HOW CAN CAAD TOOLS BE MORE USEFUL AT THE EARLY STAGES OF DESIGNING?

Towards Situated Agents That Interpret

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Abstract. This paper describes how designers can be supported in the early stages of designing through more flexible representations. It presents situated agency as a means to address this problem. Interpretation is a necessary process to give meaning to data before creating a representation. A framework for situated interpretation agents is outlined, with a focus on *push-pull* and the process of *situation*. An example for creating a CAAD representation from a raster image is used to illustrate this framework. This research lays a foundation for further work on situated interpretation agents.

1. Supporting Designers through Flexible Representation

Current CAAD tools have limited usefulness in the early stages of designing, with a tendency for designers to rely upon paper and pencil (Do, 1998; Gross, 1996; Lawson, 1994). One possible reason for the limited usefulness is that, in the early stages of conceptual designing, designers move between different internal conceptions of what they are doing. Designers often see more in what they have externalised than what they intended (Schön, 1983; Suwa and Tversky, 2002). A designer might draw something, which the CAAD tool will represent in a specific way. If they now conceive of what they have drawn differently, they must take actions to change how the tool represents it, interrupting the flow of design. Current CAAD tools typically have a fixed representation, where the way that a drawing has been created defines the way that it will remain represented unless the designer takes an action to change the representation.

CAAD representations are typically two- or three-dimensional objects without obvious singular decompositions (Bijl, 1987). We suggest that more useful CAAD tools can be produced that embody flexibility in representation. Rather than defining the representation through the steps in creating a drawing, CAAD tools can potentially arrive at a semantic resolution of a drawing with an appropriate representation, using knowledge from previous uses of the tool. The departure from existing research in this area comes from the way that the agent learns to produce appropriate representations through interaction and uses what it knows.

Previous work in creating flexible representations has looked to establish conventions that designers use and create tools that can recognise them and support them (Gross, 1996; Do, 1998). For example, the Cocktail Napkin (Gross and Do, 1996) can recognise symbols as belonging to a certain type of drawing, such as conventional symbols in sketching a circuit diagram. The program can then support the movement from a loose sketch to a more formal schematic drawing, or, in the case of the Right-Tool-Right-Time program, it can activate programs that it believes the designer will require (Do, 1998). This approach requires that the classes of drawings that can be created be defined a priori. This type of tool is interpreting what the designer has drawn and representing it, but is restricted in what it can learn from its use and relies upon pre-defined knowledge.

The situated approach that we are suggesting differs from this in that we are moving towards programs that acquire first-person knowledge through their use rather than relying exclusively on pre-encoded, objective knowledge (Gero, 2007). Objective knowledge exists independent of its use and is characterised by its independence from other knowledge and its invariance. First person knowledge comes from interaction with the world and the development of relationships between knowledge developed by an agent and its use.

2. Situated Interpretation in CAAD Tools

Interpretation is defined as the use of grounded knowledge to give meaning to data, where data can originate inside the agent (autogenous) or outside the agent (exogenous). Interpretation seeks to construct something that is both reliant upon the agent's experiences and what is contained within the data. We define expectation as any prediction that the processes in the agent make about what the world looks like.

CAAD tools are characterised as: (i) a set of possible technologies for representing designs (e.g. as vectors, as solid models); and (ii) a set of processes that can operate upon representations (e.g. Boolean operations that can operate on solid models (Mäntylä, 1988)). When a designer views a CAAD drawing, it is often unclear how the representation is structured (Jun and Gero, 1996). Representations will typically be well suited for some processes and unsuited or unusable for others. This is shown in the way that the square shapes in Figures 1(a) and 1(c) appear to be similar representations. What is not apparent from looking at them is that they are structured differently. This creates very different results when the same scaling operation is carried out on both of them, leading to Figures 1(b) and 1(d) respectively.

Situated interpretation occurs in agents that: (i) create meaning by fitting concepts together (rather than simply activating concepts); (ii) can be changed by the process of interpretation; and (iii) are capable of constructing new knowledge (for the agent) through interpretation. The first of these is based upon the assumption that a part of the meaning of concepts comes from their relationship to other concepts. An agent uses concepts that relate to what it thinks it is doing; there is a process that fits concepts together rather than simply using them. The second of these recognises that an agent can be changed by the process of interpreting data, that the use of first-person knowledge can change it. The third of these recognises that designers need to be able to conceive of a world that is different to the world that they encounter. The construction of novel interpretations is a part of this capacity.
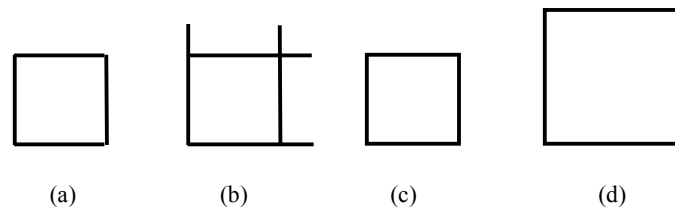

Figure 1.   The result of the same operation (scaling) on different representations: (a) a square made from four lines and (b) the resulting representation; and (c) a square as a closed shape and (d) the resulting representation

Situated interpretation in CAAD tools considers that for data that is to be represented in the CAAD environment, there are many possible representations. We look at agents that sense data, construct an interpretation, and produce a representation inside the CAAD environment based upon this data. The production of the representation is an action based upon the interpretation, not the interpretation itself. In developing situated agents that interpret we focus on: (i) the way that differences between expectation and data are managed in the agent; and (ii) the way that concepts are put together by the agent in the process of *situation*.

Consider an agent that views data, in the form of a CAAD representation, and needs to carry out actions. For this agent the representation and the intended action will frequently be incongruent. If it has had appropriate experiences, the agent should be able to use expectation based upon experiences to construct a representation that has the potential to be more useful to the designer. We take a situated approach that recognises that designers, at various times while they are designing, see the world in a different way, which affects what they do. This forms the foundation for the framework, that at each stage of interpretation expectations potentially change the representation that is constructed if needed.

3. A Framework for Interpretation in a Situated Agent

This framework for interpretation in a situated agent has four distinct processes: sensation, perception, conception and situation. In one direction, the output from each of these processes becomes the input for the subsequent process. In the other direction, the output from each process changes the expectations produced by the preceding process, Figure 2. The processes

operate in parallel. 'An interpretation' consists of the data held in the entire system.

The two ways in which this framework differs from existing frameworks is through *push-pull* (Gero, 2002) and the process of *situation* (Smith and Gero, 2005). Push-pull allows expectations to change the data brought into the process, and to construct from it data to match expectations. Situation is a process for constructing a structured set of concepts from a collection of potential concepts.
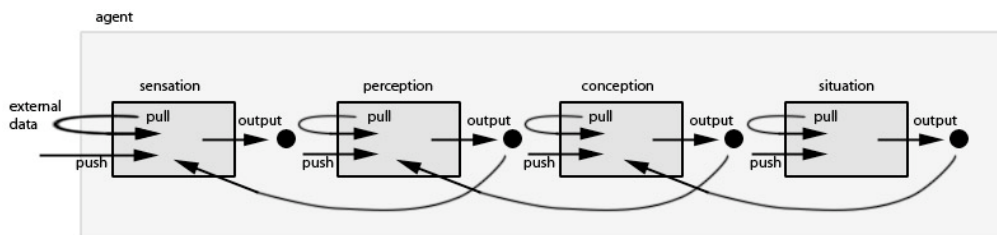

Figure 2.   The processes in the interpretation framework

3.2. PUSH-PULL

Push and pull are different ways that data is brought from outside a process into the process. Pull is the process itself exerting control over what comes into it, by selecting data and changing it to match expectations. Push is the data outside the process making itself recognised by the process. Push is control over what comes into the process from outside the process.

Pull is a process that has some control over input data brought into the process. This control is used to find data that matches expectations. Pull can construct data based upon expectations.

An eye can be described as a sensor that creates sense data from light. The process of sensation has control over this sensor, such as where it is directed and whether it is open or closed. Consider that the agent is trying to find a specific expected stimulus, say, the horizon. Sensation may receive some expectations that lead it to exercise control over the eye so that it is pointing to the place where it expects the horizon to be. A process (pull) in sensation has exercised control over the sensor (the eye) using expectations (on where the horizon will be) to pull data. In this way the process of sensation is partially controlling its own input data.

Pull can also construct data using pushed data on the basis of expectations. An example of this can be seen in conception building expectations of finding certain percepts. Conception expects the triangle shown in Figure 3(a), but the pull process finds only the shape in Figure 3(b). Depending upon the way that the concept is using the percept (i.e. depending on the situation) this shape may be used for constructing something that is able to meet the expectation. For example, if the agent is trying to find a triangular birthday cake then Figure 3(b) may be sufficient to construct a triangle that meets the expectation, but if the agent is trying to solve a tangram then it may not be adequate (this is described in more detail as *conceptual slippage* by French (2001)).

(a)   (b)

Figure 3.   (a) Expectations of conception; and (b) a percept that can be made to match expectation in some situations.

Pull is the way that expectations manifest themselves by selecting and changing data. In interpretation we require the influence of both expectations and data. Push is the way that some data pushes itself into the process. The data that is pushed into a process depends upon the structure of the data receptor for the process and its sensitivity to certain data. Push-pull occurs in all four processes within the agent.

3.3. USE OF EXPECTATIONS

Expectations are created from queries of memory. Through pull, the data coming into a process is made to look like these expectations. This can involve cases of: (i) changing the values of data to be closer to expectation; and (ii) filling missing properties with data from expectations.

We are currently working to formalise the way that this occurs through the conceptual spaces framework of Gärdenfors (2000). Conceptual spaces uses geometric representations to achieve results similar to prototype theory (Murphy, 2002). Expectations can then be represented as regions within domains. The data that is close to an expectation region might be changed to fit within it. If a domain is not represented in the data then it may be constructed from a region of expectation.

It is through expectations that past knowledge is brought to bear upon current data. Pull is able to use expectation to construct, rather than to simply classify.

3.4. SITUATION

The process of situation gives structure to concepts and changes them to look like expectation so that the whole set of concepts activated make sense together, as determined by experience. Situation differs from context. We define a context as something that exists outside an agent, whilst a situation is something that only exist within agents; situation requires experience rather than simply proximity (Gero and Smith, 2007). A new situation can be constructed from the concepts that come together, in the same way that new concepts can come from percepts that are brought together. This is a departure from the 'context' described in the Cocktail Napkin (Gross and Do 1996), as it allows for an agent to create new situations through experience rather than requiring them to be defined a priori.

3.4. UTILITY OF REPRSENTATIONS

In this work we have not discussed how useful a representation may be to a designer or how to measure utility. The problem of creating representations useful to a designer has been reframed as two problems: (i) the creation of an

agent that develops and uses first person knowledge; and (ii) making such an agent function in a way that is useful to designers. Here we are focussed on the first of these problems, the way that knowledge is used in the construction of an interpretation.

4. An Example of How Design Tools Could be More Useful

Consider that a designer is using a CAAD tool and that they have drawn the two overlapping squares shown in Figure 4(a). The designer sees the emergent square created by the two squares and wishes to manipulate it in some way. For the sake of the example, let's say that they wish to scale the square and make it larger, so they draw a marquee to select the emergent square, Figure 4(b). We suggest that it would be useful if the tool could change its representation based upon what the designer is doing. One possibility in this case would be for the tool to shift to a representation that has two 'L' shapes and a small square. This would allow the designer to continue with design activity, perhaps creating the result in Figure 4(c).
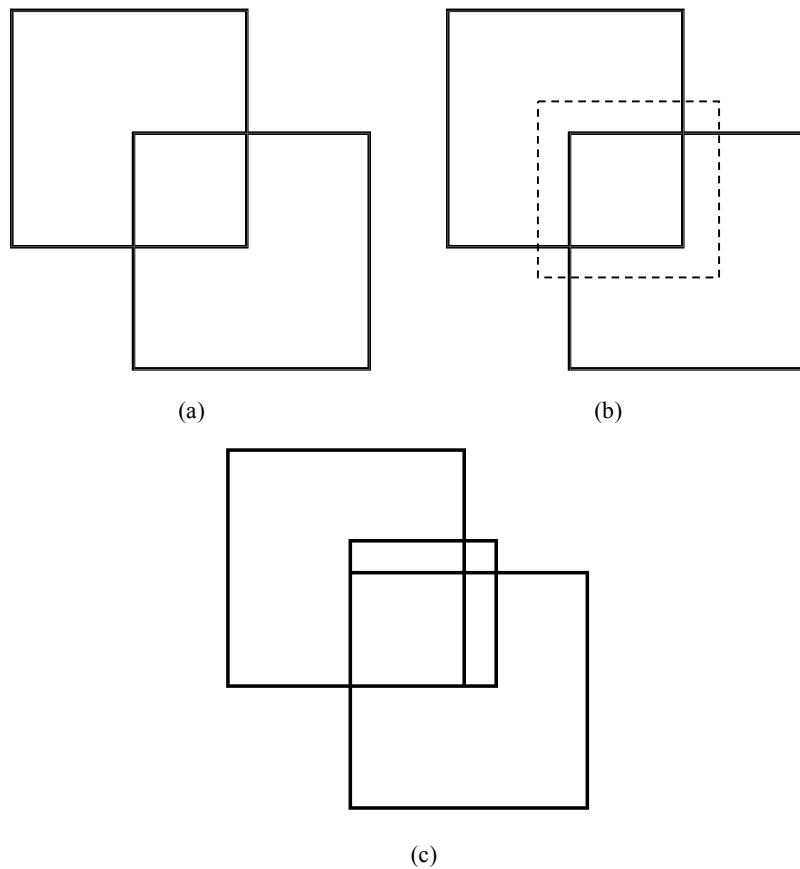
Figure 4. (a) A designer draws two overlapping squares in a CAAD tool; (b) a marquee selection of the emergent square is made; and (c) the emergent square is scaled

The point of this example is to show that a change of representation can be useful to a designer to maintain the flow of design. The reason we require situated agents is that what is useful in some circumstances may not be

useful in others.   We require an agent that is able to interpret what is going on inside the tool.

Looking at this from the point of view of the agent, the interpretation that it creates will be the product of what it knows, of its grounded knowledge and of its expectations. We are concerned here with the way that the agent uses what it knows, rather than upon its proficiency in computer vision.

Sensation brings data from outside the agent into the agent and turns it into sense data. An example of sensation is a camera that turns light into sense data that can be used by the agent.

Perception gives structure to this sense data. This could be done by grouping data along certain dimensions. For example, pixel data from a camera might be grouped by proximity and intensity. There are likely to be multiple ways that perception can group sense data.

Conception gives structure to percepts. There are often many concepts that could be used to structure percepts. For example, there will often be more than one concept at different levels of abstraction and situation is used to decide which of these to use (this is the problem of establishing basic level; Rosch, 1978). It may also be unclear which concepts a percept is most like, e.g. a shape may be somewhere between a square and a circle. In this example a single percept of a large rectangle may be produced, perhaps four percepts that look like lines or perhaps the features we can recognise as doors, windows and walls. Expectations, as the driver for a pull process, are used to determine which percepts are appropriate.

Situation gives structure to concepts. Based upon experience certain concepts might fit together and others not. Concepts can be changed by the way that situation fits them together, in much the same way that conception changed percepts to make them fit a concept. Conceptual spaces can be used as a way situation might achieve this is by looking at the domains that concepts inhabit. For example, a concept that we might call a line occupies dimensions of space, whilst a concept that we might call a wall holds information in additional domains. Situation produces consistency in structuring concepts, so it will depend on the situation whether a concept will associate a window with a line.

For the processes to work like this requires expectations within each process. Pull selects data and changes it based upon expectations. Situation activates a set of integrated concepts that is the equivalent of a world view. In general expectations are based upon a query of memory within a process, using the current input data and the current output data of the subsequent process. For example, conception holds expectations about concepts. These expectations are created based upon the experiences that conception has had that are relevant to: (i) the current set of percepts; and (ii) the current situation. This creates a dynamic system that sends data in both directions. The result is that the agent moves towards something that works for both the expectations and the data.

5. Towards More Useful CAAD Tools

This research uses a process-oriented view of representations. The approach is to be able to change the representation to suit what the process is trying to do rather than having one or more fixed representations. There are two

stages. If a representation is available it can be selected based on the expectations of the process that needs it. If the representation for carrying out the process is not available then the process is able to construct this based upon the agent's experience.

We have proposed that CAAD tools can be made more useful to designers through representations that can be constructed, rather than fixed based on the ideas of the CAAD system's original designers. We have presented a conceptual framework for the generation of interpretations with a focus on the use of expectations founded on situations. This work will proceed by implementing a prototype that demonstrates these ideas.

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