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Instability and Irrationality: Destructive and Constructive Services within Intelligent Environments

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Abstract. Does chance have a role in intelligent environments? In this work-in-progress paper we argue that chance and non-deterministic behaviour can play a fundamental and important role in intelligent environments. We discuss how this behaviour can be both destructive and constructive. Underpinning our ideas is the view that intelligent environments may be seen as a complex system of interacting services. In the first part of this paper we show that such complex systems can produce unexpected interactions that cause unplanned and often undesirable instabilities. However, not all instabilities are undesirable and in the second half of this paper, we present a conceptual notion that views system instability as a form of irrationality and propose a quantum control model for service agents within smart environments. We conjecture that irrational control models enable the service agents to perform better than if they were using traditional, rational, control models. Our purpose in presenting this work is to both provoke discussion and describe our early research on what we hope will be an interesting direction for intelligent building research.

Keywords. Intelligent environments, system instabilities, quantum decisions

Introduction

As has been widely reported a popular vision for intelligent environments is that they will be composed of a large network of smart devices, working together to provide services to the environment and the human occupants. Part of the intelligent or smart operation results from these devices coordinating actions. Thus, naturally, such a network of smart devices will lead to interdependencies in the behaviour of the devices. Typically a device will be programmed to behave in a particular way by following a set of rules, which are triggered according to environmental contexts, or interactions with users or other devices. However, as the number of interdependencies increases their interactions become more complex and their nature becomes unpredictable, taking on a 'life of their own'. Such unpredictable behaviour leads to unexpected instability within the device ecology which is undesirable. Whilst such instabilities are generally

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undesirable in inter-agent behaviour, we speculate that within controllers (the brains of the system) they can endow AI systems with interesting and useful properties. In this first half of this paper we show how destructive inter-agent instabilities can be detected and prevented. In the second half, we look at a constructive form of instability that might usefully be modelled within the agent controller. The particular form of instability we examine for this purpose would be recognised in psychoanalytic terms as irrationality [2]. In this approach we add a probabilistic disturbance to the system based on quantum mechanics.

1. Instability between Intelligent Agents

Instability has been found in different domains, such as telephony [5], spreadsheets [6], software agents (email)[7], discrete dynamics [4], and ambient intelligence [8,9]. In nature this behaviour has also been observed in colonies of termites [10]. Each agent has a set of rules, and due to unplanned interaction between them, this periodic behaviour can arise.

The phenomenon of instability is characterized by periodic oscillations that can be represented by

$$S(t) = S(t + np \pm d) \qquad (1.1)$$

where $S(t)$ is the state of the system at time t, p is the period and $n \in Z^+$. The variable δ measures deviations from the strictly periodic case, due to network delays, latency, the different processing speeds of the devices, and changes over time in general. An example instability is the case of a set of home lights turning on and off recurrently.

From Complex Systems theory [4], it has been found that it is not possible to predict theoretically if a given set of rules could suffer from cyclic instability. However, it is possible to prevent this behaviour.

A first step towards the prevention of this phenomenon is to find a suitable and accurate representation of the problem. This is provided by a formalism called Interaction Networks, that captures the dependencies of the rules between the agents.

1.1. Interaction Networks

An intelligent device or agent A is an autonomous device with a boolean state $s \in \{0,1\}$, where 0 and 1 mean *on* and *off* respectively. In the case of n autonomous agents $A_1, A_2, \ldots, A_n$ the state of the system is $S = (s_1, s_2, \ldots, s_n)$. Each device A_i has two consistent rules:

$$\text{If } \varphi_i \text{ then } s_i = 1 \qquad (1.2)$$

$$\text{If } \psi_i \text{ then } s_i = 0 \qquad (1.3)$$

where

$$\varphi_i, \psi_i : S_n \to \{0,1\} \qquad (1.4)$$

The case of contradictory rules is avoided due to the fact that $\varphi_i = \psi_i^{-1}$. The functions φ and ψ can be defined either automatically [14,15] or manually [16,17]. In both cases several users, under different circumstances and motivations could have been involved in the definition of the rules.

An Interaction Network (IN) is a digraph (*V*,*E*) in which the vertex $v \in V$ is a pervasive intelligent device or agent A and $(v_i, v_j) \in E$ if the Boolean functions φ_j or ψ_j of the pervasive intelligent device A_j depends on the state s_i of the device A_i [3]. In other words, an Interaction Network is a graphical representation that captures the dependencies of the rules between the agents involved.

1.2. Instability Prevention System INPRES

As we mentioned previously, it is not possible to predict if a given system will suffer from cyclic instability. However, by finding cycles in the Interaction Network associated it is possible to identify potential instabilities. The strategy defined by INPRES is based on locking a member of each cycle found in the Interaction Network; with this, the feedback loop between the rules of the agents is broken [3]. As each member of a loop in the Interaction Network is a candidate to be locked, the connectivity of each agent is analysed; the agent with less connectivity in the IN will be locked. The connectivity of agent A is called functionality, and is represented by $f(A)$. A high-level architecture of INPRES can be seen in figure 1.

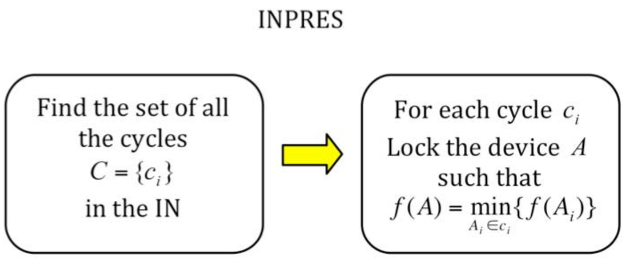
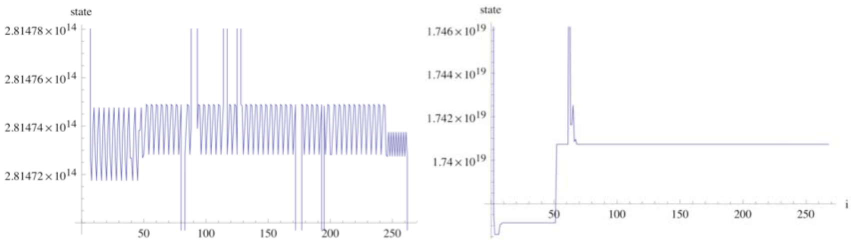


Figure 1. Architecture of the Instability Prevention System INPRES.

The strategy defined by INPRES was successfully tested using an Interaction Benchmark (IB), which is a grid of 4x4x4 interacting agents (see figures 2 and 3). The Interaction Benchmark enables a homogeneous and ordered distribution and visualization of the cycles.

(a) (b)

Figure 2. Interaction Benchmark with coupling in one point. Each layer has 5 cycles.



(a)

(b)

Figure 3. Evolution of the system with 20 coupled cycles. In (a) the system is unlocked, showing three modes of oscillation. In (b) INPRES removed the oscillations successfully.

2. Instability within Intelligent Agents

The previous section considers the external interactions that can occur between agents and how we can prevent these interactions leading to undesirable inter-agent instabilities. On the whole, we expect service agents to perform and behave in a logical, rational, deterministic manner according to their their control programs. In this section we consider instabilities from within the agent, from the perspective of its controller and ask the question, what if we purposefully introduced instabilities into a service agents control program? Our earlier work explored such an idea [19]. We did this through the concept of multiple personas. A persona being the result of a functional splitting of a personality [2,18]. Multiple personas in philosophy and psychoanalysis are seen as one explanation for irrationality and are based upon the generally pathological process of splitting. In this instance splitting for functionally sound reasons is suggested as a possible aide to robust and efficient working within a variety of different contexts. We are not recommending the multiple persona model because they can produce irrationality, but because this constructive form of instability represents a useful way of modularising skills and powers and providing a repertoire of responses to new situations that make the persona model more flexible and capable i.e. in people the positive aspects of multiple personas the father, brother, son, uncle, the manager, the worker, the lover, the craftsman and so on, can be mobilised when the circumstances require it and sometimes there is a cross application of skills, for example, you become managerial with your mother or paternal with your colleague. Our conjecture is that modelling these irrationalities within an agent will enable the agent to act against the logical nature of the world and its own internal world model enabling it to handle certain environmental contexts in a more flexible way, leading to improved performance, in a similar way to people. The next section presents our control model which we extend to explain how this model can implement the concept of multiple personas. In the following sections we use a service robot as an exemplar agent, although the control model could be applied to any intelligent agent.

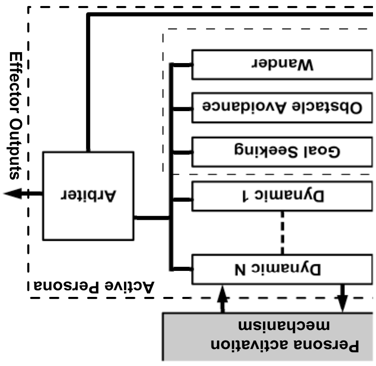


Figure 4. Persona enhanced behaviour based control architecture.

2.1. Control Model

One of the most successful approaches to controlling mobile robots has been behaviour based architectures, proposed by Rodney Brookes in 1985 [20]. In this, the higher levels operation of the robots is deconstructed into a set of lower level behaviours, a process akin to task decomposition in social models. Typically, the behaviours for a simple robot might be the ability to wander, to avoid obstacles, to follow walls and to steer to physical goals. Each behaviour is implemented as a separate software process or task, each vying with the other to get control of the steering of the robot. Some form of arbitration is required to determine which behaviour has dominant control of the robot at a any particular time, which, in turn, depends on the context of the robot. Generally these behaviours are solely reactive in nature, with no persistence or deliberation. However, at Essex we have developed models that can dynamically manage the creation, adaptation and death of behaviours, introducing a persistent experience based *evolving* control model of the world. This architecture is illustrated in figure 4, modified in include the persona model. In general terms, the Essex architecture utilises fuzzy logic and genetic system principles, the fundamentals of which are widely known and thus are not reproduced here [14, 21] .

2.2. Multiple Personas

Our control model defines a persona as a collection of dynamically generated behaviours as shown in figure 5. Each behaviour in the active persona competes for dominance of the robot, defining the robot's persona. Only one persona is active at any one time, any behaviours which are generated or destroyed only effect the current persona. At any time another collection of behaviours, or persona, may assert itself over the controller and take over. The question arises what triggers a persona switch? According to the psychoanalytic models regarding multiple personality disorders there is no identifiable central arbiter controlling these switches [2]. For the purposes of our model we supply a persona transfer function with contextual information and the current activation states of all personas, it is this transfer function that decides if the current persona should remain active, or make a switch to another persona, selecting the persona to activate if a switch is to be made. The contextual model should account for social contexts i.e. modelling which persona is the most socially acceptable persona to be active, and environmental contexts i.e. modelling which persona is the most environmentally acceptable persona to be active. At the simplest level the context model might encode a function of the behaviour activation levels within each of the personas. In this sense irrationality might be expressed by activating a persona that does not have the highest activation level for the given context.

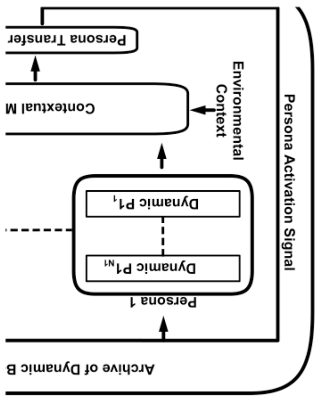


Figure 5. Persistent dynamic behaviours clustered into personas. An appropriate transfer function decides which of the personas is currently active based on context.

2.3. A Quantum Persona Transfer Function

We have chosen to experiment with quantum logic decision models to implement the persona transfer function. Quantum logic differers from traditional statistical models, such as Markov models, in two important ways, firstly, quantum logic describes complex valued probability values over time and secondly, quantum entanglement allows for probability interference effects, these are not possible with traditional probabilistic decision models [1]. Moreover, quantum entanglement effectively obscures the causation of the quantum measurements that decisions are based upon. Accordingly this will effectively hide the effects of any arbitration for persona selection, effectively making the persona selection appear to be without a central arbiter, supporting the psychoanalytic theories [2].

The contextual information is binary encoded to allow the use of binary valued quantum bits, or Qbits. This simplifies that quantum logic and simulations [11]. The output of the quantum logic block is measured to resolve the quantum entangled states, these measurements form the persona activation signals, as modelled in figure 6. The next phase of our research will implement the quantum transfer function and experiment with various simulated quantum logic block configurations.

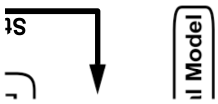


Figure 6. A quantum based transfer function, contextual inputs are derived from the activation levels present within each persona, the binary outputs determine which behaviour is currently active.

3. Bringing it Together

Whilst the cyclic instability methodology is well developed, clearly the quantum controller aspects of this work are largely at a conceptual stage and will be the focus of much development. Our conjecture is that adding irrationality within intelligent environment agents, and particularly service robots will enable them to perform better, by employing some of the same irrational mechanisms that seem to serve people well. However, whilst our ideas are based on established theories from psychology and psycho-analytic studies there is clearly a long way to go before these ideas can be properly tested. In this we intend to establish a baseline performance metric by measuring the performance of a service robot using a standard controller against the performance of a service robot using the persona enhanced version. The expectation being that the persona enhanced version should perform better overall. Initially, we intend to conduct our experiments in simulation, within a virtual intelligent environment leveraging Sci-Fi prototyping ideas, such as those presented by Johnson in this conference [12]. Our intention is to use Sun Microsystems Wonderland simulation tools that we are already using to investigate the development of more human-like avatars [13]. Finally, we will explore how the ideas underpinning quantum controller might be combined with cyclic instability. For example, we envisage that if there were multiple robots, each with a quantum controller, then the collective social behaviour would be described by cyclic instability theory whilst the internal operation of the robot controller (i.e. the multiple persona switching) would be determined by quantum theory thereby requiring both parts for a stable but creative multi agent system.

4. Conclusions

In this conceptual paper we have described the role of chance and instabilities in intelligent environments. We have discussed how at one level (system wide interactions) such instabilities can be destructive and we presented methods to detect and remove such cases. At a second level (within a controller or a brain) we have argued that such instabilities might play a fundamental role in providing more human-like intelligence by providing some irrational behaviour in agent. We noted that, on the one hand unregulated probabilistic behaviour (cyclic instability) threatens the vision for ambient intelligence whilst, on the other hand, directed probabilistic behaviour (quantum controllers) enables it. Thus probabilistic perturbations can be both an enemy and friend of intelligent environments. In this work we have presented both proven concepts that fix existing problems (INPRES) and speculative ones that conjecture of improved AI methods (quantum controllers). In terms of the speculative aspects of our work, we leverage Sci-Fi prototyping ideas advanced by Johnson extending the notion of system instability to encompass the concept of irrationality and multiple personas within service agents, borrowing from models presented in philosophy and psychoanalysis. While our model could be applied to any agent that provides a service to an intelligent environment, as an exemplar we have chosen service robots to experiment our model with. The control model uses a quantum logic gate arrangement to implement the persona transfer function. The next phase of this work in progress is to implement the quantum transfer function and test our model in simulation against a base line standard control model. Another challenging area we intend to investigate is understanding instabilities when there is only a partial or incomplete view of the system. This would be closer to the reality of distributed pervasive computing and psychoanalysis where there is incomplete information. Finally we plan to integrate the various facets of instability into a more general theory that includes purposeful instability in quantum controllers and unwanted instability in system wide social system of agent based intelligent environments.

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