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Building the pyramid of awareness

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Awareness for computerized systems is possible by chaining functions in a control loop that monitors sensors, recognizes objects, predicts problems and, ultimately, learns.

Our common notion of awareness includes perception, recognition, thinking, and prediction. In order to exhibit artificial intelligence (AI), computerized machines, too, require a form of awareness, one by which we can transfer knowledge to them, enabling them to exhibit intelligence.

Artificial awareness entails much more than computerized knowledge, however. It must also incorporate means by which an AI can perceive events and gather data about its external and internal worlds. Therefore, to exhibit awareness, intelligent systems must sense and analyze components as well as the environment in which they operate. Determining the state of each component and its status relative to performance standards, or service-level objectives, is therefore vital for an aware system. Such systems should be able to notice changes, understand their implications, and apply both pattern analysis and pattern recognition to determine normal and abnormal states. In other words, awareness is conceptually a product of representing, processing, and monitoring knowledge.

We can divide awareness into two major classes: self-awareness concerning the internal world and context awareness regarding the external world. We can imagine other intriguing classes as well, such as situation awareness or classes that draw our attention to specific problems, including operational conditions (operation awareness), control processes (control awareness), interaction processes (interaction awareness) and navigation processes (navigation awareness). Although awareness classes may differ with respect to subject, they all require perception of events and data from the subjective context "within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future."[1]

The mechanism of awareness might be built using a complex chain of functions that pipelines processes over raw-data gathering (facts, measures, events, etc.), passing, filtering, conversion, assessment, projection and eventual learning. We call this mechanism the Pyramid of Awareness (see Figure 1). Each pyramid

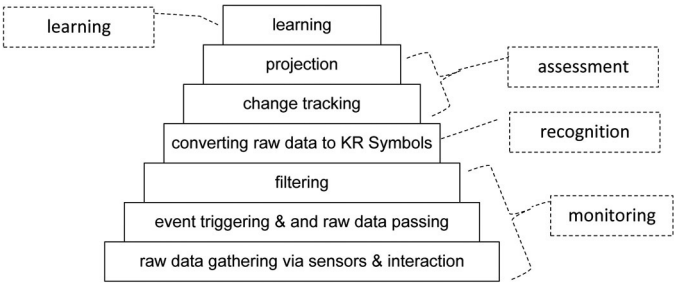

Figure 1. *The Pyramid of Awareness.*

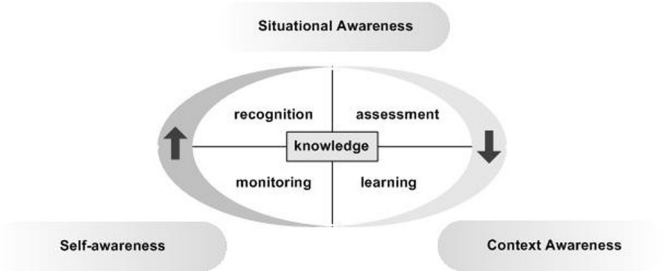

Figure 2. *Awareness control loop*[3].

level consists of a set of awareness functions that falls into one of four task categories: monitoring, recognition, assessment or learning. Aggregation can enter the process as a subtask at any function level to improve overall awareness performance, such as by aggregating large amounts of sensory data prior to processing or by improving classification to aid recognition functions.

The four awareness function groups require a comprehensive and well-structured knowledge base (KB) that represents knowledge about the system itself and the environment in knowledge-representation (KR) symbols.[2] Grouped together, these functions form a special awareness control loop in which various classes of awareness may emerge (see Figure 2).

To elaborate, the awareness function groups consist of the following functions: monitoring, recognition, assessment and learning. Monitoring collects, aggregates, filters, manages, and reports internal and external details, such as metrics and topologies gathered from the system's internal entities and context.

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Recognition uses knowledge structures and data patterns to aggregate and convert raw data into knowledge symbols. Assessment tracks changes and determines points of interest, generates hypotheses about situations involving these points, and recognizes situational patterns. Learning generates new situational patterns and maintains a history of property changes.

Awareness can be regarded as a complex product with several levels of exhibition and, eventually, degrees of awareness. These awareness levels might be related to data readability and reliability, i.e., the system could encounter noisy data that requires cleanup and eventual interpretation with some degree of probability. Other levels of awareness-exhibition might include early awareness, a product of one or two passes of the awareness control loop, and late awareness, capable of more mature conclusions and projections.

An efficient system would rely on early awareness in situations that require a quick reaction and call on late awareness for circumstances that call for more precise thinking. Awareness must support learning, both as part of the cognitive process and as the basic mechanism for introducing new facts into the system (the alternative to having a human operator add new facts to the KB). An efficient awareness mechanism should thus rely on both past experience and new knowledge learned by the system.

If we think of an example with exploration robots, we may think of navigation awareness, which requires context-relative plots of position so that the system can infer robot speed and direction. With this in mind, landmarks should be represented as part of the KB, and the navigation awareness mechanism should use KB symbols to build a special 'navigation map' on the fly at the beginning of a navigation process. At intervals, navigation awareness reads sensor data from cameras and plots the robot's position, thereby establishing its course and land-reference speed.

Self-aware systems becoming capable of self-adaptation and learning is the road to AI. It is in this field that the long-term impact of awareness-related research and development will be felt.

Machine intelligence depends on the ability to perceive the internal and external environment and react to changes. The Pyramid of Awareness and the associated awareness control loop together provide a chain of special functions by which an aware system can take raw sensor data and, from it, recognize objects, project situations, track changes, and learn new facts. This awareness may manifest at different levels of maturity and relevance due to various factors, such as noisy data or the number of iterations in the control loop. Ideally, the approach I've outlined will help an intelligent system behave like a human, progressively realizing, and reacting to, situations and changes. In humans, a first impression can trigger a reaction, but that reaction might shift as that person's understanding of the situation changes. Likewise, an AI using the Pyramid of Awareness might change a reaction born of early awareness if its progressive realization of the situation indicates that it should.

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References

1. M. R. Endsley, *Toward a theory of situation awareness in dynamic systems*, **Human Factors 37** (1), pp. 32–64, 1995.
2. E. Vassev and M. Hinchey, *Knowledge representation and reasoning for intelligent software systems*, **IEEE Computer 44** (8), pp. 96–99, August 2011.
3. E. Vassev and M. Hinchey, *The challenge of developing autonomic systems*, **IEEE Computer 43** (12), pp. 93–96, December 2010.