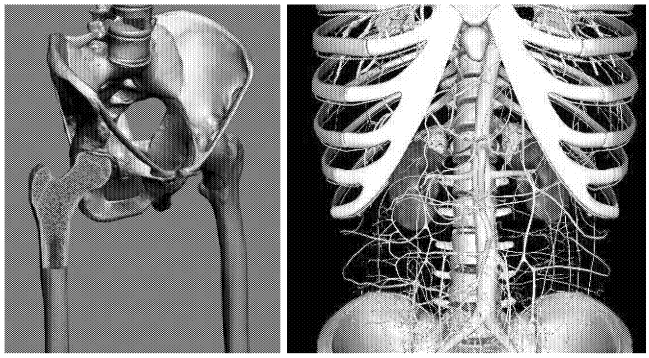


Fig. 3: Bones and Vascular System Details

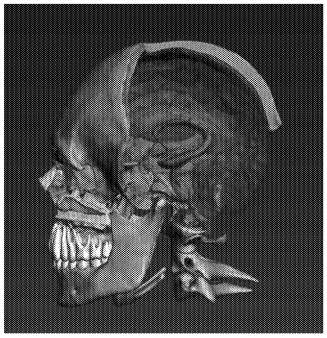


Fig. 4: Brain Detailed Visualization

The requirements of high realism and consistency specific for 3D models of human bodies used in virtual simulators lead to a technical challenge of interoperability. Human body parts and systems introduced by different developers and implemented in various simulation solutions should be compatible and interchangeable. The solution was made to develop several versions for different types of body constitution considering possible pathologies. To reduce confluence and overlapping blood-vascular and excitatory (nervous) systems were designed in correspondence to other internals.

The existing 3D models are supplemented with the results of real digital volume computer tomography and magnetic resonance tomography images (see Fig. 5). This example illustrates how carious medical data can be visualized in a single complex picture. On the contrary, 3D models can be constructed o the basis of CT and MRT results of the specific patient individually. This approach is used for detailed diagnostics and surgery simulation as part of decision making support. The results of virtualization and 3D visualization of the individual model is given in Fig. 6.

Adaptive visualization in real time is also required in surgeon decision making support in the process of surgery intervention using Virtual Reality headset. Intelligent scheduling is performed on the basis of personalized 3D models of human body derived from individual digital volume computer tomography and magnetic resonance tomography images. The VR based system for decision making support provides the unique functionality of surgery simulation and control in real time that helps reducing the time of intervention and risks of postoperative complications.

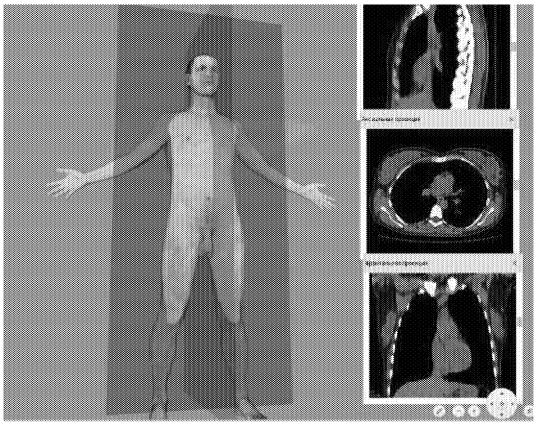


Fig. 5: CT and MRT Images

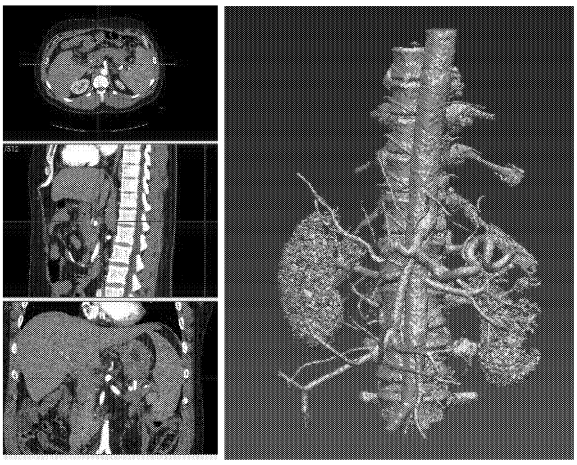


Fig. 6: Individualized 3D Scene Reconstruction

## IMPLEMENTATION

The proposed approach balancing the 4P target goals of medical data visualization: Performance, Persistence, Perception, and Personalization. The example of successful implementation of it in practice is "Inbody Anatomy" anatomic atlas that can be used in "Pirogov" Interactive 3D anatomy study table (see Fig. 7). This solution (http://www.nash-pirogov.ru/en/) is an interactive software implementing a clear-structured natural science study program for undergraduate and graduate medical specialists, including such study fields as applied anatomy, morbid anatomy, forensic medicine, surgical studies, ophthalmology, human virtual dissection, otorhinolaryngology etc. This software as the surgeon guide allows building a complete study cycle, starting from entry level anatomy studies based on visual and descriptive materials, to knowledge assessment and automatic test results control.



Fig. 7. Adaptive Visualization by 3D Anatomy Study Table

The described models processing and display is based on the common principle of adaptive visualization. In addition the basic software there is introduced an intelligent module that monitors and captures the user's behavior and operates the visualization procedure. The displayed scene options are presented in knowledge base in the form of a semantic network that describes 3D models of human body parts with different granularity. These 3D models have different level of detail (LOD) and are interchangeably loaded to visualization scenes, which leads to high adaptation of them for each user individually. This allows decreasing the computational complexity of 3D models processing in real time.

## CONCLUSION

The proposed approach of adaptive visualization of human body can be used in different medical applications of diagnostics, monitoring and health care. Based on LOD control it provides the managed complexity of the displayed 3D scenes that allows effective balancing the 4P target goals of medical data visualization: Performance, Persistence, Perception, and Personalization. The provided examples illustrate the benefits of the proposed solution in practice. High perspectives of the proposed approach in medical applications motivate further developments in this area.

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# APPLICATIONS OF 3D-MEASUREMENT FOR PROCESS INNOVATION

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**KEYWORDS**
Planning and control, 3D-Measurement, Process-Integration, Logistics, Forming

**ABSTRACT**
This paper presents an innovative approach to 3D measurement based on Multi-Camera-System (MCS) and the principles of stereophotography and fotogrammetry to generate three-dimensional point clouds. The presented system is modular and can thus be integrated into production lines, while allowing a high measurement speed and accuracy. Due to these specifics the system and the generated 3D-data can be used as base for various tasks, of which two are presented.
The first part of this paper describes the system, while the second part gives an overview on possible applications which are currently being developed.

## INTRODUCTION

The society and nearly all aspects of living are evolving steadily, driven by global phenomena and the resulting megatrends. This results in a multitude of novel requirements, but also technological solutions for modern products and processes, which would not have been viable a few years ago. Delivering high-quality products has become a crucial competitive factor in a globalized world, which increases the importance of quality management due to the increased global competition modern companies have to face. This aspects importance increases, as globally operating companies do not only sell their products in different markets, but also have local production facilities and supply chain networks around the world. Therefore, it is necessary to develop smart connected systems, able to work along the whole value chain.
To reach the required high quality levels in every production facility, strict and reliable quality controls are necessary. For this the actual measured values of a produced good have to be compared to the required reference values. Modern 3D-measuring systems can be used to generate three-dimensional models, which can be used for quality control, but also for other tasks such as product identification. These models can further be used for applications along the whole product lifecycle. Which leads to a further merge of the real and the virtual world.

## PROCESS OF OPTICAL 3D-MEASUREMENT WITH A MULTI-CAMERA-SYSTEM

In most production lines, a documented and secured method of quality management is essential. To achieve this there are generally two different methods of 3D-measurement: contact (mechanical) and non-contact (optical) measurements. As modern processes require a swift solution for quality control, the practical applications of optical systems have shown its advantages in comparison to their mechanical counterparts. As the general focus with these systems is laid on measurement speed and accuracy, 3D-measurement systems based on an optical MCS, which use the procedures of stereo photography and photogrammetry, appear to be promising options. The MCS is a multi camera system with a patent-pending matrix of stereo camera units, which are arranged in pairs. Each stereo camera unit consists of two cameras and one projector (Figure 1) which generates a three-dimensional point cloud as result of the measurement process. With this device it is possible to conduct three-dimensional surface and geometrical measurements, even on large objects with high precision in the measurement process and without the need for any mechanical movement. (Schumann et al. 2013)

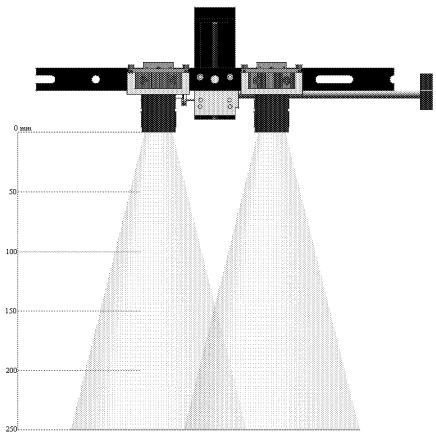


Figure 1: Stereo camera module

The size of the measuring space can be adapted arbitrarily due to the freely selectable number of the stereo camera units. The controlling unit calculates a point cloud, with an arithmetic procedure based on the results of the stereo photography and ensures an accuracy of 30 – 40 µm throughout the whole measuring area at a high measuring speed. (Schumann et al. 2015)

## INTEGRATION IN PRODUCTION LINES

The performance of modern production plants is improving steadily. In the context of „Industry 4.0" the focus of production is increasingly set on individual products, improving efficiency and high-quality standards (Lasi et al., 2014). Due to changes caused by the increasing automation and robotization new innovative solutions in quality management are required. For reducing the amount of defective goods and failure costs, it is necessary to implement a continuous quality management system, which is integrated in the production line. The main goal is the identification of deviations from the quality standard as early as possible and to intervene in the process accordingly. Therefore, a measurement system that can be integrated in the production process - such as introduced in this paper - is particularly usable and allows the measurement of each produced part.

The process-integration of 3D-measurement comes along with the following advantages:

- Immediate root-cause analysis in case of quality problems
- Direct comparison of measurement data with 3D CAD reference data
- Reduction of time and labor for quality management processes due to high measurement speed, reduction of scrap and rework due to automated analysis
- Increased process performance due to continuous quality control in manufacturing
- Process performance will be more stable and robust with consistently higher quality. (Schumann et al. 2013)

Due to the integration of the 3D-system, the surface of the parts that are to be measured is captured and the measured data is compared to reference data (e.g. CAD). Thereby, the visualization of variations and thus the detection of faulty parts or sub-areas is possible. (Schumann et al. 2015)

For subsequent steps there are various opportunities to visualize the measured 3D-data and generated models via Augmented or Virtual Reality (AR/VR). Related research of the authors is engaged in the possibilities of Augmented Reality for maintenance applications (Clauß et al., 2015) (Forkel et al., 2014) (Clauß et al., 2014) (Götze et al., 2014).

## APPLIED RESEARCH & DEVELOPMENT

### 3D-Measurement in Forming Processes

Production processes in the automotive industry require a multitude of measurements for single components and the finished products. As a quality control for each part with currently used measurement systems appears to be lacking economic feasibility, due to the missing possibilities for process integration, these measurements are usually carried out with the application of sampling methods and the inspection of single parts from a batch.

However, especially the manufacturing of car bodies, usually accomplished by forming processes, would require the control of every produced part, as the increasing utilization of light metals, such as magnesium due to its advantages in terms of weight and stiffness, results in more challenging and thus increasingly fault-prone process due to the process specifics necessary for forming these materials. (Kulekci, 2008) (Mordike and Ebert, 2001)

These issues are being addressed in an interdisciplinary research project between the faculties of business science, engineering and informatics. The goal of this project is the creation of a concept for utilizing 3D-measurement data for quality control in magnesium forming processes.

This is achieved by using the deviations between the measured values and a reference model are used to identify faulty work pieces. Based on the qualitative data from a previously prepared Failure Mode and Effects Analysis (FMEA), occurring failures could be linked to their roots. (Bouti and Kadi, 1994) (Segismundo and Miguel, 2008) This knowledge allows the definition of various zone of interest on the surface of the magnesium work piece, such as the overall surface geometry or edges and folds.

These zones as well as the knowledge from the FMEA can be used as knowledge base for a rule-based-system. (Grosan and Abraham, 2011) (Jones, 2008) (Negnevitsky, 2002) The first step for the application of this system is the identification of a deviation of values between the reference model and the measured data. Once a deviation has been detected, the system would use the predefined zones of interest, to locate the fault. Based on the information from the FMEA, the manifestation of the fault can be further examined, which allows the identification of its roots.

As soon as the roots have been identified, the system will be able to send an information about the fault identification and the necessary maintenance steps to the relevant positions, which allows a swift removal of defects within the production line and thus helps to reduce the amount of defective goods and based on this the waste of energy and other resources.

### Identification of Products and Parts in Logistics

The application of 3D-measurement in a company's intralogistics, but also the logistics sector as a whole, is another promising field of research and application, as the modular structure of the presented system allows the identification of components and products based on their possibly complex surface and shape.

This approach is currently tested in a research project with the focus on developing an automated sorting plant for various types of wooden pallets.

As wooden pallets consist of multiple, damageable parts it is necessary to examine them individually in order to prevent the shipping of defective pallets to a logistic company's customers. The necessity for this sorting plant is caused by a growing number of disposable pallet types for various applications and the resulting amount of possible error patterns, which previously had to be located manually.

The innovative part of this sorting plant is based on the combination of a 3D-measuring unit and a knowledge-based process control system. Stacks consisting of various pallet types are transported to the plant, where each pallet will be measured by the 3D-measuring unit. In the following step, the measured data is compared to various predefined reference models, which allows the precise identification of the measured pallets type, by comparing the pallets shape, dimensions and the number of identifiable parts such as planks and blocks with the reference values (Figure 2).

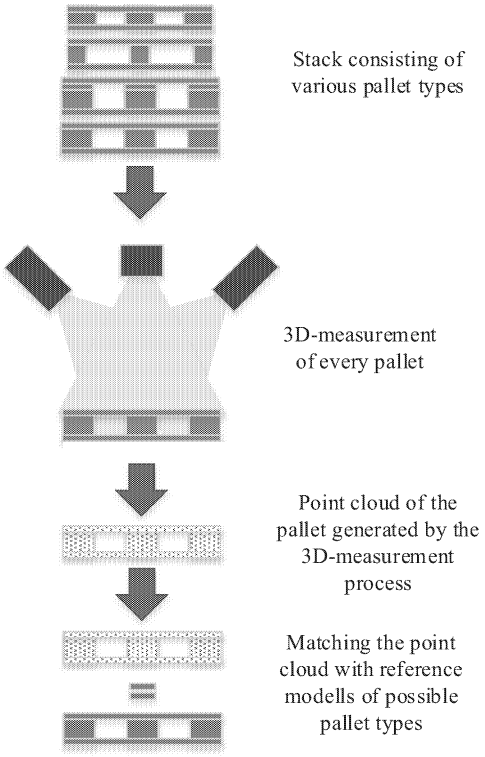



Figure 2: Schematic depiction of the pallet identification process

Additionally, the comparison of these values allow the identification of damaged parts, as soon as the determined differences cross specific tolerance ranges, which in turn allows the system to inform workers about the defect, while giving them instructions on possible repair steps and solutions in the same turn.

According to the identified pallet type and a possible damage, pallets will afterwards be sorted on type-specific stacks, from where they can be transported to their destination within the storage area.

The utilization of this storage plant will allow an efficient identification of a multitude of pallet types, with the additional benefits of identifying defects and aiding workers in resolving them, which results in an increased feasibility for the reutilization of disposable pallets and thus reduced costs and a more sustainable approach. The system will also reduce the amount of physical workload for the workers that previously had to examine the pallets manually, including lifting and turning steps for each pallet.

## CONCLUSION

This paper gives an overview on the subject of a 3D measurement system utilizing the concepts of stereo photography and photogrammetry within a Multi-Camera-System. This system can be integrated into production lines or used in logistical processes, where its application will lead to advantages in regards to an easier and more efficient quality control, the possibility for root-cause analyses in case of a detection of faulty parts and thus a reduction of scrap.

Due to its modular nature, this system can be used for various applications such as quality control, the process integrated detection of faulty products, as well as the identification of components or products in the logistics sector. The presented research projects give an insight into the various application possibilities for this system and the generated measurement data.

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