Domestic robots developing EM construals

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Abstract

This paper considers the possibility of getting robots to develop Empirical Modelling (EM) construals. This would allow robots to make models of their surroundings which would help them to perform their tasks better. I look at the possibilities of robots in the home using EM to learn their environment and to help them locate where they are and where they need to go. The first section of this paper looks at the three main aspects of EM and discusses the benefits and difficulties of robots producing these. In the second section I discuss two scenarios (and their respective models) which a robot may find themselves in.

1 Introduction

Robots in the home to perform everyday chores have long been the dream of scientists and even the average home owner. These ideas have been on the mind of many science fiction authors for decades, few more famously than Isaac Asimov who created the "I, Robot" series of stories and the "Three Laws of Robotics" and whose novels of robots have been made into films in the recent years. But how close to reality is this idea of having domesticated slave robots? Is it feasible to think that we could soon be surrounded by mechanical house wives?

With the rate at which technology is advancing, we could soon be at a place where the mechanical practicalities of having a robot in the home will be overcome (e.g. moving up and down stairs with ease, being able to visually distinguish between different objects etc). One of the largest and most complicated obstacles however, is the cognition, recognition and adaptability that humans achieve so well, but is a very complex activity indeed. Imagine for example, a robot could be programmed to sweep a floor without any obstacles on it. It could decide on a point to sweep all the dust on the floor to, and then collect that dust with a dustpan. However, if you introduce some furniture into the room along with some child's toy and maybe some mail scattered around the floor, the task of sweeping the floor becomes more complicated indeed. The robot may be able to sweep under furniture such as a foot rest by moving it aside, but not under something as large as a sideboard containing crockery. Also, how would the robot be able to distinguish between items which can be discarded such as empty envelopes and important documents such as bills to be paid? The task becomes increasingly complicated.

In this paper, I want to investigate whether Empirical Modelling (EM) could be used within a robot to help with this complexity of problem. In EM, the modeller can create a computer- based artefact which will represent their understanding of the situation which they are modelling. They will have gained this understanding by interacting with or experiencing the referent being modelled. The term construal is used to describe this artefact. If a robot were to develop such models in a similar way then it would allow the robot to learn more about it's environment and tasks.

There are other researchers who are looking at how robots could be made with adaptable learning capabilities. One of the most exciting I have found is Cognitive Developmental Robotics (CDR), developed by Minoru Asada et al in Japan. The design principle of CDR is to develop robots that will learn by interacting with and experiencing their environment. There are two sides to this:

1. “The design of a self-developing structure inside the robot’s brain.”
2. “How to set up the environment so that the robots embedded therein can adapt themselves to more complex tasks in more dynamic situations.” (Asada et al, 2001)

I believe it could be possible to achieve this self-developing structure by enabling the robot to develop EM construals. As the robot experiences more of it’s environment, it can further develop it’s construal to make it more accurate to it’s surroundings.

In the first section of this paper, I will discuss the possibility of enabling robots to produce construals through their experience of a house using EM principles. I will then move on to look at some scenarios which a domesticated robot might find itself in and look at how EM construals could prove useful.

2 Robots making EM construals

The question I want to address in this section is can EM principles be used to develop construals within a robot to enable the robot to learn through experience? I will look individually at the three main principles within EM; observables, dependencies and agency, and see how each could be used to achieve robots that develop construals. I will also address any assumptions that I am making about the abilities of the robots.

2.1. Observables

An observable is an aspect of the situation we are modelling which we can attach an identity and, more importantly, a value to. Observables are the core item in EM as dependencies are formed between two observables and agents act upon observables and are actually observables themselves. Even when dependencies are changed by agents, the changing dependency acts as an observable. Some examples of observables in a model of a lift in a building [1] could be the people using the lift or the floors the lift visits. Observables can also be less tangible aspects of the situation being modelled such as the floor the lift is currently at or even the total weight of the people inside of the lift.

If a robot were to making EM construals, then it would have to both recognise relevant observables and record them within it’s model. With current technology, some observables would be easier to recognise than others. IF a robot wanted an observables such as the width of the room it was currently in, this could be done relatively easily using laser measurement tools built into the robot. However, if a robot’s job was to clear a dirty plate from a dining table, it would have trouble creating an observable for the plate as present robotic vision technology would struggle to distinguish between a plate and the table itself, or maybe a Frisbee also on the table, for example.

2.2. Dependencies

A dependency expresses a relationship between two or more observables which describes how the values of these observables are affected if there is a change in one of the observables values. Dependency links different aspects of the model so that it is not a group of autonomous individual parts but a sometimes complicated system of interactions. An example of dependency in the lift model mentioned earlier is that a person’s position depends of the current position of the lift, when that person is actually in the lift.

A robot would have to be able to discern dependencies between observables and record these dependencies in a model to make a useful construal. Getting a robot to discern dependencies would be very hard to achieve as we make dependencies by applying our knowledge of the world or the referent we are modelling. A robot may require some pre-learnt information of a situation to be able to make dependencies. This is one possible way in which CDR (mentioned in the introduction) could link with EM. If a robot could learn some knowledge about it’s environment, it could then apply that and use it to discern dependencies. These dependencies could later be updates or

[1] This model is available from the Empirical Modelling website. See the references section at the end of this paper for the URL to this model.

change as the robot discovers more about it's referent.

2.3. Agency

An agent is an aspect of a model which is perceived to be able to cause a change of state. Understanding of agency within a model may evolve as the construal develops. Agency makes a model active. Observables and dependencies are facts about the model but the agency makes these facts interact with one another. An example of agency in the aforementioned lift model are, if a lift user presses the call lift button on a floor then the lift will move to that floor, thus changing the state of the model.

Similarly to dependency, agency would be something the robot would need to learn or pre- acquire. For example, a typical state change in a house situation would be the opening and closing of a door. Children learn this through seeing their parents regularly repeating this motion. A robot would need to learn where is best on the door itself to pull or push. If a robot were able to create an observable of the handle and its position on the door (which as I discussed earlier is currently a hard task), then the agency between pulling the handle and the door opening could be added to the robot's EM construal.

As you can see, developing an EM construal within a robot's memory is currently quite a hard task. Observables are challenging to recognise, dependencies and agency have to be learnt. However, EM is a great tool for learning[2], and could also be used to enable a robot to learn both dependency and agency. If a robot was "pre- installed" with a basic model of a house, it could update this model as it discovers more about it's environment, thus making the construal more accurate to it's referent.

3 Scenarios in EM

In this section of the paper I will look at a couple of scenarios which a domesticated robot may find itself in. For each of the following scenarios I will first describe how a human may deal with the situation. I will then discuss how a robot could deal with the situation and any problems that the robot may encounter. I will then describe the actual EM models I have created in parallel to this paper and how these may be used to help solve the problem.

3.1. Knowing the room you are in

This scenario deals with the problem of getting a robot to realise what room it is in within the house or office it could be working in. How do I know that I am sat at *my* desk in *my* bedroom in *my* house? I believe this comes from a couple of factors. When I left the Christian Union evening this evening, I drove the usual route from campus to my house which I assumed (rather feasibly) hadn't moved location. I then unlocked and entered my front door using my house key (thus confirming my earlier assumption). I then walked to my room and after getting a drink, I sat down at my desk. So my regular movements to my room confirmed that this room I am in is indeed my room. Secondly, I know this is my room because it has my things in it, in the positions I left them in.

How would a robot achieve such a realisation of it's location? In replication of the two ways I know I am in a certain room, a robot may be able to know what room it is in if it has travelled there using the model of the house in it's memory. However it is possible that on some occasions (for example, when switched on first thing in the morning in a house) the robot may be unaware of it's present location. It could be that the robot is in the same location as it was when it was switched off, but it is feasible that the robot may have been moved overnight. So what observables can the robot use to decide it's location? Furniture may have moved and so may other small items. The robot could measure the dimensions of the room. IF these matched one of the rooms in it's memory, then it could assume it is in that room. I see two possible problems with this. Firstly, there is the rare occasion where the room may change it's dimensions, due to an extension on a house. Secondly, if a robot was working in an office block, a problem arises since many offices in a block have similar dimensions. In both these cases, the robot could simply

[2] For more information about EM as an education tool, see Beynon's paper Empirical Modelling for Educational Technology in the references section.

leave the room and see if the room it then enters is in it's memory.

The EM model I have created for this scenario models the situation where the robot is placed in one of three rooms and it has decided which of the rooms it is in by the values of known rooms within it's "memory". The model[3] contains three rooms which the robot (represented by the circle) can be placed into by clicking the relevant buttons. When the robot enters a new room, the model simulates the robot measuring the distances from itself to the four walls of the room. It then uses the data and compares it to the values of room dimensions that it knows. The robot decides upon which room it is in and displays it's decision. Even though this model is quite trivial, it does show how a robot may decide which room it is in by using the observables of the unknown room's dimensions.

3.2. Finding the door

This scenario deals with the problem of getting a robot to find a door in the room it is in. This is a relatively easy task for a human being. One swift look around a room and the human eyes can locate the door. Even if the door has the same colour as the wall, the door is recognisable as there is usually a door frame and a door handle. There is the famous example of the Oval Office in the White House in the USA where two of the doors are in exactly the same décor as the surrounding wall. The only items distinguishing them are the small door handles and a faint outline.

A robot on the other hand would find this task very challenging. As discussed in section one, a robot would struggle to create an observable of the doors location just by looking around the room. With today's robotic vision technology, distinguishing the difference between a wall and a closed door, or an alcove in a room and an open door is a very challenging if not impossible task. As this technology advances, a robot may be able to scan the room as humans do and find the door immediately and then it would be able to create an observable for it. Today however, this is not possible. One solution would be for there to be some form of marker above the centre of each door. This marker could be something as simple as a radio transmitter. If the robot picks up the set frequency, then it knows there is a door where the frequency is coming from. A technician could feasibly come and install the robot into your home and place one of these transmitters above every door. The robot is now able to make an observable of the door and head towards it whenever it wants to go through the door.

The EM model I have created for this scenario models the situation where a robot is placed in a room with a door which it wants to go through. In the model[4], there are two observables (doorCentreX and doorCentreY) which simulate this marker being placed above the door. When the robot is commanded to find the door, it will adjust it's position to move to the door. In the model, it is also possible to change the position of the door, thus making it less trivial.

4 Conclusion

Technology wise, there are still significant hurdles to be jumped before we see robots vacuuming our floors. There is also still a way to go before the robot's "brain" is able to cope with daily activities around the house. Empirical Modelling seems to hold potential to enable robots to learn and to perform their tasks by creating EM construals of situations. As the robot experiences more of it's environment, it can edit and enhance the model, thus making it more reliable.

There are still many problems regarding how a robot may recognise and discern the three main aspects of EM; observables, dependencies and agency. These problems will have to be overcome before EM could be used within a robot.

It would be interesting to investigate the possibilities of installing an EM environment on a small robot in a controlled layout of a series of rooms. The robot could be tested to see how well it remembers its way around the layout, and it's learning capabilities could also be tested.

[3] The model can be viewed by running the file scenario1.e in tkeden

[4] The model can be viewed by running the file scenario2.e in tkeden

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