Is Adaptivity a Core Property of Intelligent Systems? It Depends

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***Abstract*—Autonomous systems rely upon intelligence to enable them to function without the need for human intervention. In many cases, these systems must *adapt* to properly react to numerous scenarios. This adaptivity could be a simple action such as activating an additional server, or could be incredibly complex in creating a completely new adaptation strategy. In the following work, we address the question "Is Adaptability a Core Property of Intelligent Systems?" We determine that due to the ambiguity of the term 'intelligent system' and the wide range of such systems, that there is no clear and definitive answer to this question. This paper details the deliberation of three AI/Self-Adaptive researchers in addressing this question. We use several scenarios of intelligent systems ranging from a simple motion detector to a complex 'humanoid' futuristic artificial system to demonstrate the complexity of this question.**

I. Introduction

From smart thermostats to self-driving cars, AI is changing our world. It is imperative for many of these systems to have the capability of adapting to innumerable internal and external events in order to remain resilient and accomplish system goals. For example, a self-driving car will encounter a nearly infinite number of possibilities and scenarios that it must properly react to. Imperfect or inappropriate decisions by the vehicle could lead to catastrophic failures, even resulting in the loss of human life. However, many 'intelligent' systems are far more elementary and mundane. For example, a motion detector in a classroom that activates the lights when a person enters the room has a limited number of possible options and actions, with a failure leading to very little negative consequences. Any significant amount of complexity or robust adaptability that is built into a basic system such as this would likely be impractical and lead to wasted resources.

In the following work, we detail the deliberation of three AI/Self-adaptive systems researchers in answering the question "Is adaptivity a core property of intelligent systems?" While at a topical level, this question may seem simple, we determined that it is far more complex, with even many of the fundamental terms in this area being debatable.

We began by first discussing what an 'intelligent' system was, which is a definition that we could not come to a consensus upon. We looked up the definition of intelligence, which we found stated as "the ability to learn or understand or to deal with new or trying situations[1]". We next examined definitions of intelligence and intelligent systems from existing research. In 1961 Ross stated that an intelligent system is anything which achieves appropriate selection [1]. More recent works have expressed a difficulty in creating a definitive definition for what 'intelligent' systems are, discussing how it can be an ambiguous and subjective term [3]. Additionally, some works state that intelligence and adaptation are not interchangeable or synonymous terms. Piaget *et al.* [5] explicitly separates intelligence from adaptation. In his view, adaptation might be achieved by a complicated process, "its spatiotemporal articulations are welded into a unique whole with no independent or separable parts". Contrary to that, intelligence "involves a certain number of paths (in space and time) which can be both isolated and synthesized". Furthermore, Kanazawa *et al.* [4] distinguishes between 'general-intelligence' and 'domain-specific adaptation' where intelligence is not the process of solving problems based on past experience (which comes from adaptation), but rather the process of solving new problems without direct prior knowledge or experience of them.

Based on these definitions and previous works, two of the authors felt that a simple reactive system such as a motion detector could be intelligent since it acquired knowledge about possible motion activities in the room, and applied these to activate/deactivate the lights. One author felt that systems that are entirely pre-programmed and do not modify their state or behavior should not be classified as intelligent. However, many in the machine learning community would likely denote a pre-trained neural network as intelligent, even if this kind of static computational method is technically no different than `if` statements controlling a smart thermometer except in terms of scale (*i.e.,* more mathematical operations).

Due to this complexity and ambiguity of what an 'intelligent system could even be deemed to be', we determined that that there is no conclusive answer to the question of if adaptability is a core principle of intelligent systems. The authors felt that leaving the definition of intelligence up to complexity seemed problematic – because it is not really feasible to draw a line between intelligent and non-intelligent (*e.g.,*, a neural network with 999 neurons is unintelligent, but a neural network with 1,000 neurons *is* intelligent). Lastly, it was noted that some systems which may at least claim to be complex (*e.g.,* an autopilot or automated power plant management system) may have explicit requirements to be non-deterministic and non-adaptable due to regulatory concerns. For example, in order for aircraft components to be certified for use, they cannot have non-deterministic components.

[1]https://www.merriam-webster.com/dictionary/intelligence

II. Intelligent System Categorization

We categorized potential intelligent systems into: (I) *static intelligent systems*: those which do not modify their internal state or behavior, (II) *adaptive intelligent systems*: those which do modify their internal state in response to external input, and (III) *next generation intelligent systems*: those which modify both their state and behavior based on external input. In following sections, we detail several scenarios that illustrate the complexity of these different types of "intelligent" systems as a means to get closer to what really is a core property of an intelligent system. Some of these examples demonstrate that adaptivity is an essential component of an intelligence system, and other examples where it is of little importance.

A. Basic Motion Detection Automatic Lighting System

We will use a simple motion detection system as an example of a very basic intelligent system. This automatic lighting motion detection system activates the lights in a room when its sensors detect motion, and turns off the lights when motion has not be detected for a determined amount of time. We debated if this was truly an intelligent system due to its simplicity, with us essentially agreeing to disagree. According to our previously defined definition of intelligence, one could argue that it acquires the information of if a user was in a room, and applies this knowledge to turn a light on/off; therefore making this an example of an intelligent system. In such a system, adaptability would be of little importance due to the limited actions the system could perform. Therefore, we determined that in a basic intelligent system such as this, adaptivity would not be a core property of this system.

B. Adaptive Intelligent System

Adaptive intelligent systems apply to most of the common machine learning strategies utilized today. Most statistical learning methods, including neural networks, are capable of training themselves by updating their state (*e.g.,* weights in a neural network) based on a supervised learning process. Given the response to an input with a known target value, the system can learn which internal state produces the correct result. This distinction leads to some interesting observations. Even an extremely deep pre-trained convolutional neural network (popular in deep learning) with millions of weights would not qualify as adaptive (even though some may call it intelligent), however a small single cell pre-trained gated recurrent neural network (which have memory cells to preserve data) would. However in both cases if after being trained they continued to update their weights (*e.g.,*, via online backpropagation) they would be considered an adaptive intelligent system.

C. Advanced Adaptive System

We defined an "advanced adaptive system" to be an adaptive intelligent system that can change its state *and behavior* in response to external input. A self-driving car is an adaptive system that has a mission of navigating and avoiding unexpected obstacles. The task of obstacle avoidance is of an adaptive nature [2], which can be categorized as the kind of intelligence Kanazawa [4] labeled as "dedicated intelligence" where adaptation comes from pre-embedded intelligence or experience. A self-driving car exploits the predefined logic to perform an analogy between the actual obstacles in its routes and the ones predefined to it, or it learns about during its operations but within predefined boundaries. At this level of intelligence, the system can change its internal and external status to adapt to the external stimuli as long as these stimuli are part of the embedded experience into the system's memory, and also within the predefined boundaries (collection of rules and constraints) of the system. Such a system can identify an obstacle if it is already precisely predefined or if it has a specific predefined logic to build an analogy and decide if it should maneuver around it. However, this system might fail to identify obstacles that were not introduced to it beforehand.

D. Futuristic 'Humanoid' Example

We will use a futuristic humanoid adaptive system for our most advanced example. We assumed that this system would emulate a human as closely as possible, and could be tasked with conducting numerous tasks that are frequently performed by humans. Such a system would act completely autonomously, and would need to quickly and effectively react to a wide variety of variability, changing mission objectives, and priorities. Therefore, we agreed that adaptivity would be a core principle of such a system because the system would:

1) Encounter innumerable situations and scenarios, and it would be impossible for a human designer to consider all situations at the system's inception.
2) Need to develop adaptation strategies on its own, and autonomously improve on any human-defined strategies.
3) Almost surely encounter changing scenarios and objectives that it would need to effectively react to.

Due to these reasons we agreed that adaptivity would be a core principle of such an advanced system since a system that did not have adaptivity as a core principle would be completely ill-suited to accomplish its defined objectives.

III. Conclusion

We determined that due to the ambiguity of the definition of an 'intelligent system' and the wide variations of these systems, that it was impossible to definitively state if adaptivity was a core principle in all intelligent systems. Perhaps classifying systems by levels of adaptivity can help dictate the amount of subjective 'intelligence' that the system possesses.

References

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