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Artificial intelligence moving serious gaming: Presenting reusable game AI components

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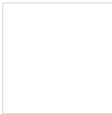
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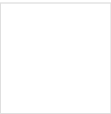
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Abstract and Figures

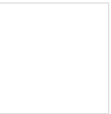
This article provides a comprehensive overview of artificial intelligence (AI) for serious games. Reporting about the work of a European flagship project on serious game technologies, it presents a set of advanced game AI components that enable pedagogical affordances and that can be easily reused across a wide diversity of game engines and game platforms. Serious game AI functionalities include player modelling (real-time facial emotion recognition, automated difficulty adaptation, stealth assessment), natural language processing (sentiment analysis and essay scoring on free texts), and believable non-playing characters (emotional and socio-cultural, non-verbal bodily motion, and lip-synchronised speech), respectively. The reuse of these components enables game developers to develop high quality serious games at reduced costs and in shorter periods of time. All these components are open source software and can be freely downloaded from the newly launched portal at [gamecomponents.eu](#). The components come with detailed installation manuals and tutorial videos. All components have been applied and validated in serious games that were tested with real end-users.



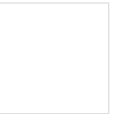
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Artificial intelligence moving serious gaming: Presenting reusable game AI components

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Abstract

This article provides a comprehensive overview of artificial intelligence (AI) for serious games. Reporting about the work of a European flagship project on serious game technologies, it presents a set of advanced game AI components that enable pedagogical affordances and that can be easily reused across a wide diversity of game engines and game platforms. Serious game AI functionalities include player modelling (real-time facial emotion recognition, automated difficulty adaptation, stealth assessment), natural language processing (sentiment analysis and essay scoring on free texts), and believable non-playing characters (emotional and socio-cultural, non-verbal bodily motion, and lip-synchronised speech), respectively. The reuse of these components enables game developers to develop high quality serious games at reduced costs and in shorter periods of time. All these components are open source software and can be freely downloaded from the newly launched portal at gamecomponents.eu. The components come with detailed installation manuals and tutorial videos. All components have been applied and validated in serious games that were tested with real end-users.

Keywords Serious games · Artificial intelligence · Software reuse · Game development · Component-based architecture · Intelligent tutoring systems

1 Introduction

Computer games have been linked with artificial intelligence (AI) since the first program was designed to play chess (Shannon 1950). The challenge to defeat human expert players in rule-based strategy games such as Chess, Poker and Go has great

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advanced the domain of AI research, affecting breakthroughs in e.g. computational intelligence, algorithms, machine learning, and combinatorial game theory (Fujita and Wu 2012). In turn, such new AI methods have been used in computer games, for instance to enhance graphical realism, to generate levels, sceneries and storylines, to establish player profiles, to balance complexity or to add intelligent behaviours to non-playing characters (NPC; Yannakakis and Togelius 2015, 2018).

Over the years, however, various authors (Champandard 2004; Bourassa and Massey 2012; Yannakakis 2012; Yannakakis and Togelius 2018) have pointed at the marginal penetration of academic game AI methods in industrial game production. This limited uptake has been attributed to 1) research projects largely focusing on advanced, but non-scalable projects of little commercial or practical value, and 2) game studios reluctant to adopt and include promising but risky AI techniques (such as neural networks) rather than established, fully scripted technologies in their games. The game industry's reticence to embrace advanced AI may partly be explained by the manifest failure of AI during the 1980's and 1990's to live up to their promises of enabling expert systems and intelligent dialogue. Ever since, the marriage between AI and gaming has appeared brittle, which is readily attributed to the limited interconnection and exchange between research and industry.

Research policy makers and politicians both at national and international levels have recognised that the transfer of knowledge and technologies from research and development organisations to societal sectors in order to create economic and social value, is a fundamental problem that should be urgently addressed. This failure is generally known as the “knowledge paradox” (European Commission 1995), referring to the fact that in many countries increased public investments in science and technology do not translate into economic benefits and job creation, while leaving many scientific findings unused. The process of knowledge valorisation often fails, which is painful as such in the case of games for learning, because of their dual role in both innovating the domain of education and contributing to raised skills levels in other content domains. This failure has been manifestly the case for the game industry, in particular the serious game industry (developing games for serious purposes rather than entertainment), since the serious game industry sector is composed of a large number of small independent studios (Stewart et al. 2013) that lack the scale and capacity to easily access new research knowledge and technologies and include these in their projects. Having recognised the potential of games for teaching and training and other societal sectors, the European Commission has stimulated diverse collaborations between game research and game industry. This article presents the main outcomes of the RAGE project, which has been the principal and most sizable research and innovation project in the European Horizon 2020 funding programme addressing serious games. Its goal and research assignment has been to investigate how a framework of reusable, intelligent game software components should be devised to structurally accommodate technology transfer from game research to the game industry, to assess and validate the outcomes, and propose measures for sustained societal impact. Rather than addressing AI per se, the research essentially focuses on the opportunities of the practical application of AI in serious games.

This article is the very first aggregate publication of the RAGE research programme carried out by over 130 researchers from all over Europe. We will first summarise related work of recent advances in game AI. Next, we will briefly explain the proposed

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results from the various application pilots will be summarised and discussed in the light of the anticipated knowledge and technology transfer mechanism for the serious gaming community.

2 Related work in game AI

Game design is essentially about creating valuable interactive experiences for the players. These experiences are effected by a variety of orchestrated game elements, including narratives, challenges, graphical representations, sounds, timing of events and phenomena, and the entities that directly interact with the player, be it opponents, allies, or other objects in the game environment. AI techniques will become indispensable to coordinate the ever-growing complexity and dynamics of games. From a pragmatic perspective, game developers are happy to use ad hoc cheats that offer players the illusion of intelligence, instead of any deep intelligence (Rabin 2017). This can work well until extended interaction reveals the tricks used breaking down the game experiences. As hardware capabilities improve, new types of interaction will emerge that would need better AI. In recent years, AI in games has improved appreciably (Lewis and Dill 2015). Below, we refer to example usage of advanced AI techniques in mainstream commercial games, mostly applied to control NPC behaviours. Artificial Neural Networks with 3 layers were used in the real-time strategy game *Supreme Commander 2* [Gas Powered games, 2010] to control platoons' reaction to encountering enemy units (Robbins 2013). From robotics research, systems for collision avoidance based on Reciprocal Velocity Obstacle (RVO) techniques (Van den Berg et al. 2011) have been made available as libraries and found their way into *Warhammer 40,000: Space Marine* [Relic, 2011] and many other games. The game *Guild Wars 2: Heart of Thorns* [ArenaNet, 2015] used an advanced utility-based decision architecture to solve problems related to tactical movement and skill use selection for its Non-Playing Characters (NPC) (Lewis 2017). *Forza Motorsport 5* [Turn 10 Studios, 2013] and its successors gather data about how players drive, that is then processed using Machine Learning techniques. This allows for the creation of "drivatars" that mimic a specific player driving style, and can then be used to play against. A similar goal was attained in the *Killer Instinct* fighting game [Iron Galaxy Studios, 2014] using case-based reasoning. For other uses of Machine learning techniques in games, the survey by Nguyen et al. (2015) provides a good start. Multi-agent systems have been suggested as powerful solutions to intelligent NPCs (Dignum et al. 2009). However, real-time synchronisation of many agents acting autonomously, for instance in battlefield games such as the *Call of Duty* series [Infinity Ward, from 2003], easily produce performance problems. Several advanced techniques for optimisation such as flow field and congestion concepts (Pentheny 2013, 2015), context steering (Fray 2015), and even robotics-inspired Velocity Obstacle techniques (Guy and

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Karamouzas 2015) have been applied. The blockbuster game *Grand Theft Auto V* [Rockstar North, 2013] uses multi-agent based architectures for the simulation of subsystems, as do most of the real-time modern strategy games, like those based on the Clausewitz Engine from Paradox Development Studios.

Adaptive gameplay has been accommodated with various algorithms used for matching two human players, such as TrueSkill (Herbrich, Minka and Graepel 2000) and variations of Elo (Elo 1978), or matching game task difficulty to players' skill, such as the Computerized Adaptive Practice algorithm (Klinkenberg et al. 2011). Hierarchical Task Networks (HTN) were used in the planner implemented for the third person shooter *Transformers: Fall of Cybertron* [HighMoon, 2012] (Humphreys 2013).

Advances in Natural Language Processing (NLP) have opened up new opportunities to support natural dialogues with NPCs, either companions or enemies, and to support interactive storytelling (Yannakakis and Togelius 2018). In the multiplayer online battle arena *League of Legends* [Riot Games] NLP trained models have been used to recognise and remove toxic behaviour from the player chat channels (Maher 2016).

Generally, these applications of AI are proprietary solutions bound and tuned to

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3 Platform-independent game AI

3.1 Lightweight game software reusability framework

Given the diversity of software platforms, programming languages, browsers and operating systems, favourable conditions for the reuse of software by game developers should be accommodated by a shared architectural framework. The main starting points for the architecture include: 1) Extensibility (The architecture should be robust over extending the set of components with new software components, 2) Addressing platform and hardware dependencies (Direct access to the operating system should be avoided; a conservative approach as to avoid browser version issues as much as possible), 3) Portability across game engines and programming languages, 4) Avoiding dependencies on external software frameworks and libraries (such as jQuery or MooTools for JavaScript), 5) Neutrality with respect to different software design methodologies (the development process), 6) Neutrality with respect to game genre, design and style (avoiding direct access to the interface; components just provide smart functionality under the hood), and 7) Truly lightweight (easy to use in different operational contexts). In close collaboration with game industry representatives, a component-based design framework (Bachmann et al. 2000) has been developed (Van der Vegt et al. 2016a, b). Although the architecture is self-contained and supports component-to-component communication its application context is generally driven by a game engine that can access the component's functionality once the component or its service is declared and integrated in the engine. Client-side plug-in characteristics of software components are created by relying on well-established coding practices and software patterns that procure abstraction, viz. decoupling functionality and its implementation. Most notable software patterns used for communication with the game engine are the Bridge pattern and the Broadcast/Publish/Subscribe pattern (Gamma

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et al. 1994); Birman and Joseph 1987.). Remote communications with server-side components are covered by web services. The architecture has been extensively tested and validated in connection with a wide diversity of development tools, target platforms and programming languages that are being used in practice (Van der Vegt et al. 2016a).

3.2 The gamecomponents.eu portal

The recently launched gamecomponents.eu portal funded by Horizon2020 is the technical platform for exchanging advanced game technologies and associated resources: it accommodates an open marketplace, which is driven by the RAGE Foundation. Notably, the portal offerings are fully platform independent, while – in contrast - existing game portals are either driven by commercial game platform vendors (e.g., Unity, Unreal from Epic, CryEngine from CryTek), by vendors of other creative software tools (e.g., Adobe), or by general media stock asset marketplaces (e.g., [graphicriver.net](https://www.graphicriver.net)). Moreover, existing portals focus mostly on media assets (e.g. 3D objects, textures, sounds) rather than software. Also, the gamecomponents.eu portal specifically targets serious games, while other platform primarily address leisure games. Nevertheless, leisure games could also benefit from the technologies exposed on our portal. Figure 1 shows a screenshot of a software catalogue page, revealing taxonomy-based filtering, keyword search and a results section displaying available game components. Software developers can describe and submit their contribution through a component-authoring widget that provides a stepwise guidance through the submission process, allowing for entering the software or software references (e.

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Fig. 1 A screenshot of the software catalogue at the marketplace portal (gamecomponents.eu)

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Github), its metadata (a specific game component metadata schema was designed for this (Georgiev et al. 2016)), and supporting artefacts such as technical documents (installation guides), training materials (e.g. video tutorials), and marketing materials. In addition, it offers an interactive stakeholder map, a set of tools for taxonomy management, training course creation and eCommerce management, and it uses open-ID user management, offers social API for the exchange with social networks (e.g. Slideshare, Mendeley) and includes a rating system based on scores by end-users. The portal is available at gamecomponents.eu.

3.3 First batch of public game AI components

An initial set of about 40 game components are exposed on the portal. The components exposed at the portal cover a wide range of AI-based functionalities that are relevant for serious game development, including personalisation, game difficulty balancing, assessment, player analytics, competence modelling, social gamification, language technologies and affective computing, among other topics. All components are open source and free of charge. Most client-side components, which need to be directly integrated with the game engine, are available in C#, while some also offer versions in JavaScript (TypeScript), or C++. Additional conditions to promote the adoption and reuse of the software have been met: 1) successful integration has been demonstrated with various game development environments (e.g. Unity, Xamarin, Cocos, Mono), 2) the integration in games is easy, 3) all components have been used and tested in real games with real end-users to provide empirical evidence of practicability; 4) the components have been enriched with ample documentation, tutorials, demos, research articles and evaluation results; 5) they use the highly flexible Apache 2.0 license (white label software), which allows for reuse by third parties both for commercial and non-commercial purposes, either under open source or closed source conditions. To further the viability and sustainability of the marketplace portal and to attain critical mass of relevant game software, third-party providers – either game research projects or IT-oriented companies – are expressly being invited to port their game software, whether or not compliant with the component-based design framework, onto the portal.

4 Selected game AI components

4.1 AI key areas

This section presents a selection of reusable game AI components that have been made available at the gamecomponents.eu portal. The selection focuses on Play

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among the flagships of game AI research (Yannakakis 2012; Yannakakis and Togelius 2015). Their relevance for serious games is readily explained by the pedagogical frame of teaching, which assumes a teaching agent (cf. NPC) that frequently probes and assesses the learner's mental states (cf. PEM) and, when

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needed, engages in a supportive dialogue with the player (cf. NLP) to provide guidance or feedback.

4.1.1 PEM: Player experience modelling

PEM can be based on a variety of player data, including the player's behavioural and performance data from the game (e.g. speed, score, decisions) and multiple player-related input modalities such as speech data (intonation, text), images (pupillometry, gaze tracking, gesture and bodily movement tracking), or physiological signals (EEG, respiration, blood volume pulse, skin conductance). So far, however, the capturing of physiological signals has been problematic since it requires hardware (sensors) that are often too obtrusive and unpractical for continuous application. In this article three unobtrusive PEM-related AI components will be presented:

- Real-time facial emotion recognition
- Adaptation and assessment
- Stealth assessment

4.1.2 NLP: Natural language processing

Natural language processing is the field of AI focused on the understanding, interpretation and manipulation of human language by computers. It allows the computer to assess any textual messages or documents sent by the player, and thereby it allows to respond to these automatically in a meaningful way. So far, NLP has scarcely been used in games. The following NLP services will be presented:

- Natural language processing: sentiment analysis
- Natural language processing: automated essay grading

4.1.3 NPC: Non-playing characters

Game AI for NPCs has a longstanding history, in particular focused on navigation and other low levels of control (Yannakakis 2012). Recent research, however, has been focusing on a variety of high level NPC behaviours that should effect more flexible, believable, knowledgeable, human-like, and intelligent behaviours, including realistic bodily motion, NPC emotion modelling, and compliance with socio-cultural conventions. This reflects a more holistic perspective on the NPC capable of flexible responses, as opposed to fully scripted applications. The following NPC components will be presented:

- Role play character: emotion appraisal and social importance dynamics
- Nonverbal bodily motion: behaviour mark-up language
- Nonverbal bodily motion: lip-synchronised speech

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4.2 PEM: Real-time facial emotion recognition

4.2.1 Emotion recognition

Artificial Emotional Intelligence (AEI), which is also known as emotion recognition or emotion detection, is a technology that extracts human emotions from displayed behavioural or physiological features (Schuller and Schuller 2018). Human facial expressions have demonstrated to produce the most informative data for computer awareness of emotions (Sebe 2009), outperforming approaches that make use of either speech and vocal intonations, physiological signals, body gesture and pose, text, or combinations of two or more of these approaches (Bahreini et al. 2016). So far, the use of emotion recognition functionality has not been a feasible option well within reach of game developers, because of the complexity of the implementation involved, limited accuracy, problems with facial hair and glasses, specific requirements with respect to lighting conditions, extensive post-processing and some more (Pantic et al. 2005). The real-time facial emotion recognition component, created by the Open University of the Netherlands, solves many of these problems (Bahreini et al. 2018).

4.2.2 Relevance for learning and teaching

Emotions are a significant influential factor in the process of learning, as they affect memory and action (Pekrun 1992). Any classroom teacher would take into account the emotional states of learners during the lessons. In computer-based learning, however, the learner's emotion has been systematically neglected as a learner model variable, because it was hard, if not impossible to detect. Now that emotion recognition technology is becoming available and accessible, learner models in serious games can include the learners' emotions and thereby improve the quality of personalised guidance and feedback. Also, the players' emotions can become part of the learning content or game scenario, for instance in games for communication training, conflict management, or actor training (Bahreini et al. 2017). Finally, emotion recognition can be used to collect emotion data during play testing.

4.2.3 AI approach

This software component uses artificial emotional intelligence to unobtrusively cover unbiased facial expressions of emotion from any image, either from a still, a video file, a video stream or a webcam. The technology uses a combination of fuzzy logic rules and machine learning. The fuzzy logic AI algorithm uses unordered fuzzy rule induction (FURIA algorithm; Hühn and Hüllermeier 2009), which is trained with a reference set of recorded emotions. It detects happiness, sadness, surprise, fear, disgust, anger and the neutral face, with accuracy above 80%, which compares or even outperforms human experts. Alternative machine learning approaches, such as neural networks, Bayesian networks, and decision trees are less practical for real-time operation as they require extensive processing while offering weaker performance.

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4.2.4 Application cases

A usage example of the real-time facial emotion recognition component would be the Jobquest game, which offers a job application interview training (Gutu et al. 2018). During the job interview, the players should control their manifest emotions and never display anger, fear or disgust. During the exercise, they receive direct on-screen feedback about the displayed emotion through the player's webcam shot and the associated emoticon (upper left corner in Fig. 2).

Emotion recognition has also been used for communication training in th

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4.2.5 Technical considerations

The real-time facial emotion detection is a client side software component that is to be integrated in the game engine. While using the player's personal webcam, it detects emotions in real-time. It returns a string value representing the seven basic emotion classes, which can be used for further processing in the game. It can also process a single image file, or a recorded video file. Also, presence of multiple players in one shot can be accommodated as it can detect multiple faces and interpret their emotions at the same time. It can easily be integrated in many game engines, including, for instance Unity3D.

4.3 PEM: Adaptation and assessment (TwoA)

4.3.1 Game balancing

The TwoA software component offers a dynamic game difficulty balancing mechanism, which automatically matches the difficulty of the player's task to the player's skill

Fig. 2 Direct emotion feedback in the Jobquest application interview game (upper left corner)

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(Nyamsuren et al. 2017). Game difficulty balancing is deemed an essential mechanism to preserve player engagement, improve player motivation, and improve the overall gameplay experience. Gee (2003) suggests that the secret of a video game is not in the fancy, high quality, immersive 3-D graphics, but it is in the underlying mechanism that balances the challenges offered to the player with the players' abilities "...seeking at every point to be hard enough to be just doable". Dynamic game difficulty balancing avoids both frustration of the player (when tasks are too complex) and boredom (when tasks are too easy). This also holds for teams: difficulty balancing is commonly applied in online multiplayer games such as the first-person shooter series Halo and multiplayer online battle arena games like League of Legends to ensure that opposing teams are evenly matched in terms of skills (Claypool et al. 2015). While the adaptation mechanism is often mistaken and confused with a simple if-then-else structure or a level closure, it should incorporate a sophisticated self-adjusting optimisation algorithm that frequently reiterates both task difficulty and skills mastery. The implementation and testing of such algorithm is anything but straightforward. The adaptation and assessment component created by the Open University of the Netherlands offers a fully automated, self-adjusting balancing algorithm that exposes superior reliability and stability. It comes as an easy to use software component that can be readily integrated in various game engines.

4.3.2 Relevance for learning and teaching

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balanced serious game enhances and preserves learner motivation, which is a principal determinant of learning. In accordance with the Zone of Proximal Development theory (Vygotsky 1978), a real-time adaptation of the game difficulty enables a smoother learning experience. The AI algorithm controls difficulty so that the player is challenged to improve a skill or acquire new knowledge without facing overly difficult tasks beyond player skill level. As a result it produces an optimised learning curve, since it iteratively re-assesses the player's skills mastery and continually adjusts task difficulty to the appropriate level. This means that the learning process becomes highly efficient: progression is optimised, while no time is wasted on tasks that do not contribute to learning. Continued assessment of the player's skill serves as a form of formative learning analytics that can be used by the player or the teacher to monitor learning progress and identify potential learning barriers (Hofman et al. 2018). Finally, game difficulty assessment also enables the analysis and optimisation of the game's learning content (Nyamsuren et al. 2018a).

4.3.3 AI approach

The AI algorithm developed for this adaptation software component is strongly rooted in the Elo rating system that was originally developed to assess chess players' skills (Elo 1978). This also holds for one of the widely-known examples of such balancing algorithms, namely TrueSkill (Herbrich et al. 2006) developed by Microsoft. However, TrueSkill was designed specifically to assess and match players in large-scale commercial online games. Another example would be the Computerized Adaptive Practice

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system (CAP), which was specifically developed to assess player skill in a serious game (Klinkenberg et al. 2011). It extends the Elo algorithm with methods from Item Response Theory (IRT; Lord and Novick 1968). The methods from the Elo system enable CAP to (re)estimate both the player skill and the game difficulty based on the player's real-time performance. In turn, the methods from IRT enable CAP to adapt the game difficulty based on the player skill using the previously estimated ratings. The Adaptation and Assessment component presented here adds several theoretical and practical improvements to CAP. TwoA considerably improves CAP's adaptive capabilities by minimising selection bias that may be present while choosing an appropriate difficulty level. This is achieved by expanding the IRT methods with fuzzy logic (Hühn and Hüllermeier 2009). Multiple selection criteria can mitigate the selection bias, and fuzzy logic allows to combine these criteria into a single selection rule. As a result, the improved algorithm is more robust and accurate than CAP especially during the calibration period when true skill and difficulty ratings are not well approximated (Nyamsuren et al. 2018b).

4.3.4 Application case

The effectiveness of CAP was extensively demonstrated with its application in Math Garden (www.mathsgarden.com), a popular Dutch serious gaming platform addressing primary school children (Van der Maas and Nyamsuren 2017). Publicly available data from a Math Garden game collected from over 1500 Dutch schools featuring 87,000 unique players were reused to validate the improved performance of the algorithm of the adaptation and assessment component. The TwoA component has also been used in an entrepreneurial skills training game (Hatch) at Hull College.

4.3.5 Technical considerations

From a practical perspective, this adaptation and assessment component offers an open source, highly portable, and easy-to-use implementation of the AI algorithm. As reusable component compliant with the RAGE architecture, it can be easily integrated with the most modern game engines (Van der Vegt et al. 2016a). The component hides all the complexities of the algorithm behind a simple interface. Apart from the management of player and game data, its operation requires only two method calls

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4.4.1 Using log game data for assessment

Stealth assessment is a promising methodology for applying formative assessments in serious games to unobtrusively assess the players’ knowledge or skills mastery based on the player’s behaviours and decisions in the game (Shute 2011). This means that behavioural data (e.g. log files) are analysed at a certain point in time to determine the player’s mastery without the need for explicit tests, e.g. multiple choice questions. In practice, however, the application of stealth assessment in serious games is a complex and time-consuming process (Moore and Shute 2017). Therefore, its uptake has been

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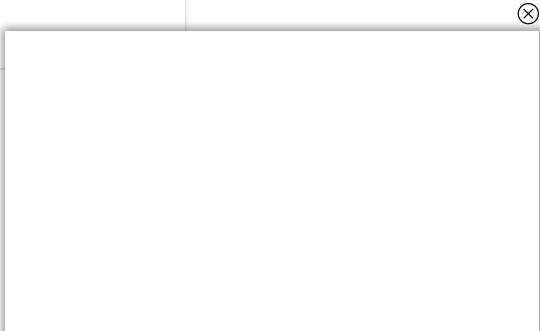
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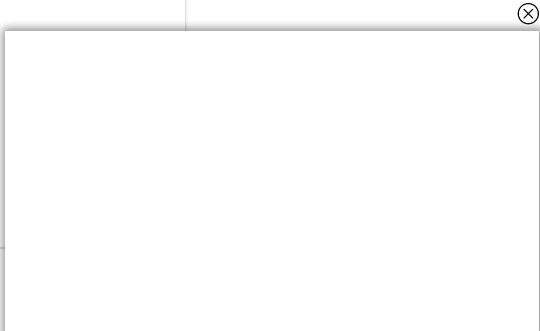
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... La contribución de la IA para esta técnica incluye la modelación del jugador (reconocimiento de emociones faciales al instante, adaptación de la dificultad en forma automática y evaluación del sigilo) y el procesamiento de lenguaje natural (evaluación en tiempo real del contenido y entonación de lo dicho), entre otros elementos (Westera et al., 2019) , inclusive hay aplicaciones que realizan diagnósticos y contribuciones específicas como predecir la dislexia, identificar autismo, déficit de atención y corrección simultánea de la pronunciación de distintas palabras. ...

... Estas analíticas, resultan ser muy valiosas para tener un mejor conocimiento del entorno educativo, lo que podrá orientar las estrategias hacia una formación correcta, por ejemplo crear espacios personalizados adaptados a las necesidades individuales de los alumnos. Otro punto a favor es que las instituciones que administran los sistemas educativos, podrán utilizar la información para predecir situaciones de riesgo, fortalecer el monitoreo, recomendar acciones a seguir, tomar decisiones y acordar las políticas que orientan los procedimientos formativos (Westera et al., 2019)

... En particular para la educación, se deben plantear diseños pedagógicos que consideren las potencialidades y desafíos intrínsecos en la IA, con el fin de impulsar una educación que, respondiendo a las necesidades de la sociedad moderna, pueda al mismo tiempo despejar los temores, actuar con realismo y abordar sus dificultades (Tuomi, 2018; Westera et al., 2019) . Asimismo, a través de políticas educativas pertinentes mitigar los riesgos y preocupaciones relacionadas con el uso de la IA, protegiendo la privacidad de la

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... The ECD has been used in a few studies to design embedded game-based assessments (see Jaffal & Wloka, 2015;Shute, Ke, & Wang, 2017;Shute & Rahimi, 2021). However, the design process is considered complex and time-consuming, and requires advanced statistical and machine-learning skills (Kim et al., 2016;Westera, 2019; Westera et al., 2020) . These make the use of this framework for classroom learning and assessment challenging as the requirements of educators are significant. ...

... It has shown to be useful for designing embedded and external assessments, for a new or pre-existing game designed to be played on any device. This framework could potentially be a reliable alternative to existing game-based assessment frameworks like the ECD which is considered 'complex, laborious, and time-consuming' to implement (Westera, 2019; Westera et al., 2020) . Compared to the ECD and Stealth Assessment (Shute & Ventura, 2013) which uses the ECD framework, the GBAF is less complicated to use. ...

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... For example, an AI notebook app provided writing feedback by recognizing and analyzing kindergarten students' handwriting (i.e., the shape, order, and direction of the segments) (Bonneton-Botte et al., 2020). (4) Increasing adaptability and interactivity in digital environments: AI technologies capture student learning data and enable interactions for more adaptive digital environments (Samarakou et al., 2015; Westera et al., 2020) . They also revealed that the biggest challenge is finding a suitable evaluation method (Expectation 1). ...

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... Samarakou et al (2015) created an advanced environment for e-learning for engineering students. Westera et al (2020) assessment, and facial emotion recognition to profile students. Additionally, they used techniques like nonverbal bodily motion and lip-synchronized speech to create non-playing characters. ...

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... As a complementary tool, Edgine supports a smart configuration of limited-resource edge devices in order to send the proper information to a cloud-based measurement management system [31]. Westera et al. [32] provide an important general resource, as it provides a comprehensive overview of artificial intelligence (AI) for serious games. Particularly, it presents a set of advanced game AI components that enable pedagogical affordances and that can be easily reused across game engines and platforms. ...

Implementing Deep Reinforcement Learning (DRL)-based Driving Styles for Non-Player Vehicles

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... The ECD framework has been used to design stealth assessments [1] and other games/simulation-based assessments [10][11][12]. Although the ECD provides a systematic process of assessment design for measuring competencies in complex learning environments, the process is often considered tedious and time-consuming and requires expertise in advanced statistics [13][14] [15]

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... Level/ Progress bar/ Levels of difficulty, metaphors and semiotics (Bucchiarone et al., 2023); (Tsopra et al., 2020); (Petrina and Gutica, 2021) Progression (Bucchiarone et al., 2023) Point/Reward systems/scores/Achievement (Bucchiarone et al., 2023); (Westera, 2019); (Tsopra et al., 2020); (Karakasis and Xinogalos, 2020); (Tsiotras and Xinogalos, 2021); (Jamshidifarsani et al., 2021) Leader board (Tsopra et al., 2020) Scaffolding (instruction in text format) (Karakasis and Xinogalos, 2020) repeatability (a player masters a task by repeating a set of actions) (Petrina and Gutica, 2021) Gameplay (Tahir and Wang, 2020) Artificial intelligence (AI) (including personalisation, difficulty balancing, evaluation, player analytics, competence modelling, social gamification, technical considerations and affective computing)/ Technical (Westera et al., 2020); (Tahir and Wang, 2020) Dilemma/Challenge provided/Increasing complexity/ Game play (Tang et al., 2019); (Silva et al., 2019); (Tsopra et al., 2020); (Harker-Schuch et al., 2020); (Lui and Au, ...

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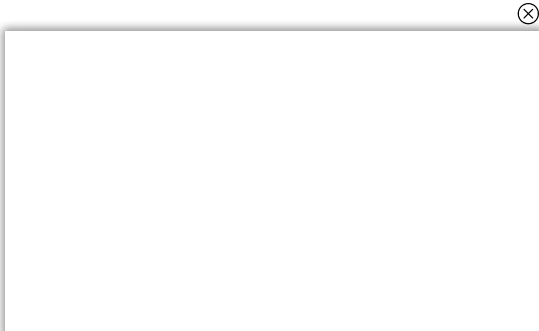
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Idiom-Based Features in Sentiment Analysis: Cutting the Gordian Knot

April 2020 · IEEE Transactions on Affective Computing

● Irena Spasic · ● Lowri Williams · Andreas Buerki

In this paper we describe an automated approach to enriching sentiment analysis with idiom—based features. Specifically, we automated the development of the supporting lexico—semantic resources, which include (1) a set of rules used to identify idioms in text and (2) their sentiment polarity classifications. Our method demonstrates how idiom dictionaries, which are readily available general ... [\[Show full abstract\]](#)

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Modeling Math Identity and Math Success through Sentiment Analysis and Linguistic Features

May 2018

Scott A. Crossley · ● Franklin Bradfield · ● Jaclyn Ocumpaugh · [...] · ● Ryan Baker

A number of studies have demonstrated strong links between students' language features (as found in spoken and written production) and their math performance. However, no studies have examined links between the students' language features and measures of their Math Identity. This project extends prior studies that use natural language processing (NLP) features to examine student language features ... [\[Show full abstract\]](#)

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Rapid Prototyping of a Text Mining Application for Cryptocurrency Market Intelligence

August 2016 · SSRN Electronic Journal

Marek Laskowski · ● Henry M. Kim

Blockchain represents a technology for establishing a shared, immutable version of the truth between a network of participants that do not trust one another, and therefore has the potential to disrupt any financial or other industries that rely on third-parties to establish trust. Recent trends in computing including: prevalence of Free and Open Source Software (FOSS); easy access to High ... [\[Show full abstract\]](#)

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Synesketch: An Open Source Library for Sentence-Based Emotion Recognition

July 2013 · IEEE Transactions on Affective Computing

● Uros Krcadinac · ● Philippe Pasquier · ● Jelena Jovanovic · ● Vladan Devedzic

Online human textual interaction often carries important emotional meanings inaccessible to computers. We propose an approach to textual emotion recognition in the context of computer-mediated communication. The proposed recognition approach works at the sentence level and uses the standard Ekman emotion classification. It is grounded in a refined keyword extraction method that considers a ... [\[Show full abstract\]](#)

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