Policy-Based Awareness: Implications in Rehabilitation Video Games

Amir Talaei-Khoei, Pradeep Ray, Nandan Parameshwaran
Asia-Pacific ubiquitous Healthcare research Centre (APuHC), The University of New South Wales, Australia
amirtk@student.unsw.edu.au, p-ray@unsw.edu.au, paramesh@cse.unsw.edu.au

Abstract

Interactive video games are being used increasingly to transform the dull and repetitive nature of rehabilitation exercises into an enjoyable play by moving limbs or whole body. One major benefit of using video games in rehabilitation is the possibility of home-based treatments. Video games open up new options for occupation therapists to remotely supervise the compliance of patients with their rehabilitation therapy while monitoring changes in patients’ functions over a period. For this to happen efficiently, in this paper we propose that some routine activities of occupational therapists be partially incorporated into software agents. These agents should recognize the relevance of patient’s problems to their exercise tasks based on their awareness about patients’ conditions. We present a 3-step process, called Required Awareness of Agents based on Policies (RAAP), to create awareness about policies in agents where policies are obtained from the domain of rehabilitation treatment, and demonstrate that the actions of such agents are always policy compliant.

1. Introduction

Falls and fall-related injuries are a common and often devastating problems associated with ageing, causing a tremendous amount of morbidity and mortality. Most of these falls are associated with muscle-weakness of elderly while stepping. Researchers in rehabilitation have been investigating different rehabilitation exercises in step movements to prevent falls. Physiological Profile Approach (PPA) [1] deals with impairments, irrespective of physiological causes, due to falls in aged people. The key idea in PPA is that the maintenance of balance depends on the interaction of multiple sensory, motor, and integrative systems. One of the major concerns in PPA is that training treatments involving muscle force and reaction time. Muscle force practices force production of three lower-extremity muscle groups, i.e. knee flexors, extensors, and ankle dorsiflexors, and these muscles are important when performing daily tasks such as rising from a chair or walking. Reaction time relates to the required minimum response time to move muscles.

A comprehensive review on some of existing problems in rehabilitation which can be addressed by rehabilitation video games is provided in [2]. Rehabilitation by its nature is repetitive and repetition makes the treatments dull and reduces the patients’ motivation. Traditional rehabilitation is done one-by-one, that is, one activity at any time. Thus, the cost of treatments tends to be high-making rehabilitation treatments difficult in remote areas. Rehabilitation video games have been recently considered as a promising approach in rehabilitation treatments.

In parallel with advances in the functional recovery, the engineering professions have witnessed recent developments in mobile monitoring and video gaming technologies. In recent years, interactive video games where an individual interacts with the game by moving her limbs or whole body have found applications in the field of home-based rehabilitation medicine. The engaging nature of games increases adherence to rehabilitation training exercises. The dull and repetitive nature of rehabilitation exercises is transformed into entertaining and interactive games that motivate the elderly [3] and increase adherence to rehabilitation.

Home-based rehabilitation however presents supervision problems. Smith et al [4],[5] propose an SMS-based monitoring system for rehabilitation practices using rehabilitation video games. In rehabilitation practice, an Occupational Therapist (OT), focusing on the abilities of a patient observed from her previous activities, identifies the relevant purposeful tests. This requires cooperation between the OT and the patient. However home-based rehabilitation with video games by their very nature engenders situations in which cooperation may require unknown information to decide which treatment should be granted to a patient. The monitoring system designed for this kind of games automates the process of sending the rehabilitation game results to the OT. In practice, the OT is rarely available to answer an SMS message, and sporadic contacts between the OT and the patient result in inadequate cooperation. Enhancing cooperation requires the OT to understand the relevance, called awareness, of patients’ conditions in choosing an appropriate game. This paper discusses a strategy where software agents can provide the necessary awareness [6].
As shown in [6], currently there is no definitive method to recognize which information is required to achieve the required awareness level. While awareness and policies are well researched topics, we propose in this paper that awareness about policies is necessary for the OT in his decision making process while selecting what games to grant to the patient. We use the Logic of General Awareness [7] to specify awareness that is relevant in a given context of the agents’ knowledge. We present a framework called Required Awareness of Agents based on Policies (RAAP), to create awareness from a given set of policies. RAAP provides (1) an approach to model policy-based agent systems, and (2) a stepwise process to create awareness based on a given set of policies. Applying RAAP, a software agent installed in the OT’s computer at home can rely on the available policy guidelines to offer the appropriate games to the patient through SMS messages.

The rest of this paper is organized as follows. In Section 2 we present a rehabilitation treatment scenario in a motivation domain. Section 3 presents the background for this research. Section 4 discusses our framework in which the main contribution of this paper is discussed. In Section 5 we present the different steps in RAAP. Section 6 evaluates RAAP by simulation. Section 7 discusses implications and limitations of the method and concludes the paper.

2. Motivation: Sporadic Contacts between OTs and Patients in Rehabilitation Video Games

The rehabilitation process often takes place in four steps (1) Referral: The GP Doctor refers the patient to the Occupation Therapist (OT) and informs the patient’s problem to the OT. (2) Planning: The OT gives a rehabilitation plan to the patient. (3) Progress Report: The patient reports her/his progress to the OT. (4) Discharging: If the OT is certain that the patient will be able to do her daily tasks, the OT discharges the patient. (Otherwise the rehabilitation process goes back to Step 2.)

The above rehabilitation process will work as described above provided that the patient and the OT are located physically at the same place. However, in home-based rehabilitation games when the patient typically is at home, it is unlikely that the communication between the patient and the OT will take place regularly and promptly.

In an earlier work (Smith et al [4],[5]), we proposed the application of mobile technologies for monitoring the patient when she plays the rehabilitation game at home. This is an agent-based system meant for efficient and effective cooperation between the patient and the OT by communicating the patient’s progress to the OT promptly. It also provides the OT’s feedback to the patient. Figure 1 presents the mobile monitoring system for home-based rehabilitation using video games. It uses two types of software agents: (1) Resident Agents, which are implemented on the game running on the patient’s computer at her home and on the OT’s computer. (2) Mobile Agents, which are implemented on the patient’s mobile phone (See Figure 1).

![Figure 1 Mobile Monitoring in Rehabilitation Video Games][4],[5]

The interaction sequence is as follows: (1) The doctor refers the patient to the OT informing the patient’s problem. (2) The OT recommends a game taking the patient’s condition into account. (3) The OT agent sends an SMS containing the game details to the patient agent. (4) The patient agent displays the game details to the patient. (5) The patient selects the game that the OT wants her to play and plays the game. (6) The Game agent sends the score to the Patient agent (via bluetooth). (The score is calculated based on the z-Score system as explained in PPA [1].) (7) The patient agent sends an SMS containing the z-score to the OT agent. (8) The OT queries the OT agent for the patient’s z-score. (9) The OT agent displays the z-score to the OT. This score shows the fall risk of the patient. (10) If the z-score is satisfactory and the OT can make sure that the patient is not at fall risk, OT then discharges the patient and sends a STOP command to OT’s agent; otherwise, the OT repeats Step2. (11) The OT agent sends the STOP SMS to the Patient agent. (12) The patient agent displays the STOP SMS to the patient and the patient terminates her game.

In practice, since the OT is not available at all times to participate in the dialog above automating the process minimizing the dependence on the OT will improve the overall rehabilitation process.

Suppose that in step 2 above, the OT recommends to the patient that the patient play a game that is related to reaction time rehabilitation exercise and in step 7, the score shows that the patient is at the fall risk. In such a situation, there often exist two different possibilities [1]: (1) The problem of reaction time (that is, how satisfactory are the reaction time values from a given game) has not been solved satisfactorily, and patient still needs more practice, and hence must continue to play the game. (2) The problem of lower-extremity muscles, which requires granting a new game for muscle force treatments.

If the problem is because of lower-extremity muscles and the doctor recommends continuing the reaction time treatment, then the patient will be injured.
by too much stress on her lower-extremity muscles[1]. Therefore, although the OT agent does not know whether the patient has a problem in her lower-extremity muscles, the OT agent must recognize the relevance of this information. Once the OT agent recognizes the relevance of the information (that the patient in her lower-extremity muscles has pain), it grants force muscle game to see if there is actually a problem in these muscles. If the result is satisfactory, it then asks the patient to continue the game for reaction time treatments. (This scenario has been borrowed from [1].)

2.1 Challenges: Need for Awareness

We enhance the cooperation between the OT and the patient by implementing a policy aware intelligent agent (the OT agent) assisting the OT to improve his awareness about the patient’s rehabilitation problem.

Guidelines are available in PPA [1] which can be used to provide policy awareness in software agents. A policy rule states that if the patient fails in reaction time treatments, while she has problem with lower-extremity muscles, continuing response time treatments is forbidden. Thus, when the OT observes the failure of patient reaction time, he must realize whether the information that the patient has a problem with lower-extremity muscles or not is relevant to the situation. The OT should grant a game appropriate for force muscle treatment and find out if the patient has a problem with her lower-extremity muscles. If the patient has a problem with these groups of muscles then the OT is forbidden to grant reaction time treatment. In order for this to happen, we need a method to find the information that is relevant (i.e., required awareness [6]) for each step in the treatment.

In this paper, we propose Required Awareness of Agents based on Policies (RAAP), as an effective way to compute the required awareness based on a given set of policies from the domain of home-based rehabilitation video games monitoring.

2.2 Research Objective: Awareness based on Policies in Rehabilitation Treatments

In our scenario explained in Section 2, we note that (1) the OT should understand the relevance (i.e., should have awareness) of the policy guideline in PPA; (2) the OT should understand the relevance of the patient’s problem with her lower-extremity muscles; and finally, (3) the OT should grant rehabilitation game for force muscle treatment and find out whether the patient has any problem with her lower-extremity muscles.

Our RAAP system executes a 3-step process based on a given set of policies to create awareness. This method creates (1) policy awareness; that is, which policy is related to a given situation; (2) policy-based information awareness; that is, in order to comply with the policy, which information the agent should be aware of; and (3) being aware of the information; that is, how an agent can let this information affect its behavior.

2.2.1 Research Context

In our earlier work [4], we have developed a series of modified video games that are appropriate for use by older adults to train their stepping abilities. In particular we have established the range of different steps in the games in which the adults can successfully interact with the game. We can quantify performance by measuring the results come out from the game such as timing or success in a particular step in the game. These parameters can be used to track performance changes over time as the patient plays the video game in their own home. We correlate these parameters with the PPA. Changes in performance in the video game can therefore act as a home-based proxy for rehabilitation treatments. The mobile monitoring system introduced in [4],[5] will be used to send these parameters to OT. In order to do so, we are planning to install our mobile monitoring system on the video games at patients’ homes. Therefore, this study measures the PPA metrics by game performance through the game equipments and thus there is no muscle movement are being detected.

3. Background and Related Work

In order to enhance cooperation, CSCW facilitates the participants with intelligent IT tools to recognize the relevant information [6]. In such situations, the management system must support a knowledge based environment that facilitates cooperation considering relevant information leading to the successful resolution of the situation [6]. Currently, there are different integrated standards in distributed and autonomous networks such as Internet Simple Network Management Protocol (SNMP), Open System Interconnection (OSI), Reference Model of Open Distributed Processing (RM-ODP), Telecommunications Management Network (TMN), and Internet Engineering Task Force (IETF) that assume cooperation is already adequate for their purposes. Readers wishing more details are recommended to refer [8].
Research in CSCW has long been interested in awareness among problem solvers. Gutwin et al. [9] state awareness is recognizing the up-to-minute relevance of information for an individual to cooperate. Proposing a four-step process for cooperation enhancement, Ray et al. [6] annotate awareness as understanding of relevant information that is required to cooperate. Ray et al. [6] also state that currently there is no definitive method to determine required awareness.

3.1 Logic of General Awareness in Agents

The research in agent-oriented systems has long been interested in the natural semantics for mental attitudes, i.e. knowledge as informal states of the agent[5]. The classical approach in possible-worlds model provides an intuitive semantics for mental attitudes but it also commits us to logical omniscience and perfect reasoning. The assumptions [10] here are: (1) The agent is omniscient, e.g. it knows all the valid formulas. (2) The agent is a perfect reasoner, i.e. it knows all the consequences of its knowledge. This is clearly an idealization since people mostly only know (a subset of) the relevant truth and the relevant consequences.

3.1.1 The Problem of Logical Omniscience and Perfect Reasoning in Rehabilitation Video Games

Going back to our scenario discussed earlier, Figure 2 shows the situation when the OT receives the failure of patient. In such a situation the following two problems appear:

- **Logical Omniscience**: Although the patient has a problem with her lower-extremity muscles, the OT does not know, because the OT does not take it as relevant information for the situation. Therefore, the OT recommends continuing the reaction-time game while this is forbidden (due to the problem in the patient’s lower-extremity muscles).

- **Perfect Reasoning**: In fact, the OT must recommend muscle force game to the patient and find out if there is any problem with the patient’s lower-extremity muscles. Then, the OT can choose a proper treatment.

Not surprisingly, many approaches have been introduced to solve the problem of logical omniscience and perfect reasoning, which will be briefly overviewed below.

3.2 Awareness in Agents

There are four different categories of approaches in the literature to address the problem of logical omniscience and perfect reasoning [10],[11]: Algorithmic Approach, Syntactic Approach, Impossible-worlds Approach, and Awareness Approach. Halpern and Pucella [11], and Sillari [10] claim that these approaches are equi-expressive, although in practice, for some cases, there may be a natural interpretation for each of these approaches, which makes the pragmatic approach stronger. Clearly, in our problem, there is a pragmatic interpretation for awareness, which motivates us to use awareness approach and in particular Logic of General Awareness [10]. The basic idea of this logic is relevance of knowledge. Under the possible-worlds interpretation, a valid sentence and its consequences are true in every world that the agent considers possible. The known sentence and its known consequences may or may not be relevant. Therefore, Logic of General Awareness defines awareness of a formula as relevance of that formula to the situation (which is also stated by the definition of awareness in the CSCW [6],[9] and can be applied in cooperation enhancement [6]). Defining awareness, Logic of General Awareness differs from explicit and implicit knowledge in the way that an agent explicitly knows a formula when it implicitly knows it and also it is aware of it. Halpern and Pucella [11] also state the importance of the source of awareness and how we can compute awareness. In our RAAP system, we use policies as an alternative way to identify awareness. We now provide the definition of awareness as used in this paper.

**Definition** Awareness is a set of propositions that are believed to be relevant by the agent in a given situation.
4. RAAP Framework: Modeling Policy-based Agent Systems

In this section, we briefly discuss how to define an agent based system that is able to analyze policies and become aware of the results in rehabilitation practice.

4.1 Why Modelling Policy-based Agents for RAAP

In our scenario, software agents, using RAAP, assists the OT and the patient to identify the relevance of information and obtain their awareness. In order to implement software agents, we need to model the system which provides the data structure for the software. This will be presented as RAAP framework in this section. Then, providing a step-wise process based on the RAAP framework, the agents create their own awareness about what they identify as relevant information in a given situation.

In this section, we lay the foundation work in which the awareness identification process is grounded. In RAAP framework, we provide our definitions and semantics between theses definitions. This will help us develop software agents that are able to create their awareness based on RAAP.

4.2 RAAP Views to Model Policy-based Agent Systems

Following the research in multi-agent systems and based on General System Theory (GST), we now present a four-perspective model of multi-agent systems that are able to create awareness from policies. This can be portrayed along two dimensions: (1) in agent-oriented systems there is a rough discrimination between design-time and run-time. (2) In general system theory, a system is a set of interrelated parts. Therefore, we can not understand the whole of the system by understanding the components, because interactions between components affect the whole system. As such, we study the system as “a whole” i.e. holistic view and then we zoom in and study the system in terms of its components, i.e. composite view.

In the following sections, we briefly present the model of the system in our scenario using RAAP (see Figure 5). While our focus is more on the application of this meta-model in mobile monitoring of rehabilitation games, readers wishing details of technical aspects, meta-model and the formalism are recommended referring [12].

4.2.1 Holistic View in Design of Rehabilitation Video Games

The objective of this view is to capture the macro-level features of the system in design-time.

Figure 2 shows that the system has eight different situations, i.e. $s_0$ to $s_7$. We have two important results: “the patient has reaction time problem.” and “the patient has a problem with lower-extremity muscles.” These results are being measured by two metrics. The values for these metrics have been borrowed from PPA [1] based on z-scoring ranging from -2 to 2 where -2 shows the strong failure and a marked fall risk, -1 shows failure and moderate fall risk, 0 shows satisfactory and a mild fall risk, 1 shows success and a low fall risk, and 2 shows strong success and a very low fall risk. While the metrics are valued, we find that each of these two results of the rehabilitation test is either true or false. The system also accepts three different primitive events: Failure in reaction-time game, Failure in muscle force game and Success in muscle force game. Given the results of different games played by the patient at home, the system is required to automate proper treatments to the patients through SMS messages.

4.2.2 Holistic View in Running of Rehabilitation Video Games

The objective of this model is to capture the macro-level features of the system in each situation i.e. from $s_0$ to $s_7$.

Figure 5 shows that while the system is at $s_1$, “the patient has a problem in reaction time.” is true. Following Figure 2, being in $s_1$, there are three different paths for the OT: If the OT recommends the reaction-time game, then the system moves to $s_2$. If the OT recommends muscle force game to find out whether there is a problem with lower-extremity muscles of the patient as another property of the system, then the system changes to an appropriate next state.(Note that this result is true in $s_5$ but false in $s_4$)

4.2.3 Composite View in Design of Rehabilitation Video Games

In this model, we capture micro-level features of the system at design time.

As shown in Figure 2, actions are depicted by arrows, each of which changes the system from one situation to another. These are being presented in Figure 5 in the appendix by the source and destination situation e.g. $s_0$ – $s_1$. We design two agents: OT Agent and Patient Agent. Each of these agents has a plan consisting of a set of different possible paths, and the agents have policy rules. For example, in our scenario, OT has a forbidding policy rule stating: If the OT receives an SMS for showing that the reaction time is too low (z-score is less than 0), the patient is suffering from a problem in her lower-extremity muscles, then recommending reaction-time game is forbidden.
4.2.4 Composite View at Run Time of Rehabilitation Video Games

The objective of this model is to capture the micro-level features of the system in each situation (See Figure 5).

As shown in Figure 2, at s1, while the OT agent has already received the event for failure of the patient in reaction-time game, the OT explicitly knows about the patient’s problem for reaction-time. Figure 5 presents the composite view of our scenario at s1, s4 and s6. At each of these situations the agent has awareness, implicit knowledge and explicit knowledge. Once the agent becomes aware of its implicit knowledge, its implicit knowledge becomes an explicit knowledge. In fact, the explicit knowledge is the implicit knowledge when the agent identifies it as relevant. As shown in Figure 5, the OT agent explicitly knows about the problem in reaction-time.

At s1, in order to recommend muscle force game to the patient, the OT agent should follow the following three steps: (1) It creates its awareness to the forbidding policy rule. (2) Being aware of the policy rule, in order to comply with the rule, it computes its awareness of the patient’s problem in lower-extremity muscles. (3) Being aware of the problem in lower-extremity muscles as a relevant information to the situation, the OT agent selects a path that brings it to the situations in which it can know whether the patient is actually suffering any problem in lower-extremity muscles or not.

Following these three steps, the OT at s1, will be only aware of the problem in lower-extremity muscles and will not have any knowledge to that. Although taking the steps above the agent has identified the relevance of information about lower-extremity muscles, it still doesn’t know the truth of falsity of this result. This will be shown at s4 and s6 in which the agent implicitly knows the falsity and truth of problem in lower- extremity muscles, respectively. Accordingly the OT agent will have acquired the explicit knowledge. The following section formalizes these three steps required for identifying the relevance of information.

5. Awareness Identification in RAAP Framework: Steps towards Policy-based Awareness

RAAP, based on Logic of General Awareness, defines policy-aware agent and proposes a step-wise process to (1) recognize the relevant policy rules, (2) recognize the relevant information that is required to comply with the relevant policy rules, and (3) change the behavior based on the recognized relevant information and policy rules. This step-wise process is intended to provide computational details for awareness defined using Logic of General Awareness where we propose policy rules, using DEN-ng, as a source to create awareness. While in this section we focus on different steps in RAAP and its application in mobile monitoring for home-based rehabilitation using video games, the formalism for each step is available in [12].

5.1 Step 1: Policy Rule Awareness

The objective of this step is to show how agents take a policy rule as relevant to a given situation. We define policy-aware agent as an agent that computes awareness to a policy rule when it believes that there is a possibility that the agent may violate the rule sometime in future. Since permitting and deterring are not in force, they can not inevitably change the behaviors of the agents [13]. As a result, breaking policy rules can happen only in forbidding and requiring policy rules.

5.1.1 Policy Rule Awareness of OT in Rehabilitation Video Games

In state s1 in Figure 2, the OT has already received an event for the failure of the patient in the reaction-time game. The OT agent is suffering from the problem of omniscience in that it does not know whether the patient has a problem in her lower-extremity muscles or not. If there is a problem with these muscles, then recommending reaction-time game is violating the forbidden policy rule. Since there is a possibility of violating the policy rule, the OT agent takes this policy rule as a relevant one and computes the awareness for this policy rule.

5.2 Step 2: Policy-based Information Awareness

The objective of this step is to show how policy awareness in agents makes them aware of relevant information that is required to comply with the policy rule. The main idea here is, if a Policy-aware agent has already received an event referenced in a policy rule, it creates its information awareness for conditions involved in the forbidding and requiring policy rules.

5.2.1 Policy-based Information Awareness of OT in Rehabilitation Video Games

Going back to our scenario in Figure 2, in state s1, the OT agent has received an event for the failure of the patient in the reaction-time game. The agent is already aware of the policy rule that says that if the OT receives an SMS showing a problem of the patient in the reaction time (z-score is less than 0 ), (that is, the patients is suffering from a problem in her lower-extremity muscles) then recommending reaction-time game is forbidden. Therefore, the OT agent first should first find out whether the patient is suffering from a problem in
lower-extremity muscles or not. This makes it a relevant information that the OT agent is required to be aware of.

5.3 Step 3: Behavior based on Awareness - OT’s Behavior based on Awareness in Rehabilitation Game

The objective of this step is to show how awareness can change the behavior of agents. We have so far discussed recognizing the relevance of a policy rule and information while we have not addressed how awareness updates knowledge leading to change of agent’s behaviors.

Proposing the shortest path strategy, our agent being aware of some thing, will eventually come to implicitly know whether it is true or false. As a result, in this strategy agents, being aware of some information, choose an action that brings them to the knowledge of that information.

5.3.1 OT’s Behavior based on Awareness in Rehabilitation Game

The OT agent, being aware of the patient’s problem in lower-extremity muscles, should select an action which brings it to the situation in which the agent knows whether the patient is actually suffering from this problem or not. As such the agent needs to recommend muscle force game to see if there is any problem in these muscles or not (see Figure 2).

6. Evaluation

We evaluate RAAP with scenario-based simulations using NetLogo simulator. We designed ten different scenarios. In some of these scenarios, agents required a policy rule to react correctly and in some of them agents could behave successfully without any policy rule. We also found four actual related policies to these scenarios. Out of these four policies, we designed 18 policy rules. We implemented the policy rules as well as the scenarios in NetLogo. We also implemented a simulation program, which supported ten scenarios and ran eighteen steps. In step one it randomly chose one policy rule; in step two, it randomly chose another policy rule and added it to the existing ones; and so on. In each step, the selection processes for policy rules was based on a random function of NetLogo. In each step with different number of policy rules, the simulator applied RAAP on the ten scenarios and computed the required awareness. The program returned the difference between required and predefined available awareness, for each step. Figure 3 shows that by increasing the number of policy rules over a certain set of scenarios, RAAP recognizes more relevant pieces of information i.e. required awareness.

In the next step of our evaluation, we made the environment more random and changed the set of scenarios in each step and measured the change of behaviors using RAAP. The program repeated each step one hundred times while each time it selected random policy rules and chose four random scenarios out of the ten pre-defined scenarios. The simulator ran each selected scenario with policy rules following RAAP and without policy rules following the standard Logic of General Awareness. The program recorded the number of failures of each of the step with and without using RAAP. The failure was defined as not doing a certain action and not achieving a certain situation given to the simulator for each scenario. Thus, the number of successful responses was calculated by excluding failures from the ones that were achieved. Figure 4 shows improvement based on the number of policy rules in RAAP, which illustrates a general improvement by increasing the number of policy rules.
6.1 Outcomes of Simulations
In the first phase of simulation, we evaluated the basic idea of RAAP stating that use of policies as a source to recognize the relevance of information can improve the ability of agents to obtain the relevant information, which helps to provide more effective assistance to participants in cooperation. The result in Figure 3 shows that increasing the number of policies given to the agents has positive impact on selection of correct behaviors. Therefore, going back to the scenario in rehabilitation video games, we can conclude looking different policies in rehabilitation practice and employing software agents to analyze them i.e. RAAP can be beneficial in monitoring of rehabilitation games.

In the second phase of the Simulation, we compare RAAP with the Logic of General Awareness. The aim for this comparison is to make sure RAAP as an extension of this logic brings value to the rehabilitation video games. Figure 4 shows that by increasing the number of policy rules given to the agents, RAAP provides more effective response comparing the Logic of General Awareness. Analyzing the two fall-points in Figure 4, we found that in design of policies given to the agents to assist OT in rehabilitation treatments, we should consider the treatment procedure. As such, providing policies that involved events or actions that do not match with the treatments will not improve the efficacy of assistance provided by agents.

7. Discussion and Conclusion
In rehabilitation video games, supportive software agents can contribute to an effective choice of treatment. The dynamic nature of rehabilitation treatments in which situations can change dramatically makes recognition of relevance of information difficult, particularly when cooperation between roles is inadequate. In such situations, policies can be used as an alternative to create awareness and recognize the relevance of information.

7.1 Employing Agents as an Alternative for Human Training

In order to deploy RAAP on rehabilitation video games, patients are required to have a game set at their homes, which supports the rehabilitation treatment games. Therefore, in most of cases we need to use the modified version of video games that are appropriate for use by rehabilitation patients to train their physical abilities. In particular we should establish the range of speeds and steps across which patients can successfully interact with the game.

As we explained in the paper the result of the treatments can be measured by the metrics that are designed based on the success or failure in the different steps or games given by OTs.

As shown in Figure 1, the technology proposed for monitoring the results of treatments is based on SMS and Bluetooth communications. These features are supported by most of available mobile phones on the market. The monitoring system does not even need Internet connection in the patient’s home. Therefore, if the elderly person does not use Internet, she/he is still able to benefit from monitoring while playing the rehabilitation video game at home. The software agents are also light weight agents that do not require strong

7.2 Bridging the Supervision Gap between OT and Patient in Home-based Rehabilitation

The idea of bringing rehabilitation treatments to homes requires supervision and reviewing of patients' progress. Without using agent technology, patients report their progress time-by-time, or the OT contacts the patients sporadically which is often not enough for effective treatment. Therefore, policy-based awareness monitoring allows the OT to recognize which information is relevant to the condition of the patient and then recommend a proper action. This increases the OT's awareness of the patient's progress as well as her/his awareness to the patient’s conditions, which accordingly improves the efficacy of rehabilitation treatments.

7.3 Information Technology Infrastructure Required to Apply RAAP in Rehabilitation Video Games

Irrelevant Information In rehabilitation video games, the patient has different conditions and there are different treatments that might not be relevant to the situation.

Sporadic contacts of cooperative roles Software agents provide mediated communication among human roles. In home-based rehabilitation and in particular playing rehabilitation video games at home, there is an obvious problem of sporadic contact between the OT and patient. Therefore, although home-based rehabilitation makes it more convenient for patients, in rehabilitation literature [14], supervised hospitalized rehabilitation is more effective than unsupervised home-based rehabilitation. Agent technology can be beneficial to address the lack of supervision in home-based rehabilitation.
computing power. Therefore, the deliverable solution will not be expensive and patients, in most of cases, will not need to change their mobile phones.

7.4 Bridging the Gap between Policies and Software Agent Development

Research in software agents typically addresses awareness in terms of programming intelligent agents. We argue that programming software agents without considering policies has two weaknesses: First, the reasoned suggestions made by software agents are dependent on their understanding of the situation, limited by their programming; i.e. the problem of omniscience. As such, agents are not able to recognize the relevance of information to a situation. Second, standard approaches to software agents are technology dependent while involved government agencies in rehabilitation processes often use different technologies. Therefore, integrated cooperation can be difficult to achieve.

7.5 Limitations

There are four limitations inherent in our approach we would like to point out.

First, the policy rules may interact with each other and a new added policy rule may conflict with existing rules. There are bodies of work for policy conflict recognition.

Second, refining high-level policies to computational policy rules is a challenging problem by itself, which consists of: (1) Determining the resources that are needed to satisfy the requirements of a policy. (2) Transforming high-level policies into role-level DEN-ng policy rules. (3) Verifying that the lower level policy rules actually meet the requirements specified by the high-level policies. This opens up a new direction for research to enhance policy refinement methods.

Third, this paper presents RAAP as a beneficial method in rehabilitation video games. The idea is to take policies as a source for identifying relevant information. This can be applicable in wide range of different scenarios. Although the proposed research is new and untried in real environments, a proof of concept has been made in this paper as an exemplar while exemplars have been long used as an evaluation methodology in applicability of information technology solutions for different domains [15]. A more detailed evaluation framework has been proposed in our earlier work [5] to validate usability of the system, which evaluates the possibility of deploying RAAP for real rehabilitation in future.

Fourth, although use of intelligent software agents to assist OT in rehabilitation treatments is beneficial; it raises a number of ethical issues that are beyond the scope of this paper to address. Readers wishing more details are recommended to refer [16].

References


Appendix

![RAAP Framework for Rehabilitation Video Games](image-url)

Figure 5 RAAP Framework for Rehabilitation Video Games