Orchestration Platforms for Hybrid Artificial Intelligence in Computer Games - A Conceptual Model

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Abstract. *It is argued that hybrid artificial intelligence methods provide us with the necessary toolset to develop complex computer games. Additionally, to deploy such complex games at scale (for example in form of massively multiplayer on-line games) an orchestration platform based on microservices and multi-agent systems seems to be an adequate architectural choice. Herein we provide a state-of-the art literature review on hybrid artificial intelligence methods, their possible applications to complex computer games as well as introduce a high-level conceptual model of such a system.*

Keywords. hybrid artificial intelligence, artificial intelligence, computer games, multi-agent systems, orchestration

1 Introduction

The application of hybrid artificial intelligence (HAI) which can be defined as the orchestration of heterogeneous artificial intelligence (AI) methods including both statistical and symbolic approaches in various domains is omnipresent in current scientific literature. It is largely overlapping with the term hybrid intelligence (HI) that has been defined as *"the combination of complementary heterogeneous intelligences (...) to create a socio-technological ensemble that is able to overcome the current limitations of (artificial) intelligence."* (Dellermann et al., 2019). HI lies at the intersection of human, collective and artificial intelligence, with the intent of taking the best of each.

There have been numerous studies recently addressing issues related to HAI and HI methods in a multitude of application domains including but not limited to land-slide prediction (Li et al., 2018), drug testing (Chen et al., 2018), forecasting crude oil prices (M. Wang et al., 2018), prediction of wildfire (Jaafari et al., 2019), evaluation of slope stability (Koopialipoor et al., 2018), modeling of hydro-power dam (Bui et al., 2018), wind energy resource analysis (Fu and C. Wang, 2018), industry 4.0 and production automation (Azizi, 2019), airblast prediction (Armaghani et al., 2018), heart disease diagnosis (Manogaran et al., 2018) and these are just a few references from 2018 until the time of writing this paper. Most of these and such studies report building HAI systems by combining various AI methods to acquire better and more precise results. However, when it comes to methodology of the actual orchestration of HAI methods the usual approach is adhoc and depends from project to project. The lack of methodology in orchestrating HAI shall be addressed in this paper.

Computer games have always been connected to the development of AI. From the earliest chess minmax algorithm by Claude Shannon in 1949 to the more recent AlphaGo™ in 2015, computer games provide an ideal testing environment for AI methods. Similarly, AI has always been an important part of computer games. Computer games have often been judged by the quality of their AI and praised if they used an innovative approach like for example the ghosts in Pacman™ which had individual personality traits (1980), Creatures™ which used neural networks for character development (1996), Black & White™ which used the belief-desire-intention (BDI) model (2000), F.E.A.R.™ which used automated planning algorithms (2005) and many others (see Yannakakis and Togelius, 2018, pp. 8–15 for a very detailed overview). Artificial intelligence in games is not only used for non-player character (NPC) or opponent implementation, but also for various other parts of games (Yannakakis and Togelius, 2018, pp. 151–203) including but not limited to **generating content** (graphics including levels and maps, sound, narratives, rules and mechanics or even whole games like the Angelina game-generating system (Cook et al., 2018)), **player behaviour and experience modeling** (Yannakakis and Togelius, 2018, pp. 203–259), as well as **bot development and automated game testing** (Yannakakis and Togelius, 2018, pp. 91–151). Due to their complex nature and endless possibilities of creative design, computer games present us with an excellent opportunity to study the orchestration of HAI in various scenarios – not only for fun and leisure but also for other domains in form of serious games and/or gamification.

In a previous project sponsored by the Croatian Science Foundation (Installation Project No. HRZZ-UIP-2013-11-8537 entitled Large-Scale Multi-Agent Modelling of Massively Multi-Player On-Line Playing Games - ModelMMORPG - see (Schatten, Okreša Đurić, et al., 2017) for details) a comprehensive methodology for modelling large-scale intelligent distributed systems has been developed that includes a graphical modelling tool and code generator (described in (Schatten, Okreša Đurić, Tomičić, and Ivkovič, 2017) and in more detail in (Okreša Đurić, 2018)). The implemented toolset allows for modelling complex multi-agent organizations and could be applied to numerous applications domains (Schatten, Ševa, et al., 2016; Schatten, Tomičić, et al., 2017). Herein, we would like to propose the application and incorporation of this methodology to the development of HAI orchestration platforms for computer games.

In the previously mentioned ModelMMORPG project, we have already used an open source massively multi-player on-line role-playing game (MMORPG) called The Mana World (TMW) for which we have implemented a high-level interface to test intelligent agents playing the game. Additionally a number of connected game quests have been developed for various scenarios which allowed us to build an automated game testing system (Schatten, Okreša Đurić, Tomičić, and Ivković, 2017). Herein we would like to use this interface to test orchestrated HAI methods, but also develop other testbeds for the planned platform.

Therefore, the main contribution of the current ongoing project (O_HAI 4 Games - Orchestration of Hybrid Artificial Intelligence Methods for Computer Games - HRZZ-IP-2019-04-5824) shall be: (1) a comprehensive framework for the orchestration of hybrid artificial intelligence methods for computer games allowing to define models of HAI for various purposes, (2) an open source distributed cloud platform that will allow to implement such models based on existing HAI methods and connect them directly from game development platforms, (3) a set of best practices in developing HAI ensemble models tested in at least four specific testbeds described bellow.

The rest of this paper is structured as follows: firstly in section 2 we provide an overview of the domain of HAI in computer games. Then, in section 3 we outline a high-level conceptual model of the planned cloud-based orchestration platform and describe the details of its architecture. In the end in section 5 we draw our conclusions and provide guidelines for future research.

2 Domain Overview

Whilst HAI methods have recently been applied to numerous application domains with various degrees of success, their use in computer games seems to be an exception. Computer games usually do use various heterogeneous AI methods including finite state machines (FSMs), behaviour trees or rule based planning systems to implement different parts of a game's AI system, but there seems to be a lack of methodology when it comes to orchestrating these methods into a coherent playable game. Most literature for AI implementation in games (see for example (Funge, 2004; Nareyek, 2004; Yannakakis and Togelius, 2018)) does not address the issue of orchestration. Some older papers (e.g. (Nareyek, 2004) from 2004) do state that standardized interfaces between AI systems are necessary to make their integration into games as easy as possible and also provide possibilities for reuse, but still no such interfaces were developed, or if they have, aren't fully applicable to contemporary techniques in AI. Games are specific in terms of requirements they pose on AI and consequently HAI methods, for example they have to work in real-time not to disturb gameplay, ensembles of methods have to be coordinated and timely to provide a consistent behaviour of the game or its characters, and they have to be believable to not become frivolous.

In (Liapis, 2015) the term of creativity facet orchestration is defined as the "*aims to combine generation across the multiple creative domains that comprise game design*". There are six core facets in computer games: (1) level design, (2) game design, (3) audio, (4) visuals, (5) narrative and (6) gameplay, all of which can benefit from HAI methods as mentioned earlier (see Yannakakis and Togelius, 2018). As already stated, the current project has the main objective to establish a sound methodology in orchestrating HAI methods to be useful for computer games (including serious games and gamification systems) in all above mentioned facets. Additionally, it shall provide a cloud-based platform for building orchestrated HAI systems for games that will address the needs for real-time, coordinated and believable ensembles. During the project the newly developed methodology and platform shall be tested in at least four gaming-related environments: (1) a MMORPG game, (2) a gamified platform possibly with virtual assistants, (3) serious game related to autonomous vehicles as well as (4) a to be developed holographic / volumetric (Ho/Vo) gaming platform.

In order to develop a framework for orchestrating HAI methods one has to have the heterogeneity of the methods that have to be orchestrated in mind: they can include everything from simple expert systems to deep learning neural network models, from swarm intelligence optimization to automated planning systems, from rule-based knowledge bases to complex natural language processing (NLP) agents. A platform allowing to organize such methods and make them work together has to be distributed, robust, and scalable similar to big data platforms since the amount of data and processing resources for some of those methods can become quite demanding. Such a platform has to provide standardized interfaces to allow for coordination between various used methods and allow continuous data-streams and messaging. Multi-agent systems provide a natural abstraction for building such systems (Wooldridge, 2009), and have already been shown to be valuable in developing large-scale systems (see (Schatten, Ševa, et al., 2016) for a detailed overview).

In the mentioned ModelMMORPG project we have developed a methodology for modelling large-scale multiagent systems (LSMASs) based on an ontology (e.g. (Schatten, 2014)) which was the input for creating a metamodel (Okreša Đurić, 2016) for a graphical modelling language (Okreša Đurić, 2017a; Okreša Đurić, 2017b). It was shown that this ontology can be integrated with other domain ontologies to provide additional semantics, for example for massively multiplayer on-line (MMO) games (Okreša Đurić and Konecki, 2015; Okreša Đurić and Schatten, 2016), for virtual intelligent environments (Okreša Đurić, Rincon, et al., 2018) or even smart cities (Tomičić et al., 2018). Thus, during the proposed project an additional ontology for HAI methods shall be developed as a basis for a LSMASs model of a distributed HAI orchestration platform.

3 Conceptual Model

In the following we will outline the basic architecture of the planned HAI orchestration platform in form of a conceptual model. The HAI orchestration platform can be modelled conceptually as shown in Fig. 1.

The conceptual model depicted in Fig. 1 is visually divided in several elements. The distributed orchestration platform provides a set of interfaces including application programming interfaces (APIs) for various game engines and an administration user interface (UI). The platform, which is to be implemented as a multi-agent system provides load balancing, service allocation, and orchestration through an orchestrations subsystem like Docker Swarm or Kubernetes to a set servers playing the role of holons (see (Horling and Lesser, 2005) for details on the concept of holarchy or holonic organisations where each element can consist of multiple elements, i.e. each holon can either be a single element (a holon) or an organised group of elements), which, in turn, enables new holons to be added dynamically, i.e. *on the fly*. A single holon, i.e. a single service instance may comprise multiple other service instances on an, arguably, lower level, although such services can be standalone holons.

Each service is to be implemented as a single agent in a multi-agent system. It will be located in the same environment as the other agents providing other implemented services. This shared environment does not negate the concept of a distributed system, though, as the agents can be physically distributed even though they are a part of the same intelligent virtual environment (IVE) of the same system. Each agent is containerised insomuch as it must be run in a secure environment that is not allowed to be influenced by any external effects other than the usual communication with other agents of the system.

The applicable services are to be modelled as filter applications that are capable of utilizing the standard input and output channels, with optional arguments for fine-tuning the service's processes. Naturally, services are to feature system-wide standardised inputs and outputs that can consist either of single values as provided data that should be processed by a holon, or a stream of data, thus providing the basis for implementing dynamic and real-time systems, such as are required for the domain of computer games, as described earlier in this paper.

Since individual services are containerised, an apt implementation concept is a container orchestration platform like Docker Swarm or Kubernetes. This idea is motivated by efficient load balancing features that allow for on-time service allocation and orchestration where needed. Considering the distributed orchestration platform provides more holon-based services than necessary at any given point in time, the docker swarm is deemed as a good solution for the general application domain of the part of the research described in this paper.

Furthermore, the distributed orchestration platform itself is to be implemented as a multi-agent management system, since agents can operate individually, cooperate when cooperation is needed, communicate and reach an agreement using any of the communication methods, including auctions and bargaining, and they can be instantiated dynamically, i.e. agents can be run depending on the existing load of the system or the extension and the amount of requests towards the platform.

4 Application Domains

As already mentioned previously, AI and consequently HAI methods can be used in computer games for a number of various tasks like (1) implementation of NPCs and opponents, (2) automated playing and testing, (3) generation of content as well as (4) game analytics. Herein we will outline four particular use-cases for each of these domains.

Intelligent opponents in MMO games . MMO games *per se* present a complex task for implementation especially from the perspective of performance when thousands or hundred of thousands of players interact in parallel. The usual approach in generating opponents is to use simple AI methods like finite automata or behaviour trees in order to keep computation low and allow for fluid gameplay. Using a hybrid orchestration platform with numerous redundant servers more advanced HAI methods could be used to implement much more *intelligent* and thus more interesting opponents. New opponents

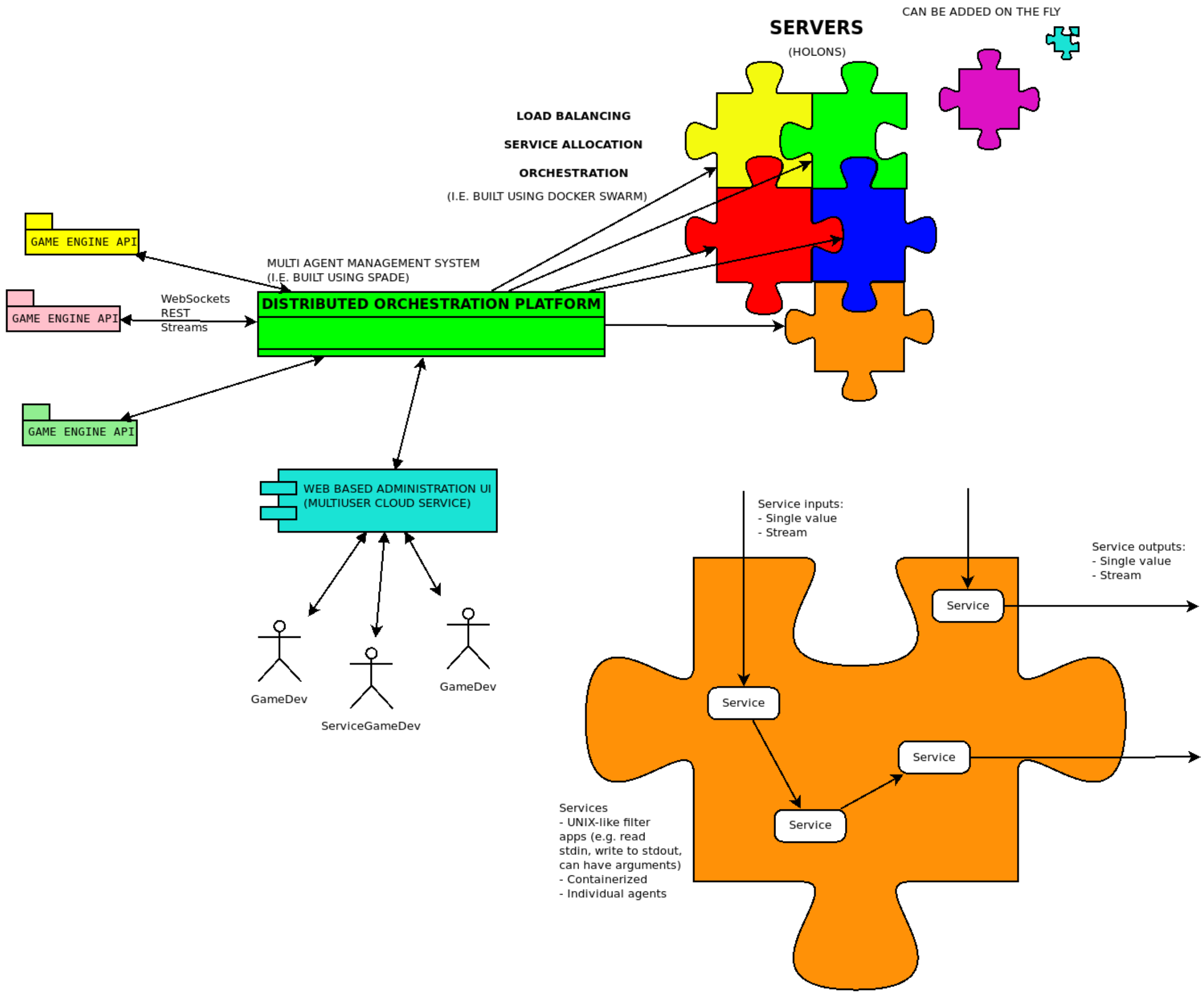

Figure 1: High-level Conceptual Model

could be generated *on the fly* just by instancing new services (agents) on the orchestration platform. This would lead to individual opponents that do not enact easily predictable behaviour and could result in much more realistic games.

Large-scale automated testing . While performance testing in MMO games has been well implemented in numerous platforms, when it comes to gameplay testing (especially for example in MMORPGs), large-scale testing becomes a very complex task as outlined in (Schatten, Okreša Ðurić, Tomičić, and Ivkovič, 2017). Not only do we need to test the various logic puzzles and tasks a player has to perform in order to advance in the game, but also the emerging interactions between players which might change the outcome of the game completely. By using a distributed orchestration platform automated players could be added to the game at will by instancing new agents. Additionally, test results could be reported and analyzed by adding additional reporting and/or analysis agents.

Heteregeneous content prediction in game streaming . Game streaming platforms like Google Stadia or NVidia's GeForce Now have just recently been gaining momentum. When put in a network multiplayer game or even MMO context, such platforms (but also networked multiplayer games in general) suffer from network lagging - e.g. the time from pressing a button on a game controller until the game's resulting actions on all players' screens is not zero due to network transmission and graphich and audio processing time. Some game engines have thus recently been experimenting with HAI methods for player prediction in which they try to predict the possible next moves of a player and generate all likely (visual and audio etc.) outcomes. When the actual action packet arrives, the generated outcome is automatically sent to all players' game clients. With a hybrid orchestration platform such a prediction system would be much easier to implement, since new possible outcomes for each player could be generated *on the fly* by just assigning new generating agents each time a new player joins the game.

Player analytics and game adaptation . Analysing the behaviour of players while playing and interacting with a particular game is of great interest to game studios. Not only do such behaviour logs provide isights into bugs or loopholes which need to be fixed, they also provide interesting insights into the actual interaction of the player with the game as well as feedback information: what does a player like, what doesn't she/he like, where does the player spend most of her/his time, etc. Such data can be used to improve the game and recent advancement in AI and data science allow us even to automate some of this improvements, i.e. some parts of the game (which a player likes more for example) could be made longer by generating additional content. By using a distributed orchestration platform analytics and improvement agents could be established for each player and allow for a individualized experience of the game.

5 Conclusion

Although there is a significant body of research dealing with the application of hybrid artificial intelligence, we argue that there is a lack of methodology in orchestrating HAI methods, which we are addressing within this paper.

As well as presenting the state-of-the-art literature review on hybrid artificial intelligence methods and their application domains, with focus on complex computer games, we have introduced a high-level conceptual model of the framework for orchestrating HAI methods, that would be able to deal with a significant level of the methods' heterogeneity, real-time requirements, distributed nature, robustness and scalability requirements. We have chosen multi-agent systems as a natural abstraction for building such a large-scale system as it was already proven to be a feasible choice.

We have graphically presented a tentative representation of the to-be-developed system, generally composed of distributed orchestration platform, APIs, UI, load balancing, service allocation, as well as orchestration services, and a proposed structure of a single holon/multi-layer service instance, which is to be implemented as a single agent in a multi-agent system.

We have also presented numerous application domains of such a distributed orchestration platform by providing four particular use-cases in which such a platform could solve major problems in game implementation and provide creative, new and unseen possibilities for games.

Our future research will be focused on the implementation of the basic architecture of such a system in order to test various types of HAI methods in various types of games including but not limited to searious games and gamification.

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