Conceptual Architecture of a Cognitive Agent for Telemedicine based on Gamification

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Abstract. *In this article, we argue the possible use of cognitive agents and gamification principles in telemedicine applications. We propose an initial framework for developing such cognitive agents based on the B.A.R.I.C.A. system, a cognitive agent architecture which has been developed by the Artificial Intelligence Laboratory at the Faculty of Organization and Informatics of the University of Zagreb. Possible use-cases and implementation guidelines are given.*

Keywords. cognitive agent, telemedicine, gamification, natural language processing

1 Introduction

Cognitive agents represent intelligent agents which use various types of artificial intelligence (AI) methods in order to allow interaction and learning from humans (Lee, 2010). Such methods might include speech to text (STT) and text to speech (TTS) technologies, machine learning (ML) and deep learning (DL) models, natural language processing (NLP), belief-desire-intention (BDI) models, knowledge bases (KBs) as well as system automation. Cognitive agents have been used in numerous domains including but not limited to mental health therapy (Suganuma et al., 2018), Internet of things (IoT) and fog computing (Foukalas, 2020),education (Baylor, 1999), home service robots (Van Dang et al., 2017), cognitive radio (Mitola, 2002) and many more.

The art and science of gamification has raised major interest from both academia and industry (Marinela Schatten and Markus Schatten, 2020; Markus Schatten and Marinela Schatten, 2019; Tomičić and Markus Schatten, 2020). We usually define gamification as "*the use of game design elements in nongame contexts*" (Deterding et al., 2014; Huotari and Hamari, 2012), and in a broad sense can be considered a successful motivation technique, supporting user engagement and enhancing positive behavioral patterns on various services like increase of activity, quality of work, socialization and hence productivity (Hamari et al., 2014).

The World Health Organization (WHO) defines telemedicine as the "*delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities*" (WHO, 1998)

The basic idea behind this paper is to argue the possible use of cognitive agents and gamification practices in telemedicine. In this context, we will firstly provide an overview of related work in section 2. In section 3, we introduce the Beautiful ARtificial Intelligence Cognitive Agent (B.A.R.I.C.A.) cognitive agent system that we have developed for student support. Then, in section 4, we establish a proposal of a framework that combines cognitive agents, gamification practices and telemedicine. In section 5, we discuss possible use-cases and implementation issues. In the end, in section 6, we draw our conclusions and provide guidelines for future research.

2 Related Work

The key feature (J. Craig and Patterson, 2006; WHO, 1998) setting telemedicine apart from the concept of conventional medicine is the fact that the relevant parties are separated in either space or time, or both. J. Craig and Patterson (2006) further state that telemedicine episodes can be classified based on the type of interaction, and on the type of information transmitted during the episode. The agent discussed in this paper is aimed to provide synchronous real-time interaction, thus providing immediate feedback to its users, where possible, as opposed to providing feedback in an asynchronous manner. Considering the nature of information being transmitted, one of the aims of this agent is to communicate with their users using a voice interface, possibly aided with a visual interface.

Use of AI is observable in many a major and mi-

nor area of human life and many services of the modern society (Markus Schatten, Tomičić, et al., 2017). In the context of telemedicine, according to Pacis et al. (2018), trends in using AI can be observed in the domains of patient monitoring, organising and managing health records, intelligent assistance and diagnosis, and information analysis and collaboration, to name a few. Arguing in the broader context of telehealth, Kuziemsky et al. (2019) recognise two main areas where AI is utilised: quality improvement for existing clinical practice and service delivery, and development and support of new models of care. The importance of telemedicine, and the quality of the services it provides, is especially emphasised by the ongoing COVID-19 pandemic during which there is an observable increase in telemedicine episodes (Florea et al., 2021; Koonin et al., 2020). The prospects of AI in telepsychiatry, as a subclass of telemedicine, are discussed in detail by Thenral and Annamalai (2020).

As a form of AI in the context of telemedicine, chatbots are used for: mitigating the severity of panic disorder (Oh et al., 2020); weight loss (Holmes, 2020) and promoting healthy living (Prasetyo et al., 2020); providing social and emotional support (Wang et al., 2021, February 4); holding follow-up conversations with patients (Lei et al., 2021); delivering a self-help program for college students who self-identify as having symptoms of anxiety and depression (Fitzpatrick et al., 2017); helping prevent suicide and self-harm (Hinesley, 2018); providing primary healthcare education, information and advice to patients (Bharti et al., 2020); caring for discharged elderly patients living in rural areas (Fadhil, 2018). Some chatbots are granted a detailed character and a physical appearance in order to make them easier to be adopted by their intended patient group (Liu et al., 2018).

For a comprehensive review of chatbots and their features, in the context of mental health, the authors would kindly advise the reader to consider (Abdalrazaq et al., 2019; Moore and Caudill, 2019).

Naturally, when information systems and applications are considered in the context of medicine, even more so in the context of telemedicine, it is vital to consider the importance and implications of ethical aspects of the involved data (Álvarez Díaz, 2021; Sepahpour, 2020, August 18; Stiefel, 2019).

One of the mechanisms utilised by the chatbot presented in this paper, that is aimed at increasing patient engagement with the chatbot, and the efficiency of telemedicine visits, is gamification. The ideas of gamification can be applied to various activities performed in many areas of the modern world. Roca et al. (2020) argues that gamification is one of the main management societal innovations introduced by the IT-revolution, and that utilising gamification policies is well known for achieving the following: power, stamina, innovation, bonus points, and level up. Furthermore, gamification is discussed by Jansson et al. (2020) as "*an opportunity to increase engagement in a given health behaviour and, eventually, the possibility of reaching improved outcomes through continued or consistent behaviour.*"

Although a substantial body of research exists on the gamification techniques applied to elderly care (Martinho et al., 2020), only a limited amount of information is available on the methods and success of using gamification in the context of engaging the elderly telemedicine users in particular (de Vette et al., 2015). Recently, Kalhori (2021) argued towards some necessary structural requirements for successfully using telemedicine with the elderly.

3 B.A.R.I.C.A. Cognitive Agent

The B.A.R.I.C.A. cognitive agent system's software architecture is shown on Figure 1. It consists of a cloud-based back-end and an on-site front-end.

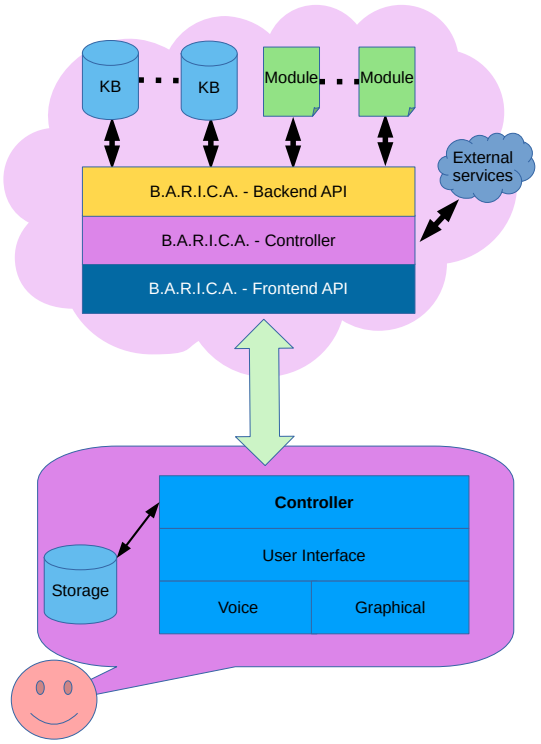

Figure 1: B.A.R.I.C.A. software architecture (Markus Schatten, Okreša Đurić, et al., 2021)

The cloud-based back-end being part of a larger framework being developed by the O_HAI (4) Games project (Orchestration of Hybrid Artificial Intelligence Methods for Computer Games) has already been reported in (Markus Schatten, Okreša Đurić, and Tomičić, 2020; Markus Schatten, Tomičić, et al., 2020) (an initial implementation concept has also been given in Markus Schatten, Okreša Đurić, and Tomičić, 2019). It consists of a microservice orchestration platfrom

based on holonic multi agent systems (HMASs) (Rodriguez et al., 2011). Its components are:

1. A back-end application programming interface (API) which allows connecting various microservices including but not limited to knowledge and databases, AI related modules and external services.

2. A controller which acts as microservice orchestration system that allows connecting these various microservices into a coherent system.

3. A front-end API which allows for the implementation of front-end applications one of which is the B.A.R.I.C.A. front-end.

4 Framework Proposal

In the following, we present a cloud based telemedicine framework that is focused on the integration of AI (especially cognitive agents) and gamification into telemedicine. Figure 2 provides a high-level overview of the proposed framework.

The model subsumes four types of users:

1. **Physicians and specialists** – providing medical advice and data to other system clients.

2. **Patients** – the end-users.

3. **Nurses / Technical assistants** – providing patients with technical assistance and common procedures.

4. **(Client) physicians** – using the system to get assistance and data from specialists.

These types of users can use any Internet enabled device to access the platform including smart phones, personal computers, laptops or smart television sets to get various types of services depending to the implemented and orchestrated microservices of the platform.

The platform's conceptual model is shown on Figure 3 (Markus Schatten, Okreša Đurić, and Tomičić, 2020). The orchestrated AI gamification platform provides interfaces that can be accessed by various types of client applications including gamified web and mobile systems implemented. The platform is an application framework that allows for building various AI and game oriented ensembles by orchestrating existing microservice templates into meaningful applications. These templates include various AI methods that can be tailored into microservice instances like concrete ML models, expert systems, finite state machines (FSMs), chatbots etc.

The platform is descibed in more detail in (Markus Schatten, Okreša Đurić, and Tomičić, 2020) and is the basic underlying back-end of the B.A.R.I.C.A. cognitive agent. Its mayor application area is the creation of services for various game engines and gamified platforms, but can be used for any type of microservice oriented applications. It is based on a holonic multiagent systems (MASs) architecture (Hahn and Fischer, 2007) in which individual microservices are represented as agents whilst ensembles are represented as holons. For the sake of telemedicine applications the framework can be extended with various microservice instances needed for the specific telemedicine oriented applications and services.

5 Use-cases and Implementation Guidelines

In the following, we present a number of potential use-cases for cognitive agents in telemedicine that could be implemented using the described platform as well as guidelines for gamification where possible. The use-cases have been compiled based on a literature and policy review.

AVATAR therapy or treatment of distressing voices with Audio Visual Assisted Therapy Aid for Refractory auditory hallucinations (T. K. Craig et al., 2015) which is based on using virtual avatars that are associated by patients with some aspects of their disease could be implemented using cognitive agents in which these agents would provide a virtual instance of the avatar. Such cognitive agents would have to be adaptable (learning) in order to absorb the various aspects that are associated with them, monitor progress and reproduce it when needed.

Chronic disease management and prevention including but not limited to asthma (Global Initiative for Asthma, 2017), allergies and the reaction to anaphylactic shock (Simons et al., 2011), diabetes (Members et al., 2013), chronic kidney disease (Levey et al., 2003), acute coronary syndrome (Neumann et al., 2018) are a potentially fruitful application domain. For the most of these chronic diseases, there are established and very detailed guidelines for various procedures which have to be performed on a regular basis. Some of these procedures can be performed by the patients and there are already a number of products including mobile phone applications which ease the daily routine. Most of these routines could be gamified by using a number of gamification techniques like virtual avatars, history of disease statistics, quests and similar; or could even be implemented as games in which a patient (player) advances through the game by applying the adequate procedures.

Prevention programs allow for the diagnosis in the earlier stages of a disease, which increases treatment options and overall survival in leading causes of death including lung cancer, breast cancer, cervical and colon cancer (Winett, 1995). Cognitive agents and educational games could be used to raise awareness and encourage people to participate in preemptive examina-

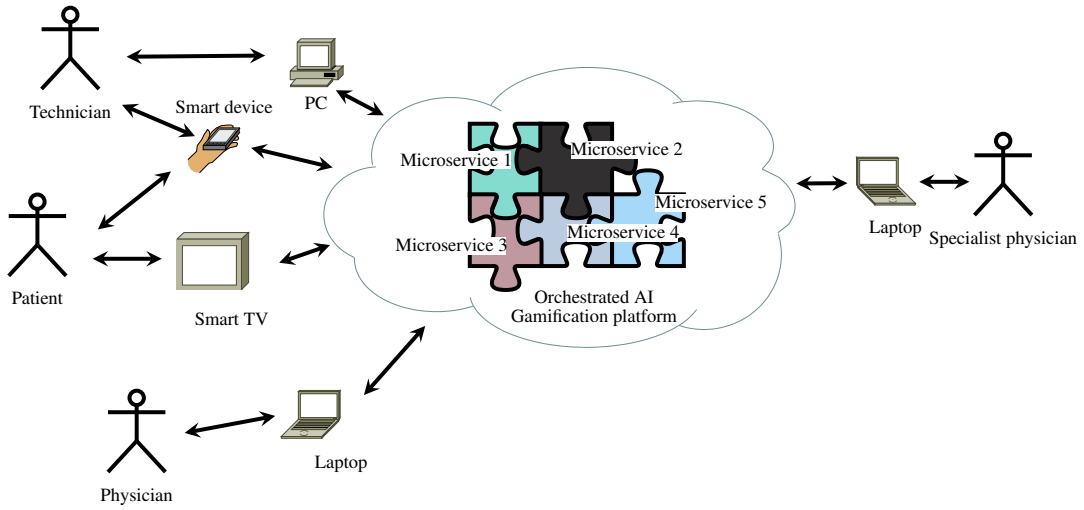

Figure 2: Conceptual System Model

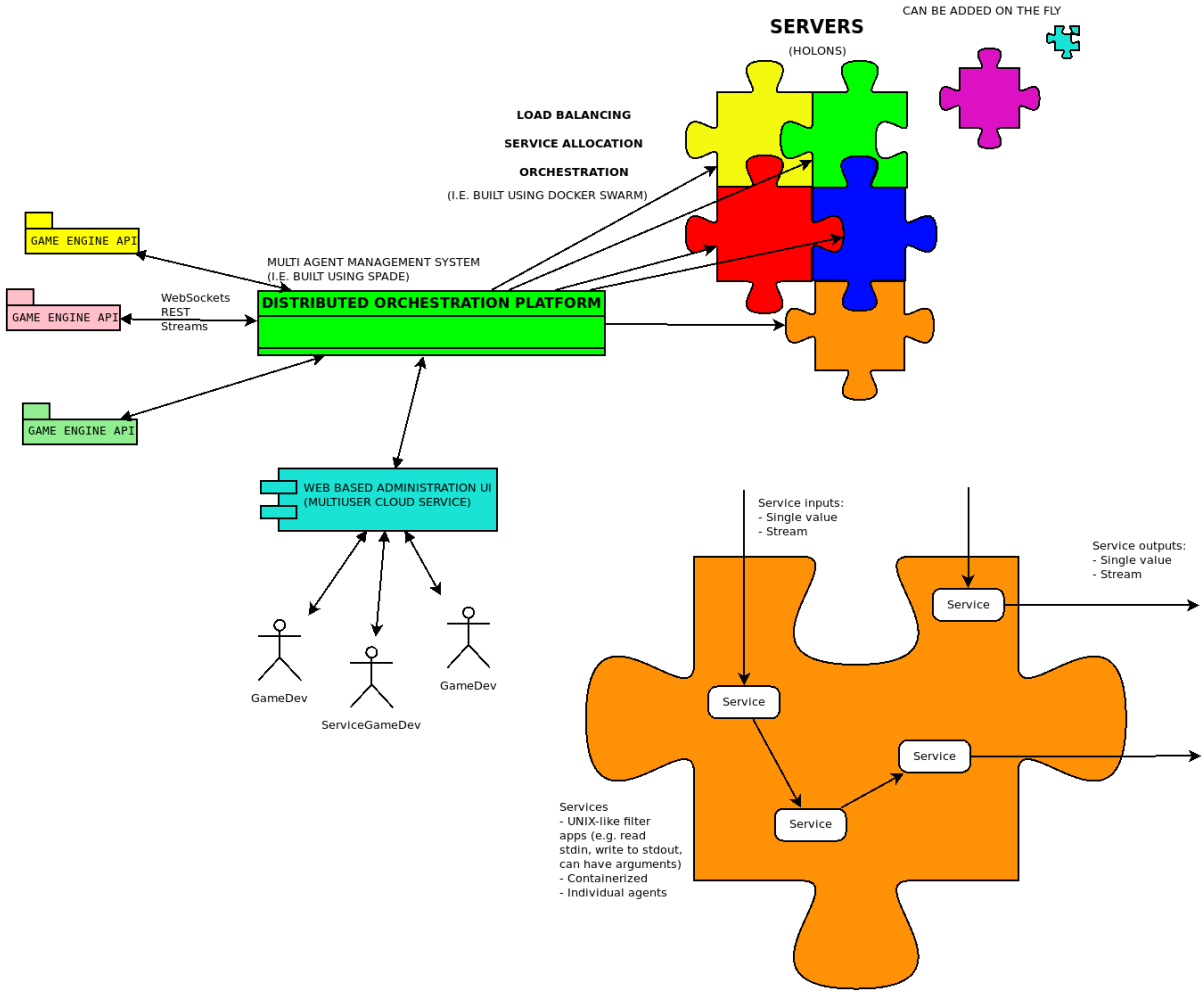

Figure 3: High-level Conceptual Platform Model

tions. For example, a cognitive agent that implements an expert system about the possible symptoms of a disease could answer questions and provide guidelines for a needed examination.

Protection and promotion of breastfeeding. Similarly to the previous use-case, a lot of countries has implemented national programs for the protection and promotion of breastfeeding (Croatian Ministry of Health, 2018 for example). Again, by using cognitive agents and educational games, such programs could

gain traction and reach a higher number of participants.

Emergency call reception. There are emergency call reception protocols defined for operators (NAKOS, 2018 in Norway for example) which define detailed procedures, questions and control points. An operator could be assisted by a cognitive agents which listens to the conversation and provides suggestions based on reception protocols, thus reducing human error. This cognitive agent could be gamified using various elements like instant feedback loops to foster learning and reduce reaction times.

Protocol on treatment and protection against heat is a set of rules and guidelines on how to prepare, behave, and act in case of an impending emergency due to a heat wave, applicable to the national and local levels (Ministry of Health, 2017). An integral part of the protocol are risk mitigating guidelines as well. A proactive agent could be used to notify and alert their users of a possible or incoming heat wave, provide them with suggestions on how to act and reduce the risk of being exposed to the heat wave. The rules might be gamified and e.g. badges rewarded for successfully following them, while users might be notified if there are experts or experienced players in their neighbourhoods.

Guidelines for treating patients with COVID-19 are to be used by infectiologists who are working on treating patients diagnosed with COVID-19. Such guidelines (Balenović Krpan et al., 2020) are being defined worldwide, and are customised and adapted to the particular situation in a particular geo-political area. Although the number of end-users (the infectiologists) is limited, the guidelines could be modelled as a gamified process, possibly with suggestions on how to help a patient based on their state, and the staff might keep a score based on the number of patients they treated.

Control of antibiotic resistance is a set of guidelines (Interdisciplinarna sekcija za kontrolu rezistencije na antibiotike, 2021) and recommendations on how to behave while consuming antibiotics, when to consume them, and when to prescribe them, how the consumption of antibiotics affects the resistance of bacteria, etc. The main goal of these guidelines is to preserve the effectiveness of antibiotics. Gamified guidelines combined with a virtual avatar of patients with specific personal stats that change in accordance with the behaviour of patients, where positive behaviour is boosted, and negative behaviour is discouraged, along with quiz-enriched educational games accompanied by a simplified simulation based on the life of bacteria and their reaction to antibiotics, might prompt the patients to re-think their bad habits or encourage their good habits in the context of antibiotic consumption.

Using automated external defibrillators (AEDs) is no easy task. AEDs installed in public urban places such as stations, stadiums, airports and similar, is a Croatian national program (Ministry of Health, 2021) that aims to educate and enable citizens to use public AEDs in case of emergencies and possibly save a fellow citizen's life. Before using an AED, a player might be guided through a set of steps that must be followed in order to assess the state of the unfortunate person, with points awarded by an on-site expert if the steps were followed correctly. Educational games could educate citizens on how and when to use an AED, or how to recognise a situation where an AED should be used.

Colonoscopy diagnostic procedure is a set of rules that aim at preparing the patient for an oncoming scheduled diagnostic procedure, e.g. colonoscopy (Klinička bolnica "Sveti Duh", 2019). Rules of such a protocol can be translated into achievements that should be unlocked on a path towards the ultimate award – taking part in the diagnostic procedure.

6 Conclusion

In this paper, we have introduced an initial attempt at using cognitive gamified agents in telemedicine. We have introduced our microservice orchestration platform which might act as a backbone for the implementation of such applications. We have also described the B.A.R.I.C.A. cognitive agent which has been implemented for university student support and is partially based on the mentioned platform. We have argued that a similar approach can be used in telemedicine.

Afterwards, we have introduced a high-level conceptual model of an orchestrated AI gamification platform for telemedicine systems. The platform allows for the implementation of numerous microservice instances based on existing microservice templates which then can be orchestrated to create meaningfull applications and services. In the end, we have demonstrated a number of use-cases in which such a platform could be used in order to provide better telemedicine services to patients, physicians and technitians.

Our future research will be aimed on the actual implementation of some of the provided use-cases using the orchestration platform.

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