Identifying an Object that is Perceptually Indistinguishable from one Previously Perceived.

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Introduction

People often encounter objects that are perceptually indistinguishable from objects that they have seen before. When this happens, how do they decide whether the object they are looking at is something never before seen, or if it is the same one they encountered before? To identify these objects people surely use background knowledge and contextual cues. We propose a computational theory of identifying perceptually indistinguishable objects(PIOs) based on a set of experiments which were designed to identify the knowledge and perceptual cues that people use to identify PIOs. By identifying a PIO, we mean deciding which individual object is encountered, not deciding what category of objects it belongs to. In particular, identifying a PIO means deciding if the object just encountered is a new, never before seen object, or if it has been previously encountered, which previously perceived object it is.

Our agent's beliefs and reasoning are based on an intensional representation (Maida & Shapiro 1982). Intensional representations model the sense (Frege 1892) of an object rather than the object referent, itself. The terms of our representation language, SNePS (Shapiro & the SNePS Implementation Group 2002; Shapiro & Rapaport 1992), denote mental entities. Some such entities are propositions; others are abstract ideas; others are the agent's "concepts" or "ideas" of objects in the world. This is important for the task of identifying PIOs, because before the identification task is complete, the agent may have two mental entities, e_1 and e_2, that it might or might not conclude correspond to the same object in the world.

The base cases in the identification of PIOs

What is a base case. Experiments with human subjects showed that there are four conditions under which human subjects find the identification of PIOs to be very easy. We'll call these four conditions the base cases of the identification task. Subjects tried to put themselves into a position where they could use one or more base case to identify the PIOs in the experiment.

When the computational agent identifies a PIO using a base case, it does not form a new mental entity for the object and then try to reason if it already knows about this same object already. The agent only creates new entities as needed for cognizing information (Maida & Shapiro 1982). The object that the agent is perceiving is either *the one* that it has seen before, or a new object. If the object is *the one*, then the agent ought to use the original mental entity for it and not conceive of something new which the agent then believes really refers to the same object. If the object is a new one, a new mental entity is created for the new object.

Base case 1: Simultaneous perceptions. If an agent perceives two PIOs in its sensory field at the same time, the agent can trivially conclude that the two are not the same object.[1]

Base case 2: Objects with a unique appearance. If the agent believes that an object has a unique appearance and the agent never sees more than one such PIO at a time, then the agent can instantly identify the object as soon as the agent perceives an object with that appearance. The agent can and ought to use its original entity for the object in this case.

Base case 3: Immobile objects. Immobile objects are defined here as those objects which cannot move or be moved. We're also including those objects which humans think about as not being movable such as a house or a park bench bolted to the ground.

The location of an immobile object is the most important feature to identify immobile PIOs since the location doesn't change. Either the agent knows about an immobile object of this kind at this location already, or the agent has never encountered an object like this at this location, so the object must be a new one.

Correct use of this base case depends on an agent correctly identifying its current location. Subjects were vulnerable to mistaking one room for another if the two looked similar. Kuipers and his colleagues (Kuipers & Beeson 2002) call this sort of mistake "perceptual aliasing" when discussing its implications for robotic agents. When agents fall victim to perceptual aliasing, use of location to identify immobile objects is fallible.

[1] We are ignoring the use of illusions with mirrors and other deliberate attempts to make a single object appear to be multiple objects.

Base Case 4: Continuous viewing. Pollock (1974) has discussed reidentification of objects, a subproblem of identifying PIOs. He notes that an object under continuous observation can be reidentified at a later time as the same object, stating that "continuity of appearance is a logical reason for reidentification."

Continuous viewing of an object also appeared in the human subjects trials as a base case for identifying PIOs. This ease of identification of objects while under continuous observation seems to be implicitly assumed in Coradeschi and Saffiotti's (2003) *Track* functionality.

A General Algorithm for PIO identification

To identify an object with description *D*, just encountered by agent *A*, *A* should first decide if it has ever seen anything that looks like D before. If not, then the object is a newly encountered object. If *A* has seen something that looks like *D* before, then *A* then checks the base cases of identifying PIOs. If there is only one thing with description *D* visible to *A* now, and *A* believes that there is only one thing e_1 that looks like *D*, and *A* has only seen one such object before, *A* assumes that it has encountered e_1 again. Otherwise, if objects that look like *D* are immobile, *A* must decide if it has seen an e_1 at the same location before, if so, then the object is e_1, else the object is something new. Otherwise, if *A* believes that it has continuously viewed an e_1 as it traveled to the place that A now sees the object, *A* believes that the object is e_1. If none of these base cases hold, then for each place that *A* currently sees an object with description *D*, *A* should create a new mental entity e_2. With each e_2, *A* should consider if that e_2 actually refers to the same object in the world as some previously conceived entity e_1.

We make a simplifying assumption at this point: that a moving object will move at a constant speed. When trying to decide if e_2 refers to the same entity as e_1 *A* first considers the rate of movement of each. If the rates are not the same then e_1 and e_2 refer to different objects. If *A* doesn't know the rate of movement, *A* cannot make an informed decision about the identity of e_1 and e_2. Next *A* checks to see if the distance that e_1 could have traveled is less than the shortest path (that *A* knows about) between the place it last saw e_1 and the place *A* sees e_2. If so, then e_1 and e_2 refer to different objects. Next *A* should consider if it believes that the motivations and capabilities that it believes e_1 has would disallow e_1 from being in the place that e_2 is currently being encountered. If so e_1 and e_2 refer to different objects. At this point, A should consider if the possible range of e_1 is larger than an environment specific constant ("it could be almost anywhere by now"). If so, then *A* cannot decide with certainty if e_1 and e_2 refer to the same object. Otherwise *A* should decide if e_1 and e_2 are coreferential given that only a short distance could be traveled.

When there is only a short possible distance to travel, the agent can now make the closed world assumption. Since an object moves at a constant speed, any other object that might be mistaken for the object being identified will also move at the same speed, and thus be restricted to a small travel distance of its own. So *A* now checks to see if it knows of any other PIOs except for e_1 and e_2 that could reach the place where e_2 is now. If not, then it assumes that e_1 and e_2 are coreferential. Otherwise, if e_1 was headed toward the place e_2 is now seen but no other PIOs were, then *A* assumes that e_1 and e_2 are coreferential. If there is another PIO headed in the same direction, *A* can't be sure if e_1 and e_2 are coreferential. If none of the above cases hold, the agent will assume that e_1 and e_2 are not coreferential.

Conclusions and Future Work

We have presented a cognitively plausible computational method of identifying PIOs. We are currently implementing this algorithm in a simulated robot(Santore & Shapiro 2003). The simulated robot will then be tested on the same tasks as the human subjects to gauge the performance of the algorithm.

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