The Concept of Intuition in Artificial Intelligence

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DISCUSSION: current developments in the implementation of human intuitive processes in artificial intelligence (AI) based on the review of literature.

The concept of intuition has been discussed in various fields of cognitive science – psychology, philosophy, economics, and artificial intelligence, however, it remains an under-researched area. The existing theories and models offer some worthy explanations of the phenomenon but lack methodology for its practical implementation. The research on intuition based methods in artificial intelligence and machine learning has encountered both conceptual and practical difficulties. In particular, implementation problems are due to the fact that mental intuitive processes do not yield to straightforward explanations in terms of mathematical representation. Moreover, the concept of intuition as such has not been studied sufficiently in other fields of cognitive science.

The Concept of Intuition

There is no consensus among scholars about the definition of the concept. Until recently, intuition did not yield to rigorous scientific methods of study and, often associated with mysticism, has been habitually avoided by researchers. So far, the discourse on the subject has lacked coherence and method. Opinions have been cited stating that a comprehensive definition of intuition is not possible (Hodgkinson, Langan-Fox, Sadler-Smith, 2008) due to the range of properties of the concept.

The definitions of intuition[1] vary, but all have the following features in common: unconscious, non-rational, quick. For example, Jung understood intuition as perception via the unconscious (Jung, 1921). Damasio referred to it as ”…the mysterious mechanism by which we arrive at a solution of a problem without reasoning toward it” (Damasio, 1994, p. 188). Dane and Pratt (2007) defined intuition as “affectively-charged judgments that arise through rapid, non-conscious, and holistic associations” (p. 40). With the advance of computer science, the definitions of intuition have gained such elements as information processing, pattern recognition, and pattern-matching.

There seems to be an agreement in the cognitive scientific community about the unconscious foundation of intuition, as well as its evolutionary adaptive nature. For example, Myers (2002) described intuition as an “ancient biological wisdom” (p. 33) that evolved to

[1] The etymology of the word itself can be traced to Latin *intuire* meaning “knowing from within” (Merriam-Webster Dictionary).

protect human beings facing potentially dangerous novel situations. Thus, this evolutionary device had to develop as a quick, automatic, and holistic trigger for a reliable, survival benefiting response.

Gigerenzer (2007) considered intuition a powerful decision-making tool and emphasized that this unconscious mental process used rules which, unlike rational analysis, did not include the evaluation of all possible factors but only of the most useful ones for the problem at hand. He believes that the so called gut feelings do result in valid practical decisions and serve as underpinnings of moral decisions.

Lately, the role of the emotional component in intuition has been recognized. In the words of Kahneman (2011) "… emotion now looms much larger in our understanding of intuitive judgments…" (p. 55). Studies by Damasio (1999) confirm the importance of affect in intuitive decisionmaking. In the area of AI, Morgado and Gaspar (2008) acknowledged emotion as a relevant aspect for embodied virtual agents and proposed a biologically inspired model for agent emotional characterization.

The evolutionary and unconscious aspects of the concept of intuition led some scientists to refer to it as *adaptive unconscious* (not to be confused with Freudian unconscious), which is understood as a processing system inaccessible to conscious awareness and older than the conscious mind (Wilson & Bar-Anan, 2008).

Empirical evidence of intuition as a distinct mental processing has been studied in various spheres of human activity, from chess players to fire-fighters to intensive-care nurses (Klein 1998; Benner & Tanner, 1996). The studies ascertain that professionals use intuition to make appropriate decisions in the situations that require an urgent decision to act. Interestingly enough, it has been noted that people confronting danger and feeling huge responsibility do not even consider alternatives to their intuitive decisions.

Intuition and AI

Computerization of human-like intuitive processes has been problematic so far. The main challenge is the issue that intuition is driven by non-logical reasoning, while most of the AI models are logic governed.

Some scholars do not believe that such intrinsically human ability as intuition can be ever implemented in artificial intelligent agents. For example, Dreyfus insisted that "Human beings have an intuitive intelligence that 'reasoning' machines simply cannot match" (Dreyfus & Dreyfus, 1986); in Roger Penrose's opinion (1989) the mind could never be algorithmic; and John Searle (1990) maintained that "programs are neither constitutive of nor sufficient for minds." Yet, other thinkers are more optimistic about the possibility of cybernation of human-like intuitive processes. Marvin Minsky believed that computers will do the things humans are programmed to do and Newell and Simon envisioned that properly programmed machines could do anything that an intelligent person could do (cited in Dreyfus & Dreyfus, 1986).

Theories and Models of Implementation of Intuitive Processes in AI

The current efforts to implement intuition-based processes in AI are based on several theories formulated along the development of computer technology. Herbert Simon provided a seminal explanation of the commonality between human and artificial intelligence with his statement that both humans and computers use search-like processes that lead to sudden recognition of underlying patterns (1987). He endorsed the Bounded Rationality concept that human computational abilities and memory have limitations in regards to the ongoing information from the environment and believed that intuition extended human abilities (cited in Frantz, 2003).[2] Simon defined intuition as an unconscious information processing that by-passes orderly sequential analysis, is fast, based on experience, and leads to unconscious pattern recognition. However, he did not believe that intuition operated independently of analysis, but "…rather the two processes are essential complementary components of effective decision-making systems'' (Simon & Gilmartin, 1973, p. 33). Within the framework of artificial intelligence, he considered Intuitive Rationality to be a subset of Bounded Rationality and intuition a rational, albeit unconscious, analytical method of decision making (Simon, 1987). Simon's theories of Expertise and Intuition include the chunking theory which postulates that experts' knowledge that supports their intuition is composed of information chunks (Chase and Simon, 1973).

Dreyfus agreed with Simon's view that intuition played a defining role in expertise but disagreed with the computational approach to it. In his theory of experts' intuition Dreyfus declared that humans did not use symbols, but perceived their environment and made decisions using holistic processes. According to Dreyfus, the holistic nature of intuitive processing made it incompatible with AI because human cognition is embodied, situated, and experiential (1986).

[2] Interestingly, Damasio (1999), while confirming the duality, believes that it is "…the conscious component [that] extends the reach and efficacy of the nonconscious system" (p. 302); which is consistent with the notion that the nonconscious system is evolutionary older.

Gary Klein (1998) proposed the idea of intuitive pattern-matching in his Recognition Primed Decision Model (RPD). According to this model, the intuition of experts originates in the ability to perceive salient environmental cues and instantly match them to familiar patterns. The situation matching is followed by the evaluation of its result, which may involve another quick pattern-matching cycle, and further by simulation of chosen action through imagination; thus, the decision is reached when the simulation results coincide with the desired outcome.

More recent theories offer other approaches, perhaps more suitable to modeling of human intuitive processes. Cobet & Chassy (2009) presented a new theory of intuition - the Template Theory - based on the chunking theory, which explained the intuitive expert behavior as a result of the usage of mental templates that encode information representatively and make for rapid pattern recognition. This theory stresses the interaction between perception, attention, learning, and emotion. The authors concluded that, while aspects of expert intuition can be holistic, the mechanisms that lead to them are local.

Presently, the view of the human brain as a parallel processor seems to dominate the understanding of mental processes and this view is reflected in the Dual-Process theories which represent the most fitting to date theoretical foundation for cybernation of human intuition.

One of the first example of dual-process theories is the cognitive-experiential self-theory (CEST) developed by Epstein and his colleagues. It reflects the view that human cognition has two parallel interactive modes of information processing: the rational and the experiential. The first mode works at the conscious level, is analytic, verbal and relatively affect-free; it obtains information intentionally through analyses. The second mode works automatically, at the pre-conscious level and is mostly non-verbal (Epstein et al., 1996). The two modes are in seamless interaction and produce action; however, they can sometimes clash resulting in a conflict between “the heart and the head” (Epstein, 2000, p. 671).

A comparable distinction between two basic systems of human brain information processing - automatic (intuitive) and effortful (logical) systems - was proposed by Stanovich and West (2000) who described them as System 1 and System 2 processes respectively.

In his recent book *Thinking, fast and slow* Kahneman (2011) offers the following explanation of the functioning of these systems. Intuitive System 1 operates automatically and quickly, with little or no effort and no sense of voluntary control. System 2 uses the effortful mental activities, including complex computation. System 1 processes context, associations and uses heuristics, while System 2 depends on agency, deliberate attention, and choice. The important difference between the two systems consists in their consumption of cognitive resources - System 1 is much more economical.

Kahneman asserts that the minimization of effort and optimization of performance is precisely the goal of such division of labor between the two systems. The interplay between the two systems was empirically validated by Damasio (1999) who stated that "… the unconscious system is deeply interwoven with the conscious reasoning system such that the disruption of the former leads to an impairment of the latter" (p.302).

The principles of the Dual-Process theories are consistent with the empirical evidence of the brain's ability to carry out multiple cognitive operations simultaneously. Epstein (1996) suggested that the intuitive and analytic processing systems are highly interactive but are served by separate cognitive systems in the brain.

This assertion is supported by the neuroimaging studies by Lieberman and his colleagues (2004). Their research indicated that the intuitive (phylogenetically older) system operates on parallel processing and is fast operating, slow learning and spontaneous. The authors identified its neural correlates located in the structures of the basal ganglia, ventromedial prefrontal cortex, nucleus accumbens, amygdala and lateral temporal cortex. The analytic (phylogenetically younger) system is based on serial processing, and is slow operating, fast learning and intentional; its corresponding brain structures are thought to be in the lateral prefrontal cortex, posterior parietal cortex, and hippocampus along with surrounding medial temporal lobe structures. This research raises the expectation that the growing understanding of biological neural networks will inspire viable models of artificial neural networks.

One of the most recent models of the implementation of human intuition was offered by Dundas and Chik (2011) whose stated purpose was "to simulate intuition for quickly obtaining accurate results for a given dataset" (p. 3). The intuition-based process model is described as using a holistic approach and is based on mapping and pattern recognition. The model uses the principles of connectivity and unknown entities. The model relational mappings between experience elements and the attributes of these elements allow cross-reference of far-spaced associations. The authors consider the following sets for explaining the model: Problem Set at time ***t*** and Experience Set at time ***t***.

The Problem Set element can be a representation of a question, for example, "What is the expected GPA score that I'll get this semester?" The Experience Set represents the vast knowledge in the brain or database; all values are mapped as elements of stored knowledge and each element represents a **past** value; for example, "Last year's GPA was 4.0." The sets are dynamic and can change values of any type, dimension, or value. The model represents them in static elements as a simple representation of the current problem. The correctness of the solution depends on the mapping of the correct element of the past experience.

To solve the problem at hand, the agent would go through the following steps (see diagram in Appendix 1):

- obtain an element from the Problem Set
- obtain an element from the Experience Set based on mapping
- obtain the importance, priority of the processes
- obtain the secondary thought processes
- apply the adjustment factor on all the considered processes
- calculate the final answer
- check for any external influences that change the values
- present the answer to the user after the final adjustments

After testing their model, the authors concluded that intuition process cannot be a "replacement for the logic-based methods, but it can be a necessary addition to the current approaches in the field of problem solving and artificial general intelligence" (Dundas and Chik, 2011, p. 11).

In other words, the authors have managed to model intuition only as a supporting part of a logic-based model that processes all the steps in a sequential manner. Undoutedly, the model is a step forward toward finding a way to implement human intuition in AI, however, it does not emulate human experience of instant unconscious decisionmaking.

Challenges

The models described above reflect the difficulties of the computerization of the human brain's intuitive processes. The problems can be divided into two major sets – concept related and application related. The concept of human intuition is still not fully understood and defined. Such assumptions as the brain processing information in discrete operations according to formal rules have not been validated by empirical evidence. The argument about holistic or symbolic mental processing has been inconclusive. Nor has the possibility of formalizing all knowledge been established.

In the area of AI applications the main problem is failure to explain intuition in terms of mathematical representation because of the non-logical process of intuition. Logic-based processes need a large search space and many calculation steps, which makes them rather slow, while human intuition copes with the time constraint in real life situations in milliseconds. For example, the Watson supercomputer, using the *DeepQA/UIMA* algorithms, can extract a correct answer to a query in less than 3 seconds, which is still slower than an estimated 20-millisecond human intuitive reaction.

Other problematic issues include the unclear possibility of the world representation by independent symbols. Sub-symbolic approaches to cybernation of mental activity have been created in general but not developed for implementation of intuition. Testing the models of human intuition has shown that current algorithms cannot obtain optimal results comparable to human intuition.

Perhaps, the most difficult issue in AI applications is the unconscious quality of human intuition, especially the unconscious perception of cues that trigger the intuitive process under the conditions of time pressure and high stakes of the situation at hand. The cues hidden from the conscious mind can hardly be identified and much less mathematically represented and introduced into the intelligent agent's dataset. Another problem is creating a vast, comprehensive data representing accumulated human experience. This difficulty is due the infinity of human experiences and the problem of separation between individual and collective experience. Even if the mapping of the correct elements of all past experience were attainable, a model would still fail to encompass situations where the human mind produces optimal intuitive solutions in the domains where it does not have any experience.

The future research has a difficult task of studying each of the elements of the work done so effortlessly by human adaptive unconscious: "…sizing up the world, warning people of danger, setting goals, and initiating action in a sophisticated and efficient manner" (Wilson, 2008).

Conclusion

While considerable progress has been made in the implementation of human intuitive processes in AI, the task of translating into machine language the human evolutionary and innate ability to instantaneously perceive, process, and act upon demanding situations continues to be difficult. Despite the development of computational neuroscience, the capacity of the existing supercomputers and models to imitate human intuition remains limited. Future research needs to address both conceptual and practical aspects of the problem. Because of its multidisciplinary complexity, the problem should be addressed from the perspectives of different, mutually informing areas of cognitive science.

Appendix 1

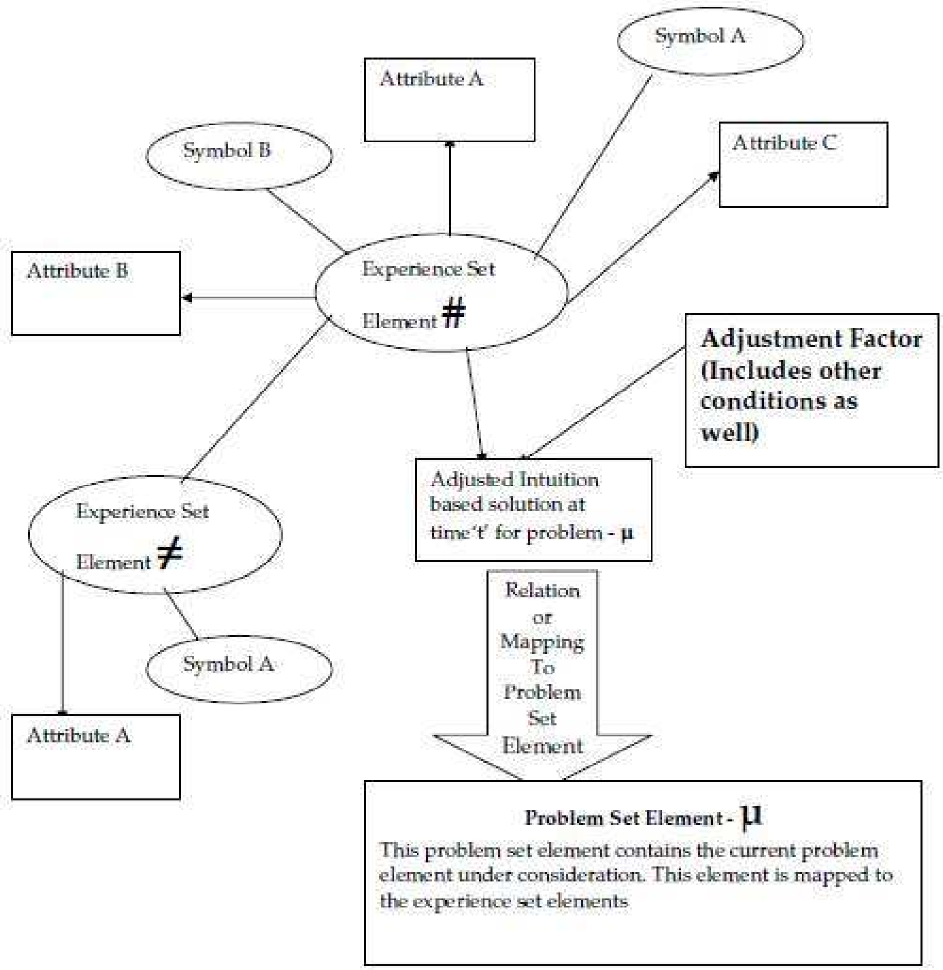

Figure 1. The intuition based process model. The space of intuition contains relational mappings between experience set elements and their associated attributes. The experience set element # is related to experience set element ≠. Note the values are taken and then adjusted against time and error handling to get the final value.

Source: Dundas, J. & Chik, D. (2011). *Implementing human-like intuition mechanism in artificial intelligence*.

References

Benner, P., & Tanner, C. (1987). Clinical judgment: How expert nurses use intuition. *American Journal of Nursing*, 87(1), 23–31. Retrieved from CINAHL database www.cinahl.com/cgi-bin/refsvc?jid=112&accno=1987060588

Chase, W. G., & Simon, H. A. (1973). *The mind's eye in chess*. In W. G. Chase (Ed.), Visual information processing (pp. 215–281). New York: Academic Press.

Damasio, A. (1994). *Descartes' error: Emotion, reason, and the human brain.* New York, NY: G.P. Putnam's Sons.

Damasio, A. R. (1999). *The feeling of what happens: Body, emotion and the making of consciousness.* London: Vintage.

Dane, E., & Pratt, M. G. (2007). Exploring intuition and its role in managerial decision making. *Academy of Management Review*, 32(1), 33-54. doi:10.5465/AMR.2007.23463682

Dreyfus, H., & Dreyfus, S. (1986). Why computers may never think like people. *Technology Review*, 89, p. 42. Retrieved from http://go.galegroup.com.ezproxy.umuc.edu/ps/i.do?id=GALE%7CA4080941&v=2.1&u=umd_umuc&it=r&p=CDB&sw=w

Dundas, J., & Chik, D. (2011). *Implementing human-like intuition mechanism in artificial intelligence*. Retrieved from www.arXiv:1106.5917v1

Epstein, S., Pacini, R., Denes-Raj, V., & Heier, H. (1996). Individual differences in intuitive-experiential and analytical-rational thinking styles. *Journal of Personality and Social Psychology*, 71, 390–405. doi:10.1037/0022-3514.71.2.390

Epstein, S. (2000). The rationality debate from the perspective of cognitive-experiential self theory. *Behavioral and Brain Sciences*, 23(5), 671-682. Retrieved from http://journals.cambridge.org

Frantz, R. (2003). Herbert Simon: Artificial intelligence as a framework for understanding intuition. *Journal of Economic Psychology,* 24, 265–277. doi:10.1016/S0167-4870(02)00207-6

Gigerenzer, G. (2007). *Gut Feelings: The Intelligence of the Unconscious.* New York, NY: Viking Press.

Gobet, F., & Chassy, P. (2009). Expertise and Intuition: A Tale of Three Theories. *Minds & Machines* 19,151–180. doi:10.1007/s11023-008-9131-5

Hodgkinson, G. P., Langan-Fox, J., & Sadler-Smith, E. (2008). Intuition: A fundamental bridging construct in the behavioural sciences. The British Journal of Psychology, 99(1), 1-27. doi:10.1348/000712607X216666

Jung C. G. (1921). *Psychological Types*. Retrieved from http://psychclassics.yorku.ca/Jung/types.htm

Kahneman, D. (2011). *Thinking, fast and slow*. New York: Farrar, Straus & Giroux.

Klein, G. (1998). *Sources of power: How people make decisions*. Cambridge, MA: MIT Press.

Lieberman, M. D., Jarcho, J. M., & Satpute, A. B. (2004). Evidence-based and intuition-based self knowledge: An fMRI study. *Journal of Personality and Social Psychology*, 87, 421–435. doi:10.1037/0022-3514.87.4.421

Morgado, L., & Gaspar, G. (2008). Towards background emotion modeling for embodied virtual agents. Proceedings of the Seventh International Conference on Autonomous Agents and Multiagent Systems, Portugal. http://www.ifaamas.org/AAMAS/aamas08/

Myers, D. G. (2002). *Intuition: Its powers and perils*. New Haven and London: Yale University Press.

Penrose, R. (1989). *The emperor's new mind*. Oxford, UK: Oxford University Press.

Searle, J. (1990). Is the Brain's Mind a Computer Program? *Scientific American,* 262(1), 26–31. Retrieved from MasterFILE Premier Database.

Simon, H. (1987). Making management decisions: The role of intuition and emotion. In W. Agor (Ed.), *Intuition in organizations* (pp. 23–39). London: Sage.

Simon, H., & Gilmartin, K. (1973). A simulation of memory for chess positions. *Cognitive Psychology*, 5(1), 29–46. doi:10.1016/0010-0285(73)90024-8

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioral and Brain Sciences*, 23(5), 645–726. Retrieved from http://journals.cambridge.org

Wilson, T., & Bar-Anan, Y. (2008). The unseen Mind. *Science,* 321(5892), 1046-1047. doi:10.1126/science.1163029

Wilson, T. (2003). Knowing when to ask: Introspection and the adaptive unconscious. *Journal of Consciousness Studies,* 10(9-10), 131-140.