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A photograph of a large, leafy tree standing in a field of tall grass. The sun is low on the horizon, creating a warm, golden glow and casting long shadows. The sky is a mix of blue and orange.

# GROWING KNOWLEDGE FOR GAMES

*RESULTS FROM THE GATE RESEARCH PROJECT*



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# LOOKING AT THE FUTURE OF GAMES



The goal of the GATE project (Game Research for Training and Entertainment) is to develop awareness, insight and technology that can be used both in the entertainment gaming industry and in the serious gaming industry, with a special focus on learning and training experiences. Success factors for effective gaming and training transfer are:

- Realistic and challenging problem situations and scenarios.
- Realistic behavior of computer controlled entities.
- Realistic modeling, visualization, and simulation of the environment.
- A high level of interaction.
- Options for analysis of skills, effectiveness of procedures, fitting with training goals.

This is an implementation of the research agenda originally set up by the founding fathers of GATE: Jeroen van Mastrigt-Ide (Utrecht School of Arts), Mark Overmars (Utrecht University), and Peter Werkhoven (TNO). Under the strong but open directorship of Mark Overmars (listed by the magazine *GameDeveloper* as one of the fifty most influential game developers in 2010), the project took off. Three strands of activities flourish in pushing game technology forward: pilot projects, research work packages, and knowledge transfer projects. This resulted in a diverse, multi-faceted project, see the GATE movies (to be found at <http://gate.gameresearch.nl/>).

This is the GATE way: a lot of freedom to excel in many different ways, without much overhead and interference, but with supporting organization and dissemination activities. The project has impact by its research results, which find their way into knowledge transfer projects, stimulated by the pilot projects.

## IMPACT

The four research themes (Modeling the virtual world, Virtual characters, Interacting with the world, Learning with simulated worlds) resulted in many scientific papers, conference contributions, and nineteen PhD positions. Five pilots have been developed in the areas of education, health, and safety. Fifteen knowledge transfer project valorized the developed knowledge and software, leading to innovation in the Dutch game industry. In this booklet, *Growing Knowledge for Games*, we get a glimpse of the project results, an idea of the potential and achievements of games, and a foresight of future challenges and impact.

The GATE project ran from 2007 till 2012. Its role in stimulating research and innovation in gaming will be continued by the planned innovation network GATHER (GAMES for SafeTy, Health, Education, and IndustRy), which will address many exciting questions. How will game technology help address the grand challenges for our society? What is needed for creating engaging virtual worlds, populated by meaningful virtual characters, which initiate natural interaction, and result in effective transfer of gaming? I look forward to the future of games.

*Remco Veltkamp, Utrecht University  
January 2012*

Remco Veltkamp is professor in Multimedia at Utrecht University, working on developing new technologies for the analysis of 3D scenes, video, images, and music, and teaching in game and media technology. He was director of GATE since 2011.

# RESEARCH PROJECTS

## INTRODUCTION

**T**he feeding element of innovation within the GATE project is the research program. The goal of the research is to substantially advance the state-of-the-art in gaming, simulation, and virtual reality to creating highly effective entertainment products and experience learning systems. In the research program the complementary and multidisciplinary knowledge of the partners is combined. The goal is to increase the international research position by a unique combination of fundamental research and application development and to attract excellence by creating a stimulating environment and a concentration of talent, best students and best professors. There are four research themes:

1. Modeling the Virtual World, on techniques for semi-automatically creating convincing and engaging virtual worlds that can be used in games.
2. Virtual Characters, dealing with the creation of realistic behavior for the virtual characters that inhabit the virtual worlds and games.
3. Interacting with the World, about novel interaction techniques that will improve the way users can steer their games.
4. Learning with Simulated Worlds, studying how games and virtual worlds can best be used for training and education.

# SENSE, MAKE SENSE, GAME!

## SENSE, MAKE SENSE, GAME!

CREATING GAME WORLDS FROM REAL WORLD SENSOR DATA

IN A FEW DAYS AN IMPORTANT EVENT WILL TAKE PLACE DOWNTOWN. THE SITE HAS BEEN SURVEYED EXTENSIVELY WITH SENSORS. WITH A ONE-TOUCH OPERATION THE SENSOR DATA IS TRANSFORMED INTO A GAME WORLD FOR REHEARSAL...

Serious gaming with a virtually replicated real world scene can help first responder units and other security personnel in the preparation for major events. Likewise, many other serious gaming applications can be thought of when an accurate reconstruction of a real world scene can be obtained quickly and at low cost. To get to this point, methods and techniques are required that transform raw sensor data like photo images and laser range measurements into fully functional game worlds.

### SMALL PIECES MAKE A LARGE PUZZLE

Getting the full pipeline in place that automatically reconstructs real world scenes into game worlds is like working on a large puzzle with many small pieces. With the GATE research results we have provided some valuable pieces to the puzzle.

### ROBUST IMAGE ALIGNMENT

Often, the reconstruction starts with a set of photo images from the scene. The first step is to align the images. We need to know the exact position and orientation of the camera for the various images as well as the camera calibration data. These can all be computed by analysing the images, starting with the identification and matching of key points within the images. We have studied various key point matching algorithms, with a focus on robustness when photos to be

matched look from largely different angles on the scene. We have studied improvements on existing algorithms and have shown that algorithms that account for perspective distortion as well as colour characteristics of the scene, perform best. (Figure 1)

### POINT CLOUDS

After images have been aligned properly, photogrammetric techniques are available that measure 3D points in the scene, resulting in so-called point clouds. Alternatively, these point clouds can be obtained by laser range measurements. In both cases, huge sets of 3D points are computed. These point clouds are the basis for automatic scene reconstruction. The key to success is to have methods that automatically make sense out of this bulk of data that - for a human - may seem an obvious representation of the real world, but for a computer is just a set of unrelated points. (Figure 2)

### FITTING SURFACES

Part of our research has focused on the fitting of flat surfaces to point clouds that represent urban scenes. Since urban scenes exhibit a large amount of simple - often rectangular - flat surfaces, methods to find these surfaces can significantly contribute to the analysis of urban point clouds. We developed a novel method - the so-called guided  $\alpha$ -shape method - that finds subsets of points that define a flat surface in the

scene. Our method is guided by information from surrounding surfaces to optimize the boundary of a surface. This ensures that neighbouring surfaces are well-connected, even when data is missing for certain parts of the scene. (Figure 3)

### MAKING SENSE

Finding points and surfaces is not sufficient. We need to know more to build a true game world. We need to know the semantics of the world: what kind of objects are in the scene, what are their characteristics and how do they relate to each other?

We have demonstrated methods that automatically make sense out of satellite imagery. A complete game world has been derived from a single image pair without any manual editing of the model. Statistical methods based on spectral and geometrical properties of objects were used to identify features like buildings, roads and vegetation. (Figure 4 & main image)

### WAY AHEAD

The way ahead is set by finding more techniques to transform point clouds into a set of well-defined semantically rich models. Models for which not only geometry and appearance is known, but also function and behaviour. This will enable fully functional game worlds, served by a one-touch transformation of sensor data: sense, make sense, game! •



Figure 1

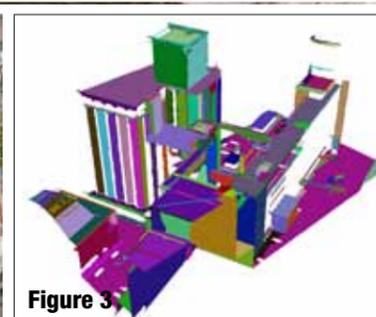


Figure 3

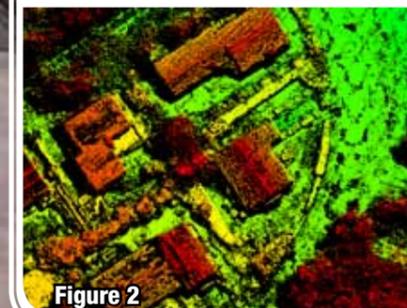


Figure 2



Figure 4

### SUMMARY

Among the many challenges in the pipeline that transforms sensor data like photo images and laser range measurements into fully functional game worlds, GATE has contributed on three of them. We have shown how the alignment of photos from different (large) view angles on a scene can be made more robust with improved image descriptors. Secondly, we have introduced a novel method that extracts flat faces with a well-defined boundary from point clouds, a useful method for the reconstruction of urban scenes. Lastly, we have demonstrated methods that extract semantic features like roads, vegetation and buildings from satellite imagery.

### CONTACT

**Frido Kuijper** is a senior research scientist at TNO, a Dutch research institute. He has 20 years experience in the field of modelling and simulation. Currently, he is the lead scientist for TNO in research that aims at the generation and application of synthetic environments for simulation and gaming applications. Frido has been the lead for the GATE team of TNO and Utrecht University that worked on real world modelling.



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VIRTUAL WORLD CREATION MOSTLY STARTS WITH DESIGNERS SKETCHING THEIR VISION, AND PROCEEDS WITH MONTHS OF MANUAL 3D MODELLING AND FINE-TUNING OF ALL ITS TINY DETAILS. NOVEL MODELLING, SOLVING AND INTERACTION TECHNIQUES CAN SPARE MUCH OF THIS ROUTINE WORK.

Nowadays, a large part of game development budgets is spent on designing virtual worlds. However, as virtual worlds become larger, more detailed and life-like, two challenges are becoming apparent. First, the effort required to model all that content by hand becomes simply too large. There are various techniques for (semi-) automatically creating digital content but, unfortunately, most tools currently available for these purposes offer designers very little control and hinder them to express their ideas. Even worse, these tools are typically quite complex and require in-depth knowledge, being therefore unsuitable for non-experts. Second, the complexity of integrating such a huge variety of content in a virtual world is increasingly high; and the same can be said of maintaining its consistency throughout the design process. This, for example, makes it impractica-

ble to modify parts of the virtual world at a later stage, even though there might be good design reasons to do that.

#### DECLARATIVE MODELLING

We developed an intuitive content generation approach that allows designers to interactively create their virtual world. This approach is called declarative modelling of virtual worlds, and it lets designers focus on what they want to create, instead of on how they should model every tiny detail of it. Ultimately, it enables designers to really concentrate on their irreplaceable creative role, by liberating them from distracting and tedious modelling tasks.

A striking feature of declarative modelling is procedural sketching. It substantially automates virtual world creation by using a rough sketch as input, just like anyone would do when drawing a simple map on paper: you paint the

areas containing mountains, hills, deserts, and the like, you schematically draw rivers and roads on the map, and you sketch outlines of forests and cities. Meanwhile, as you sketch each virtual world element, its details are automatically generated to create a realistic terrain feature. Eventually, when you are satisfied, your sketch has been automatically turned into a complete 3D virtual world. Moreover, all these features are generated so that they fit each other and are consistent with their surroundings. For instance, a road's embankment is integrated in the landscape, and when it crosses a river, an appropriate bridge is inserted in place. Procedural sketching and many other declarative modelling features were implemented in our prototype system SketchaWorld. (See [www.sketchaworld.com](http://www.sketchaworld.com) for more details).

One of the main challenges of the it-

erative nature of design is to maintain virtual world consistency, e.g. by preserving past manual changes whenever an area is modified or re-generated. Declarative modelling of virtual worlds has the potential to seamlessly integrate procedural sketching and manual editing, enabling designers to iteratively and freely experiment, eventually creating the virtual world that precisely matches their intent.

#### SENSIBLY STUFFED GAME WORLDS

Another important feature of our declarative modelling approach is that virtual objects are enriched with semantics, i.e. information about their functionality and roles, including relationships to other objects. We developed layout solving methods that use these semantically-rich objects to automatically produce realistic layouts for virtual environments, e.g. building

interiors, gardens or city streets. Using an intuitive scene description language, you can specify how a particular scene should be populated, e.g. which objects you would typically find in it, and how they should be placed around. Based on these descriptions, the semantic layout solver can, for example, generate an entire office building, complete with hundreds of different offices, meeting rooms, common areas, etc. Eventually, every such environment can also be automatically refurbished and decorated by applying so-called semantic filters. These filters can further help customize virtual worlds, for example to make a street look vandalized, make a living room appear like after a party, or make a building look old and deteriorated.

#### SMART OBJECT BEHAVIOUR

Using the above descriptions and layout solver, level designers can quickly

create consistent virtual worlds. And once these already contain semantically-rich objects, which know e.g. about their functionality or physical characteristics, that information can most naturally be used while playing the game. Our declarative modelling approach embeds objects with real-world behaviour so that, for example, they behave as one expects whenever a player interacts with them. Besides, the immediate effects of any action undertaken by a player or agent are handled automatically, as well as their long term results over time.

We believe that declarative modelling can offer designers the best of two worlds: it makes it possible to quickly generate detailed and consistent virtual environments; and it allows designers to specify smart object behaviour more intuitively, enabling a more immersive gaming experience for players. •



#### SUMMARY

Declarative modelling of virtual worlds is a novel approach that allows designers to concentrate on what they want to create, instead of on how they should model it. Its main characteristics – semantically-rich content and procedural content generation – mutually combine to support and amplify designers' efforts, thus empowering their creativity. Semantically-rich content provides a vocabulary close to designers' creative way of thought. Furthermore, once available in-game, it can dramatically improve object interaction and, therefore, gameplay. Our prototype system SketchaWorld demonstrates the productivity gain of procedural generation methods, while still offering abundant control and flexibility. By significantly reducing its complexity, SketchaWorld makes virtual world modelling accessible to whole new groups of users and applications.

#### CONTACT

**Rafael Bidarra** is associate professor Game Technology at Delft University of Technology, where



he leads the research line on game technology at the Computer Graphics and Visualisation Group. His current research interests include procedural and semantic modelling techniques for the specification and generation of both virtual worlds and gameplay; semantics of navigation; serious gaming; game adaptivity and interpretation mechanisms for in-game data.

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Workpackage partners: Delft University of Technology, TNO

VIRTUAL ENVIRONMENTS MAY BRING ABOUT REAL EMOTIONS

## WHO IS AFRAID OF VIRTUAL DARKNESS?

SERIOUS GAMES AND VIRTUAL TRAINING ENVIRONMENTS PREPARE TRAINEES FOR ACTING IN DIFFERENT, AND OFTEN DANGEROUS, CIRCUMSTANCES. THE VIRTUAL TRAINING ENVIRONMENT MUST CONVEY THE URGENCY OF THE SITUATION, SO TRAINEES EXPERIENCE STRESS OR ANXIETY, EVEN WHEN USING A DESKTOP COMPUTER OR A PROJECTION SCREEN.

**3D** environments on desktop computers are increasingly used to represent situations for training that cannot be created in the real world for reasons of safety, cost, time, etc. The success of simulations and serious games is often attributed to the convincingness of the situation that is represented, in which the trainee can experience the events as real. Their popularity and the expected effectiveness in learning are related to the 'gaming experience' of the trainees, and their emotional response to the applications.

It is important to develop environments that support the intended emotional response of the user: if the trainee is drilled to perform in a stressful situation and experience a high level of arousal, the virtual environment must match the arousing events in the training. The virtual environment functions like a stage on which the trainee performs. It may create a specific ambience and be perceived as realistic, or, on the contrary, may not be appropriate to the events at all and distract the user. On a desktop computer or projection screen tactile information is lacking, and much of the visual and auditory information of a real environment is lost. How does the modeled environment influence the emotional response of the viewer, and how can we determine this response?

### IT IS ALL IN THE MIND

In a virtual training, trainees play a role, for instance as first responders, and focus their attention on the

events and required procedure. First responders for example practice emergency evacuation procedures in hospitals. What they see and hear in the virtual training is complemented by their knowledge and experience with events in reality. Together these sources create a mental image of the situation and the location; this mental image determines the emotional response of the trainee. Cues in an environment can help to trigger this process, but only if they are relevant for the trainee in that situation. Subtle speed and depth cues that improve the representation of traffic on a highway for instance create a stronger feeling of risk for a traffic inspector. On the other hand, trainees easily ignore elements in an environment that are crudely represented if they are not directly relevant for their actions; they adjust to the style of the environment. Even the absence of sounds in a training environment can sometimes go unnoticed.

### ATTENTION AND ENGAGEMENT

Desktop monitors and projection screens only occupy a small part of the field of view of a viewer. The direct surroundings of the display are very important for the experience of the trainee because visual and other distractions have a negative impact on the attention and engagement of the trainees and diminish their emotional response to the training. Engagement enhances the emotional response to a virtual training environment. The context of the training and the usability of the application (for instance navigation and feedback to actions) are often neglected in practice, but careful at-

tention to the context of the presentation of a virtual training and the devices used for navigation can improve the overall effect on the viewers to a great extent. Interesting and surprising features in the virtual environment itself, such as dynamic features that indicate a storm, or animals that move about, also make the environment livelier and keep users engaged

### MAKING AN ENVIRONMENT LIVELY, SCARY OR UNPLEASANT

Virtual environments are generally considered rather static, dull and lifeless. Dynamic elements (moving clouds, water, and trees) or surprising details (street furniture, decorations on buildings, bright colours) make the environments livelier. Features that are considered unpleasant in real environments such as litter, indications of vandalism or severe weather conditions are recognized as disagreeable but at the same time also make the virtual environment more interesting and vivacious. However, the impact of common negative cues in a desktop virtual environment is not strong, which makes it difficult for developers to create a very unpleasant or dangerous environment. Another example of this effect is darkness. In real environments ambient darkness elicits fear by concealing potential dangers and escape routes. In desktop virtual environments darkness only has minor effects on the emotions of the viewer. In training environments darkness may be used in some scenarios to increase the stress of trainees indirectly: low visibility complicates performing the required actions or gathering information, which increases the danger of a situation. •



### SUMMARY

Features of a virtual training environment may influence the emotional response of trainees, and make them more aroused or aware of danger. However, in our research we found that other elements of a virtual training also modify the impact of the displayed environment: the mental representation created by the trainees of the event in the training, the attention and engagement of the trainees, and the context of use. To attain the required response to any virtual environment, these elements must be considered during the whole design and development process.

### CONTACT

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([J.M.Houtkamp@uu.nl](mailto:J.M.Houtkamp@uu.nl)) is a researcher at the Centre for Geo-information, Alterra, Wageningen University and Research Centre. Her research focuses on the usability of and affective response to 3D environments used for visualization of natural and man-made environments, and for serious games and training. She is in charge of workpackage 1.3, CAVA (Creating Ambience by Visual and Auditory means).



**Lex Toet** is a researcher at TNO, Soesterberg. His research focuses on crossmodal perceptual interactions between the visual, auditory, olfactory and tactile senses, with the aim to deploy these interactions to enhance the perceived quality of serious gaming programs for training and simulation. Workpackage partners: Delft University of Technology, TNO

# HUMANS SHOW VIRTUAL CHARACTERS HOW TO MOVE & INTERACT

WE STUDIED HUMAN MOTION BEHAVIOR IN ORDER TO DEVELOP REALISTIC PARAMETER-BASED MOTION MODELS FOR VIRTUAL CHARACTERS AND TO DEVELOP REALISTIC NON VERBAL BEHAVIOR IN A CONTINUOUS INTERACTION STYLE.



## CONTACT

**Job Zwiers** is associate professor at the Human Media Interaction group of the department of Computer Science of the University of Twente. He is currently active within the Dutch Commit project, where the results on continuous interaction and the Elckerlyc system will be used for coaching and serious gaming.

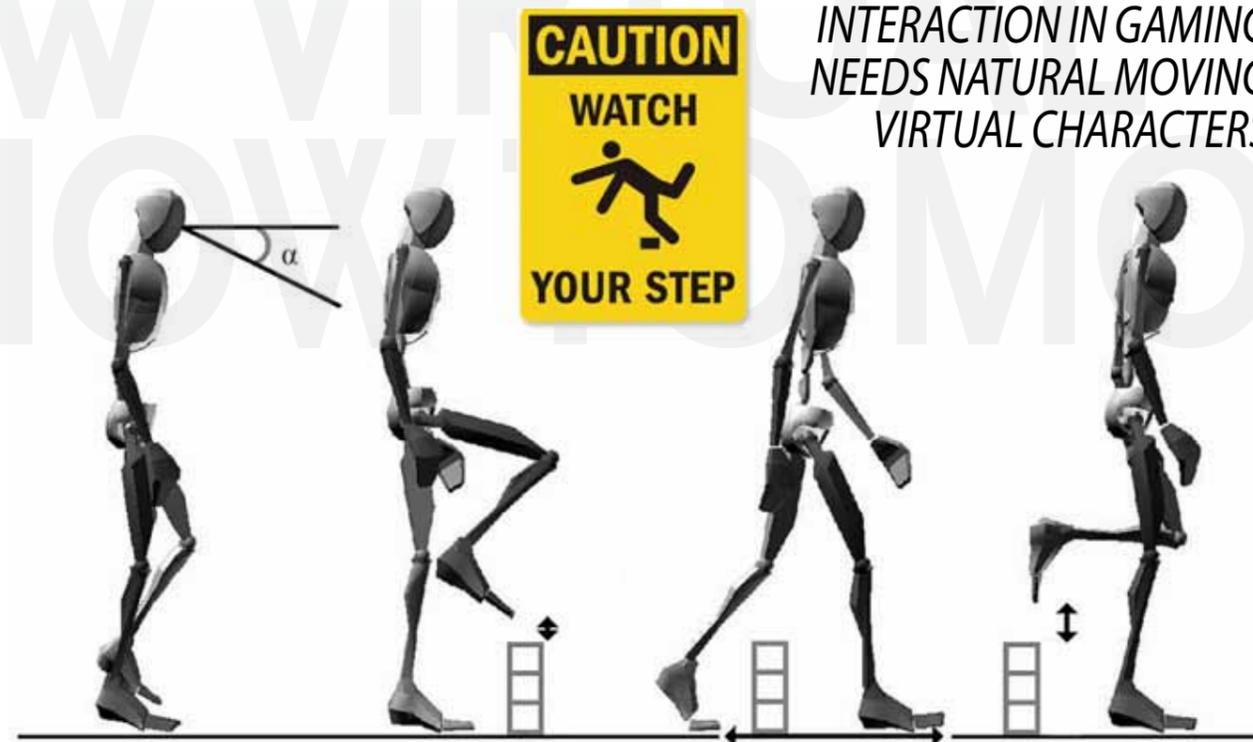
**Lex Toet** is currently a senior scientist at TNO (Soesterberg, The Netherlands) where he investigates crossmodal perceptual interactions between the visual, auditory, olfactory and tactile senses, with the aim to deploy these interactions to enhance the perceived quality of serious gaming programs for training and simulation. [lex.toet@tno.nl](mailto:lex.toet@tno.nl)



## SUMMARY

The fidelity of virtual characters critically depends on their ability to show natural movements. New realistic parameter-based motion models have been developed to animate virtual characters. We performed a wide range of human motion studies to gather input data for these models. In obstacle avoidance tests we found that visual field size significantly affects human motion behavior, and in mutual collision avoidance tests we observed striking gender and height effects. We created a behavior realizer for generating multimodal behavior for social interaction. It enhances communication by means of gesturing and body language, according to the continuous interaction paradigm.

## INTERACTION IN GAMING NEEDS NATURAL MOVING VIRTUAL CHARACTERS



Virtual characters play an essential role in many action games and simulations. To be convincing, they should move and gesture naturally. An important aspect of their motion behavior is the way they walk through realistic (obstacled) environments, their reaction to each other's movements, and the way they generate gestures or show body language in interaction.

### VIRTUAL CHARACTERS STUMBLING ALONG

Most game engines currently use motion-captured or hand-crafted animations in combination with procedural character animation. Both the method and its results are typically unsatisfactory, time consuming and costly. Procedural translation of the character does not take the physical constraints of the body into account. As a result virtual characters frequently behave in clumsy and hilarious ways, when they appear to be footskating (instead of walking) or bumping into objects or other characters.

### SO YOU THINK THEY CAN MOVE AND GESTURE NATURALLY?

A combination of procedural and physics-based animation appears an attractive alternative to recorded and hand-crafted motion clips. Procedural motion allows detailed and precise control over the movement of a virtual character, through a large number of parameters, but it lacks naturalness.

Physical simulation provides natural integration with the physical environment and physical realism. The combination of both techniques may be an effective way to let virtual characters move naturally.

### HUMAN INTERACTION BY MEANS OF BEHAVIOR GENERATION IN ELCKERLYC

In traditional 3D games and VR applications, interaction via body posture, gesturing, or other non-verbal behavior is hampered. There are many applications and games where this won't do. Think of police training in the form of a serious game: handling challenging social situations asks for good social skills and good interaction techniques. It is not just what you say, but also how you say it, using correct body language. We have created and experimented with our open source behavior realizer "Elckerlyc". It can generate body poses, gestures, speech, and facial expressions from descriptions written in Behavior Markup Language (BML).

### CONTINUOUS INTERACTION

Speech-only dialogues often have a turn-based character. Adding non-verbal behavior opens up the possibility of backchanneling, showing understanding or (dis)agreement, for instance by means of nodding, or by looking towards or away from other persons or characters. This allows for a continuous interaction style, as opposed to turn-based interaction.

The development of realistic human motion models requires knowledge of the way humans move through realistic environments, with different crowd densities, and different viewing conditions. To gather this data we performed a wide range of human motion studies.

### OBSTACLE AVOIDANCE: PERSONAL SAFETY FIRST

In obstacle avoidance tests (ducking, stepping over, avoiding) with different visual field restrictions, we found that even a small limitation of a person's visual field significantly affects walking behavior. For progressively smaller viewing angles, participants first enlarge their obstacle clearance (e.g. by lifting their feet higher when stepping over obstacles or by maintaining a larger distance to the walls), and then reduce their walking speed. In all conditions, people tend to optimize their personal safety at the expense of spending more energy.

### MUTUAL COLLISION AVOIDANCE: SEX AND SIZE MATTERS

In a human-human collision avoidance behavior study we observed some striking gender and height effects. To avoid collisions, males tend to cooperate less than females, and the minimum interpersonal distance maintained by two males is smaller than between a male and a female. Also, taller people tend to collaborate less than shorter people, independent of their gender. •

# MY VIRTUAL CHARACTER UNDERSTANDS ME!

TO FACILITATE THE EVOLUTION OF MORE SOPHISTICATED VIRTUAL CHARACTERS WE AIM TO ENDOW THEM WITH MENTAL, SOCIAL AND EMOTIONAL CAPABILITIES. SUCH ENHANCEMENTS INCREASE THE BELIEVABILITY AND REALISM OF VIRTUAL CHARACTERS, AND THEIR EXPLAINABILITY AND PREDICTABILITY.

The human player's avatar asks his virtual team mate to explain an unexpected action

This work package within the GATE project is concerned with the investigation of cognitive (mental) and social attitudes of agents in a game (both virtual characters and human players), how they are represented and how they are related to the behavior of the agents. Typical mental attitudes concern the beliefs, desires (goals) and intentions of agents. Typical social attitudes concern issues of communication and conversation. In this work package questions are

studied such as: What is the influence of the mental and social attitude of an agent on its behavior and, vice versa, how does the behavior of other agents in the game affect an agent's mental and social attitude? Furthermore, we are interested in several forms of what we could call 'mental state ascription' (i.e., ascribing (aspects of) the mental state to an agent on the basis of its behavior) in order to understand and predict the behavior of agents involved in the game (virtual characters as well as human players!). One particular application of mental state ascription that we have investigated is self-explaining agents in virtual training systems. Finally, also social attitudes of virtual characters are investigated such as verbal and nonverbal communication, (social and emotional) conversational behavior, and interpersonal relations, more in general. In the interaction between a virtual character and its conversation partner, mental state ascription plays a role, too, as we shall see below.

## MENTAL STATE ASCRIPTION TO VIRTUAL CHARACTERS

Mental-level modeling of software is a powerful abstraction in artificial intelligence that is encountered, for example, in the case of autonomous BDI-based agents. An agent of this type is equipped with goals that it attempts to achieve by selecting plans that it considers to be appropriate in light of particular beliefs that it holds. Those

goals and beliefs can pertain to its 'physical' environment, but also to the mental state (goals and beliefs) of other agents. Having and maintaining a model of the mental state of others is important for believable social behavior, as is desirable in the case of human-computer interaction, but also in the case of computer-based characters that interact with each other in software applications like (serious) games as we are interested in in the GATE project. Ascription of a particular mental state (such as beliefs and goals) helps to explain the behavior of virtual characters in a game and enables the beholder to predict future behavior of those characters and (counter)act accordingly.

The more theoretical work on mental state ascription has particularly focused on the explanation of (partially) observed behavior by means of mental state attribution, and in doing so has focused on the perspective of a virtual beholder-entity that observes others' actions. In case those actions are of a computer-based agent, it may be so that the rules determining that agent's behavior are also available to the beholder for explanation. A scenario where this may occur is in applications that demand believability of virtual characters, and where it is feasible to give a beholder some notion of others' behavior-producing rules but not the full details about their goals and beliefs. In that case, defeasible ('ab-

ductive') explanatory reasoning can be employed in regard to observed actions, in order to obtain a notion of the observed agents' possible mental states. This subproject was aimed at formalizing this form of reasoning, presenting both an abductive logical account as well as a specification for its implementation in terms of answer set programming. Since reasoning about observed actions involves a notion of 'dynamics', a special logic (PDL, Propositional Dynamic Logic) is employed as a tool for modeling those dynamics, focusing on the case where actions of computer-based agents are observed. Moreover, PDL is used to formalize first-order 'mindreading' - a term which is typically employed in the literature as a theory-neutral term for referring to the explanation of behavior in mentalistic terms. Existing psychological models of mindreading are used as a basis for determining the logical format of particular patterns of mindreading. Having a formal grasp on this format can be helpful both in the elicitation of concrete instances of those patterns pertaining to behavior in particular (software) environments, as well as their implementation as an aspect of AI.

## EXPLAINING AGENT BEHAVIOR

Computer games are increasingly often used to train competences like leadership, negotiation and social skills. In a training game, a human trainee interacts with one or more virtual characters

that play the trainee's team members, colleagues, or opponents. Intelligent software agents can be used to generate the behavior of the virtual characters automatically. Using intelligent agents instead of human players allows trainees to train independently, where and whenever they want.

A potential problem of using intelligent agents in virtual training is that trainees do not always understand the behavior of the agents. For instance, virtual team members (played by intelligent agents) that do not follow the instructions of their leader (played by the trainee) may have misunderstood his instructions, or disobey their leader on purpose. As the underlying causes of behavior are unclear, the trainee does not know whether he should communicate clearer, be more persuasive, or give better or safer instructions. This problem can be solved by letting virtual agents explain the reasons for their behavior. These explanations may enable trainees to obtain a better understanding of the events, which helps them in learning from virtual training. Within the GATE project we have developed an approach for building agents that are able to explain the reasons for their behavior. Psychological research shows that people usually explain and understand human (or human-like) behavior in terms of mental concepts like beliefs, desires (goals), and intentions (BDI). Therefore, in our approach, an agent's behavior is speci-

fied in terms of BDI. An example of a goal is 'to extinguish the fire', a belief could be 'the house is almost collapsing', and a plan to achieve the goal in this particular context is, for instance, 'to extinguish the fire from outside'. The agent determines its actions based on a reasoning process on its beliefs, goals and plans. Thus, the mental concepts that are responsible for the selection of an action can also be used to explain that action. An important question is what beliefs

MODELING THE RELATIONSHIPS BETWEEN COGNITIVE / SOCIAL ATTITUDES AND BEHAVIOR OF VIRTUAL CHARACTERS WILL MAKE GAMES MORE BELIEVABLE AND HUMAN-LIKE, EXPLAINABLE AND PREDICTABLE



## SUMMARY

The research done in this work package has focused on the relation between mental and social attitudes of agent-based virtual characters and their behavior. Mental attitudes comprise notions such as beliefs, desires (goals) and intentions, while the social attitudes studied particularly concern communication and conversational behavior. This work enables one to enhance the believability of virtual characters as well as the possibility to explain their behavior (using mental state ascription), and predict and anticipate their behavior, so that training systems become more realistic as well as more effective.

## CONTACT

**Prof. dr John-Jules Meyer**

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(Utrecht University, Intelligent Systems Group, Dept of Information and



Computing Sciences) is the leader of the subproject on virtual characters. He obtained his Ph.D. from the Vrije Universiteit in Amsterdam, was a full professor in Amsterdam (VU) and Nijmegen, and since 1993 he has been a full professor of computer science at Utrecht University. The following persons collaborated in this subproject: the PhD students: Maaïke Harbers (UU/TNO), Michal Sindlar (UU) and Bart van Straalen (UT). Karel van den Bosch (TNO), Mehdi Dastani (UU), Dirk Heylen (UT), John-Jules Meyer (UU) and Anton Nijholt (UT) acted as (co-)supervisors of the respective subprojects.



This BDI-character feeds back his view on the situation to the player to achieve common understanding.

and goals need to be delivered to the trainee in order to explain a particular action satisfactorily. Providing all beliefs and goals usually results in too long explanations. User studies were conducted to investigate which information is considered most useful for learning. It was found that people generally prefer explanations that contain a combination of the belief(s) that triggered the action, and the goal that is achieved by the action. Subsequently, studies were conducted to investigate the effects of agents explaining their behavior on training and learning. The domain of the first study was negotiation training with a trainee having to negotiate with a virtual partner. Results indicated that explanations increased subjects' understanding of the agent's behavior. In a second study it was investigated how explanations affect coordination in human-agent teams. Results showed again that explanations improved subjects' understanding of the agents' behavior. The main conclusions of this subproject are: (a) the developed approach is suitable for developing agents that can explain their actions in terms of goals, beliefs and plans, and (b) that the explanations generated by these agents increase people's understanding.

#### SOCIAL VIRTUAL HUMANS

Virtual humans in serious games and training-simulations often need to fulfill the same function as humans in the real-life equivalent of such situations. Such functions strongly depend on the nature of the task but often include performing behavior that is related to the training and being able to explain why such behavior was se-

lected (for example, in the simulation of firefighters). Furthermore, virtual humans need to be able to communicate with the human trainee through language and nonverbal behavior. This should not just express information related to the task, but also express the emotions that are appropriate and the social relationship that holds (formal/hierarchical, politeness, intimacy, etc.). In this subproject we focus our research on the latter function by enhancing conversational virtual humans with capabilities to recognize and display social and emotional conversational behavior and to model the various processes that are involved in this. Also, the interpersonal relation that exists between two interlocutors is taken into account.

In order to enhance our virtual conversational humans a solid and plausible framework of the cognitive processes involved in recognizing, processing and selecting social and emotional conversational behavior have to be constructed. To facilitate this, various conversational virtual human systems and psychological approaches to cognitive, emotional and social processes have been examined to provide insight and inspiration. The virtual human should be capable of forming beliefs about the world and have goals and intentions that it wants to achieve through conversational behaviors. Typical goals in conversations are to change the beliefs and emotions of the person one is talking to. A virtual human thus also needs to be able to form an idea about the beliefs and emotions of the interlocutor and needs to know how its actions are likely to change

these in the desired direction. What also needs to be taken into account are the interpersonal relations that exist between the virtual human and the user, for example the roles both interlocutors have in the conversation such as doctor and patient. Subsequently we have studied how conversational behaviors can be associated with the various features in the cognitive model. Through analysis of real-life conversations we have determined a set of elements which describe the purpose and meaning of certain conversational behaviors (e.g. the intended and expected effects of a behavior). These elements are similar or related to the features in the cognitive model, allowing us to link them to the cognitive state of the virtual human, thereby being able to explain why the virtual human has selected a particular conversational behavior.

Analysis of real-life conversations has also provided us with insight in the interpersonal relation that exists between two interlocutors that exceeds individual conversational behaviors. This interpersonal relation is represented in the cognitive model through terms such as rapport, trust and division of roles and influences the selection and realization of conversational behaviors, for example through the degree of politeness. This interpersonal relation not only influences the selection and realization of individual responses, but also steers the course of the entire conversation. For example, a person will be more inclined to provide information about his mental state to an interlocutor he trusts. In addition to the interpersonal relation we also investigated how the emotional states influence the selection and realization of conversational behavior. There is a distinction between the way emotions lead to the selection of a certain conversational behavior and the manner in which the behavior is realized. The same holds for conversational behavior that is influenced by social features. •

# CONTROL YOUR VIRTUAL CROWD

CREATING COMPELLING PATHS FOR VIRTUAL CROWDS

A CHALLENGE IN CURRENT GAMES IS TO CREATE A LARGE CROWD OF CHARACTERS THAT EXHIBIT BELIEVABLE BEHAVIOR. RECENT WORK AT UTRECHT UNIVERSITY HAS PROVIDED NEW INSIGHT TOWARD A MORE REALISTIC PATH PLANNING APPROACH.

Interactive virtual environments, such as games, are increasingly populated by numerous characters that navigate through the virtual world. Such characters can have individual goals. They can wander around by themselves while satisfying these goals, or they can join small groups or large armies. Existing solutions have difficulties when trying to efficiently steer a crowd of characters along realistic routes.

#### NAVMESH: COLLISION-FREE SPACE

We developed a fast method to steer thousands of characters at interactive rates. Our method relies on a convenient representation of the walkable space of the environment. This representation is automatically computed and forms a 2D or multi-layered navigation mesh. The method is fast and can be used in real-time within large environments.

#### INDICATIVE ROUTE METHOD

Once the mesh is constructed, our Indicative Route Method is used to guide the movements of the characters. This method is based on a simple idea. Instead of using a steering method to produce a *path*, we produce an *indicative route*.

When we plan our paths in real life we do not compute a precise route. Instead, we determine a global (indicative) route toward our desired goal. For example, we determine the streets we have to follow in order to reach our destination, but we do not decide in advance on which side of the street we will walk, or where and how we will

cross the streets. Similarly, given the start and the goal position of a character, an indicative route indicates the character's preferred route. This route can either be drawn manually by a level designer or computed automatically to encourage certain character behavior. The character does not need to traverse the indicative route exactly, but rather uses it as a guide to plan its final motion. For that reason, a corridor, which is a collision-free area around the indicative route, is extracted from the mesh. This allows the character to locally adapt its route so that it can avoid collisions with other characters.

#### COLLISION AVOIDANCE

Our collision avoidance approach is based on the hypothesis that an individual adapts its route as early as possible, trying to minimize the amount of interactions with others and the energy required to solve these interactions. Building upon this hypothesis, a character predicts possible future collisions with other characters and then makes an efficient move to avoid them. Consequently, the characters do not repel each other, but rather anticipate future situations by avoiding all collisions long in advance and with minimal effort. This ensures smooth avoidance behavior and reproduces emergent phenomena, such as lane formation, which have been observed in real crowds. The technique is easy to implement and is fast.

#### SMALL GROUPS

To enhance the believability of a crowd, we also developed a novel approach that simulates the walking behavior of

small groups of characters. Here, we focused on how group members interact with each other, with other groups, and with individuals. Our model is based on recent empirical studies and has been successfully combined with the Indicative Route Method. We showed, even in challenging scenarios, that the groups safely navigate toward their goals by dynamically adapting their formations. •



#### CONTACT

**Roland Geraerts**

([R.J.Geraerts@uu.nl](mailto:R.J.Geraerts@uu.nl)) is an Assistant Professor in the Department of Information and



Computing Sciences at Utrecht University in the Netherlands. His current research focuses on path planning and crowd simulation in games and virtual environments. He teaches several courses related to crowd simulation and games. Roland has organized the Creative Game Challenge and is one of the co-founders of the annual Motion in Games conference. More information can be found on his webpage: <http://www.staff.science.uu.nl/~gerae101/>. This research was carried out with Ioannis Karamouzas.

# SIMULATING VIRTUAL CHARACTERS



NEW TECHNIQUES FOR CHARACTERS INTERACTING WITH THEIR ENVIRONMENT

ANIMATED CHARACTERS IN GAMES CAN GENERALLY PERFORM ONLY LIMITED MOVES IN THEIR ENVIRONMENT. WE HAVE DEVELOPED TECHNIQUES TO HAVE MORE CONTROL OVER CHARACTER MOTIONS, WHILE ENSURING THAT THE MOTIONS LOOK REALISTIC.

## SUMMARY

Characters in games perform a variety of different tasks: walking, running, jumping, but also tasks such as picking up objects, opening doors, and so on. Commonly, these characters are animated using motion capture data. The more complex a game becomes, the more motion capture recordings are needed, which leads to huge motion capture databases. Furthermore, a lot of manual effort is required to ensure that transitions between motions look natural. We propose a method for adding high-level parameters to motion which can then be used to automatically generate new motions. We have shown how to use such a system for foot placement control, as well as reaching control, and the combination of the two.

Characters in games perform a variety of different tasks: walking, running, jumping, but also tasks such as picking up objects, opening doors, and so on. Commonly, these characters are animated using motion data obtained from real actors by using specialized motion capture equipment. The more complex a game becomes, the more motion capture recordings are needed, which leads to huge motion capture databases. Furthermore, a lot of manual effort is required to ensure that transitions between motions look natural. Our goal is to generate realistic motions fully automatically, while relying on a limited number of motion capture recordings.

## ADDING PARAMETERS TO MOTION

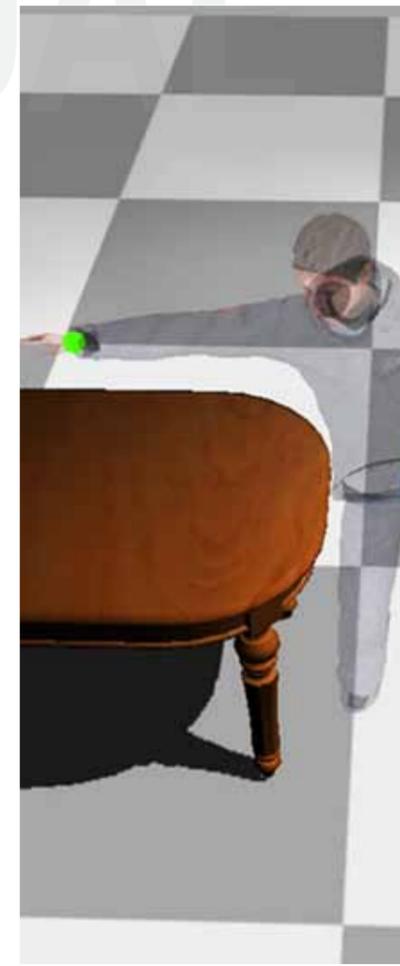
In order to have controllable characters, simply recording a lot of different motions and playing them on demand

is not going to be enough. In our approach, we augment the motion capture clips with high-level parameters. There are many different kinds of parameters that one can think of: foot-step positions, reaching locations, but also more abstract parameters could be used such as 'happiness' or 'arousal level'. Characters can then be controlled by these high-level parameters, while the animation system takes care of translating these parameters into a corresponding motion.

## OUR TECHNIQUE IS FULLY AUTOMATIC AND NEEDS NO EDITING OR POST-PROCESSING

Generating walking motions using foot placement

An example of using parameters to define motion is by placing footprints, and animating a character that walks along these foot placements. These foot placements can be drawn by an anima-



tor, or they could be automatically calculated from a path that the character has to follow. We store a database of walking motions which are automatically separated into different footsteps. New motions are then created by smartly interpolating between the footsteps in the database. Because of our interpolation scheme, the interpolated motions adhere exactly to the required parameter values. Finally, we combine the different footsteps in order to get the final animation. Our technique is fully automatic and needs no editing or post-processing. Furthermore, the technique is real-time, and it is possible to modify the foot placements while the character is already walking, resulting in a very flexible, interactive walking control mechanism.

## GENERATING REACHING MOTIONS

Another example of using parameters to control motion is by looking at reaching motions. In this case, the parameter is the desired location of the hand or wrist. Using a very similar approach to the previous example, we have recorded a few different reaching motions. Each motion defines a posi-

tion where the character is reaching at. Together, these recorded motions span up a parameter space. Again, by smartly interpolating between the different motion samples, we can automatically generate a reaching motion for any value in the parameter space. Because we rely on real data, the resulting motion also looks realistic.

## COMBINING REACHING AND WALKING MOTIONS

A final challenge lies in the combination of reaching and walking motions. Although walking mainly is a lower-body motion, and reaching an upper-body motion, it is not a trivial task to combine the two. When someone picks up an object while walking past a table, the reaching motion has an influence on the walking motion and vice versa. For example, the walking motion might need to be slowed down so that the character has enough time to perform the reach. Also, the lower body pose might need to be shifted towards the reach point, so that the character doesn't lose balance. We have developed a system that transfers both spatial and temporal information between

## CONTACT

### Arjan Egges

is an Assistant Professor at the Games and Virtual Worlds group in the Department of Information and Computing Sciences, Univers on the integration of motion capture animation with navigation and object manipulation tasks. He teaches several courses related to games programming and computer animation. Arjan is also an associate editor of the Computer Animation and Virtual Worlds journal published by Wiley and he is one of the founders of the annual Motion in Games meeting.

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upper and lower body motions. As a result, we can synthesize these combined motions with great realism.

## WHAT'S NEXT?

Our technique is beneficial for many game applications. We can automatically generate realistic motions according to different parameters, which is not possible with current techniques. Also, our technique relies on a small motion capture database. Game companies can therefore spend more time and money on other aspects of their games. We are currently investigating how to generalize our parameterized approach to include abstract parameters such as emotional state. We are also looking into how we can automatically generate these parameter values from the context of the environment. This includes locations of objects and how they should be picked up, but also physical properties, so that the animation is automatically adapted to the constraints of the environment. •

# MULTIPLE PEOPLE TRACKING, INTERACTION RECOGNITION

# POSE ESTIMATION AND

POSE TRACKING ENABLES CONTROLLER-FREE, REAL-TIME INTERACTION IN GAMES

VIDEO-BASED APPLICATIONS SUCH AS VISUAL SURVEILLANCE, HUMAN COMPUTER INTERACTION, ENTERTAINMENT AND SERIOUS GAMES HAVE BECOME MORE AND MORE WIDE-SPREAD IN OUR DAILY LIVES. ONE OF THE KEY COMPONENTS OF REALIZING THESE APPLICATIONS IS THE DETECTION, TRACKING AND POSE ESTIMATION OF PEOPLE.

Multiple people tracking and pose estimation is one of the most challenging topics in computer vision, due to occlusions between persons and self-occlusions. Our goal is to develop an efficient and robust multi-view based framework to estimate multiple persons' poses under severe occlusions in typical indoor interactive applications.

## MULTIPLE PEOPLE POSE TRACKING

We developed new approaches to track multiple people simultaneously and estimate their 3D pose. In order to deal with inter-person occlusions,

we researched a global occlusion estimation approach that combines the information from multiple views. The global visibility map of each individual in all the views is calculated and used to weight image observations from those views. Self-occlusion is handled by local occlusion estimation. In experiments with challenging conditions we have shown that we can track successfully multiple people' poses. In particular, the results suggest that the combination of global and local occlusion estimation results in significant improvement in system performance

regarding the tracking accuracy. Another feature of our work is that a part-based hierarchical model is used to track upper body poses. We first estimate the relatively easy detectable body parts, such as head and torso. Then from the roughly located shoulder positions, we started searching for the left arm and the right arm in parallel. Given the constraints of the human kinematic model, we assume that the finding of each body part is interdependent. Therefore our method reduces the search space dimensionality and enables a

hierarchical search. The hierarchical way of search reduces the computational complexity and speeds up the system to allow for real-time and on-line applications. This new technology makes certain practical applications possible. We have developed several pose-driven spatial games, in which players get rid of controllers and play games using intuitive body movements and poses, and serious games in which people have to interact with a simulated virtual world in real-time. We have demonstrated one of our pose-driven spatial games in the TU Delft Science Center where children loved to play it.

## HUMAN INTERACTION RECOGNITION

In addition, we designed and built the

Utrecht Multi-Person Motion Benchmark (UMPM) dataset. Its purpose is to provide video datasets recording multi-person movements and interaction with motion capture ground truth, to evaluate new techniques and algorithms for the automatic articulated pose estimation and tracking of multiple persons. These datasets are unique regarding the design of interaction scenarios, handling the missing motion capture markers caused by occlusions, and the skeletonization of the ground truth. The datasets are made available for the whole research community.

Investigating human interaction by using the pose estimation shows that by using the extracted 3D joints locations and motion information, we can separate classes like

shaking hands, introducing, pointing, waving, punching, and pushing well. This technology can help us to analyze the social relationship in a small group of people in a serious game automatically and build a social network between the members. •

## SUMMARY

Real-time 3D pose tracking and recognition for human-computer interaction have a large potential for applications in entertainment and serious games. Visibility analysis of each person in all camera views are used to weight image observations. Occlusion is handled by local occlusion estimation. Real-time performance is achieved by using prior knowledge of human kinetics and a hierarchical model to search the pose. Spatial games demonstrate the effectiveness of our developed technology. A unique dataset containing interaction scenarios and full motion capture data and ground truth is provided to the research community for benchmarking.

## CONTACT

This research is performed by Feifei Huo, Xinghan Luo, Emile Hendriks, Robby Tan, and

Remco Veltkamp, in a collaboration between Technical University Delft and Utrecht University. Emile Hendriks is associate professor in computer vision at TUD. The project leader is Remco Veltkamp. He is professor in Multimedia at UU, working on developing new technologies for the analysis of video, 3D scenes, images, and music.

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# CONTROLLING YOUR COMPUTER BY MERE THOUGHT

IMAGINE WHAT IT WOULD BE LIKE IF THE COMPUTER COULD SIMPLY INTERPRET AND RESPOND TO YOUR THOUGHTS?

Interacting with a computer, for example to navigate through a game, requires a user interface like a mouse or keyboard. These interfaces are not always intuitive to use and can drag resources away from the primary task of the gaming application. Rel-

evant information from brain signals that enable (brain controlled) human-computer interaction with minimal cognitive resources can be a more intuitive solution.

### BRAIN-CONTROLLED NAVIGATION

Brain-controlled navigation is feasible. Our system, 'the TNO tactile Brain-Computer Interface' works as follows. A user wears a vibration belt that can tap the user at different locations around his waist. Each location corresponds naturally with a navigation direction (e.g. left, right). The different directions vibrate in a random pattern and the user only attends to the desired direction. Time-locked brain responses provide the computer with information about the attended direction and can consequently be used to navigate. The user can keep his hands free to do other tasks.

### TOWARDS REAL-TIME BRAIN CONTROLLED INTERACTION

To date, pure brain-controlled real-time interaction for serious gaming is not feasible yet, due to the delay between user command and computer response. This delay is caused by two factors. First, a low signal-to-noise ratio of the measured brain response requires averaging over several observa-

### CONTACT

**Marieke Thurlings** (*M.E.Thurlings@UU.nl*) is a PhD candidate on Brain-Computer Interfaces at the Utrecht University and TNO. She studied Industrial Design at the Delft University of Technology with a focus on human-computer interaction. Her research interest is primarily in how biosignals can facilitate human-computer interaction and improve the quality of life by means of biofeedback products.

**Jan van Erp** (*Jan.vanerp@tno.nl*) is a senior scientist and program manager at TNO and holds a MSc in Experimental Psychology and a PhD in Computer Science.



tions. Second, the relevant brainwave we use occurs relatively "late", namely after approximately 300 ms. While the former factor may be overcome with technological advances, the latter one is biologically determined. We try to solve this by applying stimuli in two sensory modalities instead of one and detected brain responses related to bimodal stimuli already after 70 ms. The idea is that such fast brain signals could be applied to approach real-time interaction, which is essential for gaming.

### MEASURING CONFLICT DURING HUMAN-COMPUTER INTERACTION

Interestingly, the time-locked brain responses we use for navigation may also reflect mental states. For example, the size of the brainwave for the attended direction will be lower if attentional resources are used for other tasks. This effect can thus be used to measure a user's mental load, or for example how intuitive the design of the user interface is. We tested this by comparing a congruent (or intuitive) user interface with an incongruent one and found differences in brain responses as expected. This knowledge is valuable to optimise brain controlled devices and any type of human-computer interaction. •

# ADAPTING THE GAME TO THE TRAINEE

SERIOUS GAMES ARE FRUSTRATING IF THEY ARE TOO DIFFICULT AND ARE BORING IF THEY ARE TOO EASY. IN BOTH CASES TRAINEES DON'T LEARN MUCH FROM PLAYING THE GAME.

One of the most important factors in making trainees learn from computer games is making sure that the games have the right difficulty level for the player. Most games can be played at different difficulty levels, which you can choose before you start the game. This way you need to know how good you are at the game before you start playing the game. Different people also increase their skill level at different rates. If the increase in skill level is different than the game designer expected then the game will still become too difficult or too easy for the trainee. Researchers at Utrecht University have created a framework to adjust the difficulty of the game to the skill level of the trainee on the fly.

We created a framework for creating games that are able to keep track of the skill level of the player and adjust accordingly. We estimate the skill level of the player by dividing the game in small tasks and measuring the performance

of the player on every task that is finished. For instance a crisis management game in which a gas truck is on fire near a block of apartments could have tasks where the fire commander first has to establish the dangers in the current situation based on all information he gets from the police, the medics, the transport company, bystanders etc. If a fire commander is inexperienced it might be made obvious what type of material the truck is transporting, but for experienced commanders it might be made more difficult to find this out. One can e.g. have bystanders tell that they saw the truck at the local gas station (and thus it probably transports gasoline) while the transport company might indicate that there are two trucks in the neighborhood, one with gasoline and one with kerosene. Game designers usually create a scenario that the player follows while he is playing the game in order for him to learn certain skills. But if different players get different tasks according to their skill level then the ordering of the storyline might change and possibly ruin the experience for the player. The developed system allows games to adjust to the user while making sure that the storyline, created by the game designer, is preserved. Thus in the example above the transport company might report suddenly that they found out that the truck with kerosene is missing and thus might be the one on fire, but they should not suddenly state that the truck on fire is carrying milk as this would be a very unlikely scenario. In the same way if bystanders are crowding the area, (all trying to see the fire) it would not be natural if the people suddenly start to disperse all by themselves (while the fire is still blazing) even if this would make it easier

### SUMMARY

We have created a framework that checks the skill level of a trainee during the playing of a serious game and adjusts the difficulty level in a way to keep the trainee engaged, while challenging him most on the skills she still has to improve most. The framework has been implemented and tested in a limited setting, but the results are promising and ready to be converted into an industrial strength support tool for serious gaming.

### CONTACT

**Frank Dignum** is associate professor at the department of Information and Computing Sciences at Utrecht University. He has many years of experience in research in agent technology and its applications. He is one of the leading researchers in the area of using agents for games. Agent technology can very well be used to create adaptive and flexible game play as illustrated in the above article. The work has been conducted by Joost Westra under supervision of Virginia Dignum (TU Delft) and Frank Dignum. Frank can be contacted at: *F.P.M.Dignum@uu.nl*



for the commander to cope with the emergency.

Our framework, however, makes sure that the different elements are well coordinated in the game, such that an optimal difficulty level can be reached at every moment. Thus if it is very difficult for the commander to get the right information about the situation the framework will prevent that the bystanders will create problems by crowding the area as this combination might be too much to handle for the commander. Instead the bystanders keep this opportunity available for the case the commander has assessed all available information and is starting to fight the fire. Thus the difficulty is coordinated over different elements in the game and also over time. This ensures that all parts of the game that should be challenging remain challenging for the player.

### AGENT ORGANIZATIONS

The coordination of the actions of all the elements in the game, that are used to create the right difficulty level for the trainee, is realized through the use of agent organizations. This organization enforces certain ways of coordination between elements, just like it happens in human organizations. There is still freedom to adapt to specific situations, but only in as far as it fits within the overall organizational structure. We have shown that this makes the system easy to adapt while guaranteeing certain learning goals. The system is also reasonably scalable which is an important point for the use of these techniques in video games. •

# GAMES FOR LEARNING

## GAMES FOR LEARNING

### HOW TO IMPROVE SPECIFIC LEARNING RESULTS FOR SERIOUS GAMES

SERIOUS GAMES CAN ENABLE PLAYERS TO ACQUIRE AND IMPROVE DOMAIN SPECIFIC KNOWLEDGE. NEW MODELS HAVE BEEN DEVELOPED THAT CAN HELP GAME DESIGNERS IMPROVE THE DESIGN AND EFFECTS OF SERIOUS GAMES.

Although serious games have become a very popular medium, developers still require models that can help them to improve the design and thereby the learning results of serious games. This research fulfills this need by focusing on two specific topics: how narrative structures can be designed to improve learning processes, and how rhetorical strategies can be designed to convince players either of certain perspectives (e.g. political games) or the necessity of certain behaviors (e.g. advergaming, health games).

#### STORY-BASED COMPUTER GAMES

Many of today's popular games incorporate some form of narrative in their design. Designers try to come up with appealing story characters, elaborate story settings and exciting story events. The diversity in the current game industry makes this a challenging task, since different types of games need different types of stories.

We have used the concept of presence to investigate the variety of stories in contemporary computer games. Games produce different forms of presence, that is, games position players differently in relation to the story worlds they construct. Critically acclaimed games like *The Elder Scrolls V: Skyrim* (2011, main image) for example, allow players to become the story's hero. The results of

this research have been translated into a theoretical model. This model assists game designers in developing stories for computer games, both in a commercial as well as in an educational context. By showing how different forms of presence necessitate different forms of narrative, it helps designers in choosing the right story characters, story settings and story events for their games.

#### ADVERGAMES

We developed a model that serves to analyze and visualize persuasive structures in advergaming. This helps us to understand the way in which advertising messages may be embedded in computer games. We discovered that persuasion can be present in a game as five different dimensions: in the rules, in the history, in the audiovisual context, in the visual contents and in the texts that the player can find throughout the game. In order to develop an effective advergame it is required to build a persuasive structure, in which one of the persuasive dimensions drives the user through the other persuasive dimensions. In this way the game designer can be sure that the player receives a complete and persuasive message.

A good example of this is the advergame *Get the Glass!*, released in 2007 with the aim to increase the consumption of milk in the USA. In the game

the dominant persuasive dimension, present in the rules of the game, drives the user through the other persuasive dimensions. The player has to expose himself to the different persuasive dimensions in order to win the game.

#### POLITICAL AND HEALTH GAMES

We also developed a model for the analysis of the persuasive potential in political and health games. We answered questions like: what kind of rhetoric are serious games capable of? How can we understand serious games as a communication situation in which someone wants to convey a meaning towards someone else? Computer games focusing on entertainment don't need this kind of rhetoric, because their goal lies primarily in creating an engaging experience. The situation is different for serious games, in which the message is just as important as the gameplay, and communication is the core goal rather than a side effect. Two working frameworks have been completed: a theoretical framework to re-think serious games separately from games solely meant for entertainment by conceiving them as a form of communication, and a practical framework that will enable developers to design persuasive strategies by highlighting the different possible routes to persuasion for political and health games. •



#### SUMMARY

Building on analyses of the medium specificities of serious games, we focused on the interplay between technical, textual, psychological as well as social processes involved in game-playing situations. We developed a model that can be used specifically for the analysis and design of narratives in serious games. We also studied the qualities of serious games that enable or impede persuasion (advergaming, political and health games). We used these insights to formulate effective and efficient guidelines for persuasive game design. Designers can use this model and guidelines to improve specific learning and commercial results.

#### CONTACT

**Prof.dr. Joost Raessens** holds the chair of Media Theory at Utrecht University. His research concerns the ludification of culture, focusing in particular on the notion of play as a conceptual framework for the analysis of media use. Raessens was the conference chair of the first Digital Games Research Association (DiGRA) conference Level Up in Utrecht. He is one of the founding members of GAP: the Center for the Study of Digital Games and Play. For more information, see [www.gamesandplay.nl](http://www.gamesandplay.nl) and [www.raessens.nl](mailto:www.raessens.nl). ([J.Raessens@uu.nl](mailto:J.Raessens@uu.nl))



# WHAT FACTORS MAKE SERIOUS GAMES EFFECTIVE & ENGAGING?



## SUMMARY

Although serious games are booming business, it is not clear which factors in game design are crucial for effective and engaging learning. In a series of experiments with the game Code Red: Triage we investigated the role of cues, complexity, adaptivity and narrative elements. Our results show that particularly adaptivity and narrative elements will improve learning without jeopardizing the entertaining quality of the game.

# SERIOUS GAMES ARE EFFECTIVE

## NARRATIVE ELEMENTS FOSTER LEARNING AND ENGAGEMENT IN SERIOUS GAMES

SERIOUS GAMES CAN ENABLE PLAYERS TO ACQUIRE AND IMPROVE DOMAIN SPECIFIC KNOWLEDGE. GUIDELINES HAVE BEEN DEVELOPED THAT CAN HELP GAME DESIGNERS IMPROVE THE DESIGN AND EFFECTS OF SERIOUS GAMES.

Serious games appear to be less effective than generally expected. In our research we have investigated game design factors that foster learning without compromising the engaging nature of games.”

### EFFICACY OF SERIOUS GAMES

For our research we created Code Red: Triage, a total conversion mod of the 3-D first person game Half Life 2. In the game, the player is a medical first responder that arrives at a train station after a bomb explosion where he is ordered to categorize victims based on urgency of needed medical attention. We found that, at least in the short run, the game was less efficacious than a static PowerPoint presentation with the same information.

### GAME DESIGN AND COGNITION

We therefore determined cognitive factors that are important for serious games to become efficacious, and systematically manipulated factors in the game design to improve these. These factors are related to the different stages in which humans cognitively process information during gameplay: selecting information, organizing information and integrating this information with prior knowledge.

### CUES EFFECTIVE WITH GAME EXPERIENCE

Serious games are rich multimodal worlds that can easily overload the player's cognitive abilities. One question was whether we could support the player with visual or auditory cues to attend to and select relevant information and neglect irrelevant information in the game without hindering the immersiveness of the game. The auditory cues led to worse learning than a control group. Conversely, the visual cues were beneficiary, but only for players with extensive prior game experience. Therefore one should only use cues if

their goal is clear to the player beforehand.

### AUTONOMY IMPORTANT FOR ENGAGEMENT

Contemporary videogames are based on the idea of progressing from simple to complex in terms of the problems a player faces and the options he has to overcome these. We therefore tested whether the progressive introduction

tive victim. We found adaptivity to be more efficient, that is it reduced learning time with at least 30% for the same learning gains.

### SURPRISING EVENTS IN SERIOUS GAMES IMPROVE LEARNING

Finally, we investigated the impact of narrative elements in serious games. Interestingly, introducing short surprising events in the game prompts players to



of new options in Code Red: Triage was better than when all the options were available from the start, as well as whether a progressive presentation of problem complexity was better than a variable complexity presentation, when it came to learning and engagement. In the end neither approach influenced learning greatly, but a progressive increase of problem complexity paired with having all the player options from the start heightened the engagement of the game significantly, likely because the player felt more autonomous in choosing how to tackle problems.

### ADAPTIVITY SAVES LEARNING TIME

In the third experiment, we tested whether a serious game can be made more efficient if the game adapts the presentation of victim cases to the performance of the player. In this case, remaining victims belonging to a certain complexity level were deleted if the player scored high enough on a respec-

question their expectations and to integrate these new ideas with their prior knowledge, leading to better and deeper learning. In a related experiment we introduced a back story with foreshadowing and found that they stimulated the player's curiosity and a tendency to better recall of game related information. •

## CONTACT

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Utrecht University, [H.vanOostendorp@uu.nl](mailto:H.vanOostendorp@uu.nl). His interests are on the area of cognitive learning principles in serious games, and cognitive modeling of web navigation. Other people involved in the project: Dr. Erik van der Spek (UU) and dr. Pieter Wouters (UU).

# TRANSFER OF GAMING

HOW TO OPTIMIZE, MEASURE AND VALIDATE TRUE LEARNING EFFECTS OF EDUCATIONAL SERIOUS GAMES

THIS WORK PACKAGE HAS PRODUCED THE PRINCIPLES AND METHODOLOGIES CONCERNING OPTIMALIZATION AND MEASUREMENT OF TRANSFER OF TRAINING IN SERIOUS GAMING. IN ADDITION, TRUE TRANSFER OF JOB-SPECIFIC COMPETENCES IS DEMONSTRATED.

In WP 4.4. Transfer of Gaming, methodological knowledge concerning the validity and validation of serious gaming is developed, as well as guidelines, factors, and mechanisms affecting transfer of training of serious

games. In addition, experimental research is carried out to verify claims, such as the supposed high learning value of serious games. Also hypotheses are tested concerning the factors that elicit cybersickness. This knowledge on (improvement of) ToG helps game designers and developers to build the right games for the right purposes.

First, a review of the literature has been carried out describing educational, modeling, and motivational aspects of serious gaming as well as methodological aspects of the measurement of transfer. This review includes a taxonomy predicting effects of game characteristics on transfer of gaming and a Stepwise Reference Framework. This latter tool entails an approach for the design, specification and evaluation of serious games from a combined didactical and cost-effectiveness point of view.

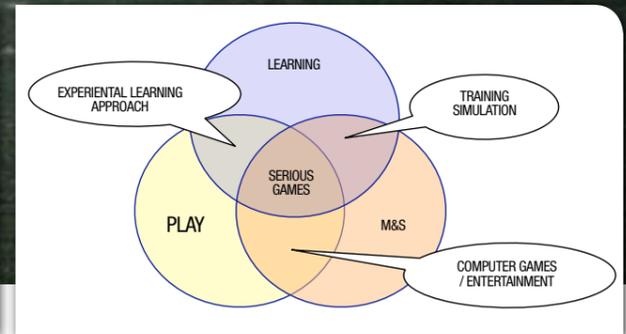
### CYBERSICKNESS

Next to this theoretical study, several experimental studies have been carried out. First, cybersickness represents sickness caused by viewing dynamic image content as generated by video games. In order to get more grip on

this phenomenon several hypotheses have been formulated and experimentally tested. In addition, an explanatory framework was developed explaining motion sickness in general and cybersickness in particular. Taking the control of body motion as a starting point, according to this framework an essential problem concerns the ambiguity between gravity and inertia. Although visual information can be used to make the distinction between these two phenomena, the visual system is yet too slow for accurate control of active body motion. The result of the apparent unsolvable ambiguity is a conflict between sensory and expected signals in a number of cases, which is highly correlated with sickness severity.

### PLAYING MICROSOFT FLIGHTSIM AND FALCON 4.0

In a more practical setting, we have furthermore evaluated training effects of serious gaming (Virtual Battle Space 2) on military tactical competences. Performance evaluations showed that military students performed better after having played several scenarios. Also a transfer of training study was conducted in TNO's high-fidelity F-16 flight simulator. In this experiment



three groups of gamers had to perform three typical F16 flight tasks, i.e., Basic flight, Tactical formation flight, and Close formation flight. The results of this experiment show that Falcon 4.0 (a PC based F-16 flight game) gamers performed substantially better on almost all measured performance variables compared to non-flight gamers, and to a lesser degree to Microsoft Flightsim gamers. Whereas, the Falcon 4.0 group showed (near) transfer on almost all flight performance measures, performance of the Microsoft Flightsim gamers even indicated far transfer. This far transfer was shown especially in the less difficult and more generic flight tasks. In conclusion, we have provided real evidence for both near and far transfer of serious job-related competences by playing games.

### INTERSECTING KNOWLEDGE DOMAINS

Finally, the knowledge that has been acquired has been described in a chapter of a Handbook on the Psychology of Digital Media at Work. This chapter discusses this topic borrowing from three intersecting knowledge domains, i.e.: Learning, Modeling &

Simulation, and Play. From each domain, those issues are presented that are most relevant for serious gaming. In addition, the possibilities and limitations of serious gaming for professional learning and training objectives are indicated. It is shown how gaming can play a serious role in training and education by taking into account the principles and knowledge of the aforementioned knowledge area's.

### ENRICHING TRAINING PROGRAMMES

In conclusion, this workpackage provides rules, principles and aimed at measuring transfer of gaming and improving transfer of gaming in educational programs. For developers of serious gaming this knowledge offers various means of support to improve, and substantiate the quality and effectiveness of their serious games. To be complete, in the design and application of serious gaming one has to consider many factors such as training program and instructional features, serious gaming didactics, fidelity, validity, types of tasks and competences, target groups, learning goals, and intrinsic and extrinsic aspects of motivation. Therefore games and play can

have a valuable role in schooling and job training; not to fully replace traditional training methods, but to substantially enrich existing training programmes, and to inspire and challenge learners. •

### SUMMARY

The present workpackage has provided principles and methodologies concerning optimization and measurement of transfer of training in serious gaming. This knowledge has been produced by literature study on describing educational, modeling, and motivational aspects of serious gaming as well as methodological aspects of ToG measurement. This has a.o. resulted in a stepwise approach for the design, specification and evaluation of serious games from a combined didactical and cost-effectiveness point of view. In addition experimental research has demonstrated factors that enhance cybersickness, beneficial effects of gaming in the training of military tactics, and near- and far transfer-effects of two different flight games on pilot performance.

### CONTACT

#### Dr Hans Korteling

is a psychophysiological and senior scientist at the TNO Department of Training and Performance Innovations with a main focus of interest in cost-effective simulation, cognitive aging (PhD thesis) and design and validation of serious gaming. In the present GATE project Hans collaborates closely with two former TNO researchers, i.e., Ralf Sluimer MSc, working as experimental psychologist and project manager and dr Anne Helsdingen, who is cognitive and educational psychologist at the Effat University in Jeddah (Saudi Arabia).



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# INNOVATIVE PILOTS

## INTRODUCTION

Within GATE a number of innovative pilot projects are carried out. The goal of these pilots is to create awareness of the potential of gaming and simulation in the sectors education, health care, and safety. In developing these prototypes we have established collaboration between various disciplines: game designers, creative artists, educational specialists, ICT experts, and domain experts.

The pilot projects are based on a systematic user co-creation approach that integrates research and innovation processes. This ensures integration through the exploration, experimentation and evaluation of innovative ideas, scenarios, and concepts in real life use cases. This way of working allows all involved stakeholders to consider design, effectiveness, usability, and its potential for adoption by users.

For example, we developed prototypes for a game for physics education, for non-verbal communications between patients and relatives, and for training mayors how to operate in disaster situations.

Scene from the game Sim City 4 — gamers play a mayor, now real mayors have their own game, see *Serious Training for Mayors*

# NEWTONIAN PHYSICS AT FULL SPEED

WOULD NEWTON TURN AROUND IN HIS GRAVE OR SMILE AT OUR RESEARCH AND DESIGN ENDEAVOUR TO BRING HIS SCIENTIFIC DISCOVERIES TO A 21ST CENTURY LEARNING AUDIENCE?

The design process of a serious game (or applied game as we prefer to call it) differs considerably from that of an entertainment game. When creating an entertainment title, the sole focus of the designers is on the future enjoyment of the player. All design parameters are available for this single purpose. For an applied game additional yet specific aims and objectives need to be met, while maintaining all qualities of gameplay intrinsic to a good game.

## THE TUG OF WAR

Applied game design processes are not seldom described as a 'tug of war'. This refers to the negotiation process between subject matter experts and game designers trying to meet demands from both perspectives. This particular choice of words makes it clear this negotiation process can be quite difficult. A shared language is an important pre-requisite.

## CHOCOLATE COVERED BROCCOLI

Many applied games that have been created in the past suffer from a poor relationship between the inner game mechanics and game play on the one hand, and the subject matter on the other. This easily leads to products that might look like a game but through play manifest themselves as poorly disguised learning tasks, or 'chocolate covered broccoli' as David Shaffer calls them. One wonders whether game designers were involved in the trajectory at all. A key research question for the Applied Game Design program of the HKU is to find the underlying design principles to create truly immersive applied games while achieving the intended learning aims and objectives in a given learning situation. Our aim is to share these insights with both students and game companies to shorten production time, help increase effectiveness and prove validity.

## A FORMULA COMES ALIVE: MEET CARKIT

For the GATE Education pilot it was decided to use a part of the HAVO 4 physics curriculum dealing with Newtonian physics. Our aim was to let the player explore some key Newtonian variables and their dynamic interplay. Textbooks teach physics based on formulas. But formulas are static and abstract descriptions of dynamic relationships between universally applicable entities like friction, mass, and force. Through a careful analysis of existing learning materials a basic set of parameters was selected to be converted into some form of appropriate gameplay. Leading the design process from a game design perspective was a deliberate choice at this stage.

Although games have several potential contributions to make to learning, one key ability of games is to represent dy-

namic systems, since games in themselves are dynamic systems. We wanted the player to be able to interact dynamically with the variables mass, force and 'braking' (the latter is a composed variable of different kinds of friction). Through experimentation they can find out what relationships exist between these variables. In order to do this in a meaningful context, we decided to opt for a race game as underlying context. Special attention was paid to create a gender-neutral race experience (and stay away from formula 1 clichés).

## AVOIDING PITFALLS

Some important design considerations were discovered in the early phases of the design. One notion was the role of the player as driver: once we would add driving as a player activity, we ran into a transparency problem regarding the learning effect. Driving ability combined with the various physics variables would lead to

unwanted interference in the learning experience. Another consideration was to design a game for the realities of the classroom. This led to a two tier design. Players can practise at home to configure their optimal vehicle setup based on numerous test runs (by setting the above mentioned variables rather than steering their vehicles). Then they bring their vehicles to the classroom, where all vehicles can be put in race mode against each other on a teacher computer. With different configurations for different types of routes, a lot of variation is offered.

## IMPORTANT LESSONS LEARNED

Being the first of three applied game design pilots in GATE (the others being for Safety, which led to the Burgemeesters game, and for Health which became Project Dream) there were a great many lessons learned. The most important lesson is the necessity of a multidisciplinary team in which subject matter experts and

designers meet frequently. This should be part of an iterative design process with meetings in between iterations. Some early yet crucial design decisions were taken without SME involvement, to be regretted later. For instance, the game engine physics proved to be limited in portraying Newtonian physics values, a rather surprising finding.

Another lesson learned related to the notion of transfer. The game design itself did not address transfer as a design decision, leaving that aspect to the teacher. It became apparent that this part of the learning process needs additional support for teachers if they lack experience in using games in their educational process. However, the classroom race mode proved a huge success with a very enthusiastic and heated crowd cheering their vehicles to the finish. •

## SUMMARY

Carkit is the first of three HKU pilots in applying game principles in a particular context. The game was developed in the context of physics education for secondary school pupils. The research objective was to design and learn from the integration of learning objectives and game mechanics, while maintaining qualities intrinsic to games in terms of playability, attraction and production value. Main lessons learned were

the necessity of involving subject matter experts in between design process iterations and the vital importance of accommodating transfer, either in the design or the implementation. These lessons learned were incorporated in the second and third pilot successively.



## CONTACT

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This research project was impossible without the invaluable contributions of Jeroen van Mastrigt, Willempje Vrins, Micah Hrehovcsik, Karel Millenaar, Niels Keetels, Duncan Waterreus, Lies van Roessel, Leo Buntjer, Eduardo Barillas, and all students involved.

# REHABILITATION THROUGH GAME PLAY: PROJECT DREAM

**“TESTING THIS APPLIED HEALTH GAME AS A GAME DESIGNER FELT LIKE STANDING IN FRONT OF A FIRE HOSE”-NIELS KEETELS**

IMAGINE CHILDREN WITHIN THE AGE RANGE OF 12 TO 20 SUSTAINING AN ACQUIRED BRAIN INJURY. THEIR LIVES AS THEY KNEW IT HAVE DISAPPEARED. A LONG AND DIFFICULT ROAD LIES AHEAD TO REGAIN AS MUCH OF THEIR LIVES AS POSSIBLE THROUGH INTENSIVE REHABILITATION. CAN WE MAKE THE OFTEN REPETITIVE EXERCISES MORE ENGAGING? MEET PROJECT DREAM.

Our third GATE pilot project aimed to apply game design to the context of health care. In close collaboration with rehabilitation center De Hoogstraat in Utrecht a game was developed to support the treatment of children with an ABI. Given the wide age range and the wide array of possible injuries these children can suffer from, this proved to be a tremendous challenge.

**OPERATING ON THREE DOMAINS.** Children with an ABI can acquire disabilities in the areas of motor, socio-emotional and cognitive disabilities. The game aims to cater for each of these

categories to create as large a footprint in usage as possible. Additionally, the Hoogstraat experts asked for a game that can be used in group therapy, therefore collaboration between children with different therapeutic needs was an important design parameter.

## USING OFF-THE-SHELF TECHNOLOGY

At the start of the pilot the Microsoft Kinect platform had not been launched yet. However, using two affordable Nintendo Wii sensorbars enabled the development team to detect the player position in 3D space. Thus, a game that triggers and is

aware of player movement could be created long before Kinect offered that capability. For this game, an advisory group of experts was formed and regular meetings were arranged with the purpose of working out a shared language to glue game mechanics and therapeutic outcomes tightly together.

## FIRST THE CORE, THAN THE GLAMOUR

First the core, than the glamour Using early prototypes with very basic graphics, the prime concern was to develop game mechanics and movement patterns matching the experts' clinical specifications. Not before the team was

happy with the basic gameplay a fictional world and storyline was created. At the onset of the project a decision was made to use a vertical slice approach: this meant that the game would have a limited amount of levels but would deliver industry standard art, game play, graphics and sound to enhance player acceptance and immersion.

Iterative design stages with player tests in between were used to validate vital design decisions and secure playability. Additional research was conducted on the preferred visual style and art for the target audience. Project Dream is a four player collaborative game where players embark on an adventure in which they have to beat a rather mean looking octopus, or collectively compose a music box song. Every team member is needed. The game features some truly unique game play aspects. Dynamically adjustable multiplayer balance. Its multiplayer capability is specifically tailored to the kind of patients intended to play the

game: scalable in terms of difficulty and mobility. All types of players can play at their personalized level of difficulty while the game maintains collaboration balance. Players can take on an attacking role (moving forwards and backwards in the room to attack or avoid counter-attack); they can heal other players, or use ranged weapons to support the team from the back of the party (depending on mobility of the player). Since patients differ in mobility from lying down in bed, sitting in a wheelchair or standing up, this variation in mobility posed severe challenges for the designers. A unique feature is the so called 'fifth' controller. This feature enables the therapists to dynamically alter several difficulty parameters during game play without the players noticing; affording the opportunity to keep the players on their toes thus maximizing therapeutic effect through the game.

Project Dream has turned into a stunningly beautiful game, designed from the ground up based on clinical speci-

fications while maintaining every aspect of an engaging yet fun-filled game.

## MULTIDISCIPLINARY TEAM

De Hoogstraat proved an excellent collaboration partner. In a preparatory trajectory extensive experience was built up using COTS games (Commercial Of The Shelf) in therapy to explore potential and limitations of existing games. With solid support from both clinical experts and management De Hoogstraat followed the project every single step along the way.

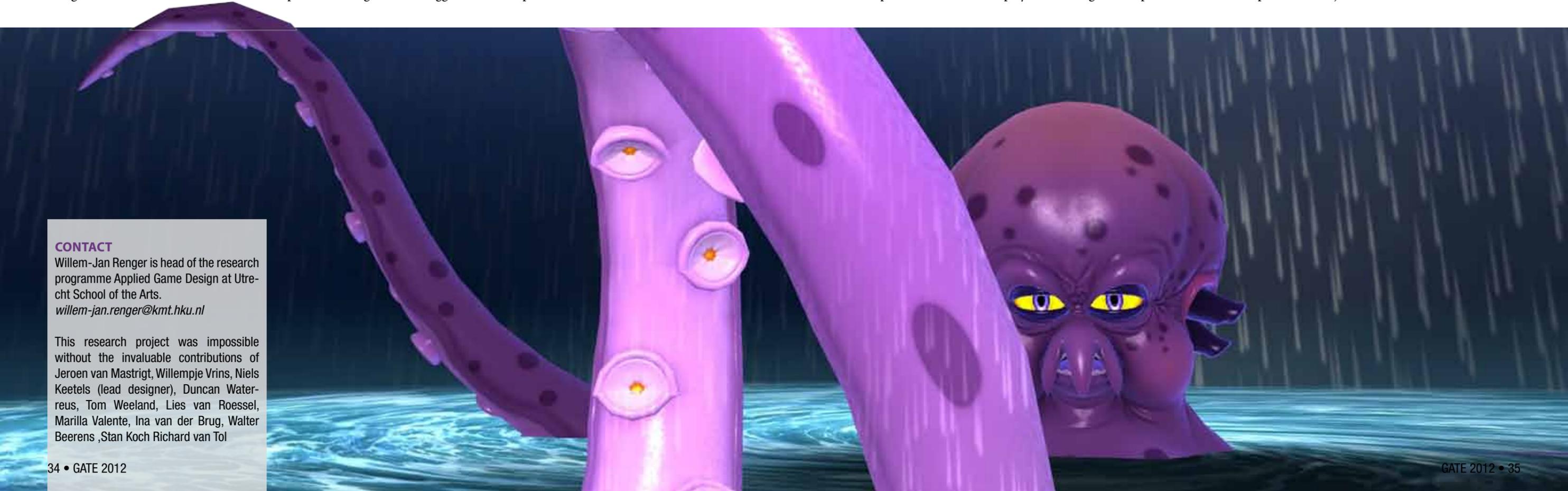
We believe Games in health care have a great potential given the challenges ahead. To illustrate this potential the Applied Game Design programme at Utrecht School of the Arts produced a documentary to support this vision (<http://vimeo.com/31304042>).

We owe many thanks to our advisory board of experts and their critical support throughout the process, Jaap Burke, Joep Jansen, Jose Ermers, Doret Brandjes and Richard Tanke. •

## CONTACT

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This research project was impossible without the invaluable contributions of Jeroen van Mastrigt, Willempje Vrins, Niels Keetels (lead designer), Duncan Waterreus, Tom Weeland, Lies van Roessel, Marilla Valente, Ina van der Brug, Walter Beerens, Stan Koch Richard van Tol



# SERIOUS TRAINING FOR MAYORS

MAYORS ARE GENERALLY BUSY INDIVIDUALS AND THEREFORE DO NOT HAVE MUCH TIME TO READ ALL KINDS OF LENGTHY CONTINGENCY PLANS FOR CRISIS SITUATIONS. SERIOUS GAMES LIKE THE MAYOR'S GAME PROVIDE A SOLUTION.

On 7 November 2011, the project team of GATE Pilot Safety presented the report HELP! Over de ontwikkeling van een serious game als oefenmiddel voor burgemeesters om zich voor te bereiden op incidenten (Help! The Development of a Serious Game as a Training Tool for Mayors to Prepare for Incidents). Led by Josine van de Ven (TNO), a group consisting of TNO, Thales, T-Xchange and Utrecht School of the Arts spent three years developing the Mayor's Game, a dilemma trainer.

HELP! openly and meticulously describes the development history of the Mayor's Game, including all of the ups and downs. HELP! shows what the team all had to do to make this game a reality. Although it looks simple, three years of work went into it, considering

all the learning objectives and parameters involved.

Mayors are generally busy individuals and therefore do not have much time to read all kinds of lengthy contingency plans that exist on crisis situations. Training for a crisis, a situation that might never happen is, given the busy schedule, not necessarily on top of their to-do-list. And, training takes a lot of time. A training session usually take about 4 hours and therefore are only used twice a year. However incidents do occur, and because incidents are complex situations a mayor should train more frequent for incidents. Serious games like the Mayor's Game provide a solution. In general, incident scenarios in the game do not last longer than 15 minutes. Therefore a complete scenario

runs on a PC in under 15 minutes, during which time the mayor must deal with a number of dilemmas. The game is designed in such a way as to 'suck' players into the dilemma, as it were. The difficulty is that dilemmas can only be answered 'yes' or 'no'. That does not give much time for reflection, which is why a post-game meeting always takes place. This meeting is in fact far more important because it is often only at this stage that the mayor becomes aware of his position and of the things that can be improved. By allowing only the answers 'yes' and 'no' the player needs to think really hard about all the aspects of an answer. For example, the dilemma of participating in a silent marsh, there are aspects of how is the victim to be remembered, will you be addressing the people, who are those people that



participate and what are the sentiments of other 'groups' to be taken into account. You see even a simple question like the silent marsh has many aspects for a mayor to consider, before giving an answer. Almost all of the mayors in the Netherlands have now played the game. Without exception, the responses were tremendously enthusiastic.

What the team has shown with the development of the Mayor's Game is how to introduce serious gaming successfully for a new audience. We have not only developed a serious game, but we also increased our knowledge on the process of how to do this. We started with the learning goals, TNO's didactic experts helped us. We then discussed conditions for a game with our expert group. Those conditions felt – certainly in the

beginning – as limitations. Designing a serious game for 15 minutes playtime, that is though especially if you want the players to learn something as well from the game. We knew our idea could work when we showed a paper-based version of our game to our expert group and a group of students. Both groups started to discuss on the dilemma's, what they would do and why. The framework of the Utrecht School of the Arts was very useful in this process. Then came the next step; translate the paper-based version into a first digital prototype. Both the experts of Thales/T-Xchange and interaction designers from TNO put effort in this translation. The prototype should capture the game mechanics of the paper-based version, but it should also be easy to play. Having a prototype it was much easier to show our target audience

what we meant with 'serious gaming for mayors'. And then it became easier to get feedback from our target audience. During gaming sessions we learned a lot about the way we should present our feedback. Pilot Safety was truly a cooperation between different parties.

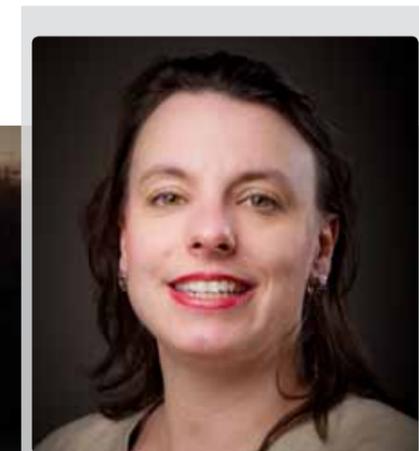
"The challenge for us now is to use the Mayor's Game as widely as possible also in 2012. We want to make it possible for this product to be used cost effectively and are therefore thinking about how best to continue the process. It's also what the administrators want." Regular introduction of new scenarios, for example, will keep the game fresh. •



## SUMMARY

Pilot Safety was truly a cooperation between different parties. With a team of experts, and a group of domain experts for external consultation, the team was able to successfully develop a serious game for mayors. Almost all of the mayors in the Netherlands have now played

the game. Without exception, the responses were tremendously enthusiastic. Based on the feedback of our target audience the feedback in the game improved. The challenge for us now is to use the Mayor's Game as widely as possible also in 2012.



## CONTACT

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T-Xchange, TNO.

We would like to acknowledge the contribution of our expert group, especially from het Nederlands Genootschap van Burgemeesters.

# STIMULATING LANGUAGE EDUCATION THROUGH PLAYFUL LEARNING

STORYBOX IS A NOVEL TOOL FOR LANGUAGE LEARNING. TANGIBLE, TECHNOLOGICALLY ENRICHED OBJECTS ENABLE CHILDREN TO LEARN TO AUDITIVELY RECOGNIZE CHARACTERS, CONSTRUCT SMALL WORDS, AUTOMATE WORD RECOGNITION AND PLAY WITH LANGUAGE STRUCTURES.



## SUMMARY

This article is an overview of the design process and the testing phase of Storybox. Making rapid prototypes from the start of the process has provided useful inspiration. Through testing the prototypes the design

team has been able to observe how children handle the blocks, and how they interact with the Storybox. This has led to ideas on how to encourage the target users to engage in a form of play.

Storybox focuses on primary school pupils (six/seven years old). It consists of a number of tangible, technologically enriched blocks. Every block contains a sound (vowel and consonant sounds) that can be listened to individually or in a series, using a 'stethoscope'. Pupils are challenged to form words out of the sounds. For example, when the 'v'-sound is linked to the 'i'- and 's'-sounds, one hears 'vis', Dutch for 'fish'. When the combined sounds do not form a word, the user hears nothing but the separate sounds.

The 'Storybox' provides a tool for the pupils to change the sounds in the blocks. By connecting a sound-block to the radio-tool, one can search for a different sound by turning the radio. Once the sound one was looking for is heard through the stethoscope the corresponding letter has to be written on the touch-screen. If this is successfully done, the sound-block is loaded with that particular sound.

The 'Storybox' also provides a 'machine' in the small factory that forms the Storybox for loading word-blocks. At the left side of this tool one puts in the connected sound blocks, on the other side one puts a word block. By pushing a big button the word will be loaded in the wordblock.

The third feature of the 'Storybox' is the chimney. The chimney prints out the words that are manufactured once a word block is connected to the 'fire place'. The stethoscope is made out of two 'half' headphones. With Storybox pupils will be working together in pairs. To make sure a pair is still able to communicate, each headphone only covers one ear. Because the headphones are connected to the same stethoscope both players get the same auditive feedback.

Pupils not only get auditive feedback by listening to the sound- and wordblocks, but also are challenged to write down the corresponding letter of a sound on a touchpad in the 'Storybox'. With Storybox after all we also aim to address the important link between phonemes and their graphic representation: letters. In case pupils have difficulty writing a certain letter, the touchpad provides a presentation which can be traced. In addition there is a little screen on the stethoscope on which the sound (consonant, vowel or word) that is listened to appears in text. To complete their word-construction it's possible for children to print the word at the chimney.

The use of serious games in education is mostly in individual setting for skill and repetition; in addition most serious games are either predominantly virtual (web based / mobile) or predominantly physical. Games that incorporate both modalities and focus on social interaction are rare. Physical play can enhance the learning experience, as is for example shown in research on embodiment and gestures in mathematics education and on embodied media learning environments. Especially playing with blocks can stimulate language education. Children learn to place the blocks on a line. They learn to play with structures, which stimulate the brain for language learning.

## EXPECTED RESULTS

During the end of 2011 'Expertise Centrum Nederlands' tested a group with the new prototype. In these user evaluation sessions the development team focused on game and educational logic, tactility and materials and logistics of the factory metaphor but also the effects of Storybox on language learning. The results are not known yet, but we



expect the results to show that special needs children, especially those with dyslexia, who find it difficult to distinguish different word sounds learn language with Storybox easier and better than children who only learn from pure textbook methods. Due to expected budget reductions in the education system, including special education, Storybox might allow more special needs children to attend regular schools without the need for additional learning support. As Storybox also addresses the spatial, collaborative and creative abilities of the pupils the design team hopes to find positive learning effects on those aspects as well. •



## CONTACT

At Waag Society Marieke Hochstenbach worked as an educational developer. Hochstenbach co-developed the project Spelfactory. She worked together with schools and the expert group. Currently Marieke is responsible for Waag Society's educational services as manager Creative Learning Lab.

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SCOTTIE SUPPORTS SOCIAL CONNECTEDNESS BETWEEN PEOPLE WHO SHARE A CLOSE RELATIONSHIP, SUCH AS PARENTS AND CHILDREN

# REMOTE HUGGING THROUGH ICT

NON-VERBAL COMMUNICATION, LIKE A PAT ON THE BACK OR A LOVING HUG, IS AN ESSENTIAL PART OF PERSONAL RELATIONSHIPS, BUT IS LOST WHEN PEOPLE ARE SEPARATED. CAN YOU MEDIATE THOSE ACTS OF AFFECTION AND INTIMACY THROUGH ICT?



## SUMMARY

Scottie is one of GATE's healthcare pilots, in which playful use of technology was explored to foster social connectedness between people who are physically or geographically separated. The prototype, a family of multimedia buddies, was developed in an iterative process, in which users played an important role. Observing how users respond-

ed to the prototypes led to new and improved versions of the concept and helped define the use and implementation strategies that needed to be developed around Scottie. The user evaluation indicated a potentially interesting shift from hospitalized children towards seniors in nursing homes.

The aim of Waag Society was to explore ways to stimulate a feeling of virtual presence or connectedness that can contribute to (social) wellbeing in real life. The project focused on the development of novel forms of communication: abstract, playful, pleasant and uplifting; exploring visual, tactile and auditory stimuli. To mediate the relationship that people share an abstracted, physical shape was created, named Scottie, that in its final version facilitates two intuitive forms of play between people: creating light patterns and creating sound patterns together.

## CONTEXT OF SCOTTIE

Scottie is envisioned as a health buddy, a means of play for children who are hospitalized and separated from their family and friends. Most (mediated) communication is limited to the use of verbal or text based expressions and images. The



## CONTACT

Dick van Dijk is concept developer at Waag Society. Waag Society investigates the interplay of art, science and technology in relation to society, education, culture and healthcare. Dick is responsible for Waag Society's interactive concepts and design research. He is foremost interested in the crossover between virtual and physical interactions, in creating a narrative space, a place for imagination. As concept developer he has worked on projects such as Scottie, the Personal StoryTable, Operation Sigismund and the MuseumApp. [www.waag.org](http://www.waag.org)

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non-verbal, implicit, social-emotional modes of communication that in normal, daily interactions confirm that you are part of a relationship or group, need special attention however when people are apart from their loved ones.

## DEVELOPMENT PROCESS

Prototyping fulfils an important role in Waag Society's creative research process, especially when exploring playful interactions. In each stage of development prototypes, whether they are paper prototypes or interactive 'black boxes', were used as demonstrators of (new) ideas. Observing how users responded to the prototypes led to new and improved versions of the Scottie prototypes and helped us define the requirements for use of Scottie.

## A FAMILY OF SCOTTIES

Each 'Scottie set up' consists of a family of three Scotties, communicating with each other via WIFI. Each user has his own Scottie with a distinct 'presence colour' (blue, red or green). When one of the users is online, it displays its presence colour in the extremities of the others. When a user moves Scottie around, his movement is visualised as the colour pattern mimics the physical movements of Scottie. The colour pattern is displayed in all connected Scotties and others can join in by creating their own light patterns. By tapping on the arm or leg of Scottie, a rhythm can be assem-

bled, send to and replayed by the other Scotties. This way a special rhythm can be created for a friend or a 'jam' session can be held.

## USER TESTING

Based on user testing, the design of Scottie, its shape and the possibilities of nonverbal communication were found to appeal to people. As testing with the intended participants - children who stay in the hospital for a longer time and their parents and/or friends - was hindered by practical barriers and ethical issues, initial field-testing was conducted with four families and their social circle. Each family had three Scotties. Based on their evaluation it can be concluded that Scottie lead to a feeling of connectedness and to another way of communicating with each other. A test with the next of kin of seniors who stay in a nursing home revealed a new use of Scottie, which resulted in a shift towards elderly people that are disconnected from their family and friends. This has lead to a larger user study with seniors, indicating that the use of Scottie here also lead to another way of communicating with each other. Future research will be conducted to gather additional quantitative and qualitative data on the potential outside hospital settings.



# KNOWLEDGE TRANSFER PROJECTS

## INTRODUCTION

### *Knowledge transfer, innovation, exploitation, valorization*

Knowledge transfer projects form joint development teams consisting of developers from companies and researchers from GATE research projects that collaborate on making a clearly defined body of knowledge directly accessible to industry. Indeed, knowledge is an essential capital good for companies, needed for the innovation of products and services that give them a competitive edge. There are many SME companies involved in gaming and simulation in the Netherlands. A major problem for these companies is that technology in this domain is developing at an extremely fast pace. New simulations and games must use this technology to be competitive with other products. However, various factors limit the innovative drive of SMEs. They generally don't have the time to scout new technologies world wide and generally don't have the competence to integrate new technologies into their products. An additional complication is that the field of gaming and simulation is very multi-disciplinary.

*"The knowledge transfer project enabled innovation we could not have done otherwise."*

Each of the thirteen research projects are involved in knowledge transfer projects, there are fifteen of them in total. They range in budget size from ca. one to three hundred thousand Euros. Generally, the companies provide knowledge questions and intended applications. The research center provides new technology. The knowledge transfer projects combine this into practical solutions but also pose new research challenges to the research center. In turn this will focus the research on the mid- and long-term needs from industry. The topics vary from deploying cognitive models for assessment, to developing algorithms for 3D reconstruction. To assure the sustainable transfer of expertise, sometimes a project member is employed both by the company and the knowledge institute, sometimes he moves to the company after the project. Knowledge embodied this way, is a very active and effective way of transfer indeed. Either way, the GATE project creates the knowledge base in the Netherlands that will give these companies a leading edge by helping them to integrate new technology in their future products.

Scene from the game Uncharted Golden Abyss — what if a game character falls down? See *Ouch! Measuring character injury*

# LIDAR GIVES DEPTH TO PANORAMAS

## SUMMARY

Panoramas and LIDAR point clouds can be combined to produce a depth value for each pixel of the panoramic image. With this depth information, it becomes much easier to find the 3D position of objects in an (urban) environment and to derive attributes such as height or surface area. However, due to the limitations of GPS, the relative positions of the panoramas and the LIDAR point cloud will have errors. By creating a separate, sparse point cloud from the panoramic images and then fitting it to the LIDAR cloud, these errors can be corrected.

BY COMBINING PANORAMIC IMAGES AND LIDAR POINT CLOUDS, WE CAN FIND THE DEPTH OF EACH PIXEL IN THE IMAGE. BUT FIRST, THERE IS A PUZZLE TO SOLVE.

Wouldn't it be useful if we knew the location of every lamppost, traffic sign, and park bench in the Netherlands? The height of every wall, the width of each road? Maintenance, traffic management, route planning and a host of other processes would be greatly simplified if we could easily find this kind of information. Each year, a fleet of cars travels the country to record a panoramic image for every five meters of public road. The 30 million photographs collected in this way are already being used for many applications, but they are still missing one thing: depth. In the knowledge transfer project CycART (Cyclorama-based Automatic 3D Reconstruction Tools), Utrecht University and CycloMedia Technology B.V. work together on this challenge.

## DEPTH

The position and orientation of the panoramic camera at the time each picture was taken are known from GPS and other sensors in the system. With this information, it has always been possible to figure out the 3D position of a point (like the corner of a building, or the center of a traffic sign) by identifying it in multiple images. But finding and clicking on the same point in several images is a tedious task

## CONTACT

The knowledge transfer project is performed by Arjen Swart. During the project he worked both at Utrecht University and at CycloMedia Technology B.V., which guaranteed a very direct form of knowledge transfer.

The project leader is Remco Veltkamp. He is professor in Multimedia at Utrecht University, working on developing new technologies for the analysis of 3D scenes, images, video, and music. [R.C.Veltkamp@uu.nl](mailto:R.C.Veltkamp@uu.nl)

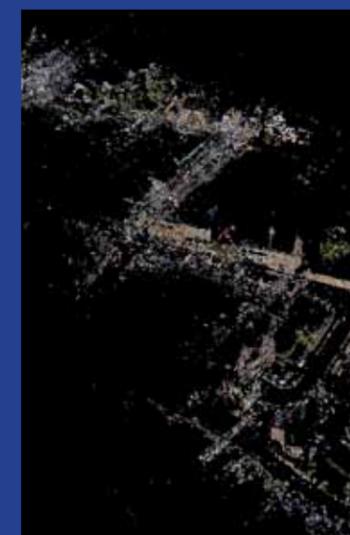
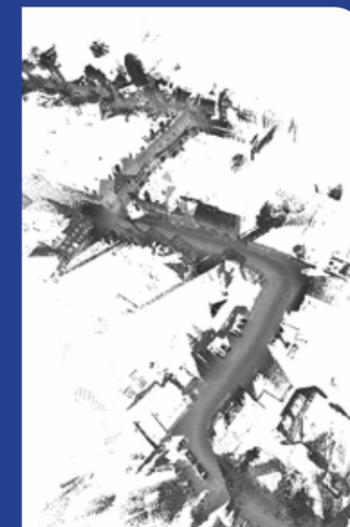
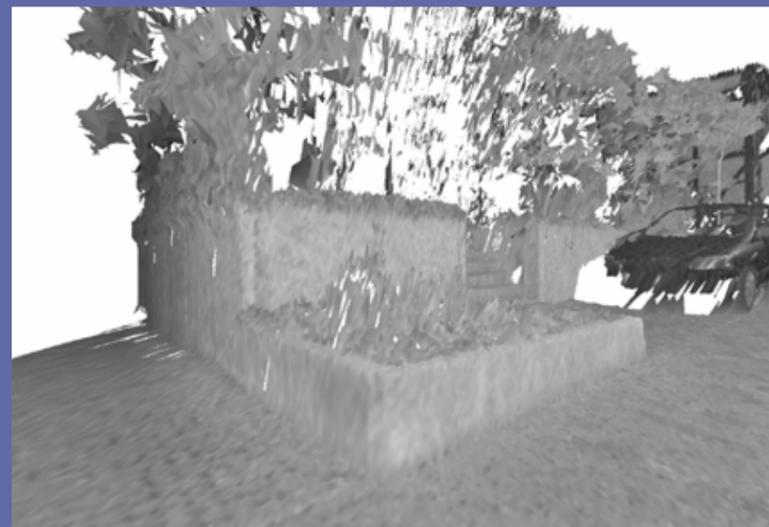
for a human operator, and algorithms to perform this job automatically are error-prone. If, on the other hand, the depth of each pixel was already known, finding the 3D position of any object would be as simple as a single mouse click, and computing other properties like height would be easy.

## LIDAR

In recent years, LIDAR has become a feasible solution to the problem of recording depth information. LIDAR works by generating a laser pulse, which is reflected by an object in the environment. The reflected light pulse is detected by a sensor. Because the speed of light is known, it is possible to work out how far the light must have traveled in the time between sending and receiving the pulse. Combined with the position of the system based on GPS, the actual 3D position of the point can be computed. In this way, a car equipped with a modern LIDAR system can easily record one million 3D points per second, creating a large point cloud model of the environment.

## FITTING THE PIECES OF THE PUZZLE

If GPS positioning were perfectly accurate, we could simply take a point cloud produced by a LIDAR system and project it into the existing panoramic images, and then we would have our depth. However, GPS is not perfect, so if we tried this, the images and the point cloud would not fit together. For example, if a user clicked on a lamppost in the image, he might get the depth of some other object from the point cloud. In order to solve this problem, we first create a sparse cloud of 3D points based on the panoramic images alone. As mentioned earlier, algorithms that can do this are error-prone, but the rest of the procedure can handle a few erroneous points. Because they are created from the same environment, this new sparse point cloud and the LIDAR point cloud must coincide when the two data sets fit properly. We keep automatically adjusting the positions of the panoramic cameras (and with them, the sparse cloud) until this is the case. The process is somewhat similar to fitting pieces of a puzzle into place, except the pieces are allowed to stretch a little bit, and they may have some unwanted bumps and holes. After this fitting procedure, we have the correct depth for the pixels in the panoramas. •



Lidar and sparse point clouds. The panoramas are fitted by aligning these point clouds.



Part of a triangulated lidar point cloud. The same part before and after fitting. In the before picture, the position and orientation of the panorama relative to the lidar cloud were not known, so the texture is projected incorrectly.



The panorama and a grayscale representation of the final depth map (darker is further away).

# LOOKING AT PEOPLE IN THE RESTAURANT OF THE FUTURE

## STATE-OF-THE-ART COMPUTER VISION TECHNIQUES FACILITATE AND SPEED-UP TEDIOUS MANUAL ANNOTATIONS IN HUMAN BEHAVIOR RESEARCH

**H**ow do people choose their food? Do other people influence this choice? Do they like what they chose? These are some of the questions studied at the Restaurant of the Future, which is a field lab equipped to study people having lunch. To make these studies more efficient, the tedious manual annotations are (partly) replaced by automatic filters implemented in the Video Analysis and Recognition Toolbox (VidART) consisting of modules for automatic people detection and tracking.

### RESTAURANT OF THE FUTURE

Noldus Information Technology BV is one of the research partners participating in the Restaurant of the Future, a facility located in Wageningen. It serves as a place allowing for close observation of consumer eating and drinking behavior and to experiment with new food products, preparation methods and self-service systems. This living lab is open for people to have their daily lunch. To observe people's behavior, the restaurant is equipped with 23 pan-zoom-tilt cameras. Most studies at the restaurant use event logging software for the collection, analysis, and presentation of observational data. Especially, the manual annotation of human behavior from video streams is time-consuming. Automating parts of this annotation process would help researchers to focus on the important parts. Imagine you want to know how often your product is chosen. By tracking the position of subjects automatically and know-

ing the position where your product is at, the system can select only those frames for further analysis, where people actually approach your product. Or, if you are interested in what kind of food people actually put into their mouth, you can track the face (or mouth) and the hands and select only those frames where a hand approaches the mouth for detailed analysis.

### VIDART

The goal of this knowledge transfer project is to develop the Video Analysis and Recognition Toolbox (VidART), a prototype toolbox for the automatic analysis, classification, and annotation of the behavior of people from video, to speed up the manual annotation process. The key ingredients are automatic detection and tracking of people from image sequences. The challenge of applying this toolbox at the Restaurant of the Future is that this facility is not a controlled environment. For example, the space has large windows and different illumination possibilities, its furniture is moveable, and no constraints are forced on people's appearance. Since the Restaurant of the Future is equipped with multiple cameras, a multi-view background subtraction technique could be applied, where deviations in the 3D geometry of the scene identify foreground objects. Another way of detecting people is to use the fact that they are people. We implemented an approach to detect the pose of a subject in still images. It finds body parts



Restaurant of the Future setup, and tracking result.

like the torso, head, arms and legs by comparing them to a set of manually annotated images. For tracking a subject, we implemented a real-time contour tracker. After proper initialization, meaning the subject is separated from the background, a bounding box is defined around the subject and two appearance models are defined: one for the foreground object and one for the background. To incorporate illumination changes, moving cameras, changing appearance, etc., the foreground and background models are adapted in time.

### UTRECHT MULTI-PERSON MOTION (UMPM) BENCHMARK

The VidART software has to be tested and verified. Since the Restaurant of the Future is a complex environment, and although publicly available data sets for single person tracking and pose estimation can be used, we created the UMPM benchmark to validate multi-person tracking, pose estimation and gesture recognition algorithms using a marker-based motion capture system available at Utrecht University. The benchmark includes 10 different scenarios, where each scenario concerns multi-person motion and interaction with static objects (chair, table, grabbing objects) and people (conversation in gestures, playing with a ball) in a controlled environment. All scenarios include 1 to 4 subjects visible in the scene, and maximally two of them wear reflective markers to measure joint positions of the body.

The joint positions found by the pose estimation software can be evaluated with these measured ones. This benchmark is available to the research community via [www.projects.science.uu.nl/umpm/](http://www.projects.science.uu.nl/umpm/) to advance the field of multi-person human motion capture.

### MULTIPLE CAMERAS

The fact that multiple cameras are available at the Restaurant of the Future offers a possibility to obtain 3D information about the position, shape or movement of a subject. In order to get this information about the subject or the scene, camera views have to be related to each other, in other words, calibrated. For static cameras, this calibration step has to be done only once and it is usually carried out by moving a well-known pattern like a checkerboard, in front of the cameras. Once the calibration is done, voxel reconstruction can be done using the standard background subtraction or the 2D tracker results by projecting the foreground silhouettes into the scene. As a result, we find the 3D position on the ground floor. •

### CONTACT

The knowledge transfer project is performed by Nico van der Aa. He first worked as a computer vision postdoc at Utrecht University, and is subsequently employed by Noldus Information Technology BV. A solid form of knowledge transfer indeed!

The project leader is Remco Veltkamp. He is professor in Multimedia at Utrecht University, working on developing new technologies for the analysis of images, video, music, and 3D scenes.

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### SUMMARY

Manual annotations form the core of eating behavior and food selection studies at the Restaurant of the Future. Although human interaction cannot be replaced fully, the amount of images to be annotated manually can be reduced drastically by computer vision techniques. The Video Analysis and Recognition Toolbox (VidART) is under development to automatically detect and track (parts of) people from video streams. This project develops and implements algorithms to detect and track people or objects from multiple video streams among multiple persons in a challenging environment.

# SERIOUS GAMES NEED AGENT TECHNOLOGY

## SUMMARY

In this knowledge transfer project between VSTEP and Utrecht University, we investigate the obstacles of employing agent technology to control virtual characters (NPC's) in (serious) games. Agent technology can be used to create natural, human-like decision-making capabilities for NPC's, but integrating this technology into game engines is not a trivial task. In this project, we have developed a middleware (called CIGA) to overcome the universal issues in coupling agent technology to game engines. As a result, it opens up the way for creating more innovative agent-based serious games while lowering the development effort.

AGENT TECHNOLOGY CAN BE USED TO CREATE MORE INTELLIGENT AND NATURAL BEHAVING CHARACTERS IN GAMES. THE CIGA MIDDLEWARE SUPPORTS COUPLING AGENT TECHNOLOGY TO GAME ENGINES FOR THIS PURPOSE.

Games and especially serious games need intelligent NPC's to make the game realistic and train the user on the right skills. Agent technology provides intelligent agents, but is not ready to be incorporated in game engines straight away. In the KTP project CIGA, VSTEP and Utrecht University have developed a middleware to couple agents and games.

Games become more attractive when the NPC's are behaving more natural and intelligent. Many efforts are made in the gaming industry to create characters (also called agents) that look and behave more realistic. At the same time there is an AI community of researchers that has developed agent technology in order to create intelligent agents that can be used to solve complex problems ranging from logistics at big airports to (support for) electronic auctions.

It seems natural to use this agent technology to create more natural behaviors for NPC's in games. One of the main characteristics of agent technology is that the agents are goal directed and thus remember why they are performing their actions and can thus reason whether to persist with their plan or give it up and try an alternative plan.

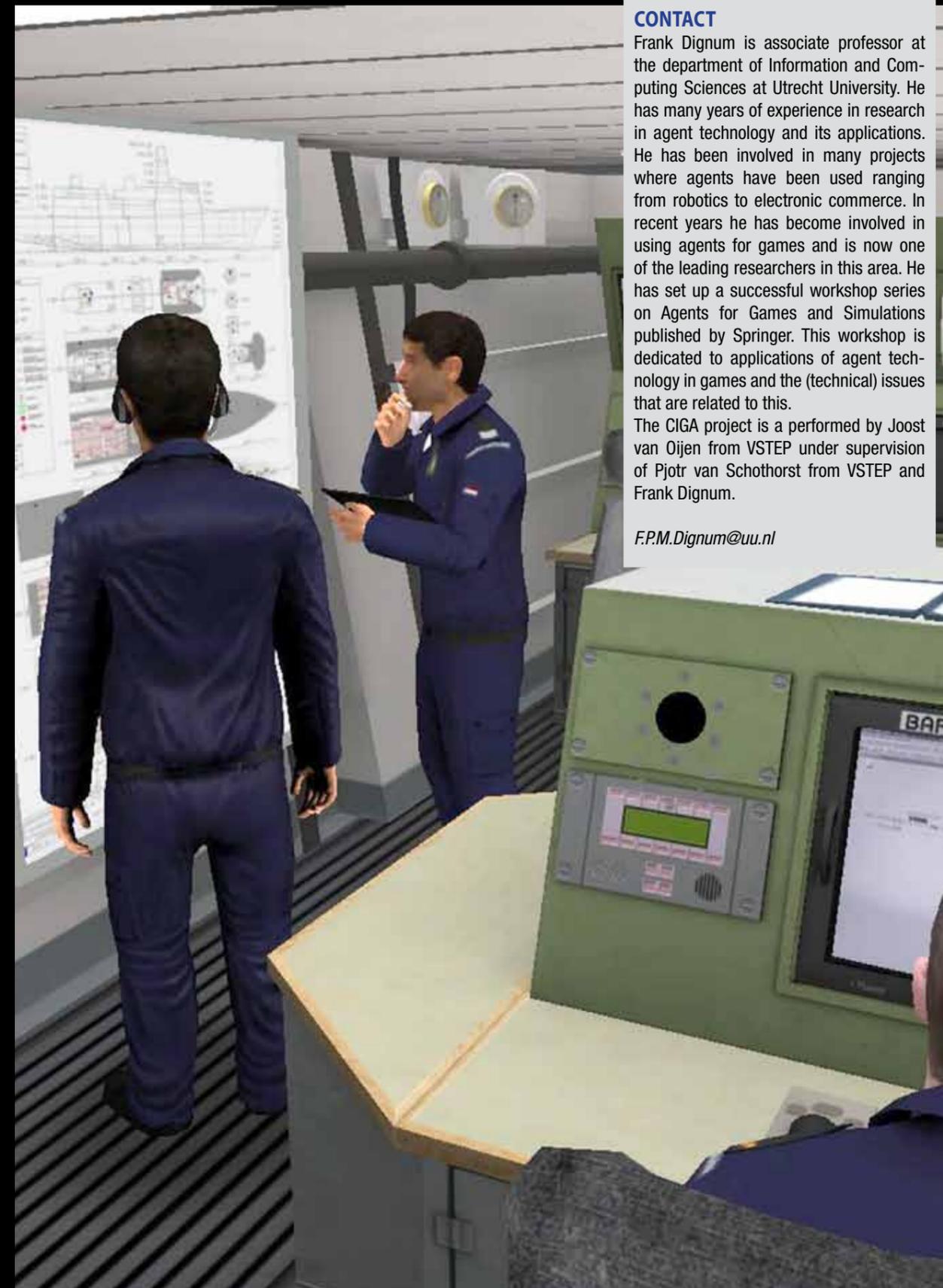
## COUPLING GAMES AND AGENTS

Although intuitively it seems a perfect match to use this agent technology for programming the NPC's of games, in practise this turns out to be not that simple. E.g. an agent playing a firefighter is used to make plans at a strategic level, having plans as: "get the victim out of the house" then "extinguish the fire" and finish by "clearing up the gear". The NPC acts on a much lower level of abstraction and these high level actions should be broken down in executable ac-

tions for the game engine. The tricky part is to take care of failures of actions in the middle of the plan. E.g. what to do if the firefighter cannot get to the victim and needs to get help? Another issue concerns the agent sensing its environment. For example, a fire extinguisher is represented in a game engine using geometry and textures. Though, an agent sensing this object requires more meaningful information to make intelligent decisions (e.g. knowing the object is a fire extinguisher, a physical object that can be picked up, something that can be used to extinguish a fire, but also something which is heavy enough to break a window). Such knowledge helps agents to understand their environment better and therefore allow them to behave more intelligently.

## CIGA MIDDLEWARE

In this KTP (Creating Intelligent Games using Agents) VSTEP and the Utrecht University have developed a middleware (called CIGA) to couple agent technology to game engines. The goal of this middleware is to abstract from game engines by tackling the above issues in a structured way. This will allow agent developers to focus on building intelligent behaviour instead of worrying about the tedious integration process. CIGA makes this possible by supporting developers in connecting their agents to a game engine with the help of middleware software and development tools. Using CIGA, we show the usefulness of agent technology in a simple scenario where an agent is located in a building and a fire alarm goes off. The aim here is to let the agent deal with the situation in a human-like manner, coping with unforeseen changes in the environment and possibly coordinating its activities with other agents present. •



## CONTACT

Frank Dignum is associate professor at the department of Information and Computing Sciences at Utrecht University. He has many years of experience in research in agent technology and its applications. He has been involved in many projects where agents have been used ranging from robotics to electronic commerce. In recent years he has become involved in using agents for games and is now one of the leading researchers in this area. He has set up a successful workshop series on Agents for Games and Simulations published by Springer. This workshop is dedicated to applications of agent technology in games and the (technical) issues that are related to this.

The CIGA project is performed by Joost van Oijen from VSTEP under supervision of Piotr van Schothorst from VSTEP and Frank Dignum.

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# CRYING BABIES AND A DENTIST DRILL

## SUMMARY

Sounds can improve the validity and effectiveness of virtual training scenarios by increasing the naturalness of the experience, by providing task-relevant information, and by affecting the users emotionally. We explored methods and techniques for the design, development and evaluation of soundtracks for virtual training environments. Sound design for serious games and virtual training is an important new domain for research.

SOUND DESIGN FOR SERIOUS GAMES AND VIRTUAL TRAINING APPLICATIONS IS A NEW AND PROMISING RESEARCH DOMAIN. UTRECHT UNIVERSITY, VSTEP BV AND RISK MANAGEMENT CONTROL COLLABORATED IN THIS INNOVATIVE KNOWLEDGE TRANSFER PROJECT.

In the development of serious games and virtual training environments, the design of soundtracks receives little attention. The effort is mostly directed towards creating realistic and flexible scenarios and high quality graphics. Sound design requires specialist knowledge, unfamiliar to most software developers. Sounds are however important instruments to enhance the level of presence and engagement, and to induce emotional responses such as arousal in the user. Emotionally compelling virtual environments

provide more effective training.

## DESIGNING SOUNDS FOR VIRTUAL TRAINING ENVIRONMENTS

In this project we aimed to develop a toolbox of methods and techniques for design, development and evaluation of soundtracks in serious games. The tools are focused on important user related aspects of the training: engagement of the trainee, perceived realism and learning goals of the training, and the training context.

We developed sounds for scenarios used for training first responders that were created in RescueSim, a training platform for safety and security professionals (VSTEP BV). In this type of training, a trainee navigates through a virtual environment and is required to perform correct procedures to handle an incident such as a fire in a hospital. The trainee communicates with an instructor who impersonates the virtual characters in the scenario.

## SOUNDS AND TRAINING GOALS

Different types of sounds may be added to a training, such as event sounds (for instance explosions), feedback on actions, ambient sounds that create awareness of the location, and sounds to increase stress and arousal. Which sounds should be added also depends on the training level. For instance, soundtracks containing many events



## CONTACT

Joske Houtkamp is a researcher at the Centre for Geo-information, Alterra, Wageningen University and Research Centre. Her research focuses on the usability of and affective response to 3D environments used for visualization of natural and man-made environments, and for serious games and training.

Pjotr van Schothorst is CTO at VSTEP BV. VSTEP develops training applications, serious games and entertainment games.

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sounds and ambient sounds make the information provided by the virtual training more complex and may interfere with the learning process in introductory training. On the other hand sounds may be used to create confusing and complex incidents, to assess the trainees' knowledge in unexpected and new circumstances. For training under stressful circumstances, so-called affectively intense training, screams of victims can be added, or nonrealistic sounds, such as a heart-beat, breathing sounds, played at high volume. The training must however still be experienced as convincing.

## DEVELOPING A SOUNDTRACK FOR TESTING

Two virtual training environments, representing a hospital and a detention center, were used for requirements research and for the development of a soundtrack. Different ambient background sounds that are characteristic of these environments were added to the database, such as beeping equipment at an IC unit, and clanking keys unlocking cell doors, confirming the situational awareness of the users. From the IADS (International Affective Digitized Sounds) database we selected sounds that are highly arousing and very unpleasant, such as the sounds of crying babies, a dentist drill, screaming and vomiting. A number of scenarios, in which a fire is detected and the building must be evacuated, were enriched with these sounds and presented to domain experts.



## EFFECTS OF SOUNDS

There is scientific evidence that emotionally arousing sounds have a positive impact on trainees' memory recall, which is relevant for training effectiveness. The first results of our experiments seem to confirm this effect. Our study also indicates opportunities for improvement. Humans are very sensitive to sounds that are repetitive, or do not match the visual information. These draw attention to the mediated nature of the environment, thereby diminishing its convincingness. Fine tuning the sound track should ideally be done by expert sound designers.

Communication with some of the other characters in training scenarios may be automated and incorporated in the training, so the trainee is not distracted by the presence of the instructor. Misunderstandings in the communication which often occur in reality and are considered very stressful may also be simulated with this technique. •

# TOWARDS AN ADAPTIVE SYSTEM FOR ORGANIZATIONAL LEARNING

## SUMMARY

The results of the project can be used to make an organizational change support system more adaptive to employees with different learning styles. The development of tasks associated to the different phases of change and the usability and design studies we performed were important steps towards this goal. Many steps however need still to be performed in order to fully achieve an adaptive system.

The overall goal of our research project is to provide guidelines to develop an adaptive system that fits to learning styles and helps employees to learn new behavioural skills and participate properly during organizational changes.

Adaptive systems for learning styles have been developed but research has focused on systems for content learning. In this project we focus on an adaptive system for organizational changes. Adaptive systems to perform tasks such as brainstorming, decision making, problem solving, group collaboration etc. have not been properly developed to date. We used the online environment SilkBricks (www.silkbricks.com) developed by entrepreneur Steven de Lira. Briefly, the main functionality is to present challenges to the user. These challenges are developed to help workers to participate in the different phases of the organizational changes.

## FUNCTIONALITIES WITHIN THE SILKBRICKS SYSTEM

The Silkbricks system contains certain functionalities to achieve its goals. The first thing that users have to do is completing the introduction and create a personal profile. This profile contains the employees learning style and his talent. In the targetpoint module of the system, in which the different phases for change and associated challenges are implemented, the organizational goal of the company is communicated and visualized. In the challenges module, employees can participate in organization improvement initiatives by participating in challenges with others or alone. The system gives advice on the right team composition. The system contains several other modules. In several empirical studies we

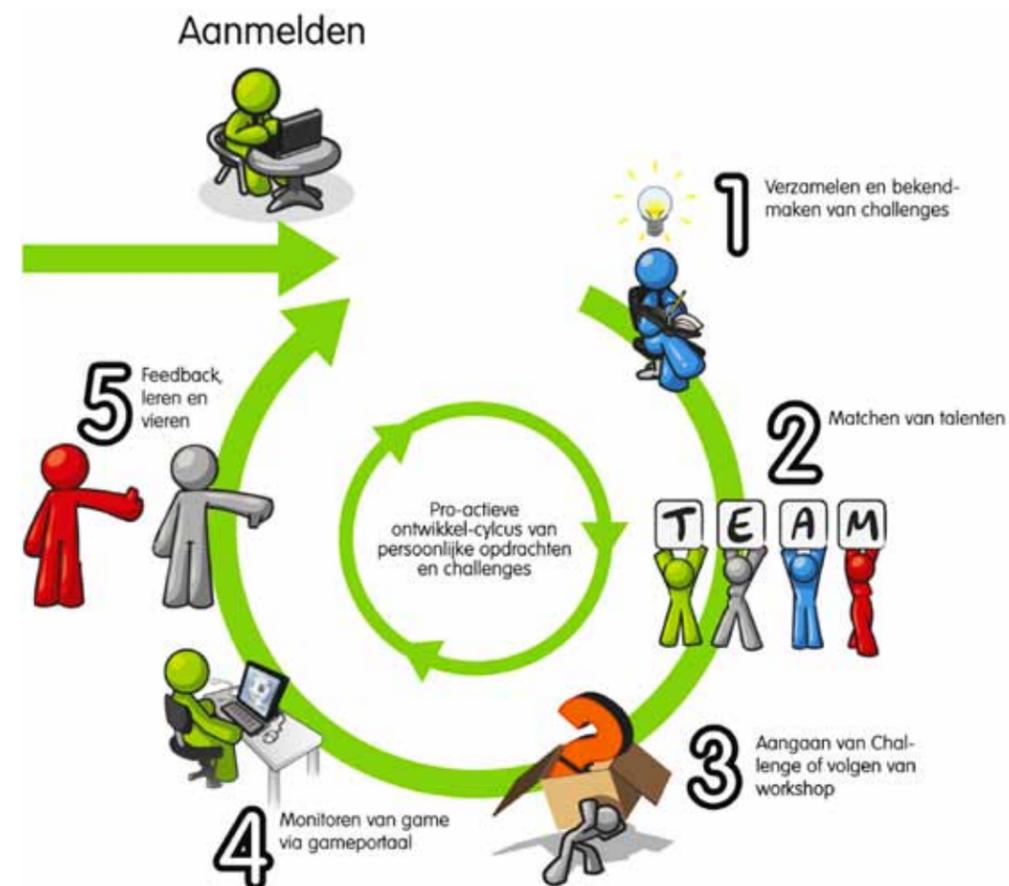
examined the relationship between different tasks, representative of a certain organizational phase and learning style, and in an usability evaluation study we provided suggestions to improve the system.

## OPPORTUNITIES TO MAKE SILKBRICKS ADAPTIVE

With learning styles as we distinguished (divergers, assimilators, convergers and accommodators based on Kolb's experiential learning theory), several ways to make the system adaptive are possible: (a) Composing teams based on learning styles: One of the functionalities of the Silkbricks system is that people can perform tasks in teams to benefit from each other's approaches and skills. The system provides suggestions for the formation of teams. (b) Use of instructional tactics: The performance of learning styles can be influenced by the way a task is presented. A distinction, for instance, can be made between example-oriented (divergers) and activity-oriented learners (accommodators). (c) Train people in other learning styles: Over a long period of time people's learning styles can change depending on the tasks they carry out in everyday life. This means that it is also possible to train other learning styles.

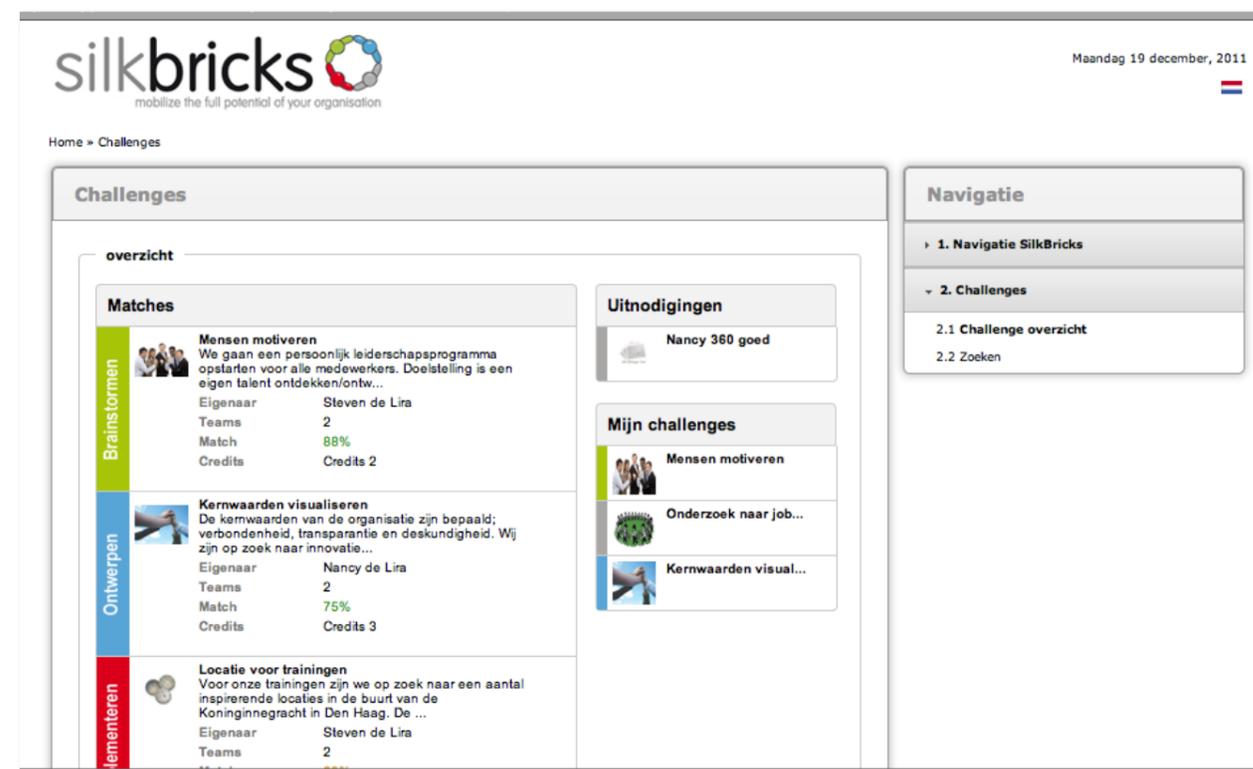
## CONCLUDING

The relevance of this project is both theoretical and practical. Theoretically it helps to understand the connection between the organizational change phases and learning styles, a relationship established by Kolb's theory and frequently accepted in organizations but scarcely investigated. In practice, the development of an adaptive system for learning skills and procedures will help organizations in the process of adapting successfully to changes. •



## CONTACT

Herre van Oostendorp has a background in Cognitive Psychology. He is Associate Professor Human-Media Interaction at Utrecht University, [H.vanOostendorp@uu.nl](mailto:H.vanOostendorp@uu.nl). His research interests are on the area of cognitive learning principles in serious games, and cognitive modeling of web navigation. Other people involved in the project: Mari Carmen Puerta Melguizo (UU), Frank Dignum (UU) and Steven de Lira (SilkBricks)



# OUCH! MEASURING CHARACTER INJURY

## SUMMARY

Determining injury levels for virtual characters is an important aspect of many games. For characters that are animated using simulated physics, it is possible to assess injury levels based on physical properties, such as accelerations and forces. We have constructed a model for injury assessment that relates results from research on human injury response to parameters in physics-based animation systems. Our research includes a user study in which human observers rate the injury levels of physics-based characters falling from varying heights at different orientations. Results show that the correlation between our model output and perceived injury is stronger than the correlation between perceived injury and fall height.

MANY GAMES ARE DESIGNED AROUND THE CONCEPT OF INFLICTING AS MUCH INJURY AS POSSIBLE ON OTHER CHARACTERS. WHEN SUCH GAMES AIM FOR HIGH REALISM, IT IS IMPORTANT THAT THE ASSESSMENT OF INJURY IS ACCURATE.

In games that use kinematic animation systems, the possibilities for assessment are limited, because there exists no direct relation to knowledge on human injury. An example indicator could be the initial height of a character that is falling to the ground, but such a measure ignores the specific forces acting on the character during impact. In physics-based animation systems, all animation is the result of simulated physics. Specific physics-based parameters can be used to estimate injury in a way that is in line with physical reality.

## INJURY IN GAMES

There exist several games that model physical injury of physics-based characters. An example is Stair Dismount, a game in which the goal is to inflict as much damage as possible on a character by pushing it from a staircase. However, there exist no publications that explain what parameters and thresholds are used as a basis for these models, nor are there any published studies that show if and how such models correlate with perceived injury levels.

## USING REAL-WORLD INJURY RESPONSE DATA

We propose an injury assessment model for physics-based virtual characters that is based on a comprehensive set of publications on human injury response levels. Our model produces a set of normalized measures that represent injury levels for several individual body parts. No tuning is required, as all parameters are directly derived from publications on injury research. Normalization enables straightforward

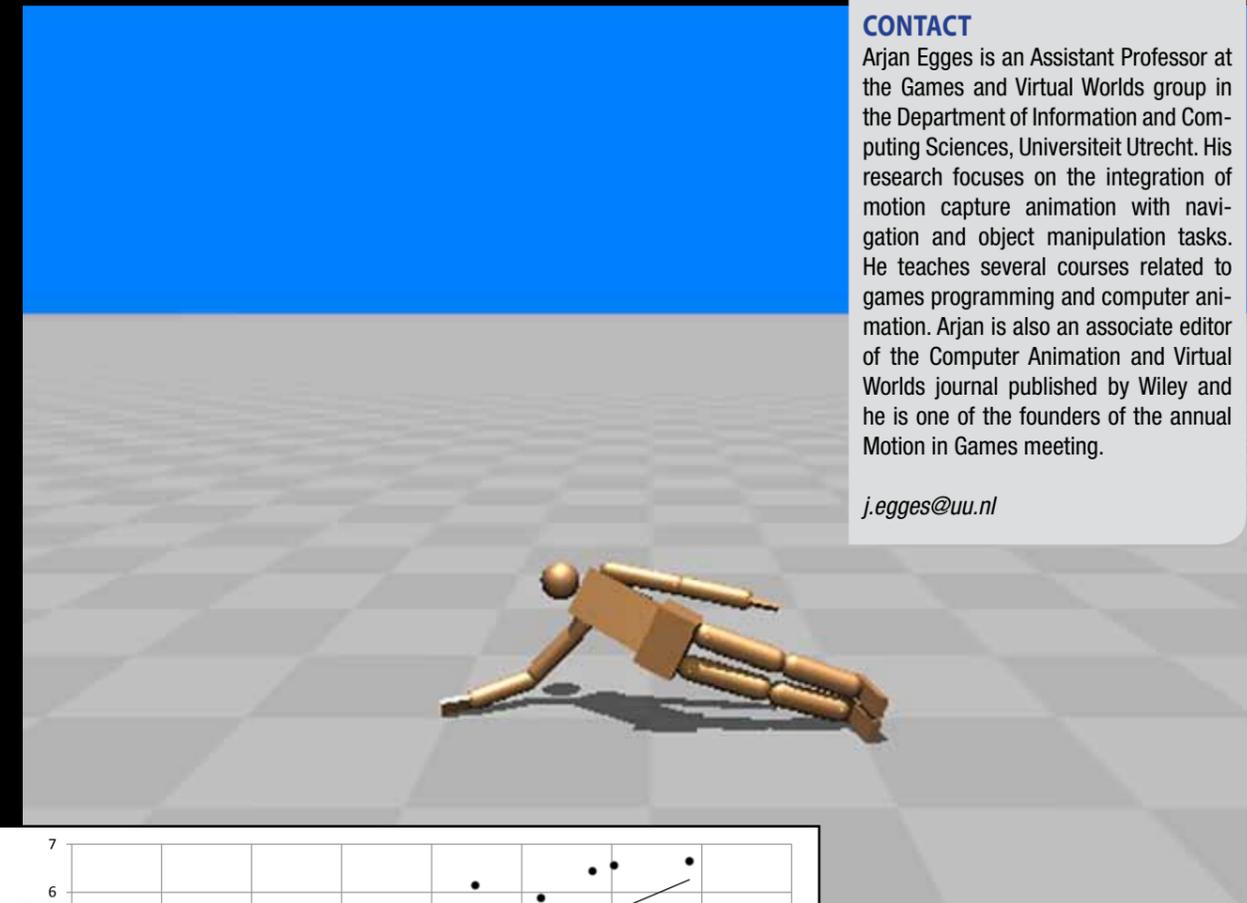
combination of individual measures into a single measure representing total injury. Our research includes a user study in which the output of our injury assessment model is compared to injury levels as perceived by human observers. Our injury assessment model consists of a set of individual measures, all of which represent a normalized maximum of a simulated variable averaged over a specific time window. The size of this time window is important, since the maximum of simulated variables such as acceleration can become very high in rigid body simulation.

## APPLICATIONS

We believe there are several uses for our model. First, it can be used to measure injury of in-game physics-based characters; either to keep track of the overall health of the character, or to monitor the condition of specific body parts. Furthermore, we expect our measure can also be used for the development of motion controllers for physics-based characters. More specifically, our measure can be used as an optimization criterion for controllers that need to minimize physical injury, for instance while falling or blocking obstacles.

## EVALUATION

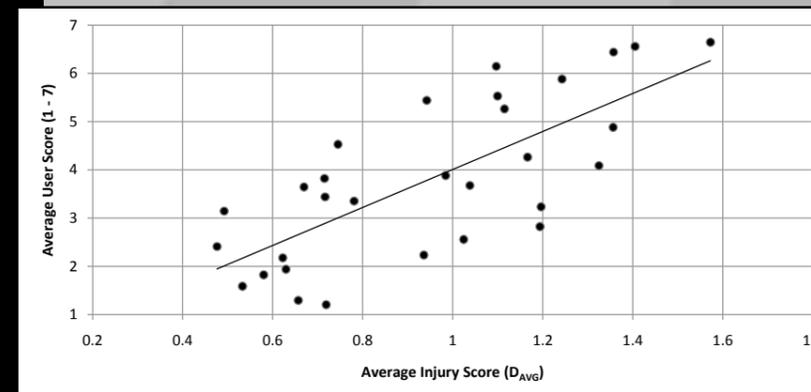
To evaluate our injury assessment model, we have conducted a user study to investigate if the output of our model correlates with injury levels of virtual characters as perceived by human observers. The trial data was presented to 34 individuals (21 male, 13 female), with ages between 23 and 35 years.



## CONTACT

Arjan Egges is an Assistant Professor at the Games and Virtual Worlds group in the Department of Information and Computing Sciences, Universiteit Utrecht. His research focuses on the integration of motion capture animation with navigation and object manipulation tasks. He teaches several courses related to games programming and computer animation. Arjan is also an associate editor of the Computer Animation and Virtual Worlds journal published by Wiley and he is one of the founders of the annual Motion in Games meeting.

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speed, character model, background color, etc. However, test results indicate our test material was at least partly representative.

## WHAT'S NEXT?

There are several limitations to our injury assessment model. Key body parts such as knees, elbows and shoulders are currently missing, because we could not locate any suitable data. However, we do not believe that these omissions have disrupted our research too much, since relevant trials had significant injury in neighboring body parts. In order to measure injury types such as shot wounds or cuts, we suggest to use a different approach than physical modeling. Even though it may be possible to create a model for tissue damage, it is questionable whether this is worth the effort for gaming applications. The use of our model is limited to injuries from collisions with large, blunt objects. Examples of such injuries are a character falling to the ground or from a staircase, a character in a vehicle hitting a wall, or a character being hit by a rock with the shape and size of a football.

Our model is an initial attempt at injury assessment for physics-based virtual characters. There is much room for improvement, while additional user studies can create better insights on how injury of animated characters is perceived. Injury is an important aspect of gaming, which validates further research in this area. •

Each individual was shown all clips in random order; they were instructed to assign each clip a value between 1 (minimum) and 7 (maximum), based on how much total physical damage they felt was inflicted upon the virtual character.

## “OUR MEASURE IS A MORE ACCURATE REPRESENTATION OF PERCEIVED INJURY THAN FALLING HEIGHT”

Results show that the correlation between our model output and perceived injury is stronger than the correlation between perceived injury and fall height. This supports the hypothesis that our measure is a more accurate representation of perceived injury than falling height, when regarding characters falling.

Perception studies often leave room for debate, and ours is no different. First, we used a very basic looking character model; a more detailed model may have triggered different responses. Second, we have only tested for straight falling motions; other motions (falling from stairs, colliding with objects, etc.) may also have triggered different responses. There are many additional appearance factors that complicate our perception study, such as viewing angle, playback

# BUYERS ARE LIARS, SELLERS ARE YELLERS

## SUMMARY

In many games, players communicate with virtual characters. Using the traditional approach of handling dialogues, players often experience the communication as rigid and unnatural. TNO and RANJ explored the BDI approach to create unique virtual characters, each fitted with their individual goals and strategies. The virtual characters initiate communication based upon these goals and can respond to the human player. The approach is very promising for realizing flexible and natural dialogues. This, in turn, should improve the involvement of the player in the game, and help to create better learning opportunities.

In many games, a player communicates with virtual characters. The common approach is to pre-define a structure or script that determines how a dialogue evolves. The player has little influence and the virtual character also has to follow the appointed schema. As a result, communication is rigid of nature. TNO and RANJ explored how artificial intelligence can be used to create unique virtual characters, each fitted with their individual goals and strategies. These characters respond to the player, not to a script. The resulting freedom in interaction leads to more natural and involving dialogues.

Serious games should enable a player to learn in a playful fashion for which interactions with characters in the game (Non-Playing Characters, or NPCs) are an essential element. In order to become an active learner, the player needs to experience that his actions and communications affect the NPC. Likewise, the NPC should not be a blank individual, but instead should have an identity that determines the way it acts and responds. This requires NPCs to be equipped with capabilities that enable them to display natural behavior in accordance with their human-like properties (e.g. intelligence, emotions, personality) and to respond dynamically to situations occurring during the game. Recently, advances in artificial intelligence have brought about new methods for modeling human capabilities. In this project we investigated whether such a method can be used successfully in games to create natural, rich, and truly interactive dialogues between humans and NPCs.

## BDI-MODELLING

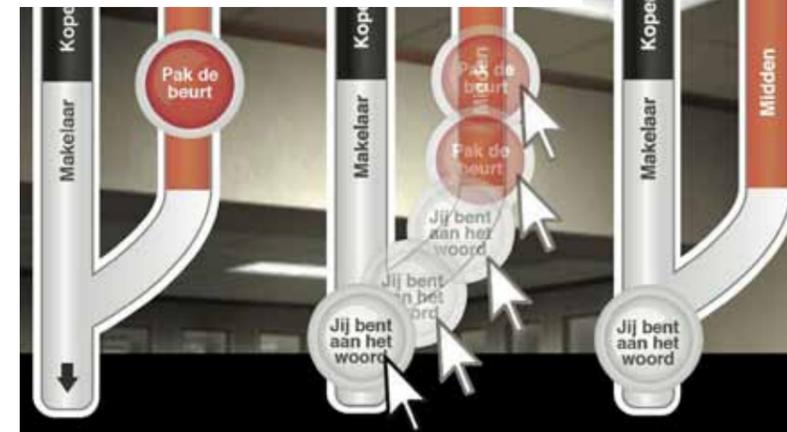
When people are asked to describe their behaviour (or that of others), they generally do so in terms of *Beliefs, Desires, and Intentions* (BDI). When NPCs are modelled us-

ing these concepts, they will therefore produce behaviour that is experienced as natural by human observers. BDI is fundamentally different from traditional methods such as scripting or FSM. A BDI character does not respond to a particular situation or state in the scenario, but to the *interpretation* of the situation. To achieve this, the character's role needs to be analyzed in terms of its underlying characteristics (role, goals, plans, etc) and the developer then specifies when and how beliefs are formed, and adjusted by events in the environment. Constructing BDI characters tends to require more development efforts, but the return on the investments are better functionality (more natural and interactive behaviour), flexibility (adaptive to scenario adjustments), and reuse (easy to use once-developed characters in new domains).

## THE GAME

TNO and RANJ developed a demonstration of BDI characters, set in a "sales" game, based upon the *Glengarry Glen Ross* (GGR) film (1992). In the film four salesmen working at a real-estate agency become desperate when the corporate announces that all except the top two salesmen will be fired. Superior sales skills (e.g. listening, persuading, negotiating) are of the essence. This game allows the player to practice these skills.

The player in the GGR-game is a real-estate salesman; the leads are BDI-based NPCs. Each NPC has its own belief base (e.g. knowledge of the house in question, wishes/demands), goal base (e.g. requesting information, deciding whether to buy the house, choosing topics to discuss), and plan base (strategies to achieve his goals). In a sales conversation, the player must discover the NPC's wishes and influence his opinions (see Figure). The player can do so by emphasizing qualities of the house desired by this buyer,



"As both the player as the NPC can take the initiative in the dialogue, a 'turn-taking' mechanism was developed."

or by providing appropriate anecdotic material. Eventually, the player must persuade the NPC to buy the house.

## DEFINING THE GAME'S WORLD

A large number of concepts related to 'house-buying' is represented in an ontology, determining the scope of the game. These, of course, include properties of the house (e.g. number of rooms; surface area; maintenance state), but also topics that are typically addressed in house-buying negotiations (e.g. safety of the neighbourhood; access to public transport/ motorways, etc.). Both the player and the NPC can refer in their communications to any of the concepts defined in the ontology. The broadness of the ontology generates an abundance of options to the player. This requires a good interface to handle appropriately, for which we used the metaphor of a dossier (see Figure).

## PROPERTIES OF THE NPC

The NPC is initialised using concepts defined in the ontology (e.g. specifying a priori knowledge and wishes on the house and vicinity, financial limits, etc.). NPCs are equipped with building blocks that enable them to develop wishes and opinions (e.g. "I want a house with a large kitchen", or "the kitchen is too little/ adequate / too large"). Fur-

## CONTACT

Dr. Karel Van Den Bosch is Senior Research Scientist at TNO. His research interest is making game-based training more effective by using cognitive software agents (e.g. agents playing the role of team mate, adversary, or instructor). He investigates how such agents can successfully support training, thus making training more systematic (uniform behaviour of agents), more effective (agents consistently eliciting intended behaviour of trainee), and more efficient (staff and team members need no longer be present during training). [karel.vandenbosch@tno.nl](mailto:karel.vandenbosch@tno.nl)



Team's project members:  
Dr. I. (Ivo) Swartjes (RANJ)  
Dr. A. (Annerieke) Heuvelink (TNO)  
Ir. T.J. (Tijmen) Muller (TNO)



thermore, NPC characters have their own personalities (e.g. extravert making them talkative and 'open', versus introvert making them withdrawn and sparse with details).

## MIXED-INITIATIVE DIALOGUE BETWEEN PLAYER AND NPC

The NPC uses its sets of beliefs, goals, and strategies to (proactively) initiate communication, and to respond to the player. For example, the NPC can ask and answer questions; make a bid; make a counteroffer; take a (buying) decision; terminate the conversation; etc. As both the player as the NPC can take the initiative in the dialogue, a 'turn-taking' mechanism was developed.

## CONCLUSION

Modelling behaviour using BDI allows the development of different unique NPCs that are internally consistent and that respond to situations in a representative and believable manner. Rather than interaction being limited to guiding the player through a predefined schema, BDI allows a truly mixed-initiative dialogue between player and NPC. From the developer's perspective, the investments of developing BDI characters yield substantial more flexibility and reuse in conversational games. •

# SKETCHAWORLD MEETS LEVEE PATROLLER

DELFT UNIVERSITY OF TECHNOLOGY, TNO AND DELTARES TOGETHER HAVE REALIZED AN EFFICIENT METHOD TO CREATE 3D VIRTUAL WORLDS FOR SERIOUS GAMES SUCH AS LEVEE PATROLLER, ENRICHING GEOGRAPHIC DATA WITH AUTOMATIC CONTENT GENERATION TECHNIQUES.

## SUMMARY

This project resulted in an efficient method to go from the real world to a matching virtual world. From geographic data, a complete 3D virtual world is automatically created. Furthermore, using SketchaWorld's intuitive sketching tools, you can modify the world to better fit our requirements. The virtual world is ready for use in Levee Patroller, a serious game for training personnel to inspect the state of levees. As a result, a levee patroller can now train inside a game world that closely mimics his inspection environment. We intend to develop this technology further and to apply it in future projects.



**L**evee Patroller is a serious game for professional patrollers, who inspect the many levees that protect The Netherlands from the North Sea and inland rivers. The training objective is to learn identify emerging failures of levees, classify them, their causes and the urgency of the situation, and report an accurate assessment back to a control room. As a levee patroller in this game, you navigate the 3D virtual world in first-person, armed with virtual measuring and communication equipment, looking for clues of potential levee failures, for instance a minor crack on the levee surface or small water breaches.

So far, Levee Patroller used hand-modelled fictional worlds resembling Dutch rural landscapes. However, it is very convenient for patrollers to also train in virtual worlds resembling the actual environments they inspect. Modelling these new virtual worlds by hand using photographs and maps is very laborious and expensive. This project resulted in a flexible method to efficiently create such geo-specific virtual worlds.

## SKETCHAWORLD

The core of this project is SketchaWorld, an innovative virtual world modelling tool developed by TNO and Delft University of Technology. The philosophy behind SketchaWorld is to let users focus on what they want to create instead of how they should create it. To achieve this, SketchaWorld combines a large number of procedural methods to generate all the features of the virtual world automatically. Furthermore, all the generated features are dynamically adapted to fit with each other, and then integrated into the landscape. Using

SketchaWorld is fast and easy: within minutes, using intuitive sketch tools, you can create a landscape with dense forests, flowing rivers, road networks or even a complete city!

## FROM GEOGRAPHIC DATA TO VIRTUAL WORLD

In this knowledge transfer project however, the real world is the starting point for the game world. This is where the geographic data comes into play. To process the geographic data, you define a set of rules in SketchaWorld; for instance, to determine which elements from the data should be made into virtual forests. These rules often use the additional information that is contained in the geographic data. In this way, for example, you can select all large pasture fields or a particular type of road. With the rules, you can already make the first choices on how the virtual world will actually look like. After you have defined your rules, SketchaWorld can do the heavy work. Using integrated procedural methods, it automatically generates the 3D virtual world. This world matches the data, but also includes newly generated details, such as bridges over water, reed in ditches, crops in fields, gardens and hedges.

## TUNING THE WORLD

Starting from this generated base, you can perform relatively large manual edits on the virtual world. This can be used to further enrich the world with new features, or to modify it to better accommodate for gameplay or training objectives. Editing is done exactly the same way as typical sketching in SketchaWorld. After each editing action, the results are updated interac-

tively to fit in the existing environment. Following the changes made to the world, the results are exported from SketchaWorld to Levee Patroller, which uses the Unreal game engine. Using Unreal's game world editor, you can make as many small changes to the 3D virtual world as desired. For instance, you could place some more decorative objects to make the world more lively and plausible, or define gameplay specific elements or scripts. Combining SketchaWorld's automatic generation and accessible editing facilities with geographic data allows you to create a complete geo-specific virtual world in a fast and efficient way. For Levee Patroller, this fully functional virtual world resembles an actual patrolling area. •

## CONTACT

**Ruben Smelik** graduated in 2006 in computer science at the University of Twente, and received his PhD from Delft University of Technology in 2011, after participating in GATE as a PhD student. Ruben is now a research scientist at the Modelling, Simulation and Gaming department of TNO, focussing on methods and techniques for creating virtual worlds for serious games and simulations.



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# THE COMPLIANCE GAME: UNCOVERING PERSONALITY TRAITS

## SUMMARY

Serious games for personality assessment are a new exciting research area. Existing assessment tools are paper or computerized tests but a risk is respondents giving socially desirable answers. To design games for assessment, existing game notations do not sufficiently accommodate interactions between game and player, we need better ways to visualize information flow and cognitive aspects within a player to structure and balance player actions adequately. This project has two research lines: development of a serious game measuring the personality trait "Compliance", and development of GameDNA (Game Discourse Notation & Analysis), a rich notation and visualization tool for serious games.

SERIOUS GAMES TO UNCOVER PERSONALITY TRAITS PROVIDE A RICH AND IMMERSIVE CONTEXT IN WHICH PLAYERS MIGHT ACT MORE NATURAL AND INTUITIVE. IT CAN PREVENT PARTICIPANTS OF GIVING SOCIALLY DESIRABLE ANSWERS.

Serious games to acquaint people with certain professional areas and enthuse them exist already. Serious games for assessment in recruitment procedures are one step further and gains popularity as a screening means. Personality tests for assessment exist already in the form of paper or computerized tests but a risk is respondents giving socially desirable answers. To design games for assessment, existing notations do not sufficiently accommodate interactions between game and player and the players' mental states and actions. We need better ways to visualize information flow and cognitive aspects within a player to structure and balance player actions adequately in order to improve communication between stakeholders. Ranj Serious Games, human resources consultancy firm GITP and the Institute of Information & Computing Sciences (Utrecht University) cooperate on:

## A SERIOUS GAME MEASURING THE PERSONALITY TRAIT "COMPLIANCE"

Compliance is the tendency of an individual to agree with an instruction from another person, even if he does not believe it, only to satisfy others or to avoid conflicts. It is a hot topic after global crises in financial services. In the game, the player acts in a setting in which compliance and its associated behavior is an everyday occurrence: the sales department of a multinational. The player acts in a story, makes decisions, expresses opinions, reflecting compliance or not.

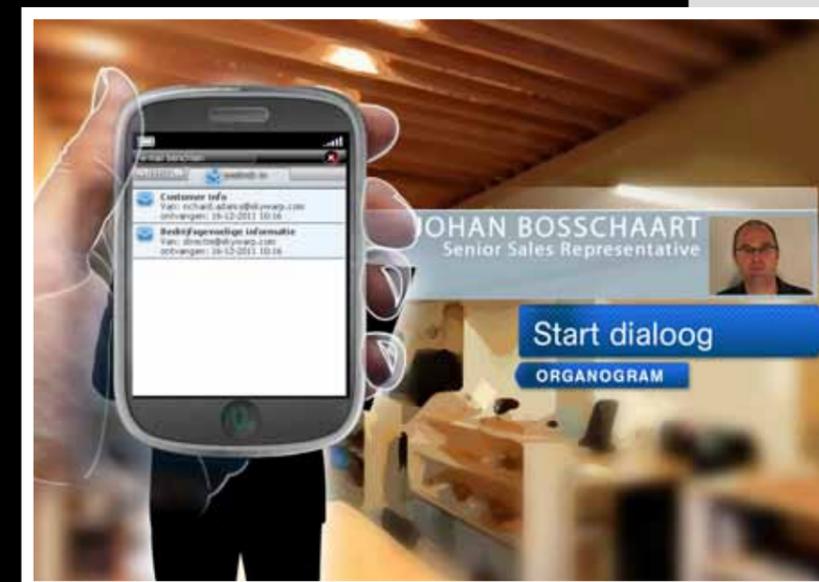
## GAMEDNA (GAME DISCOURSE NOTATION AND ANALYSIS)

There is the need of richer notation and visualization tools for serious games. To assess people there are measuring

points embedded in the game corresponding to psychological constructs. It is important to know which information flows between player and system and at what moment. GameDNA accommodates mental actions and focuses on what the player is facing cognitively, what he has to do, how the information flow is shaped and how measurable features are balanced and implemented.

The project started with requirements of what the game should measure. Then input for GameDNA was gathered regarding how game designers conceptualize, describe, document and visualize games. GameDNA dissects game events into building blocks and their relations and categories such as "perceptual actions", "mental actions" and "system actions". Next, game scenario development started, while assuring that GameDNA covers all events and mental actions we want to provoke. Then a pilot version of the game was built. It has animated realistic characters that move, talk and ask questions to the player, who also receives information on a virtual smartphone. The player has to take managerial decisions in the business process of introducing a new ICT product in the market by choosing actions/answers the game offers.

In November 2011 a first game evaluation was carried out. Quantitative results and the additional qualitative responses of 72 respondents were highly useful. Based on this input a second iteration is being built and will be evaluated further with new respondents near the end of the project. The GameDNA notation method is in progress and incorporates the notation, layering, and adjustable views of game structure and features. GameDNA will be validated towards the end of the project. •

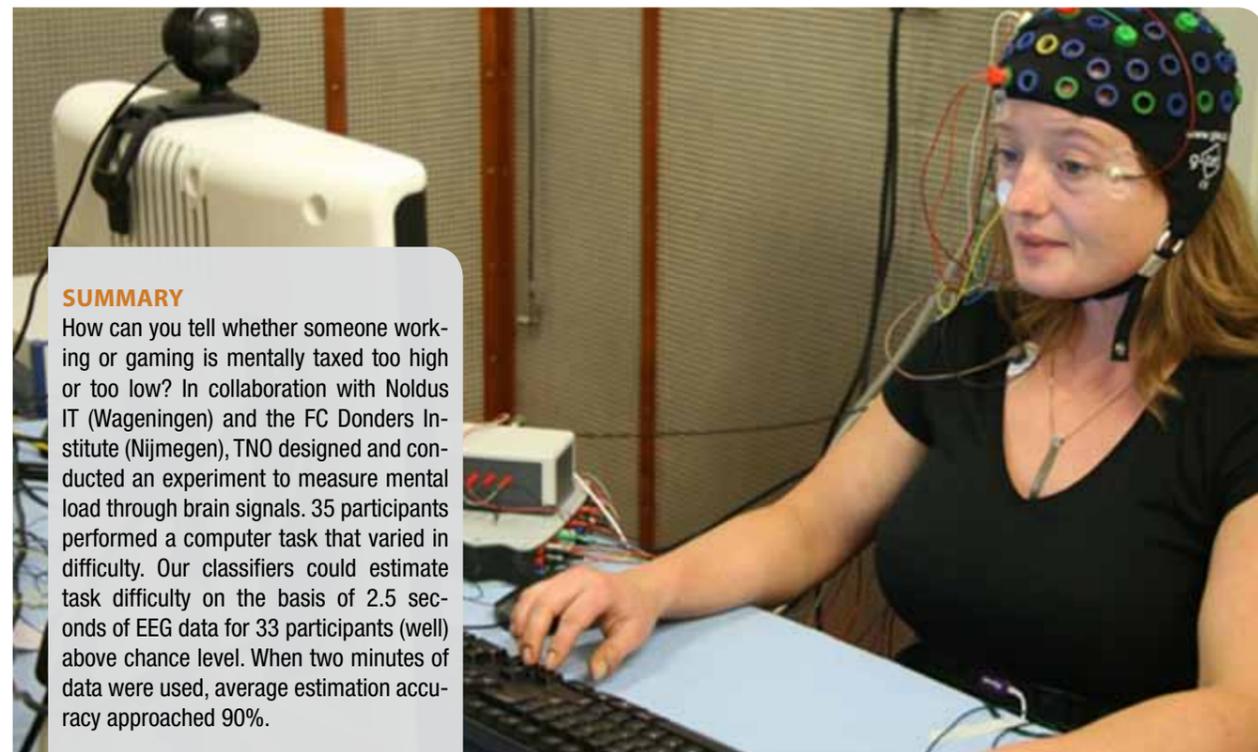


## CONTACT

Christof van Nimwegen studied Cognitive Ergonomics and worked as a usability engineer before enrolling his Ph.D. project at Utrecht University (UU). Thereafter he worked as a Senior Researcher at the Centre for User Experience Research, Catholic University of Leuven, Belgium. Christof currently holds a Post-doc position at UU. His interests are HCI and representations in interfaces. People in the project: Herre van Oostendorp (UU), Michael Bas (RANJ), Joost Modderman & Alec Serlie (GITP). Contact: c.vannimwegen@uu.nl

# DETERMINING MENTAL LOAD THROUGH MEASURING BRAIN SIGNALS

A CONTINUOUS INDICATION OF MENTAL LOAD THAT DOES NOT REQUIRE ANY ACTION OF THE USER WOULD BE USEFUL IN GAMING AND HUMAN COMPUTER INTERACTION. INDICATORS BASED ON BRAIN SIGNALS (EEG OR ELECTROENCEPHALOGRAM) ARE VERY PROMISING.



## SUMMARY

How can you tell whether someone working or gaming is mentally taxed too high or too low? In collaboration with Noldus IT (Wageningen) and the FC Donders Institute (Nijmegen), TNO designed and conducted an experiment to measure mental load through brain signals. 35 participants performed a computer task that varied in difficulty. Our classifiers could estimate task difficulty on the basis of 2.5 seconds of EEG data for 33 participants (well above chance level). When two minutes of data were used, average estimation accuracy approached 90%.

How demanding is a certain task? Is it time to take a break? Is a gamer bored because it is all too easy? Does this new interface help to reduce mental load? Mental load is a function of externally imposed task demands and an individual's mental capacity. It is high when demands are close to exceeding capacity. A measure of mental load -especially a continuous one- would be of tremendous value to keep the task demands within limits and optimize Human Computer Interaction. Our current instruments do not suffice. For instance, repeatedly asking users to rate their experienced mental load will cause an increase in load itself and is also annoying. Also, these ratings can be (in)advertently disturbed. Already in the early sixties physiological signals like heart rate and skin conductance have been studied as possible mental load indicators with mixed success. More recent studies in which both brain signals and physiological measures were analysed, concluded that brain signals are the

most promising. Noldus Information Technology, a company located in Wageningen, is interested in measuring mental load using EEG. Within the GATE program, TNO works on brain-based signals for use in gaming. Noldus and TNO joined forces in this GATE Knowledge Transfer Project. In collaboration with the FC Donders Institute in Nijmegen, we designed, conducted and analysed an experiment to investigate the best brain-based mental load indicators.

## EEG INDICATORS: POWER AND PEAKS

EEG reflects electrical activity within the brain. Both power in different frequency bands and peaks following certain events (Event Related Potentials - ERPs) have previously been identified as possible EEG indicators of mental load. For example, power in the theta band (4-8 Hz) generally increases with mental load and the P300 (a peak in EEG occurring approximately 300 ms after a specific event)

decreases in amplitude with load. We examined the relative sensitivity of power and peak measures to mental load and checked whether combining them increased the accuracy of the estimated load.

## VARYING MENTAL LOAD EXPERIMENTALLY: THE N-BACK TASK

To distil reliable load estimators, it is crucial to design task conditions that only differ in mental load. Many previous studies failed to do so, for instance because the higher load tasks also had more visual input (like the number of elements on a screen) or required more elaborate bodily motions (like pressing buttons and speech). This makes it difficult to attribute differences in physiological variables exclusively to mental load. For instance, if heart rate is high in a specific task, is this because mental load causes heart rate to go up or only because the task requires the operator to move around more? The so-called n-back task varies mental load while it does not change visual input and bodily motion and was therefore chosen for this experiment. In this task, individuals view a sequence of letters and indicate for each letter whether or not it is the same as the letter shown 'n' instances earlier. Mental load increased with increasing n which could be 2 (is this letter the same as the one shown two instances before?), 1 (is this letter the same as the previous one?) or 0 (is this letter an 'x?'). Each letter is shown for 0.5 seconds followed by a 2 seconds break.

## THE EXPERIMENT

35 participants performed the n-back task while wearing eight EEG electrodes to measure their brain activity as well as equipment to record a range of other physiological measures (electrooculogram (EOG), electrocardiogram, skin conductance and respiration) for later analysis. The challenge is to use brain wave patterns to determine the mental load of the user. In other words: the computer looks at the brain patterns and tells us whether the user did a 2-back, 1-back, or 0-back task. To be able to do this, the computer uses a so-called classification algorithm.

## CLASSIFICATION ALGORITHM

Because our brain patterns show large individual differences (like our fingerprints), we made unique classification

algorithms for each participant based on support vector machines. To simulate how the algorithm would perform as real-time classifier, we did not clean the data for eye blinks or other artefacts. We split the data into two: the first part was used to teach the classification algorithm what brain signals of a particular participant look like during the different levels of mental load, and the last part was used to test how good the classifier works on new data of that participant. We fed the classifier with either the power of the EEG, the peaks of the EEG or both.

## ACCURATE ESTIMATES

On average, all three classifiers (power, peaks and combination) can distinguish between the highest (2-back) and the lowest (0-back) load level very well, especially when decisions are based on two minutes of EEG data. The models do not differ much in performance, but best performance is 88% correct, which is reached by the "peaks" classifier (a special version that 'knows' whether the presented letter was a match or a non-match). As expected, the classifiers work better when they get a larger chunk of EEG data to build their decision on. However, for 33 of the 35 participants, the distinction between highest and lowest mental load can already be made (well) above chance after 2.5 seconds of data (where 2.5 seconds equals the presentation of only one letter). All classifiers can also distinguish above chance between the hardest (2-back) and the average (1-back) level, and between the average (1-back) and easy (0-back) level, though as expected, accuracy is somewhat lower than when distinguishing between the two extreme difficulty levels.

## FUTURE WORK

The combination classifier only slightly improved performance, and in some cases, classification accuracy even tended to be lower. Simply 'the more information, the better' does not hold. We will investigate whether more advanced feature selection methods that estimate beforehand which features carry most information (e.g. which frequency bands or electrodes) will increase performance. An important open question is about generalization across tasks. To what extent can models, trained on n-back task data, inform us about mental load in other tasks? •

## CONTACT

Co-workers on this project are Maarten Hogervorst (TNO), Tobias Heffelaar, Patrick Zimmerman (both at Noldus) and Robert Oostenveld (Donders Institute Nijmegen).

Anne-Marie Brouwer is a Research Scientist at TNO Perceptual and Cognitive Systems. After a PhD project and post-docs in the field of perception and action, she

is currently working at TNO Soesterberg on Brain-Computer Interfaces and (neuro) physiological correlates of mental state.

Jan van Erp is a senior scientist and program manager at TNO and holds a MSc in Experimental Psychology and a PhD in computer Science.  
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# CITIZEN SCIENCE FOR SMARTPHONES

THIS PROJECT INVESTIGATES HOW GAMES PLAYED ON SMARTPHONES CAN BE USED TO ENGAGE CITIZENS WITH ACQUIRING AND DISTRIBUTING SCIENTIFIC KNOWLEDGE AND DATA THROUGH PLAYFUL INVOLVEMENT.

Games played on mobile devices offer 'ordinary' citizens without a particular professional training or occupation great opportunities to become and enjoy being citizen scientists. It enables them to engage in the sensing and measuring of various environmental data, their dissemination to a broader audience of either fellow citizens or professionals, and in some instances to even act as 'professional amateur' interpreters of these data. Through the use of mobile technologies people can playfully move through their environment to acquire and distribute scientific knowledge. This knowledge transfer project (Mobile learning-Citizen science) explores how the 7scenes platform can be used for such purposes.

## CITIZEN SCIENCE ON THE MOVE

Citizen science as a term has a rather different background as one may expect when looking at the common use of the term today. Whilst a glance at contemporary websites etc. give an image of citizen science as a movement that propagates non-scientists to contribute consciously or unconsciously (e.g.

crowdsourcing) to scientific knowledge and data gathering, the term used to have a meaning that was far more radical and philosophical. In the 1970s and 80s citizen science was used as a term to denote a change in the very understanding of science itself by getting science out of its ivory tower and offering 'normal' citizens the ability to have saying over what science means and can mean. This was thought result in a more equal and free society. This meaning is helpful when we want to think about how serious games can be linked to citizen science because it actually (re) defines science in terms of creativity. This opens up possibilities for connecting citizen science to notions of play.

Games played on mobile phones present an excellent setting for exploring such possibilities. Technically, this may involve the usage of dedicated sensors designed to capture specific data. It can also comprise the use of one or more of the built-in sensors present in most high-end smartphones (positioning, accelerometer, compass, audio/video/still image capturing, proximity measurement via Bluetooth or

RFID, light intensity). In both cases data can be uploaded in real-time or shared at a later moment.

In organizational terms, a distinction can be made between institutional projects that tap into 'the power of the many' to harvest additional data, processing power or intelligence; and peer-to-peer projects initiated by 'networked publics'. The kind of data gathered can be about public issues or about private matters. Also, they can be made publicly available or kept proprietary.

## CITIZEN SCIENCE AND 7SCENES

7scenes is a mobile publishing platform that enables organizations to develop and deploy location-based projects for smartphones. 7scenes allows museums and archives to publish their heritage collections beyond the walls and opening times of their buildings (e.g. Drents Archief). 7scenes makes real-world learning curriculum possible for educational institutions (e.g. Frequency 1550 mobile game). 7scenes provides a platform for community projects in the public domain so citizens can map their surroundings. All in all, 7scenes layers cities and landscapes with new meaning and play. 7scenes provides a number of different features that make it a powerful toolkit for citizen science projects:

1. Without any technical skills serious games can be created that not only link photos, video, notes and sound to locations but also make it possible to add specific interactive gameplay that encourage players to perform challenges and receive rewards. Keeping participants continuously engaged is an important factor.
2. Additionally, alternative external data sources (with location-based scientific data) can be linked to the platform and can be directly used in the development of these serious games.
3. The smartphone apps track the participants' activity in real-time while playing. Activity includes their GPS trace, interaction with locations and also the user-generated-content (photos, notes and reviews) the players produce. The notion of user-generated-content can easily be defined more broadly so it can include any kind of sensor data as well, making the smartphone into a powerful measuring device.
4. 7scenes is also a community platform where all activities of players are published in order to make the accumulated results visible for anyone. •

## CONTACT

Dr. Sybille Lammes is assistant professor at the Department of Media and Culture Studies, Faculty of Humanities, Utrecht University. She has published on techno-science, media, games and digital cartography. Recently she was awarded a 5-year ERC starting grant for her project "Charting the Digital." As a principal investigator she will lead a research team that will investigate how digital maps can be simultaneously understood as new media, technologies and cartographies. She is one of the founding members of GAP: the Center for the Study of Digital Games and Play.

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Ronald Lenz is co-founder and CEO at 7scenes and is founder of the Urban Reality Lab at Dutch medialab Waag Society. With many years of experience working in locative and mobile media Lenz has a long track record developing research programs, leading projects, developing products, hosting events and speaking at conferences.

[ronald@7scenes.com](mailto:ronald@7scenes.com)

## SUMMARY

Games played on mobile devices offer 'ordinary' citizens without a particular professional training or occupation great opportunities to become and enjoy being citizen scientists. It enables citizens to engage in the sensing and measuring of various environmental data, their dissemination to a broader audience of either fellow citizens or professionals, and in some instances to even act as 'professional amateur' interpreters of these data. Through the use of mobile technologies people can playfully move through their environment to acquire and distribute scientific knowledge. This knowledge transfer project wants to explore how the 7scenes platform can be used for such purposes.

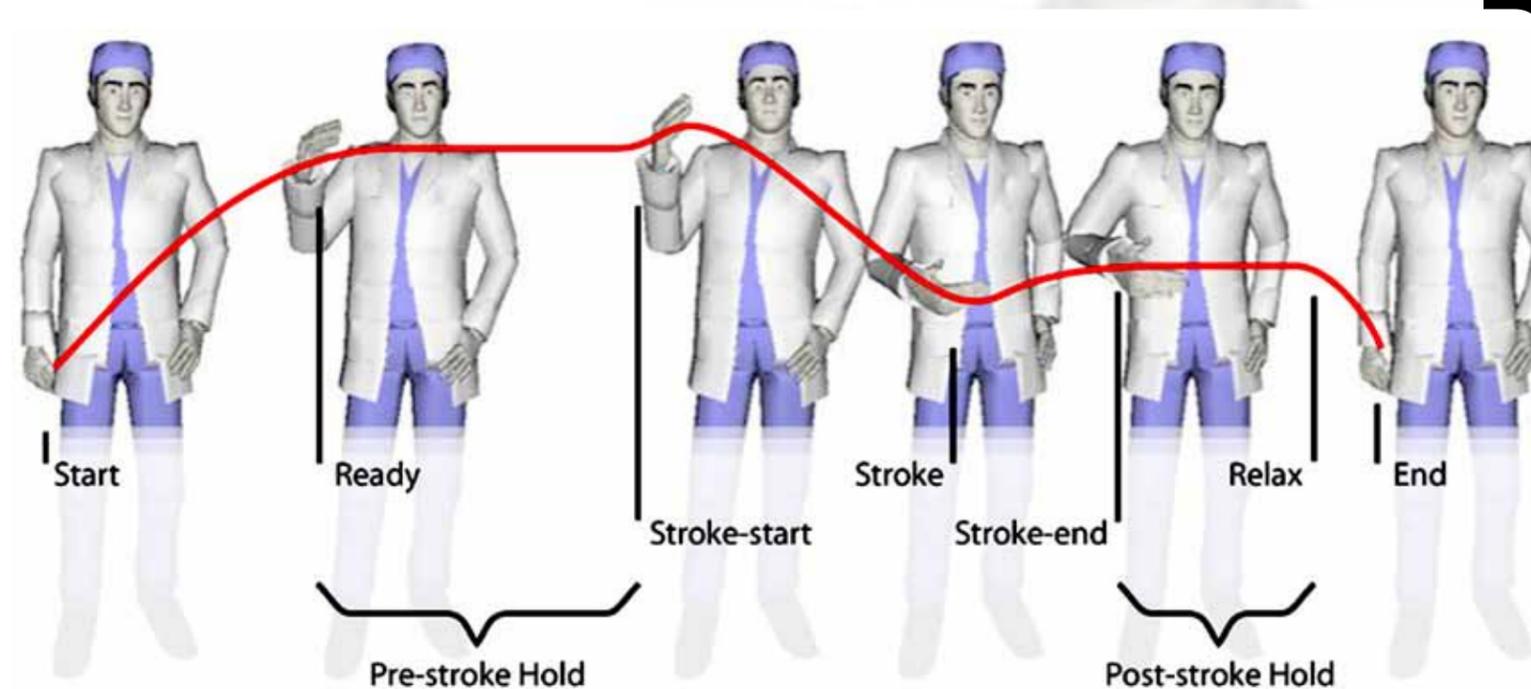


# COMPUTER ANIMATION FOR INTERACTIVE BEHAVIORS

## SUMMARY

Simulation and training environments require knowledge about the interaction between humans and systems. Non-verbal modalities like gesturing or body postures are equally important to convey the right message. Smart environments, intended for training, should therefore be able to communicate, not just by means of text or speech but also by means of non-verbal modalities.

The goal of our KTP is to create and augment virtual environments like Re-lion's Virtual Infantry Trainer where we aim at capabilities for generating and interpreting social cues for natural interaction between humans and virtual humans. We are currently creating and (user-)testing a prototype system.



## CONTACT

Job Zwieters is associate professor at the Human Media Interaction group of the department of Computer Science of the University of Twente. He is currently active within the Dutch Commit project, where the results on continuous interaction and the Elckerlyc system will be used for coaching and serious gaming. [j.zwieters@utwente.nl](mailto:j.zwieters@utwente.nl)



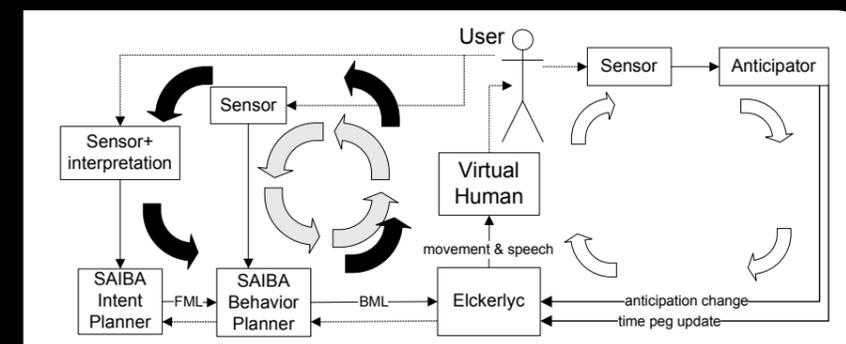
# SOCIAL SIGNALS AND

INTERACTION BETWEEN HUMANS AND VIRTUAL CHARACTERS PLAYS AN ESSENTIAL ROLE IN SERIOUS GAMING FOR COACHING AND TRAINING. THIS INCLUDES SOCIAL SIGNALS BY MEANS OF BODY LANGUAGE AND GESTURING. OUR KTP PROJECT AIMS AT DEVELOPING A SYSTEM THAT IS ABLE TO COPE WITH SUCH INTERACTIVE BEHAVIORS IN A VR ENVIRONMENT.

Virtual characters play an essential role in many action games and simulations. To be convincing, they should act, look, and gesture naturally. An important aspect of behavior is the way they generate gestures or show body language in interaction.

## FUTURE INTELLIGENT ENVIRONMENTS

Simulation and training environments require knowledge about the interaction between humans and systems. For example, police training today often employs expensive actors for simulating situations where social and cultural awareness is considered important. Communication then involves more than just verbal utterances. Non-verbal modalities like gesturing or body postures are equally important to convey the right message. Smart environments, intended for training, should therefore be able to communicate, not just by means of text or speech but also by means of non-verbal modalities. For example, by means of embodied agents that use gesturing and body language to communicate. In virtual environments like Re-lion's Virtual Infantry Trainer we expect that non-kinetic and non-verbal behavior will become an important aspect of trainings situations where it can convey signals like stress, frustration, or agreement or disagreement in dialogue. Our aim is to transfer knowledge on advanced animation, and more in particular knowledge concerning the usage and implementation techniques for the Behavior Markup Language (BML) that is currently being developed and standardized in behavior generation and behavior animation.



## GOAL OF OUR KTP PROJECT

Our long term goal is to create and augment virtual environments like Re-lion's Virtual Infantry Trainer where we aim at capabilities for generating and interpreting social cues for natural interaction between

people in the field can more easily work together and share resources. The emerging Saiba framework is backed by a large number of international institutions. An important part of the Saiba framework is the interface between behavior planning and behavior realization. The Behavior Markup Language BML acts as the interface language. It provides a player-independent description of multimodal behavior that can be used to control an embodied agent, at a rather detailed level including relative timing and detailed definition of a behavior's form.

between humans and virtual humans. For instance for back channeling useful information like stress or frustration in training situations, or for signaling agreement or disagreement in dialogue.

The focus is on advanced techniques for character motion generation that are suitable for the presentation of these social signals. We want to transfer this knowledge by creating a BML realizer component that is tightly integrated within Re-lion's simulator technology, and that will enable the employment of sophisticated animation techniques.

A second goal is to investigate the "continuous interaction" concept as it is being developed within the Elckerlyc project of the HMI group of the UT. "Elckerlyc" is a long term project, partly funded by the Gate project in the form of PhD research within the "Modeling Motor Behavior" theme, and partly by other staff within HMI, focusing more on interaction and social signals as they are used in human computer interfaces. •

# EVALUATION OF A CASHIER TRAINER

THIS KTP EVALUATES THE PRINCIPLES AND METHODOLOGIES CONCERNING MEASUREMENT AND OPTIMIZATION OF TRANSFER OF GAMING BY VALIDATION OF A CASHIER TRAINER WITH AN ELABORATE STRUCTURED CHECKLIST AND BY EXPERIMENTAL COMPARISON OF TRANSFER WITH AND WITHOUT THIS CASHIER TRAINER.



## SUMMARY

Potential users of serious gaming products (e.g. in education and companies) require useful and evidence-based games that are not only attractive and motivating, but also combine didactical surplus-value with cost-effectiveness. Knowledge on the combination of these major elements is still scarce, especially validation methods and measurement instruments to provide evidence for this surplus value. It is expected that the present practical translation of our GATE knowledge with regard to validation tools and best practices may result in more effectively designed games such as the Cashier Trainer developed by Jutten Simulation. These games include all major aspects of serious gaming such as didactics, motivation and cost-effectiveness and have high training potential.

In WP 4.4. of the GATE Scientific Program, design and validation principles for instructional games have been developed. This included, for instance, a stepwise reference framework, a taxonomy for predicting transfer, and a structured checklist for the design and evaluation of serious games from a didactical and cost-effectiveness point-of-view. However, there is still a need for a sound practical evaluation and practical elaboration of this methodological knowledge on usability, added value, best practices, etcetera. Therefore, in the present KTP we verify and improve the applicability of this knowledge with a practical test-case. In addition, we aim for hard evidence of high transfer of training of serious gaming.

## CONTACT

Dr J.E. (Hans) Korteling is senior scientist and program manager at the TNO Department of Training and Performance Innovations. His main interests concern cost-effective simulation, cognitive aging (PhD thesis) and design and validation of training simulation & serious gaming.

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Dr Esther Oprins is also research scientist at the same TNO Department. Her main expertise is training design (simulators, serious gaming), assessment (PhD thesis), performance measurement and validation.

As a test-case we have chosen the Cashier Trainer, developed by Jutten Simulation. We expect this to be a well suited case that may deliver high transfer because of its sane instructional features. The Cashier trainer is representative for a broad range of didactical serious games, since a complete range of competences are trained in a synthetic 3D PC-based environment including interaction with virtual characters, instructional tutorials and intelligent feedback.

## EVALUATION OF EFFECTIVENESS AND EFFICIENCY

More in specific, the Cashier Trainer is intended to simulate the entire cashier task, which includes operating the checkout system, communicating with (animated) customers, dealing with specific payment methods, logistics etcetera. A sophisticated Intelligent Tutoring System supports the trainees with learning the procedures independently of a human coach. With that, the cashier training is a good example of a serious game in which all kinds of skills from simple to complex can be practiced in an environment that is realistic and motivating. This trainer combines a simulation of a complete task and job environment including virtual characters with didactical principles in an attractive and accessible way. The trainer is intended to be used by retail organizations in The Netherlands. The game is internet-based and runs on the trainee's home PC. The aim of this complete game-based training for cashiers is to deliver better cashiers (i.e. effectiveness), while saving on-the-job training time and costs (i.e. efficiency).

The present project enhances and verifies the principles and methodologies concerning measurement and optimization of transfer by evaluation of the effectiveness of the Cashier Trainer in two ways: a) checklist-based expert evaluation of the Cashier Trainer, b) objective performance measurement comparing two training conditions, i.e.: game-based training using the Cashier Trainer and conventional on-the job training at the workplace (supermarket). In addition, the effectiveness of this instructional game is evaluated in terms of costs and time compared to conventional training.

## COMPREHENSIVE 200-ITEM CHECKLIST

At present, we have evaluated a comprehensive checklist that has been developed to quickly evaluate the didactic, gaming, and technical features of instructional games. The checklist consists of about 200 items that have been defined

on the basis of the literature on training simulation and serious gaming. This includes all design-, didactical, game play-, and fidelity- features of the game.

Examples of clusters of items are: comprehensiveness of the specification and design process, training program, scenario management, instruction and feedback, intelligent tutoring, game mechanics, user interface, models, visual image and content & sound.

The checklist showed outstanding usability. The data that was collected indicated that the Cashier Trainer comprised excellent didactical and instructional features with good physical fidelity and minor technical problems. Major points of possible improvement concerned game play features.

## OBJECTIVE PERFORMANCE MEASUREMENT

For the second part of the evaluation we collected objective performance data on the first working day after the (on the job or with the cashier trainer) training program, such as: duration of practice, cost of practice, number and types of errors as a cashier, performance speed. Also subjective experiences and personal data are collected from the trainees on which competences they already have acquired and which not yet (self-assessment of performance), the amount of practice, the adequacy of instructions and feedback, presence, immersiveness, difficulty of the different subtasks, other relevant competences, and computer experience.

The results of the objective performance measurements and cost effectiveness are not completely available yet. At present, we have collected all data concerning the effectiveness and efficiency of on the job training, but the data concerning the training results of the cashier trainer still have to be collected.

For developers of serious gaming this research project offers various means of support to improve, and substantiate the quality and effectiveness of their serious games. •



# REALISTIC CROWDS: WE ARE MOVING WITH YOU, SIRE! FOR SPARTA!

CROWDS IN SIMULATIONS AND GAMES

## SUMMARY

We show how thousands of virtual characters can simultaneously charge through multi-layered 3D environments while avoiding moving obstacles. Characters can replan their paths to avoid dense routes that lead to traffic jams. Each character can also prefer a certain type of terrain. For example, it may be better to haul a squeaky catapult along a paved road, but a clan of Spartan warriors may prefer to set an ambush in the woods. The researchers involved in this project are Roland Geraerts and Atlas Cook (Postdoc). The research was carried out for the GATE KTP project: Pedestrian and Vehicle Traffic Interactions in a Driving Simulation.

REALISTIC CROWD MOVEMENTS ARE CRUCIAL FOR GAMES AND SIMULATIONS. GAMES MAY HAVE THOUSANDS OF SPARTANS CHARGING THROUGH AN ENVIRONMENT WHILE SIMULATIONS CAN TEACH PEOPLE HOW TO DRIVE SAFELY.

One goal of path planning is to guide a large number of characters through a virtual environment. Each character can have a unique personality (shy, peaceful, aggressive) and unique goals (must...eat...cookies, show me the treasure chest, oohhhh...pretty). As a character moves, he or she should avoid colliding with obstacles (including other moving entities). A challenge for us is that modern games and simulations only allocate a tiny percentage of the CPU time to path planning.

## OLD-SCHOOL PATH PLANNING

Early real-time strategy (RTS) games were plagued with path planning issues. When squadrons of warriors were ordered to march through a narrow chasm, the Spartans at the rear of the army would frequently wander off in small groups in search of another route. These small groups were quickly annihilated by the enemy.

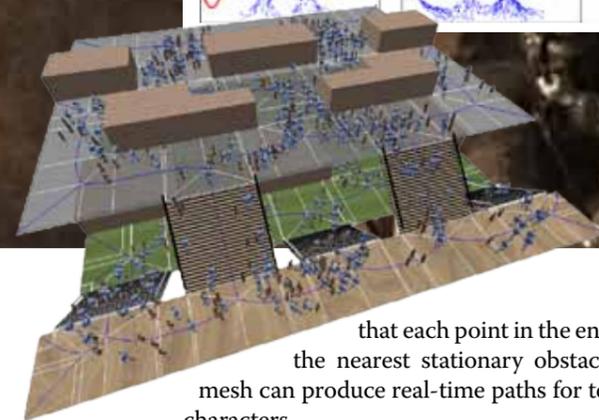
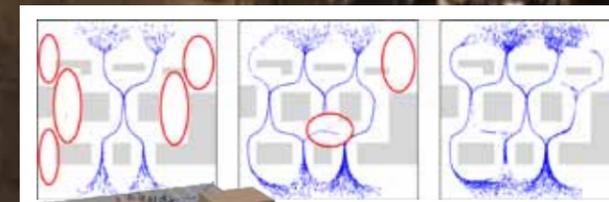
One path planning approach is to manually annotate the

traversable paths in an environment. This process is tedious, and it has led a few gamers to exclaim, "Why can't I go that way?!" when an avatar stubbornly refuses to follow a visible route that was missed by a designer.

## AUTOMATIC PATH PLANNING

Modern games are beginning to use algorithms to automatically partition an environment into a collection of two-dimensional walkable regions. The resulting 'navigation mesh' can be constructed using grid-based sampling approaches, but grids are frequently either too dense or too sparse.

Triangulation approaches have also been used to describe the walkable regions in an environment, but triangulations do not typically encode the nearest stationary obstacle to a character. This makes it more difficult for a character to avoid obstacles. We have shown that a structure called the 'medial axis' can be used to automatically partition an environment into a collection of two-dimensional walkable regions such



that each point in the environment encodes the nearest stationary obstacle. This navigation mesh can produce real-time paths for tens of thousands of characters.

## MULTI-LAYERED ENVIRONMENTS

Modern environments can have multi-storey buildings, stairs, and elevators. These environments cannot be entirely represented in 2D. However, we have recently shown how to efficiently stitch together the navigation mesh at connection points on stairs and elevators. Such a multi-layered navigation mesh also supports dynamic updates of obstacles. This permits lightning-fast dynamic path planning in city- and game-like environments.

## AVOIDING THAT TRAFFIC JAM

If shortest paths are used to guide a crowd of characters, then nearly all of the characters will frequently choose the



same route to reach their destinations. This leads to traffic jams in overutilized routes. It can also cause some routes to not be utilized at all. We have shown how to periodically replan routes based on the current crowd density information. This helps spread a crowd among the available routes.

## WEIGHTED REGIONS

Environments for driving simulators typically contain a variety of characters. Car characters should mostly travel on the roads. Pedestrian characters should mostly travel on the sidewalks. However, pedestrians should be able to cross roads, and cars should be able to park on the sidewalks when necessary. Our recent research takes these preferences into account, and the approach is being implemented in a commercial driving simulator for the company GreenDino (<http://www.greendino.nl>). •

## CONTACT

Roland Geraerts (R.J.Geraerts@uu.nl) is an Assistant Professor in the Department of Information and Computing Sciences at Utrecht University in the Netherlands. His current research focuses on path planning and crowd simulation in games and virtual environments. He teaches several courses related to crowd simulation and games. Roland has organized the Creative Game Challenge and is one of the co-founders of the annual Motion in Games conference. More information can be found on his webpage: <http://www.staff.science.uu.nl/~gerae101/>.

**GATE HAS FORMED A STRONG COMMUNITY THAT MUST NOW TAKE UP THE NEXT CHALLENGE**

# GATE PARTNERS

## GATHER FOR THE NEXT QUEST



It is game-over for GATE. The last challenges have been met, and the last resources have been spent. There is proudness over what has been achieved and sadness over what has ended. And there is a hunger for more.

Six year ago we endeavored on a quest to develop in the Netherlands an international competitive knowledge base in game design and technology and to train the talent required to enhance the productivity and competitive edge of small and medium-sized game companies. Did we succeed? That is for others to judge. But GATE did put game research on the agenda in the Netherlands achieving amazing results, it did lead to much collaboration between knowledge institutes and industry, and it did train close to 20 PhD students and involved many others in fascinating game research projects. We formed a strong community that will surely last, even though the game is over.

### LEARNING CURVE

Running GATE was a tremendous learning curve. Dealing with contracts, setting up a communication structure, creating governing bodies, organizing large symposia, and creating movies were just some of the things we had to learn. Sometimes we were really in the flow and great things were happening seemingly effortless, like during the various symposia that I truly enjoyed. But at other times we were stuck and progress was slow, in particular when dealing with the financial hazards. Piet and Rita were priceless companions for me in those situations.

### CHANGING RULES

During the game the rules sometimes changed. In particular, we could not implement the Knowledge Transfer

Project the way we envisioned. After long discussions with various lawyers we finally came up with a construction that was acceptable by the government and worked well for both companies and knowledge institutes. It led to fifteen collaboration projects in which the companies provided the 50% matching. It was a major achievement for everybody involved; it was an example of how public-private partnerships can grow, also with small companies; and it felt like a big reward for me.

### A SEQUEL

This quest is over, but there is room for a sequel. There is so much more to achieve. Gaming holds the promise to change almost every aspect of the way we live. It will connect us, train us, entertain us, protect us, and care for us. Together the Dutch industry and knowledge institutes can play an important role in making this promise come true. We should tackle bigger challenges. We should create engaging virtual worlds with meaningful virtual characters. We should create more natural and playful interaction methodology. And we should better understand the effectiveness of game design principles. We need to involve a bigger community of players. And we need to invest more resources.

### GATHER

The next step has been taken. The innovation contract for the top sector Creative Industry contains the GATHER program for the game industry. It will help us to further build the gaming eco-system in the Netherlands. Let us all fight for its realization and take on this second quest together. Again, let the game begin. •

Mark Overmars (Utrecht University), Peter Werkhoven from TNO and Jeroen van Mastrigt from the HKU are the founding fathers of GATE, and Overmars led the project during the first four years. He also set up the Game Technology education program at Utrecht University and is co-owner of two companies: YoYo Games that distributes the GameMaker software originally developed by Overmars, and Qlvr that develops educational games.



### Utrecht University

Utrecht University is the centre of gravity in academic game research and education. It offers master programs on game and media technology and on new media and digital culture. It has strong research groups in various aspects of game technology and game design principles. Current research themes are multimedia and geometry, path planning, crowd simulation, animation, cognition, communication, intelligent systems, new media and digital culture.



### TNO

TNO has a strong international position in simulation technology and human factors and applies this knowledge in particular in the areas of Defense and Safety. TNO has a substantial research program on tactical gaming, world modelling, simulation based design, soldier and crowd behaviour, distributed simulation, virtual instructors and virtual teammates, simulator effectiveness and human modelling.



### Utrecht School of the Arts

The Utrecht School of the Arts is "the" breeding ground for new generations of game designers. It offers education programs on game design and development, game animation, game art, game audio and interaction design. HKU's R&D program Applied Game Design focuses on the creative aspects of the strategic design and application of games and gameplay to motivate and help players to develop competencies, comprehension or skills that are useful beyond the game itself. The applied game R&D team consists out of 8 researcher/designers and is located at the Faculty of Art, Media & Technology of the Utrecht School of the Arts.



### Twente University – Human Media Interaction

The Human Media Interaction Department of Twente University comprises more than forty researchers working on smart surroundings, ambient intelligence, multi-modal interaction, speech and natural language processing, multimedia retrieval, embodied agents, virtual reality, adaptive user interfaces and affective computing, games and entertainment computing.



### Delft University of Technology

Delft University of Technology participates through the department Mediamatics and its three sections, Computer Graphics, Man-Machine Interaction and Information and Communication Theory. Research on game technology focuses on advanced modelling and visualization, human interaction through gestures, gaze and facial expressions, simulation in crisis management and ambient intelligent behaviour recognition.



### Waag Society

Waag Society researches, and develops concepts, pilots, and prototypes at the intersection of new technology and art, aiming for social innovation, focusing on healthcare, art and culture, education, sustainability, and society in general. Waag Society conducts experimental, interdisciplinary research, in close cooperation with a relatively small number of users: 'creative research'. Users have a central position and a large influence on the final project result: 'users as designers'.



### Thales

Thales Nederland Land & Joint Systems is the leading defence communications company in the Netherlands. The company supplies both armed forces as commercial organizations with requirements for high technology multimedia networks, with high quality integrated communications systems. It facilitates a Battlespace Transformation Centre that is used to assess new capabilities and to conduct Concept, Development and Experimentation, a process where experts of different areas combine their effort to develop new capabilities.

# GATE

## MANAGEMENT TEAM

The management team of the GATE project consists of:



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Piet Buitendijk  
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Rita Jansen  
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## STEERING COMMITTEE

The GATE steering committee takes all major decisions in the GATE project. It consists of:

Dirk Heylen • Twente University  
Erik Jansen • Delft University of Technology  
Frank Kresin • Waag Society  
Willem-Jan Renger • Utrecht School of the Arts  
Aart-Jan Smits • Thales  
Remco Veltkamp • Utrecht University  
Peter Werkhoven • TNO

## ADVISORY BOARD

The GATE advisory board monitors the progress of the project and advises the management team about desired changes and opportunities. It consists of:

Michael Bas • RANJ  
Pim Bouman • Dutch Games Association  
Arjan Brussee • Guerrilla Games  
Martin de Ronde • One Big Game  
Pjotr van Schothorst • VSTEP  
Jan-Pieter van Seventer • Dutch Game Garden  
Rogier W. Smit • PlayLogic  
Louis Vertegaal • NWO



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**Control.**

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