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USING MULTIPLE PERSONAS IN SERVICE ROBOTS TO IMPROVE EXPLORATION STRATEGIES WHEN MAPPING NEW ENVIRONMENTS

Simon Egerton*, Victor Callaghan†, Graham Clarke†

*School of Information Technology
Monash University,
Jalan Lagoon Selatan,
Bandar Sunway,
46150, Selangor Darul Ehsan,
Malaysia

†Department of Computer Science
Essex University
Wivenhoe Park, Colchester,
Essex, CO4 3SQ
United Kingdom

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Abstract

In this paper we have described our work on geometrical and perception models for service robots that will support people living in future Digital Homes. We present a model that captures descriptions of both the physical and perceptual space. We present a summary of experimental results that show that these models are well suited to supporting service robots navigation in complex domestic worlds, such as digital homes.

Finally, by way of introducing some of our current, but unpublished, research we present some ideas from philosophy and psychoanalytic studies which we use to speculate on the possibility of extending this model to include representations of persistent experiences in the form of multiple personas which we hypothesize might be applied to improve the performance of services robots by providing a mechanism to vary the balance of current and past experiences in control decisions which appear to serve people well.

1 Introduction

Isaac Asimov famously described a future where humanoid robots played an integral part in people's everyday lives, routinely undertaking chores around the home [1]. Robots are an example of intelligent embedded-agents; entities that have some reasoning, planning or learning combined with sensing and actuating capabilities [17]. Agents are an essential component for realising the vision for ambient intelligence and intelligent environments. In these environments mobile robot and appliances based agents will be able to work together to create truly intelligent environment [4]. Robots will vary in type from ones that service people's homes, robots that explore space, fix nuclear plants etc. Driverless cars and aircraft are other examples of robots. In this paper we describe work we have completed that is aimed at making more efficient service robots for the home.

1.1 Perception

In cognitive sciences, perception is described as a process for acquiring, interpreting, selecting, and organizing sensory information [9]. In mobile robotics there are two significant approaches to incorporating perception as part of motion controllers. The first approach, reactive architectures, simplifies the process to that of sensing and reacting directly on world, without the use of models or semantics, whereas the second approach involves the use of rich semantics and models which enable greater deliberation [3]. In this paper, we outline an architecture that uses a novel perceptual map or model with a behavior based reactive controller which, we argue, is well suited to opening up a novel thread of research on a "multiple persona" architectural approach to robot behaviour.

1.2. Multiple Personas

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. In this sense it is more akin to the benign forms of splitting that allow us to be parents, siblings, children, workers, partners etc. Specifically this paper tackles exploration, multiple personas and curiosity.

1.3 Previous work

In our previous work we have looked at the problems involved in developing intelligent buildings [4], mobile robotics [8], [11], [15] and combinations of these [8]. The underlying architectures are based on a combination of: Distributed Artificial Intelligence (DAI), behavior based embedded-agents and network technology. We have built a number of robots ranging from small desktop vehicles to large outdoor diesel powered agricultural vehicles.

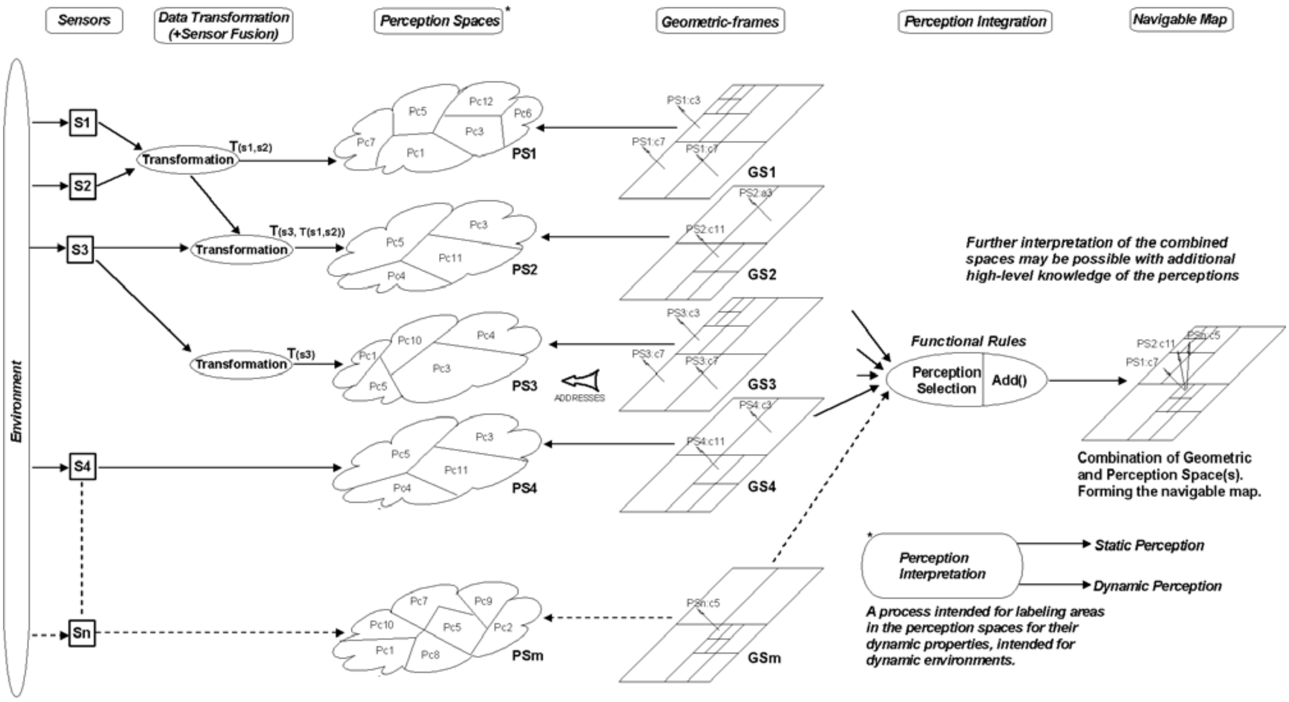

Figure 3: Illustrating the architecture of the perceptions-based spatial integration system.

2 Perceptual Survey Maps

A service robot placed in an unknown target environment such as a digital home may be required to construct a model, or map, of that environment. Such maps can allow the service robot to plan and carry out tasks optimally; this is significant, especially when the robot is battery operated with a limited energy supply. Digital homes can be complex areas to map, with numerous items of furnitures packed into relatively small geometrically varied spaces.

Figure 1: The iSpace

Figure 2: Some domestic robots in the iSpace

Figure 1 shows our experimental facility; the iSpace, a two bedroomed apartment equipped with a rich set of networked appliances and sensors which forms a digital-home. Figure 2 shows some of our robots working within the iSpace.

We have developed a *perceptions-based* mapping model to deal with such environments based on biological spatial theories [9], [11]. The model is an example of a biomimetic survey-navigation process [13] whereby spatial information is accumulated, or integrated, within a geocentric co-ordinate framework. The model is illustrated in figure 3.

The spatial model is based around two independent concepts; a *perception-space* and a *geometric-space.* The perception-space categorises *perception-signatures.* A perception-signature is a distinctive set of sensor element activations characterising some fixed physical location in the robots environment. Perception-signatures can be raw readings taken directly from the physical sensors or abstract signatures, the result of signature transformation processing in the second stage. In this case, a perception-signature may not have an equivalent sensor element activation in the physical environment. Each category in a perception-space should be active at specific locations in the environment, *perceptual-aliasing* occurs when one category is active at more than one physical location. The geometric-space addresses the perceptions within a geocentric framework, currently represented by an area quadtree [16]. Each perception-space has its own geometric-space with homogeneous areas in the geometric-space forming *perception-areas*. A navigable map is formed by applying a set of functional rules to combine the set of geometric-spaces into a navigable map.

This process can update the map whenever the robot needs to reference the map. The functional rules integrate perceptual information and allow flexible decisions to be made, for example, which perceptions should be used to form the map.

2.1 The perception-space

Current experiments have involved perception-signatures derived from a panoramic colour vision sensor. The perception-signatures are a mixture of colour and intensity vectors encoded as real numbers. The perception-signatures from stage two of the model are passed onto the perception-space modules. The type of classifier contained within a perception-space module will depend on the perception-signatures it has to classify. In our current experiments, where the perception-signatures are vectors of real numbers, we chose a range of standard self-organising classifiers to compare, the leader, k-means, growing-cell-structure neural network and the fuzzy-c-means classifiers. These experiments have helped validate our model; an example perceptual map is given in figure 4.

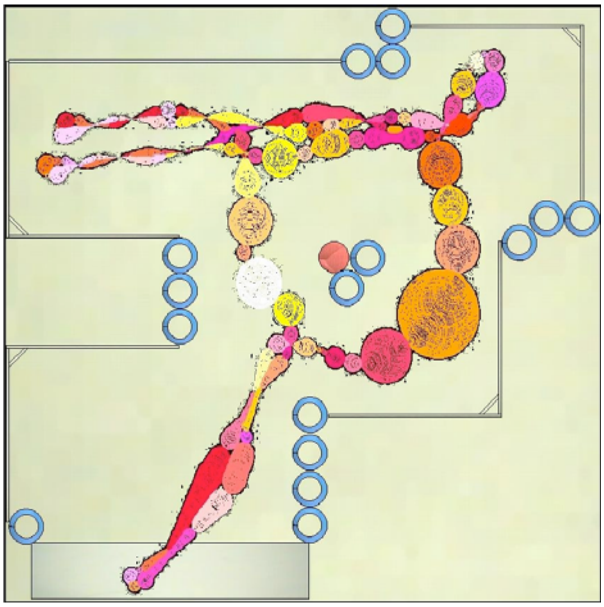

Figure 4: Perceptual map from an indoor test environment generated by the growing-cell-structure perception-space module and colour hue perception-signatures computed from the panoramic colour vision sensor.

Future work will focus on extracting knowledge based signatures from the sensors, for example linguistic descriptions from the visions sensors [14], [18]. In addition, we are also interested in exploring the merit of adding other abstractions into the perception space; for example the number of times a robot has visited a space, the periods spent in a space, the uniqueness of a space etc as a means to inform higher level controllers within the robot of the "value" of perceptions and spaces as part of higher level planning decisions. We expand on this idea later in the paper.

2.2 The geometric-space

An example of part of an environment recursively decomposed by an area quadtree into a set of perception-areas is illustrated in figure 5a, and the respective quadtree structure is given in figure 5b. This quadtree represents the part of the geometric-frame the robot has so far explored. The terms geometric-frame and quadtree are synonymous, as the quadtree is used to model the geometric-frame. Each node of the quadtree represents a square area, or quadrant, in the environment. The area of a quadrant can be calculated from its position relative to the root node of the quadtree. The area of any quadrant is $2^{2(n-k)}$ units, where 2^n is the length of the geometric frame, and k is the level of the node being considered. For example, the root node has an area of 2^{2n} square units, while node 60 in Figure 4b is three levels below the root node and so has an area of $2^{2(n-3)}$ square units. A Quadrant can be subdivided into four children; these children are labelled along the primary inter-cardinal points, Northwest (NW), Northeast (NE), Southwest (SW) and Southeast (SE). The subdivision may be repeated ad-infinitum. However, the division is typically limited until a specified level is reached, or until the minimum quadrant-area is reached.

The quadrants are represented by nodes in the quadtree. Nodes within the quadtree have different attributes, depending how they relate to other nodes in the tree. A grey node of the quadtree is a node that is a root of a sub tree. A leaf node of the quadtree is a terminal node of the tree and the attributes of the leaf node allow them to be interpreted differently. In general, leaf nodes address a perception-class, and neighbouring leaf nodes of the same perception-class group together to form the perception-areas. More specifically, a leaf node that addresses a perception-class is labelled a free space node, indicating that the robot can navigate through all or part of the quadrant area the node represents. If the leaf node does not address a perception-class then the leaf node is labelled as either an obstacle node, in which case the robot can not navigate through this area, or an unknown area node. An unknown area node is formed from an expansion of the geometric frame; thus, the node represents unexplored area. As perception-classes are only experienced at physical locations, obstacle nodes can only be inferred. However, the amount of inference required depends on the information content of the perception-class. The most basic inference would label unknown nodes as obstacle nodes if they were surrounded by free space nodes. These notions are captured by the illustrations of Figure 5b. Nodes have an internal data structure attached to them, recording various bits of information about the node, such as distance transforms for navigational purposes and perception-class statistics for map stability inference purposes.

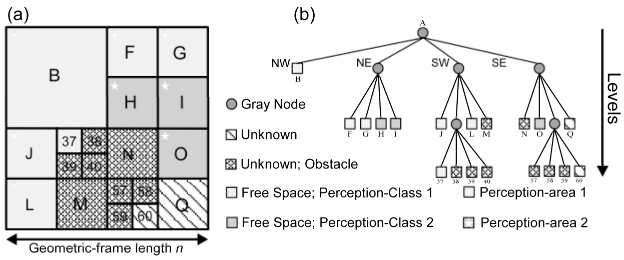

Figure 5: a) The geometric frame, represented with an area quadtree. Quadrants address the perception-classes in the perception-space. Neighbouring quadrants of the same type form a perception-area b) The related quadtree structure.

3 Exploration

A service robot situated in an unknown environment will need to explore to construct a map of the unknown environment. Where the robot has no *a-priori* knowledge exploration serves two purposes, the first to construct the perception-spaces, the second to construct the geometric spaces. The two processes can be performed simultaneously, but the initial maps will be highly dynamic as the perception-spaces converge to stability. However, if the robot has been initialised with a set of pre-existing perception-spaces, then the exploration will largely be to construct the geometric-spaces

Currently, exploration is considered as a random wander about the environment, limited, naïve guidance can be given simply by expanding the outer edges of the geometric-space, effectively guiding the robot into the unexplored areas of the environment. However, we argue in this paper, that this random wondering is not the most efficient method of exploration and we develop the notion of emotionally or persona guided exploration in the next section.

4 Multiple Persona Architectures

4.1 The Control Model

The ultimate use of the perception and geometric representations we have described is to inform a higher level controller directing a service robot so as to allow it to make the best navigational decisions at any particular time. This might be during the process of map building or later when conducting useful jobs around a digital home. One of the most successful approaches to controlling mobile robots has been behaviour based architectures, proposed by Rodney Brookes in 1985 [2]. 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 6. 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 [4], [15]

The perceptions and geometrical models described in the previous section, can be used as input to this model as indicated in figure 6. Further, the perceptions based experiences can be included, giving the service robot a wider set of data on which to base decisions.

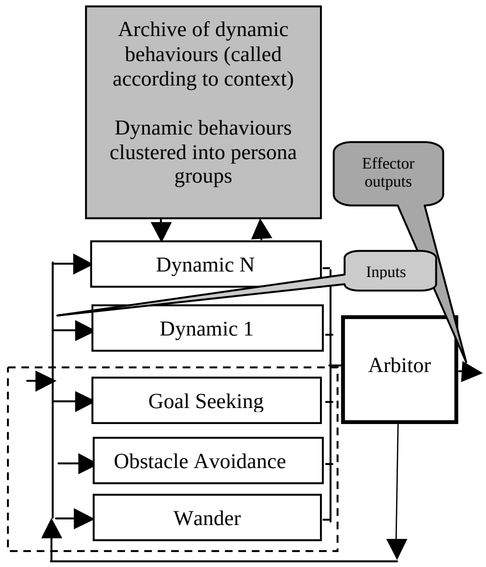

Figure 6 – Persona Enhanced Behaviour Based Architecture

4.2 The Persona Model

In a widely influential paper investigating the idea of irrationality and all that it involved Donald Davidson [10] developed the idea that irrationality was like being controlled by two different controllers cued by context with no higher level control system available to awareness. The nature of the controllers or ‘partitions of mind’ that he suggested was of coherent systems of beliefs, desires and memories acting like independent agents. Marcia Cavell [5] has argued that this model fits a wide range of psychoanalytic models of inner reality even though it was originally developed to provide an explanation of irrationality in the context of Freud’s structural theory. One of the authors has argued that in fact this model fits the thinking of one of the originators of the object relations approach – Ronald Fairbairn – much better [7] Fairbairn’s thinking relies crucially upon dissociation or splitting as it is commonly called. However even though he was deeply influenced by thinking on multiple personality disorder and thought his theory ideally suited to understand it [12] this is seen to be a pathological state. In the context that we are seeking to use these ideas however we are looking at this form of splitting as a positive state, a way of reducing the search space, of using previously accumulated experience etc depending upon context to guide our systems as rapidly as possible towards a useful outcome. While multiple personality disorder is regarded as perhaps the most extreme form of splitting, short of total disintegration of the personality, we are looking at it in this context as a way of developing specialised context related agents. In the philosophical and psychoanalytic account of multiple persona the possibility of conflict and confusion engendered by having competing alternative persona that can take control “willy-nilly” is seen to be a disruptive and potentially damaging process whereas here we are seeking to produce a degree of role specific specialisation so that the problem space is partitioned efficiently. Whether this is related to the sort of behaviours e.g. wall following, or the sort of contexts e.g. bathrooms kitchens etc, is an unresolved question at this time. This persona based approach to the architecture will allow us to explore the hypothesis that multiple personas guide our actions, that we do not make decisions purely on our immediate sensing of the world. By having a reservoir of specialised personas to call upon, the persistent and evolving nature of such personas would allow us to explore the value of accumulated experience that in us manifests itself as a somewhat ill defined ‘self’; which, when making decisions, occasionally overrides the logical nature of the world, akin to what might appear to be irrationality, putting it down to nebulous mechanisms such as “a hunch” or “a feeling”. This approach will allow us to open up a line of research to explore the nature and value of such abstracted personas and their dynamics.

5 Conclusion

In this paper we have presented our work on geometrical and perception models for service robots in future Digital Homes. We have presented results that show that these models are well suited for service robots in digital homes that need to create and maintain representations of their relatively complex domestic worlds.

We have also introduced the notion of extending this model to include representations of persistent experiences in the form of multiple personas. Whilst this work is at an early stage, it is informed by philosophy and psychoanalytic theory and we contend that this will form an interesting and useful line of research that might both cast light into our own mind and lead to improved service robots that may better share some operational properties with the people they serve.

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