

Automating the Process of Generalization

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Abstract

As various scholars have noted, the behavior of potentially any system can be represented in terms of network graphs called state spaces. Assuming that machine learning solutions can be represented as the automation of cognitive processes, it is noteworthy that in the case of the cognitive system it has been hypothesized that all thoughts (concepts and the reasoning that connect them) can be represented in terms of one proposed state space. In the case of the physical world up to and including the entire physical universe it is hypothesized that systems can be represented in terms of another proposed state space. Biological and other systems have also been hypothesized to be representable this way. Through simple, easily verifiable geometrical arguments, this paper explores how general problem-solving ability relates to the volume of this cognitive state space an intelligent system is able to navigate, or the volume it can navigate in the state space of any system the intelligent system might be targeted at solving problems about. Through those same simple geometrical arguments in state space this article explores why modeling problems in state space, in addition to increasing the ability to generalize until it spans the entire state space, is predicted to lead to an exponential increase in general problem-solving ability for intelligent systems, and this paper explores the patterns through which this increase in ability to generalize have been automated so that they can be more broadly replicated to increase narrow problem-solving ability in a sufficient range of areas for an exponential increase in general problem-solving ability to be achieved.

Keywords

generalization, machine learning, automation, functional state space

Introduction

Assume that any machine learning program is an automation of some human cognitive process, and therefore is an automation of some behavior of the human cognitive system. In deriving a model of generalization that might be automated it is then useful to define the most general possible model of the cognitive system so that to remove the necessity of making any assumptions which are only true for certain machine learning approaches as automations of cognitive processes. Various scholars have hypothesized that the behavior of any system can be represented in terms of network graphs called state spaces [1], [2], [3]. The emerging science of Human-Centric Functional Modeling or HCFM [4] elaborates the concept of state spaces into “functional state spaces” that each represent a separate domain of behavior for each system. Each state within these spaces is considered a “functional state” because the system transitions into or out of that state through one or more potentially observable processes. This approach makes it possible to observe what the system does and to understand the interaction between those functions without having to understand how the system implements those functions. In the case of cognition for example, it allows the functions of cognition to be modeled and deep insights to be gained without having to understand anything whatsoever about how those functions are implemented in terms of neurons or other structures.

For any system modeled this way, all possible processes by which the system might transition from one functional state to another are defined as belonging to a single domain when they transition from or transition to the same category of functional state. As an example, the human cognitive system is represented as navigating a space of concepts (a “conceptual space”) through the execution of reasoning processes. Each set of concepts can be represented as a single composite concept. So each reasoning process that receives a set of concepts as input and that produces a set of concepts as output

can be seen as navigating from a single concept (a single region in conceptual space) to another single concept (another region in conceptual space). This conceptual space serves as the functional state space of the cognitive system. Any behavior of this human organism that is confined to taking a concept as input and producing a concept as output is considered to belong to the cognitive domain. The concept is the domain object defining this domain.

Though machine learning programs might navigate a number of different domains, any machine learning program that navigates meaningful text based information is assumed to be an automation of human processes within the conceptual space. This distinction is important because some functions, such as visual processing, or sensory-motor processing, might or might not even have conceptual representations unless they have explicitly been contemplated by the cognitive system.

A Simple Geometrical Relationship Between General Problem-Solving Ability and Generalization

Assume that a problem in conceptual space is defined as the lack of a reasoning path from some initial concept to some target concept. Assume that a solution in conceptual space is defined as the reasoning which provides that path. It is then natural to also assume that general problem-solving ability might be defined as the ability to potentially navigate from between any set of concepts defining a problem, using any path defining a reasoning solution. This appears to be equivalent to stating that the magnitude of general problem-solving ability (which we will assume to be equivalent to “intelligence”) is related to the volume of conceptual space that can be searched for a solution per unit time.

Any metric for general problem-solving ability must be adjusted for the level of detail at which the answer must be given. In the cognitive domain a generalization of a concept or set of concepts is hypothesized to be a larger region in conceptual space which encloses that concept or set of concepts. Similarly, the specification of a concept is hypothesized to be a smaller region in conceptual space within that concept. Reasoning in terms of very general concepts is then represented by a path through conceptual space that connects very large concepts (large regions). Reasoning in terms of very specific concepts is then represented by a path through conceptual space that connects very specific concepts (small regions). The same distance in conceptual space might be spanned by a path consisting of a great many very precisely defined concepts, or a few very loosely defined ones. Assuming that the detail at which an answer must be given is related to the linear density of concepts along the path that any reasoning must move through, it is then assumed that the magnitude of the general problem-solving ability of any intelligent system is represented by the volume of conceptual space that can be searched for a solution per unit time, multiplied by the linear density of concepts that the system must move through.

Assume that each intelligent system has a finite ability to generalize, and that this ability is defined by the volume in conceptual space it is able to encompass around any given concept through the process of generalization. Any problem in conceptual space can potentially be solved through navigating between generalizations of concepts (reasoning in terms of generalizations). As the ability to generalize grows to encompass the entire extent of the conceptual space, it has been hypothesized that if the conceptual space originally contained N concepts, that the number of reasoning paths that can be achieved through generalization rises exponentially [5]. Since each reasoning path itself can be conceptualized and is therefore also a concept, this implies an exponential increase in the number of concepts and reasoning relationships. Assuming that the number of reasoning relationships connected to each concept fixes the location of that concept more precisely in conceptual space, then this increase in the number of concepts and reasoning relationships also implies an increase in the density of conceptual space. The ability of an intelligent system to generalize in this way defines an “interaction

distance” between concepts. This predicted exponential increase in the size of the conceptual space when the interaction distance (ability to generalize) spans the entire conceptual space has been referred to as a kind of “big bang” [5]. If general problem-solving ability is related to the volume and density of conceptual space that can be navigated per unit time, then an exponential increase in the volume and density of conceptual space is predicted to create the potential for an exponential increase in that ability.

Automating the Process of Generalization

Three simple patterns of solutions have been identified through various case studies as having the potential to radically increase problem-solving ability in specific domains such as science, technology, engineering, and math (STEM) [6], or such as the sustainable development goals, through making it possible to search through a far greater number of prospective solutions. Human-Centric Functional Modeling suggests these patterns might be abstracted into patterns in conceptual space [7].

If every concept in the graph of conceptual space is connected by every reasoning process through which the specific cognitive system might navigate to any other concept, then the graph of that conceptual space is a complete representation of the meaning of that concept, or in other words, is a complete semantic model. This use of state spaces as semantic representations appears to have been pioneered in philosophy [1], [2], [3]. If the graph of conceptual space is a complete semantic model, then every concept would be expected to be defined by the pattern of its relationships in that graph. Since each concept is a node in the network of the graph, and since each reasoning relationship is an edge connecting that concept to other nodes, then each concept would be expected to be represented by its own unique pattern of nodes and edges. In other words, each concept would be expected to have a unique shape. This graph might then be a language independent representation of meaning, though it might be expected to have meanings that are rooted in the biology of this human organism, and therefore might be human-centric and not provide absolute definitions of meaning.

If semantic models of concepts can be defined, then understanding rather than just information might be exchanged at far greater speed and scale. If the three simple patterns of solutions can be represented as patterns in conceptual space, then the increase in narrow problem-solving ability predicted with those patterns suggests that introducing the ability to search for these patterns, these concrete implementations of the generalization process might be used to significantly increase problem-solving ability in a wide range of problems. Abstracting the process further, if any generalization of any concept can be defined, and if any generalization of any reasoning process can be defined through the inclusion of such generalized concepts instead of specific ones, then if the patterns of those generalizations can be defined they might also be the target of searches in the conceptual space.

From the perspective of Human-Centric Functional Modeling a General Collective Intelligence or GCI [8] has been defined as a hypothetical platform that self-organizes individual users or intelligent agents working on behalf of those users, into a collective cognition able to execute collective reasoning processes coherently and with general problem-solving ability as defined in this paper. A collective reasoning process has been defined as one in which as many as N individuals or intelligent agents collaborate to execute the N steps of that reasoning process. From the perspective of Human-Centric Functional Modeling an Artificial General Intelligence or AGI [9] has been defined as a hypothetical artificial cognition able to execute reasoning processes with general problem-solving ability. Since each of these systems is defined as having general problem-solving ability, then increasing the capacity of either of these systems to generalize applies, and increasing the capacity for generalization till it spans the entire conceptual space for an individual cognition such as an AGI, or the entire collective conceptual space for a collective cognition such as a GCI, is predicted to lead to a big bang that creates

the opportunity to exponentially increase that general problem-solving ability. Furthermore, assuming that generalization can be performed at various “orders” then this big bang and these exponential increases of intelligence might be repeating phenomena. As an example, a first order GCI might consist of individuals and/or intelligent agents. A second order GCI might consist of first order GCIs and be capable of an entirely different order of generalization, and so forth up to an Nth order GCI. The same phenomena is expected to exist with AGI.

The important difference between the two (AGI and GCI) is that where an AGI is predicted to be a system that optimizes outcomes for the individual or other entity which owns it (that is, it is a system of individual optimization), a GCI is predicted to be a system that optimizes collective outcomes (a system of collective optimization). This has profound implications, since the set of all individual optimization problems would appear to include removing the possibility of any collective optimization where it prevents individual optimization, and vice versa. In other words, if an AGI comes first it would be predicted to make decisions that prevent the emergence of a more powerful GCI in order to maximize individual outcomes, and vice-versa (a GCI would be predicted to make decisions that prevent the emergence of a more powerful AGI in order to maximize collective outcomes).

Discussion

If it is true that all thoughts (all concepts and the reasoning that connect them) can be represented in terms of conceptual space, and if it is true that defining information in terms of this semantic model, and then increasing the capacity to generalize that information can be used to exponentially increase general problem-solving ability, then in the medium to long-term a General Collective Intelligence which automates this is potentially the most important research topic to every researcher today [10]. In the case of the cognitive system we can represent all concepts and the reasoning that connect them in terms of the conceptual space. In the case of the physical world up to and including the entire physical universe we can represent systems in terms of another state space. We can even represent all biological systems in terms of state spaces. Assume that through simple geometric arguments in functional state space, such as the arguments made in this paper, it can be shown that the "importance" of an innovation is represented by the increase in volume of the state space of cognition that it allows to be navigated, or the increase in volume it allows to be navigated in the state space of any system the cognition might think about. Based on the definition provided in this paper of general problem-solving ability in terms of capacity to navigate a volume of functional state space, this corresponds to the increase in capacity to solve problems related to that system.

Through those same simple geometrical arguments in state space it has been suggested in this paper that General Collective Intelligence has the potential to exponentially increase our intelligence, where this increase has never been possible before at any time in human history. This means an exponentially greater ability to solve problems in every subject, whether physics, mathematics, biology, or sustainable development. A number of specific case studies have been defined that explore how General Collective Intelligence might be applied to massively increase impact per program dollar in sustainable development, as well as exploring how GCI might increase impact in a range of engineering disciplines. In short, General Collective Intelligence is predicted to allow people or to self-assemble just like the cells in a growing organism so that they can exponentially increase their capacity to achieve some collective outcome.

Research Limitations

A complete representation of the conceptual space, or of any other functional state space, has not yet been implemented. Some of the outstanding elements that remain to be elaborated are distances, and how to make each region a self-contained representation of all the relationships with which it interacts

with each adjacent region, so that each region is a complete representation of meaning. However, solving these problems for one functional state space is expected to solve them for all functional state spaces. Since functional state spaces can potentially be defined in physics, mathematics, biology, and systems relevant to a great many other disciplines, and since defining such functional state spaces is predicted to create the potential to exponentially increase general problem-solving ability in those disciplines, where this ability is not predicted to be reliably achievable otherwise, then there is powerful motivation for scientists in these more technical disciplines to take on those challenges.

Conclusions

Simple arguments based on Human-Centric Functional Modeling predict the possibility of an exponential increase in intelligence that might be the most important technological innovation today. In some very tangible ways this innovation might be called a “technological singularity”. However, HCFM also predicts that complexity of a concept is represented by the volume and density of conceptual space within that concept, and that for any individual or group a concept like GCI represents too large and dense of a region in conceptual space to be reliably communicated to the number of different individuals in different disciplines at a level of detail that is sufficient for them to implement their part of the infrastructure required to implement a GCI. Or in other words, a GCI (or an AGI) from this perspective likely requires an AGI or a GCI for constructing it to be reliably achievable. Luckily, nature has already provided a solution to this chicken and egg problem, and this solution might be modeled and replicated. This solution appears to be an individual or group building the limited subset of AGI or GCI that they can build, using that subset to organize a larger group to solve the much larger set of problems involved in building more, and then iterating this self-assembling process. Or in other words, evolution.

It is predicted that a concept like GCI mostly requires mind share and that this mind share can only be created by a select few publications, technology influencers, or other entities in the world today that have very large and very broad technical audiences. If the relationship between HCFM, AGI, and GCI is the most important information in the world today by predicted volume of impact, then such publications or other entities are literally the gate keepers that have the key to unlock this profoundly important impact on human well-being. This paper has made some very bold claims, and discovering any potential cognitive biases preventing the communication of these claims to such individuals or entities has itself required a significant research effort involving literally tens of thousands of "penetration tests" in the attempt to hack through and make sense of what might be a great many cognitive barriers [11]. These cognitive biases include an unconditional rejection of the lack of references, which is difficult to avoid when making arguments from first principles, and an unconditional rejection of what might be considered “excessive” self-citation which might be difficult to avoid in a significantly new area of research. It might be argued that the lack of conditions for a conclusion is the very definition of bias. But if objective, quantitative arguments can be made that GCI is this important, then being insistent regarding these bold claims is simply logical, and in any case perhaps the concept of General Collective Intelligence itself could not have come without the boldness to pursue what began as completely fringe research from outside the bounds of any institutional funding or support, and to do so with the required level of persistence.

The anecdotal evidence provided by these penetration tests suggest there are profoundly important cognitive biases which only a tiny minority (perhaps less than one in a thousand or 0.1%) of scientists are even aware of, but which make it very challenging to digest these concepts. However, there is more than sufficient motivation to persist in trying. Consider a simple thought experiment. Humans might be able to reliably solve the problem of deciphering how three animals interact in an ecosystem to achieve a given outcome. But at some point, as the numbers of those animals increase, the number of possible

interactions becomes too great to explore, and by the time we get to 20,000 species, human beings are reliably unable to understand any given function of those interactions, and gaining this understanding becomes a "wicked problem" for a human that isn't reliably solvable. Any problem we can't yet reliably solve, from poverty, to climate change, might be a wicked problem, because we can't know how many interactions are involved in understanding it until we succeed in developing and proving that understanding. GCI is predicted to exponentially increase our intelligence so that for the first time in history, solving what are considered wicked problems today becomes reliably achievable.

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