Peter Voss - Essentials of General Intelligence: The Direct Path to Artificial General Intelligence (2007)

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0.1 Context

0.2 Learned in this study

0.3 Things to explore

1 Overview

1.1 2 General Intelligence

- Intelligence can be defined simply as an entity's ability to achieve goals - with greater intelligence coping with more complex and novel situations
- General intelligence comprises the essential, domain-independent skills necessary for acquiring a wide range of domain-specific knowledge
- Learning must be autonomous, goal-directed and adaptive
- The mark of a generally intelligent system is not having a lot of knowledge and skills, but being able to acquire and improve them and to be able to appropriately apply them
- An AGI system should be able to learn to recognize and categorize a wide range of novel perceptual patterns
- It should be able to autonomously learn appropriate, goal-directed responses to input contexts (given some feedback mechanism)

1.2 2.1 Core Requirements for General Intelligence

- Perceived entities/patterns must be stored in a way that facilitates concept formation and generalization
- An effective way to represent complex feature relationships is through vector encoding
- Any practical applications of AGI must inherently be able to process temporal data as patterns in time - not just as static patterns with a time dimension
- AGIs must cope with data from different sense probes and deal with attributes such as: noisy, scalar, unreliable, incomplete, multi-dimensional, etc.
- Another essential requirement of general intelligence is to cope with an overabundance of data
- The system needs to have some control over what input data is selected for analysis and learning - both in terms of which data, and also the degree of detail
- Senses are needed not only for selection and focus, but in order to ground concepts in reality

1.3 3 Shortcuts to AGI

- In addition to understanding general intelligence, AGI design also requires an appreciation of the differences between artificial (synthetic) and biological intelligence, and between designed and evolved systems
- Work focused on

  - General rather than domain-specific cognitive ability
  - Acquired knowledge and skills, vesus loaded databases and coded skills
  - Bi-directional, real-time interaction, versus batch processing
  - Adaptive attention (focus and selection), vesus human pre-selected data
  - Core support for dynamic patterns, versus static data
  - Unsupervised and self-supervised, versus supervised learning
  - Adaptive, self-organizing data structures, versus fixed neural nets or databases
  - Contextual, grounded concepts, versus hard-coded, symbolic concepts
  - Explicitly engineering functionality, versus evolving it
  - Conceptual design, versus reverse-engineering
  - General proof-of-concept, versus specific real applications development
  - Animal level cognition, versus abstract thought, language, and formal logic
- Self-improvement takes two distinct forms/phases:
  - Coding the basic skills that allow the system to acquire a large amount of specific knowledge
  - The system reaching sufficient intelligence and conceptual understanding of its own design, to enable it to deliberately improve its own design
- Many AI systems do all of their learning in batch mode and have little or no ability to learn incrementally
- In many cases they are unable to adapt beyond the initial training set without reprogramming or retraining
- Intelligent systems must be able to act
  - Acting on the "world" - be it to communicate, to navigate or explore, or to manipulate some external function or device in order to achieve goals
  - Controlling or modifying the system's internal parameters (such as learning rate or noise tolerance, etc.) in order to set or improve functionality
  - Controlling the system's sense input parameters such as focus, selection, resolution (granularity) as well as adjusting feature extraction parameters
- AGI systems must inherently be designed to acquire knowledge by themselves
- They need to control what input data is processed, where specifically to obtain data, in how much detail, and in what format
- All acquired knowledge and skills is encoded in one integrated network-like structure
- One can say that "high-level intelligence is conceptual intelligence"
- Autonomous concept formation is one of the key tests of intelligence
- Design to achieve the desired functionality of the brain rather than try to replicate evolution's design
- Here is a list of desirable cognitive features that can be included in an AGI design that would not exist in a reverse-engineered brain:
  - More effective control of neurochemistry (emotional states)
  - Selecting the appropriate degree of logical thinking versus intuition
  - More effective control over focus and attention
  - Being able to learn instantly, on demand
  - Direct and rapid interfacing with databases, the Internet and other machines - potentially having instant access to all available knowledge
  - Optional "photographic" memory and recall on all senses
  - Better control over remembering and forgetting (freezing important knowledge, and being able to unlearn)
  - The ability to accurately backtrack and review thought and decision processes (retrace and explore logic pathways)
  - Patterns, nodes and links can easily be tagged (labeled) and categorized
  - The ability to optimize the design for the available hardware instead of being forced to conform to the brain's requirements
  - The ability to utilize the best existing algorithms and software techniques - irrespective of whether they are biologically plausible
  - Custom designed AGI can have a simple speed/capacity upgrade path
  - The possibility of comprehensive integration with other AI systems (like expert systems, robotics, specialized sense pre-processors, and problem solvers)

  - The ability to construct AGIs that are highly optimized for specific domains
  - Node, link, and internal parameter data is available as “input data” (full introspection)
  - Design specifications are available (to the designer and to the AGI itself!)
  - Seed AI design: A machine can inherently be designed to more easily understand and improve its own functioning - thus bootstrapping intelligence to ever higher levels
- Discoveries in cognitive psychology point towards generalized pattern processing being the foundational mechanism for all higher level functioning

1.4 4 Foundational Cognitive Capabilities

- General intelligence requires a number of foundational cognitive abilities:
  - Remember and recognize patterns representing coherent features of reality
  - Relate such patterns by various similarities, differences, and associations
  - Learn and perform a variety of actions
  - Evaluate and encode feedback from a goal system
  - Autonomously adjust its system control parameters
- Pattern acquisition through lazy learning
  - Stored feature patterns with adaptive fuzzy tolerances
  - Recognition/Pattern matching through a competitive winner-take-all, as a set or aggregate of similar patterns, or by forced choice
- The matching algorithm is able to recall patterns by any dimension

1.5 5 An AGI in the Making

1. Development framework
2. Memory core and interface structure
3. Individual foundational cognitive components
4. Integrated low-level cognition
5. Increased level of functionality

- AGI engine with the following basic components:
  - A set of pluggable, programmable (virtual) sensors and actuators (called probes)
  - A central pattern store/engine including all data and cognitive algorithms
  - A configurable, dynamic 2D virtual world, plus various training and diagnostic tools
- Additional details:
  - Data recorder with playback
  - Data visualization and editing tools
  - A cognitive core with many foundational cognitive algorithms
  - An interface manager which communicates with the probes, the cognitive core and the data recorder

1.6 5.1 AGI Engine Architecture and Design Features

- Can be separated into three parts:
  - Cognitive core
  - Control/Interface logic
  - Input/Output probes
- Cognitive core
  - Central repository of all static and dynamic data patterns - including all learned cognitive and behavioral states, associations, and sequences
  - All data is stored in a single, integrated node-link structure
- Control and interface logic
  - Coordinates the network’s execution cycle, drives various cognitive and housekeeping algorithms, and controls/adapts system parameters
  - Via an interface manager, communicates data and control information to and from the probes

- Probes
  - Programmable feature extractors, variable data resolution, focus and selection mechanisms
- Development environment, language, and hardware
- Implemented in C#/.NET
- Practical/Proof-of-concept prototype performance can be achieved on a single PC (2 GHz, 512 MiB)

1.7 6 From Algorithms to General Intelligence

- General intelligence emerges from the synergetic integration of a number of essential fundamental components

1.8 7 Other Research

- Classifies their work in the area of agent systems and embodied cognitive science

1.9 8 Fast-track AGI: Why So Rare?

- Some technical issues worth mentioning:
  - Epistemology: Theory of knowledge, the nature of knowledge, and how it relates to reality.
  - Theory of mind: The formulation and understanding of consciousness, intelligence, volition, meaning, emotions, common sense, qualia.
  - Cognitive psychology: Proper understanding of the concept intelligence.
  - Project focus: A vision of how to get from here to there.
  - Research support
    * Incremental, real-time, unsupervsed/self-supervised learning
    * Integrated support for temporal patterns
    * Dynamically-adaptive neural network topologies
    * Self-tuning of system parameters, integrating bottom-up (data driven) and top-down (goal/meta-cognition driven) auto-adaptation
    * Sense probes with auto-adaptive feature extractors
  - Cost and difficulty: Finding the crucial fundamental functionality. Scaling up the system to human-level storage and processing capacity

2 See also

3 References

- DOI: 10.1007/978-3-540-68677-4_4
- http://www.kurzweilai.net/essentials-of-general-intelligence-the-direct-path-to-agi