Selecting Between Semantic Modeling of Intelligence and Semantic Modeling of Systems

Andy E. Williams, Nobeah Foundation, Nairobi, Kenya

Abstract
Human-Centric Functional Modeling models systems in terms of "functional state spaces". When used for modeling human cognition, or any other intelligent system, these functional state spaces potentially provide the first complete semantic model of information. When used for modeling other systems, these functional state spaces potentially provide a complete representation of the functional states those systems might occupy as well as the processes through which the systems might transition between those functional states. In addition, HCFM provides a functional definition for general problem-solving ability as well as for the magnitude of that ability, and introduces the possibility of artificial systems which might exponentially increase that ability when information about the system is defined in terms of functional state spaces. This introduces two possibilities, the first is to represent information in terms of the functional state space of cognition (semantic modeling of information within human or artificial cognition) to increase capacity to solve problems regarding a second system (the system the information describes) where that information might or might not represent valid behaviors of that second system, or to represent information directly in terms of the functional state space of the second system, so all information represents valid behaviors of that system. This paper explores the implications of both.

Keywords:
semantic model, functional state space, Human-Centric Functional Modeling

Introduction
The newly emerging science of Human-Centric Functional Modeling or HCFM [1] models systems in terms of "functional state spaces" that are hypothesized to have the capacity to provide a complete representation of the behavior of any system modeled this way. Arising from the tradition within the discipline of philosophy of defining state spaces as semantic representations [2], these functional state spaces are represented by a graph containing a network of nodes representing the functional states of the system, where those nodes are connected by edges representing the processes through which the system might transition from each functional state to another. These states are called functional states because each one is defined by all the functions or processes by which the system might transition to another state.

In functional state space problems are defined as the lack of a path allowing the system described by the functional state space to transition from one functional state to another. Solutions are defined as the paths which accomplish those transitions. All transitions between functional states (all solutions) are one of two types. Type 1 consists of direct transitions from one functional state to another, and type 2 consists of step by step transitions between intermediate functional states. Type 1 transitions are used to solve uncomputable problems, that is problems that are not computable in terms of known path segments. These problems must be solved through pattern recognition, that is, through recognizing patterns identifying cases in which the same solution has been applied to solve the problem in the past. Type 2 transitions are used to solve problems that are computable in terms of such known path segments. Where all possible transition processes can be represented in terms of a combination of some basic set of functions, those functions are said to "span" the functional state space, thereby enabling every possible process or functional state to be represented.

Type 1 and type 2 reasoning processes have been determined to apply to human cognition as well [3]. When applied to cognition or other intelligent systems, assume that any pattern recognition based computing process can be represented as the automation of a type 1 reasoning process, and that any logic based computing process can be represented as the automation of type 2 reasoning processes. For such intelligent systems, the functional states are concepts, the transition processes are type 1 or type 2 reasoning processes, and this space of concepts or "conceptual space" forms a functional state space that the system moves through it moves as it executes its computation. However, a valid representation of problems and solutions in this conceptual space as the functional state space of the intelligent system being used to compute a solution about a second system, is not necessarily a valid representation of the problems and solutions in the functional state space of the second system itself. The challenge then becomes deciding how to select between using the functional state space of the intelligent system and the functional state space of systems contemplated by the intelligent system.

Individual and Collective Intelligent Systems

The individual human cognitive system has been represented as having general problem-solving capacity measured by the general intelligence factor (g) [4]. This factor has been hypothesized by some to represent the general problem-solving ability of non-human intelligent systems as well, though others disagree [5]. All known artificial intelligent systems today are assumed to have narrow problem-solving ability. Human-Centric Functional Modeling proposes a metric both for the narrow problem-solving ability, and for the general problem-solving ability (if present) of intelligent systems. Narrow problem-solving ability is hypothesized to be the distance that can be navigated through conceptual space per unit time, multiplied by the linear density of concepts along the path of that navigation. General problem-solving ability is hypothesized to be the volume of conceptual space that can be navigated per unit time, multiplied by the volume density of concepts that must be navigated through. Narrow problem-solving ability targets a narrow path through conceptual space in order to solve a specific problem, and general problem-solving ability targets any possible path through conceptual space that is able to solve any problem in general.

Defining the collective cognition of a group by analogy as a mechanism that permits the group to execute collective reasoning processes, it has been hypothesized that groups have an innate collective cognition with general problem-solving capacity measured by the general collective intelligence factor (c) [6]. This collective cognition is distinguished from traditional Collective Intelligence (CI) solutions in that it is hypothesized to have general problem solving ability, where CI solutions are hypothesized to have narrow problem-solving ability.

The emerging science of General Collective Intelligence (GCI) [7] defines a model for a hypothetical platform able to act as a collective cognition in enabling individuals to self-assemble into potentially massive networks of cooperation on a self-sustaining basis, where these networks create the potential to exponentially increase the general collective intelligence factor over the level present in group. This implies a significant increase in the outcomes of collective reasoning.

One of the requirements of GCI in order to achieve such a significant increase in problem-solving ability is to leverage Human-Centric Functional Modeling to represent information semantically so that understanding, rather than just information, can be exchanged at vastly greater speed and scale.

As mentioned, these functional state spaces are complete representations of meaning because they describe the complete meaning of any functional state in terms of all the functions or processes that can potentially be used to transition to or from that state, and because they describe the complete meaning of and process or function in terms of the functional states they can be used to transition to or from. In the case of the individual or collective cognitive system HCFM assumes that all reasoning processes can be described as transitioning to or from concepts (the functional states of the individual or collective cognition), and all concepts can be described in terms of the reasoning processes used to arrive at those concepts, or in terms of the reasoning processes used to arrive at other concepts from those concepts. A complete representation of meaning in the case of the individual or collective cognitive system (that is, a complete representation of human meaning in the domain of cognition), is a complete semantic model. In the case of systems other than the individual or collective cognition, functional state space defines a complete representation of meaning within a given domain as well.

Increasing Capacity to Solve Problems Related to the System

For any system that might be contemplated by any intelligent system, within each domain of behavior exhibited by that system, the system has behavior described by some functional state space. Any representation of information or reasoning processes on the other hand that is valid in the individual conceptual space of the intelligent system, or in the collective conceptual space of a group of such systems, represents valid behavior of the individual or collective intelligent systems. But information about a system that is valid in the individual or collective conceptual space need not describe valid behavior of the system being contemplated. As a silly but easy to remember example, one might contemplate that pigs can fly, and one might define a valid semantic model of this thought in the conceptual space. However, flight is not one of the behaviors within the functional state space of the pig.

Since a problem in functional state space is defined as the lack of a path between one functional state and the next, solving problems in the conceptual space or in any other functional state space implies finding that path. In the case of the conceptual space this equates to finding reasoning that enables the individual cognition to navigate from the concept representing the first functional state, to the concept representing the second. In the case of any other functional state space, this equates to finding processes that enable the system to transition from one functional state to the other. For the pig, solving the problem of flight equates to finding processes that enable it to transition from any land bound state to any airborne state.

The magnitude of general problem-solving ability of a group with respect to a system can be represented in two ways. One representation is the volume of the collective conceptual space the group can navigate per unit time multiplied by the density of concepts the collective cognition must move through. The other is the volume of the functional state space of the system the group can navigate per unit time multiplied by the density of functional state the system has to move through in order to make that transition. In both cases, there are three patterns identified so far that appear to have the potential to exponentially increase this volume that can be navigated by the group during the course of problem-solving [8]. These patterns are then predicted to enable the GCI to exponentially increase the general problem-solving ability of the group with respect to these systems, creating the potential to more reliably address “wicked problems” [9].

Discussion

In deciding whether to leverage an approximation of the collective conceptual space to represent information about a system, or deciding to leverage an approximation of the functional state space of the system, when leveraging GCI to solve problems, what are the key considerations that apply? One of these considerations is the difficulty of decomposing the behavior of systems into functional state spaces [10], and the difficulty of defining a minimal set of functions capable of spanning all processes of the system. Functional state spaces have been proposed for a number of systems, including biological systems, physical systems, or even blockchain platforms, where doing so is predicted to facilitate complete blockchain platform interoperability, as to the Internet itself, where doing so is predicted to facilitate the decentralized Web 2.0 envisioned by the World Wide Web Consortium (W3C). However, to date, a set of functions capable of spanning an entire functional state space has only been proposed for the conceptual space [11].

Research Limitations

As of this writing, a representation of functional state space has only been approximated. The underlying challenge is that there are a number of elements that must be elaborated before a complete representation of the graph of any functional state space is possible, whether talking about the conceptual space, or the functional state space of any other system. One of the missing elements is how to quantify distances in functional state space. Though distances have been approximated, they have not been precisely defined. Solving the representation problem for any functional state space is predicted to solve it for all functional state spaces. Because defining functional state spaces for any given system is predicted to vastly and perhaps even exponentially increase our collective ability to solve any problem in general concerning that system, there is then great incentive for the entire scientific community, from physicists to biologists, to psychologists, to mathematicians, to solve this representation problem.

Conclusions

Functional State Spaces are critically important concepts because they create the potential to collectively achieve an exponential increase in general problem-solving ability and hence create the potential for a group to exponentially increase the collective impact of its research and other activities. In short, functional state spaces enable General Collective Intelligence as an intelligent system to potentially become an engine capable of radically accelerating progress in research regarding any given system, or regarding GCI or other intelligent systems themselves. Since this has not yet been achievable by any other means, GCI might be the most important direction of research in the world today for all basic sciences and other disciplines. In order to implement GCI however, much work elaborating these functional state space techniques still remains.

References

[1] Williams, Andy E. "Human-Centric Functional Modeling and the Unification of Systems Thinking Approaches: A Short Communication." Journal of Systems Thinking (2021): 5-5.

[2] Boucher, S.C. Functionalism and structuralism as philosophical stances: van Fraassen meets the philosophy of biology. Biol Philos 30, 383–403 (2015). https://doi.org/10.1007/s10539-014-9453-z
[a02] Ned J. Block,, Functionalism, Editor(s): L. Jonathan Cohen, Jerzy Łoś, Helmut Pfeiffer, Klaus-Peter Podewski, Studies in Logic and the Foundations of Mathematics, Elsevier, Volume 104, 1982, Pages 519-539, ISSN 0049-237X, ISBN 9780444854230, https://doi.org/10.1016/S0049-237X(09)70217-4.

[3] Kahneman, Daniel. Thinking, fast and slow. Macmillan, 2011.

[4] Sternberg, Robert J., and Elena L. Grigorenko, eds. The general factor of intelligence: How general is it?. Psychology Press, 2002.

[5] Besold, Tarek, José Hernández-Orallo, and Ute Schmid. "Can machine intelligence be measured in the same way as human intelligence?." KI-Künstliche Intelligenz 29.3 (2015): 291-297.

[6] Woolley, Anita Williams, et al. "Evidence for a collective intelligence factor in the performance of human groups." science 330.6004 (2010): 686-688.

[7] Williams, A. E. (2021. Defining a continuum from individual, to swarm, to collective intelligence, to general collective intelligence. International Journal of Collaborative Intelligence, In press (2022)

[8] Williams, A. E. (2022, February 27). Using Models to Capture Patterns for Radically Increasing Social Impact. https://doi.org/10.31730/osf.io/rqs72

[9] Williams, A.E. Are wicked problems a lack of general collective intelligence?. AI & Soc (2021). https://doi.org/10.1007/s00146-021-01297-8

[10] Williams, A. E. (2022, February 27). Towards a Domain Specific Modeling Framework for General Collective Intelligence Platforms. https://doi.org/10.31730/osf.io/xkvy8

[11] Williams A.E. (2020) A Model for Artificial General Intelligence. In: Goertzel B., Panov A., Potapov A., Yampolskiy R. (eds) Artificial General Intelligence. AGI 2020. Lecture Notes in Computer Science, vol 12177. Springer, Cham. https://doi.org/10.1007/978-3-030-52152-3_38