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A New Framework for Cognitive/Perceptual Problems

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Introduction

There are a variety of real-world domains where "analysis" of incrementally arriving perceptual input requires the simultaneous solution of a set of hard problems. We claim that basically the same set of interacting problems appears in each of these domains. While people can solve the problems in each of these domains, no automated system is close to solving the full set of interacting problems in any of these domains. The purpose of this paper is to state the set of interacting problems that needs to be solved, and present a cognitively motivated framework in which a solution is possible. Our interest is in a solution to the full set of interacting problems. We are not interested in modeling a particular statistical correlation in a data set that appears under certain conditions. An automated solution would be best, but a man-in-the-loop solution that greatly increases a person's efficiency an/or accuracy would also be acceptable.

The primary domain discussed here is understanding the situation in an image or a sequence of images. The problems and their interactions are shown in Table 1. Solving the situation understanding problem involves much of the brain, so a simple neural network is not a viable approach. What is required is a framework that specifies the process by which a person combines a priori knowledge with the observed evidence. Most of the separate functional capabilities called for in our proposed framework exist already, which give us some confidence that an implementation of the framework can be constructed.

TABLE 1 -- Problem Space Characteristics

Hard Problems	Cause of Problem	Result of Problem	Example	Problem Interactions
Segmenting regions in an image	Distinct objects may have similar statistics in many dimensions	Boundaries between objects may be missed or false boundaries	Walking stick is hard to separate from wood unless it moves.	Object ID & predicate correlation
Distinguishing between situations given only intensity distribution	A large number of objects and arrangements may be consistent with a top-level description of a situation	Knowing a situation is not enough to predict intensity distributions	Knowing the situation is a baseball game does not mean that players are on the field	All but predicting the future
Predicting the future	Situation awareness must be built up through a search sequence	Missed threats and false alerts	Not predicting an aircraft out of commercial lanes could be a weapon.	All
Object identification	Partial info is all that is available in the real world	Occlusion, lighting, or pose can make objects indistinguishable	Misidentify car as a truck	
Predicate Correlation	Situations may be described in a variety of ways	May not recognize different descriptions of the same image	Person over the water vs. person in a boat	
Finding signal in noise and clutter	Many regions in natural images. Pose and lighting make different objects look similar	Finding a particular object is hard even if objects are already separated	Where is Waldo problem	Segmentation (at leastfor clutter)

A Framework for Visual Situation Assessment

The following set of assumptions underlies our proposed framework:

1. Analysis emerges incrementally from cycles of situation understanding
2. Situation understanding has 3 components:
   - A internal map specifying the relative positions of entities potentially important in the situation
   - A consistent story about how the situation reached the current state
   - A subset of an ontology relevant to the situation
3. A situation understanding cycle consists of the following steps:
   - Situation-sensitive segmentation or search for groupings of evidence that hang together
   - Matching groupings to local patterns (activities based on plans without contingencies)
   - Update/refinement of situation story and map based on global pattern (e.g., MPT) or case matching
4. The a priori knowledge needed to update or refine situation understanding
5. People use a similar approach to understanding situations in all domain with these problems

While the neurological substrate and techniques that people employ in doing object recognition, have been the subject of extensive research,. situation understanding has not. Our choices in assembling a situation understanding framework must therefore rely on anecdotal evidence.

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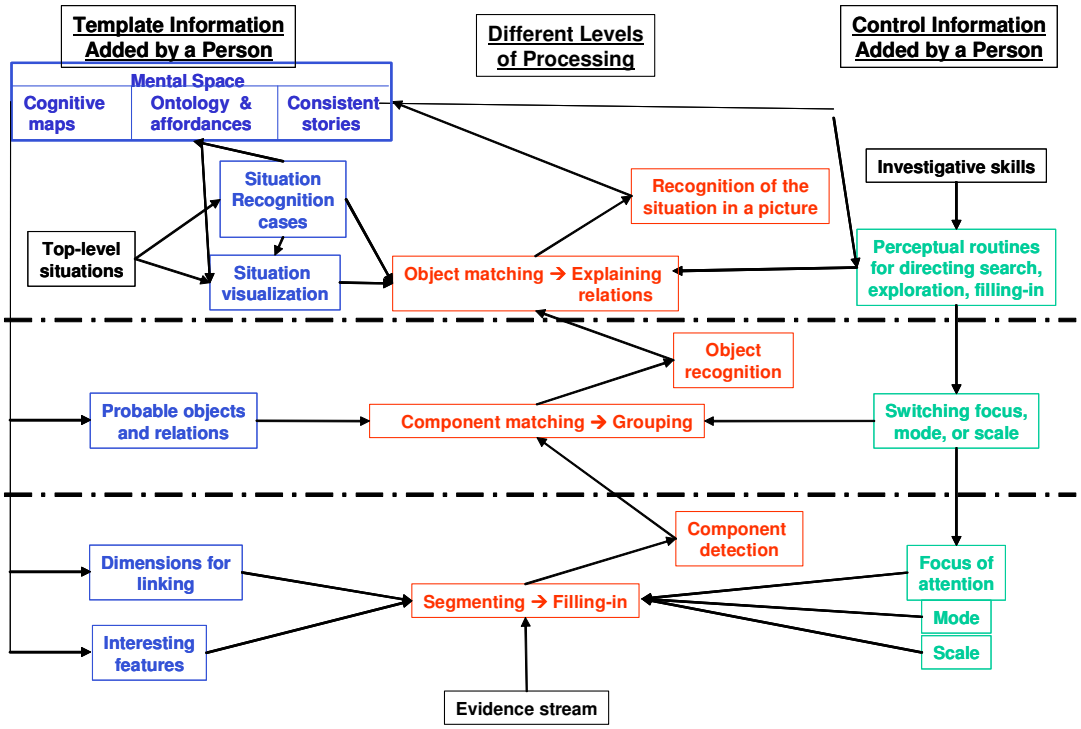

Figure 2: A Model of Cognitive Process Leading to Recognition of the Situation in a Picture

Support for various assumptions in the framework comes from multiple sources. Evidence for a primary role for situation understanding in human vision is that people are not particularly good at recognizing even familiar objects in unfamiliar contexts. For example, *Puzzle* magazine features a section on identifying common objects in real images taken at unusual scales. Looking at the routines that a person employs to visually find and utilize things shows that they have knowledge about what they are likely to see, about what these objects look like in the current context, and what characteristics of the imagery are important when segmenting objects. These types of knowledge must be learned to operate in a new context.

Recently, researchers Upada, Saha, and Lotufo (2002) have found the context-sensitive segmentation techniques work in hard real-world domains that have resisted generic techniques for many years.

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