Supermarket Game: An Adaptive Intelligent Computer Game for Attention Deficit/Hyperactivity Disorder Diagnosis

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Abstract

The This work reports the research and the application of an adaptive intelligent computer game with a fuzzy decision system developed specifically to help in the diagnosis process of the Attention Deficit/Hyperactivity Disorder (ADHD). ADHD is a neuropathology, its main signal is the severe performance impairment of activities that involves executive functions: planning, volition, problem resolution and aim oriented works. The specification, implementation and other relevant aspects of The Supermarket Game are here discussed.

1. Introduction

The main goals of this work are to report the research done about the usage a fuzzy controller in an adaptive intelligent game called The Supermarket Game applied to the complex problem of neuropatologies diagnosis process. This research work was initiated at 2003 and some preliminary results can be found in [1], [2], [3], [4] and [5].

Intelligent adaptive systems can adapt to the specific requerements of each user. This game system was developed and tested for neuropsychological application using a game engine and a computational intelligence technique: fuzzy logic. Uncertainties and imprecisions of the knowledge are easily expressed with fuzzy logic allowing elaboration of models that are closer to a real situation. The fuzzy decision systems are atable and robust as can see in [6] [7], [8] and [9], since they can operate even when decision rules are supressed, simulating an incomplete knowledge about the problem. Fuzzy logic systems are easy to build, validate and can be prototyped very fast when compared to traditional control techniques.

The fuzzy model and the process of the adaptation used in this itelligent game are straightforward. Based on the perfomance of the player on the two initial phases of the game, the next phases are adapted and automatically created using a fuzzy logic system detailed in section 4. Figure 1 shows the interface of the adaptive game called The Supermarket Game with the list of items that the player must collect.

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Figure1. Interface of The Supermarket game.

This work was made possible by virtue of the efforts of a multidisciplinary group that involves psychologists, a psychiatrist, game designers and computacional intelligence researchers. After the discussion of some relevant theoretical aspects involved in the reseach, this work presents a description of The Supermarket Game and the model of the fuzzy decision system applied to this adaptive intelligent computer game.

2. The problem : Dysexecutives Syndrome and the ADHD

There are different possible ways to analyse the dysexecutives syndromes [10]. This work is based on a neuropsychological perspective, that has main objective of correlate the neural model provided by Biology with the behavioural and cognitive impairment provided by Psychology.

Dysexecutive syndrome usually involves functional or structural problems in frontal lobes or on its conexions. The patient cannot formulate plans for future actions that deviate from his ordinary routines. The capacity for criation of new speech or behaviour is severely restricted. There is a deficit in the ability to represent schemata of actions. In sum, we are dealing with the lack of drive, the incapacity to make decisions, and faulty preparation for independent actions, in other words, a problem in the motor preparation set.

One example of these disorders is Attention Deficit/Hyperactivity Disorder –ADHD. ADHD is a highly hereditary and persistent disorder with structural and functional abnormalities of the fronto-striatal circuits at group level as revealed by neuroimaging studies [11]. The ADHD diagnosis is made based on careful and systematic review of the clinical characteristics as obtained from reports by parents, teachers, the child itself and of medical observation. Effective treatments include the prescription of medication (particularly psychostimulants) and behaviour therapy. Medication is more effective than behaviour therapy to affect the core symptoms of ADHD and is therefore the first choice of treatment, except in children under 5 years of age. Treatment should be monitored at regular times. In case of insufficient response to monotherapy, combinated treatments should be offered. Early recognition and appropriated assessment and treatment of ADHD requires collaboration

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between general practitioner, primary care psychologist, educational system, school doctors and nurses, child guidance systems, paediatricians and child mental health systems and psychiatry or adult psychiatry.

In 1998 [12] an experiment was conducted to investigate the influence of a computerized cognitive-training system ("Captain's Log") on the behaviour and performance capabilities of four severely disturbed children with Attention Deficit Hyperactivity Disorder (ADHD), ages seven to eleven. A behavioural point and monitoring of progress on computer tasks were used throughout treatment to evaluate ongoing improvements. Behavioural scales, spectral electroencephalograms, and intelligence and performance tests were assessed pre-and post treatment. There were 64 training sessions administered over a 16-week period. Outcome of the treatment was assessedy by the changes in behavioural points, pre and post measuremens. Results support the expectation that children who were most successful in the training would demonstrate the highest levels of generalization of those skills that were the focus of the treatment. Other recent research [13] indicates that both medical and behavioural therapeutic concepts are effective techniques. These results motivated us to investigate the use of intelligent techniques, like adaptive games and fuzzy logic, in the evaluation and cognitive rehabilitation, as an aditional resource in the diagnosis and the therapy of the ADHD.

3. Game Description

The Supermarket Game was designed and implemented after an investigation on the diagnosis process of executive disfunctionalities, more specifically, the ADHD, performed clinically by neuropsichologists. The diagnostic is performed through an exhaustive anamnesis process, involving interviews, questionnaires, and neuropsichological tests [11]. Many of those tests involve specific tasks in labyrinth navigation.

The Supermarket Game is basically a labyrinth that must be traversed while the player acquires items shown in his shopping list. As a constraint, the player may cross most of the paths only once. The game includes specific rules and challenges that will be punctuated positively, by acquiring a correct item, or negatively, in case the player commits a fault by breaking one of the rules.

The rules that must be followed at all phases are: Start by the client entrance and end at the checkout cashier, located at the exit. The emphasized path (see Figure 2) may be crossed as many times as necessary, while all the others may be crossed only once. All the items listed must be purchased. One point is earned for purchasing each listed item. Starting and finishing on the right locations also earns one positive point each. If the player crosses again a traversed previously section, he commits a fault penalized with the loss of one point. In the worst case, a negative final score is allowed.

The player interface contains the supermarket map, the shopping list, that is updated at every purchase, his score and the elapsed game time. Navigation is done through the usage of the arrow keys on the keyboard. Footsteps are left on the map in order to indicate the travelled path. There are two different modes of the game before adaptation. On the first mode the player's planning capability is evaluated. The shopping list is presented in a random order thus a path must be planned so that he may acquire all items in the list by passing each aisle only once, with the exception of the emphasized path, that is freely traversable. The player must determine the best path to follow, while purchasing all listed items, using the shortish time.

On the second mode, the execution capability is tested. Since the item list is already shown in the order where the items should be picked, thus indicating the correct path to them. The

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initial phases will be used to collect data (fuzzy input variables: time and score) for posterior use in the adaptation process of the latter phases. Figure 2 shows the scheme of the simulated world used in the game.

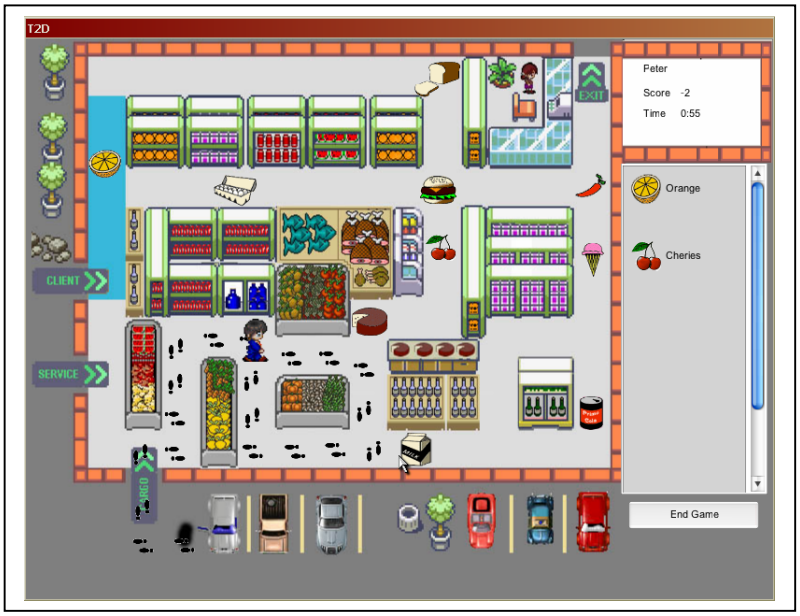

Figure 2. Scheme of the virtual world used at the adaptive game

The Supermarket game was developed using the two-dimensional game engine "Torque Game Builder" [14], that enabled a fast, prototyping development methodology since several aspects like user interface and gameplay were easily supported by the engine.

The Fuzzy Logic Inference System used by the adaptation procedure was implemented separately, in C++ programming language, and posteriorly plugged into the engine through it's own extension routines [15] and [16].

4. The Fuzzy Logic Model and the Adaptation Process

The fuzzy logic system coupled to The Supermarket Game, evaluates the points obtained by the user and also the elapsed time running the game. This is done in order to check if the tasks executed during the two initial phases were done to an acceptable degree or it is necessary to build new phases adapted to the previous results.

The three phase variables: initial time (ti_p), correct-task (ct_p) and incorrect-task (it_p) indicate the next phase of game. There is a list of tasks and rules that are shown to the player. Every time the game is played, this data is captured and then fed to the fuzzy controller that decides the next phase of the game. **P** is the phase number and pt_p, the final score as shown in equation (1).

$$pt_p = ct_p - it_p \qquad (1)$$

The adaptation process is defined by a set of rules in the fuzzy Inference System. Both parameters: time (tip) and score (ptp) represent the inputs of the decision model, yielding a new difficulty level as the output for phase **p+1**. Thus rendering it possible to adapt a new shopping list and visited loci based on the player's profile. The process ends when the user fulfills the desired goals in a reasonable time with a minimum

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amount of errors [17] and [18]. Figure 3 shows the adaptation scheme used in the Supermarket game.

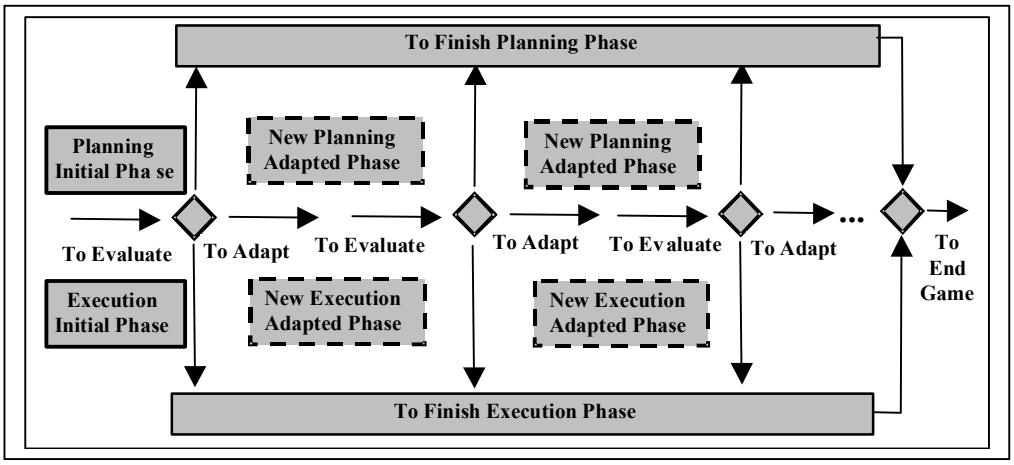

Figure 3. Adaptation scheme.

Figure 4 shows the membership functions that are used in the adaptation process between the phases of the game. Each input is divided into three membership functions representing normal, good and bad time and also few, medium and many points.

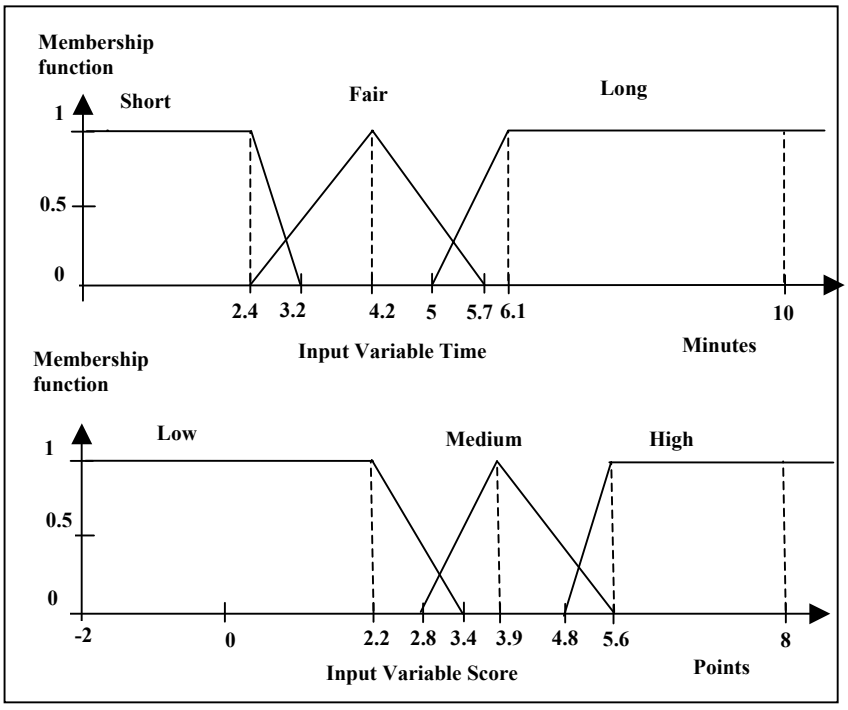

Figure 4**.** Fuzzy sets describing the input variables.

Table 1 shows the fuzzy rules that are used to decide the quantity of items that it will be necessary to collect during the next phase. DM means a great reduction, DR means

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reasonable reduction of items and DP means little reduction of items. FF means that the phase will be finished and the user assessment can be considered finished.

Table 1. Rule base matrix for the adaptive game.

Time / Score	Short	Fair	Long
Low	DP	DM	DM
Medium	DP	DR	DM
High	FF	DR	DR

Figure 5 shows the membership functions that are used to describe the output variable. The output is divided into four membership functions representing the number of items that will be removed from the list of items to collected. The defuzzification is done through the centroid method [19].

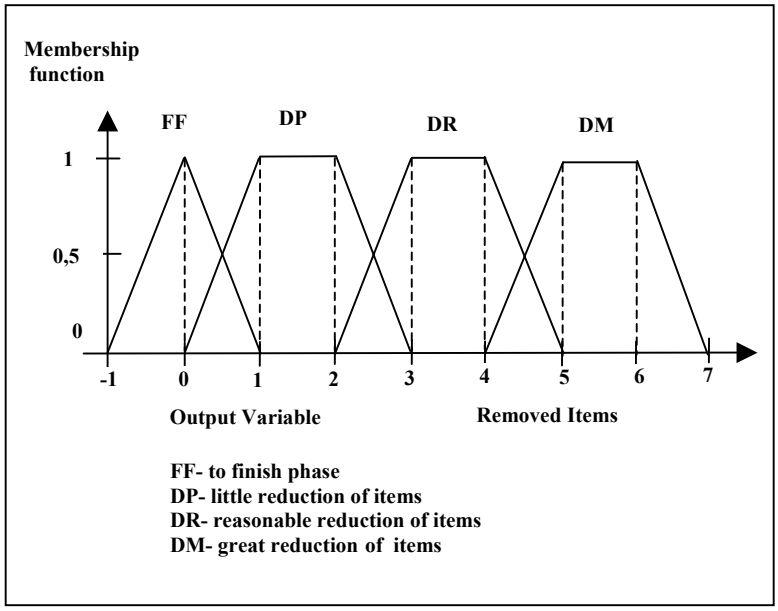

Figure 5. Fuzzy sets describing the output variable.

5. Conclusions

This work we presented an adaptive computer game, called The Supermarket Game, developed with a fuzzy decision system as an aditional resource for the diagnosis and therapy of the Attention Deficit/Hyperactivity Disorder (ADHD). The intelligent adaptive game supplies the detailed information required by neuropsychologists to complement the evaluation of possible disabilities of the player's executive functions.

A fuzzy system was used to create adaptive phases of the neuropsychological game through a virtual world like as supermarket. The adaptation in between phases contributed to make the diagnosis process less exhaustive for the patients and neuropsychologists. The fuzzy decision system implemented was straightforward and needs few input variables to acquire all necessary information in order to the adaptive model simulates more accurately the desired behaviour of the game. The simplicity and

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usability of the game suggests that many others neuropsychological test games can be developed using this technique.

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