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The Cognitive-agent Approach to Spatial Data Processing

In the computer and data sciences we typically collect, represent, formalize, and store all the spatial information about the environment that might be needed later for further processing. When the knowledge base is set up we can utilize and process the knowledge in powerful big-data computing environments. This approach is praised as the 'digital twin' approach, in which features and properties of the world are made explicit for computational processing. We aim at recording and representing all knowledge about all aspects of the world in all granularities—a never ending enterprise.

For their personal purposes, cognitive agents such as humans and other animals take a different approach: rather than producing a copy of all aspects of the world, we memorize comparatively few key facts and events and employ the environment itself as our knowledge base (Don Norman called this "the knowledge in the world"). We harvest that knowledge on demand, as needed. To this end, we take our sensors and our relatively slow processing unit *brain* directly to the spatial environment and selectively collect and process just the information that we need for solving a given problem in the specific context that we are engaged in. To do this in a goal-directed fashion, we develop methods for dealing with spatial environments in a smart way.

For example, when we need to know whether some object is hidden behind a given tree, we typically cannot expect to find this information in a formal knowledge base; therefore, we need ways to find out in the world. We have a variety of sensors for vision, sound, smell, etc. and we can move parts of our body or the entire body. But there are many ways to act, move, and perceive in space, most of which will not help us solve our problem. For example, we may move towards the tree to get a better sight—but in fact, this will enhance the hiding feature of the tree for our vision and thus will not help. We may move away from the tree; this might help disclose an object behind the tree as it diminishes the tree's hiding effect; but there is the trade-off of a greater distance to the potential hidden object that diminishes its perceivability. We could move up or down with not much change in perceivability; or we can move sideways which may have the best effects towards solving our problem.

Among others, it is such types of knowledge about spatial environments, about actions we can take in space, and about effects we can expect from such actions that make us experts for dealing with space in space [cf. Freksa, 2015].

The cognitive-agent approach has numerous advantages for spatial problem solving in certain problem configurations. First of all, we do not require a digital twin. Second, we do not need to understand environments to the same extent as is necessary for formalizing spatial relations and their interdependencies in the world. Third, we benefit from cognitive off-loading. Fourth, we do not need to reason about the world in the same way we have to do based on explicit knowledge; we can make use of affordances and other knowledge implicit in the world, instead. Fifth, we do not need to specify the context in which we solve a problem. In sum: For many everyday problems it is sufficient to have partial knowledge about actions and their effects to select suitable actions for solving spatial problems.

Up to now, we were not able to utilize the cognitive-agent approach for technical solutions to spatial problems, as we did not have the necessary action and perception capabilities to extract knowledge from the world just in time. However, this situation will be changing rapidly. In recent years, we have been experiencing tremendous improvements in robotic capabilities; as a consequence, deploying sensors in the world autonomously and intelligently will be within reach soon. Also, sensor technology has developed rapidly; as a consequence, we now have sensors for vast amounts of modalities that may be detected in the environment.

What we need to exploit future autonomous agents' capabilities is to equip them with a general sense of space. This sense of space will require abilities to relate spatial actions and perceptions to spatial effects in order to control actions and perceptions in a smart way. The cognitive-agent approach to spatial data processing may not only be relevant for artificial autonomous agents; it also may be of use for the acquisition of Volunteered Geographic Information.

My team has been exploring a variety of examples of spatial problem solving using the cognitive-agent approach [e.g., Freksa et al., 2019]; for some of our solutions we have developed software simulations.

References

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