Chapter 4

Beyond the Octopus: From General Intelligence toward a Human-like Mind

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General intelligence varies with species and environment. Octopuses are highly intelligent, sensing and rapidly learning the complex properties of their world. But as asocial creatures, all their learned knowledge dies with them. Humans, on the other hand, are exceedingly social, gathering much more complex information and sharing it with others in their family, community and wider culture. In between those extremes there are several distinct types, or levels, of reasoning and information sharing that we characterize as a metaphorical "ladder" of intelligence. Simple social species occupy a "rung" above octopuses. Their young passively learn the ways of their species from parents and siblings in their early lives. On the next rung, "cultural" social animals such as primates, corvids, cetaceans, and elephants actively teach a complex culture to their young over much longer juvenile learning periods. Human-level intelligence relies on all of those lower rungs and adds three more: information sharing via oral language, then literacy, and finally civilization-wide sharing. The human mind, human behavior, and the very ontology with which we structure and reason about our world relies upon the integration of all these rungs. AGI researchers will need to recapitulate the entire ladder to produce a human-like mind.

4.1 Introduction

Multi-strategy problem solving, spatial reasoning, rich sensory perception in multiple modalities, complex motor control, tool usage, theory-of-mind and even possibly consciousness – these and other capabilities form the target for digital systems designed to exhibit Artificial General Intelligence (hereafter AGI) across a broad range of environments and domains.

The ultimate goal of most AGI research is to create a system that can perform as well as humans in many scenarios and perhaps surpass human performance in some. And yet most of the capabilities listed above are already exhibited by the octopus, a solitary asocial creature that does not interact with its own kind save for a brief mating period at the end of its short life. The octopus learns very quickly and solves problems in idiosyncratic and creative ways. Most AGI researchers, let alone businesses and governments, would be thrilled to have systems that function with as much learning ability, creativity, and general intelligence as an adult octopus, and yet no system today comes even close.

This chapter examines the lessons AGI researchers can learn from the capabilities of the octopus and the more social animals up to and including humans. We do not attempt to characterize the intelligence of animals and humans, but rather focus on what sort of information they have to reason with, dependencies between different sorts of information, and the degree to which they learn from or pass information to others of their species.

4.2 Octopus Intelligence

The octopus is an asocial genius that survives by its wits. The common octopus (*Octopus vulgaris*) lives from 12 to 18 months. A mature female mates, lays tens of thousands of eggs [1], tends them until they hatch, and dies soon thereafter. The tiny octopus hatchlings disperse quickly and seldom encounter others of their species until they eventually mate. The hatchlings spend 45 to 60 days floating in ocean currents and feeding in the plankton layer where most of them perish, becoming food for other predators. The small proportion that survive this stage grow rapidly, “parachute” to the sea floor, and begin a bottom dwelling life in an environment that is quite different from the plankton environment [2]. When they land on the bottom, typically far away from where they hatched, octopuses must learn very quickly and be very lucky to survive.

The typical adult octopus has a relatively large brain, estimated at 300 million neurons [3]. The ratio of octopus brain to body mass is much higher than that of most fish and amphibians, a ratio more similar to that of birds and mammals. The complex lobes of the octopus brain support an acute and sensitive vision system, good spatial memory, decision-making, and camouflage behavior. “Sensory and motor function is neatly separated into a series of well-defined lobes... There are two parallel learning systems, one for touch and one for vision, and a clear hierarchy of motor control [4].” Each arm has smaller, mostly independent neural systems (about 50 million neurons each) that deal with chemical sensors, delicate touch sensors, force sensors, and control of the muscles in that arm. All this processing power supports general intelligence, but at a cost. Neurons use more energy than other cells. Just the photoreceptors in the eyes of a fly consume 8% of the fly's resting energy [5]. The metabolic costs of an octopus' large brain must be justified by its contribution to rapid learning of more effective foraging and more effective defenses against predators.

Adult octopuses are quite clever, adaptable, and rapid learners. Experts speculate that most octopus behaviors are learned independently rather than being based on instinct. At least one researcher [6] posits that cephalopods may even have a primitive form of consciousness.

The following anecdotes illustrate some of their most notable learning and creative talents:

Opening a screw top jar

A five-month-old female octopus in a Munich zoo learned to open screw-top jars containing shrimp by pressing her body on the lid, grasping the sides with her eight tentacles and repeatedly twisting her body. She apparently learned this trick by watching human hands do the same task.

Using coconut halves as portable shelters

An octopus in Indonesia was observed (and filmed [7]) excavating a half of a coconut husk buried in sand, carrying it to the location of another similar half many meters away, crawling into one half and pulling the other over itself to hide from predators.

Shooting out the lights

An aquarium in Coburg, Germany was experiencing late-night blackouts. Upon investigation it turned out that their octopus had learned to "... swing onto the edge of his tank and shoot out the 2000 Watt spot light above him with a carefully directed jet of water [8]."

Spatial learning

Studies show that octopuses learn maps of the territory in which they hunt. Researchers have "... traced young *Octopus vulgaris* in Bermuda on many of these hunting excursions and returns [*typically returning by routes different from their outward path*]. The octopuses seemed to cover different parts of their home range one after another on subsequent hunts and days [9].” In controlled laboratory experiments octopuses learn to navigate mazes and optimize their paths. They find short cuts as if they could reason about the maze in its entirety from an internal map they have constructed for themselves.

Observational learning

Formal experiments show that captive octopuses can learn to choose the “correct” colored ball from a pair placed in their tank by observing other octopuses trained to do the task [10]. More noteworthy is that it required between 16 and 22 trials to train the “demonstrator” octopuses via formal conditioning (food reward for “correct” choices and electric shock punishment for “wrong” choices), yet the “observer” octopuses learned in as few as five trials.

Camouflage and behavioral mimicry

All cephalopods can dramatically alter their appearance by changing the color, patterning, and texture of their skin [11]. A few species of octopus also disguise themselves by mimicking the shape and movements of other animals in their environment. One Caribbean octopus that inhabits flat sandy bottoms disguises itself by imitating the coloring, shape and swimming behavior of a kind of flounder (a bottom dwelling flatfish) [12]. An Indonesian octopus (*Thaumoctopus mimicus*) learns to mimic the shape, coloring, and movement of various poisonous or dangerous fish that the octopus’ potential predators avoid [13]. It impersonates several species and may shift between impersonations as it crosses the ocean floor. Individual octopuses apparently learn these tricks on their own. Researchers point out that “... all animals were well separated (50m–100m apart) and all displays were observed in the absence of conspecifics [14].”

Using its siphon to squirt an offending spotlight and using coconut halves to build a shelter against predators have been asserted to qualify as a sort of tool use. Whether or not that assertion is fully justified, the behaviors are quite creative. Furthermore, octopus mimicry suggests an intelligent response, even a possible meta-cognitive “theory of predator behavior” that is used to avoid unwanted interaction with predators. Less tangible evidence of octopus general intelligence comes from the assertion by many professional aquarists that octopuses have distinct personalities [15].

Octopuses seem to be so clever, learn so fast, and are so creative that one might wonder why 99.99% of them fail to survive long enough to reproduce. However, we must be cautious about drawing conclusions from the behavior of the rare octopus that reaches adulthood. Octopuses learn so rapidly in such complex environments that many of the associations they learn can best be thought of as ineffective or even counterproductive superstitions that may be fatal the next time they are invoked. AGI systems that jump to conclusions too quickly may face a similar fate.

4.3 A "Ladder" of Intelligence

Unlike the octopus, humans can rely upon a large legacy of knowledge learned from, and actively taught by, parents, peers, and the culture at large. Social animals also make use of legacies of information that they are able to effectively transfer from one individual to the next and one generation to the next. More effective knowledge legacies go hand-in-hand with more intelligent reasoning although the correlation is far from perfect, as the octopus demonstrates.

Here we discuss a metaphorical ladder of cognitive abilities, each successive rung of which is characterized by larger and more complex legacies of knowledge. Reasoning at each rung of the ladder subsumes the capabilities of the lower rungs and accumulates additional sorts of information required to reason about and interact with more complex aspects of the world. Animals on the lowest rung, the octopus being perhaps the most intelligent, are asocial. They sense and act within their own bodies and their immediate environment, learning by trial-and-error with no cooperative interactions with others. What they learn dies with them. Less solitary animals participate in increasingly complex social interactions that communicate information learned by their ancestors and peers. Humans can act more intelligently than animals in part because we are able to share more information more effectively via oral language, music, art, crafts, customs, and rituals. Based upon oral language, humans have developed written language that supports logic, science, formal government, and ultimately civilization-wide sharing of knowledge. Human intelligence, the eventual target for AGI, depends upon the combined capabilities of all of the rungs as described below.

Asocial reasoning, the lowest rung, does not require cooperation or communication with other animals. Asocial animals reproduce via eggs, often large numbers of eggs, and the young fend for themselves from birth without any parental guidance or protection. These animals learn nothing from others of their species, do not cooperate with other creatures, and pass nothing they learn on to the next generation. Asocial animals learn regularities in the world on their own by interacting with an environment that is at best indifferent and at worst predatory or dangerous. Typically, only a small percentage of them survive to adulthood.

Social reasoning arises in animals where the young are tended by parents and interact with siblings and perhaps others of their species. As a result, they learn in an environment largely shaped by the parents. One generation thereby passes some knowledge to the next: what is edible and where to find it in the environment, how to hunt, or what predators to avoid and how to do so.

Animal cultural reasoning, found in species such as primates, elephants, corvids, dolphins, wolves, and parrots, requires considerably more transfer of information from one generation to the next. Parents and others of such species actively *teach* the young over relatively long childhoods. Communication in these species includes non-linguistic but nonetheless complex vocalizations and gestures. Parents must teach those communication skills in addition to accumulated culture.

Oral linguistic reasoning is unique to humans despite proto-linguistic behavior at the animal cultural rung. Language not only supports a much richer transfer of intergenerational information, but also a much richer sort of reasoning. Oral language is evanescent, however, not lingering in the minds of either speaker or listener for long unless deliberately memorized. Thus oral cultures are rich in social practices that aid memory such as ritual, storytelling, and master-apprentice relationships.

Literate reasoning depends upon oral language, but is qualitatively different from oral linguistic reasoning. For its first thousand years, writing merely preserved oral utterances. Reading required speaking out-loud until the ninth century [16] and even today many readers silently verbalize internally as they read. In the western hemisphere, literate skills were confined to a small subculture of priests and scribes for hundreds of years until literacy began to spread rapidly in the Renaissance.

Language committed to writing has several advantages over speech. Writing can immortalize long complex structures of words in the form of books and libraries of books. The preserved words can be reread and reinterpreted over time and thereby enable much longer and more complex chains of reasoning that can be shared by a larger group of thinkers. The collaboration enabled by written language gave birth to science, history, government, literature and formal reasoning that could not be supported by oral communication alone.

Finally, ***Civilization-scale reasoning*** applies to the ideas and behavior of large populations of humans, even entire civilizations. Such ideas impact what every individual human says or does. Long-lasting ideas (memes) evolve, spread and recombine in huge, slow, interconnected human systems exemplified by philosophies, religions, empires, technologies and commerce over long timescales and large geographies. Recent technologies such as the Internet and worldwide live satellite television have accelerated the spread and evolution of memes across these temporal and geographic scales. Nonetheless, long-standing differences in language, religion, philosophy, and culture still balkanize civilizations.

Within a human mind, all rungs are active at all times, in parallel, with different agendas that compete for shared resources such as where to direct the eyes, which auditory inputs to attend to (the "cocktail party effect" [17]), what direction to move (e.g., fight or flight decisions), or what the next utterance will be. For example, direction of gaze is a social signal for humans and many animals precisely because it provides information about which of many internal agendas has priority.

4.4 Linguistic Grounding

Linguistic communication depends upon understanding the meaning of words (the familiar "Symbol Grounding Problem" [18]) as well as the meaning of longer utterances. In social circumstances, the meaning of an utterance may include context from a prior utterance in the current conversation or at some time in the past. Or the meaning may "simply" be that it was uttered at all in a particular social context [19].

Each rung of the ladder surfaces in human language. The meaning of individual words and multi-word utterances often are grounded far lower than the verbal rung and often involve memes at more than one level. For example, *stumble, crawl, fall, hungry, startle, pain*, and *sleep* are grounded on basic facts of human bodies. We also use such words metaphorically e.g., "stumble upon some problem or situation" or "trip over an awkward fact." We also "hunger for love" and "slow to a crawl". Words such as *regret* and *remorse* are grounded in the subtleties of human emotion and memory. An AGI cannot be expected to understand such words based only on dictionary definitions, or a semantic net, without having some exposure to the underlying phenomena to which they refer.

Consider the rungs at which the root meanings of the following English words are grounded:

- *Hide, forage, hunt, kill, flee, eat, what* and *where* are most deeply grounded on the asocial rung. They typically signal object parsing (what), spatial reasoning (where) and other survival issues crucial even to an asocial individual. Yet these same words may take on other meanings in a human social arena when they involve group behavior. To properly interpret such words either literally or metaphorically requires some "gut-level" grounding on the asocial rung.
- *Nurture, protect, feed, bond, give*, and *share* are grounded within the social rung. They refer to issues fundamental to the social relations within groups of animals, including humans. "*Who*" is especially crucial because humans and other social animals often must recognize individuals of their species to determine if they are likely to be friendly, neutral, dangerous, or a competitor. Individuals are distinguishable from one another by subtle visual, olfactory, auditory, or movement cues that do not translate readily into language.
- *Follow, cooperate, play, lead, warn, trick, steal* (as opposed to simply *take*), and *teach* (in the sense of interacting in a way designed to maximize its teaching value) are grounded within the non-linguistic animal cultural rung where more instinctive social behaviors extend into intentional meta-cognition (e.g., theory-of-mind). These behaviors occur in groups of elephants, corvids, cetaceans, parrots and primates, among others. They depend not only upon accurate classification of relationships and recognition of individuals and their relative roles, but also on memories of the history of each relationship.
- *Promise, apologize, oath, agree, covenant, name* (as in a person's name or the name of an object or place), *faith, god, game, gamble, plan, lie* (or *deceive*), *ritual, style, status, soul, judge, sing, clothing* (hence *nakedness*), and above all *why*, are grounded in the human oral linguistic rung and depend on shared culture, customs and language – but are not grounded in literacy.
- *Library, contract, fiction, technology, essay, spelling, acronym, document*, and *book* are grounded in literate culture that has accumulated collective wisdom in written documents. New but similar conventions have already grown around video and audio recordings. Not only can such documents be read, debated, and reasoned about over wide geographies and time periods, but they also support more complex interrelated arguments across multiple documents.
- Above the level of human current affairs, there are more abstract concepts such as *democracy, empire, philosophy, science, mathematics, culture, economy, nation, liter-*

ature and many others that are about vast collections of memes evolving over decades or centuries within the minds of large numbers of people. Individual humans have some local sense of the meaning of such concepts even though their understanding may be little better than a fish's awareness of water.

An AGI that could not convincingly use or understand most of the above words and thousands more like them will not be able to engage even in flat, monotone, prosaic human conversations. In our view, such an AGI would simply not be at the *human-level* no matter how well it can do nonverbal human tasks. AGI systems will need to be evaluated more like human toddlers [20] instead of adult typists in a Turing Test.

4.5 Implications of the Ladder for AGI

The ladder metaphor highlights the accumulation of knowledge from generation to generation and the communication of that knowledge to others of the species. Each rung of the ladder places unique requirements on knowledge representation and the ontologies required for reasoning at that level.

The term ontology is used differently, albeit in related ways, in philosophy, anthropology, computer science, and in the "Semantic Web" [21]. One definition of ontology commonly used in computer science is: "a formal representation of a set of concepts within a domain and the relationships between those concepts." In philosophical metaphysics, ontology is concerned with what entities exist or can be said to exist, how such entities can be grouped or placed in some hierarchy, or grouped according to similarities and differences. Within recent anthropological debates, it has been argued that ontology is just another word for culture [22]. None of the above definitions quite do the trick in our context. For the purposes of the following discussion, the term ontology is used to describe the organization of the internal artifacts of mental existence in an intelligent system or subsystem, including an AGI system.

It is not our goal here to define a specific ontology for an AGI. In fact we argue that goal is pointless, if not impossible, because an ontology appropriate for a solitary asocial octopus has little in common with one appropriate for a herd herbivore such as a bison, a very long lived highly social animal such as an elephant, or a linguistically competent human. Instead, we seek to explore the implications of the different design choices faced by researchers seeking to develop AGI systems [23]. Since we are concerned here with human-level AGI, we will discuss the ontological issues related to the human version of the rungs of the ladder: asocial, social, animal cultural, linguistic, literate, and civilization-level. Let us examine each in turn.

Asocial ontologies – Humans share with many asocial animals the ability to process and act upon visual 2D data and other spatial maps. Octopuses, insects, crabs and even some jellyfish [24] use visual information for spatial navigation and object identification. The octopus is exceptionally intelligent, with complex behavior befitting its large brain and visual system. Its ontology has no need for social interaction and may encompass no more than a few hundred categories or concepts representing the various predators and prey it deals with, perhaps landmarks in their territories, maps of recent foraging trips and tricks of camouflage. It presumably does not distinguish one instance of a class from another, for example, one particular damselfish from another. Octopus ontology also presumably supports the temporal sequences that underlie the ability of the octopus to make and execute multi-step plans such as shooting out the lights, opening shrimp jars, or building coconut shell shelters, although one can posit other mechanisms. Humans also have equivalents of other asocial processing abilities such as the ability to sense and process information about temporal ordering, proprioception, audition, and the chemical environment (smell, taste). What can AGI researchers learn from such parallels?

In humans, the rungs are not as separable as AGI researchers might wish. Human infants are hardwired to orient to faces, yet that hardwired behavior soon grows into a social behavior. Infants cry asocially at first, without consideration of impact or implications on others, but they soon learn to use crying socially. The same can be said for smiling and eating, first applied asocially, and then adapted to social purposes. In summary, many of our asocial behaviors and their supporting ontology develop over infancy into social behaviors. The social versions of asocial behaviors seem to be elaborations, or layers, that obscure but do not completely extinguish the initial asocial behavior, e.g., unceremoniously wolfing down food when very hungry, or crying uncontrollably when tragedy strikes.

Many behaviors apparent in infants are asocial simply because they are grounded in bodies and brains. Yet we learn to become consciously aware of many of our asocial behaviors, which then become associated with social concepts and become social aspects of our ontology. Because humans learn them over many years in the midst of other simultaneously operating rungs, the ontological categories inevitably become intertwined in ways difficult to disentangle. Learning to understand the issues characteristic of the asocial rung by building an asocial octopus-level AGI would therefore be a good strategy for separation of concerns.

Social ontologies – Social interaction provides a richer learning experience than does hatching into an asocial existence. It ensures that learned ontologies about the environment, foods, and early experiences are biased by the parents and siblings. By sharing a nest or other group-defined environment the experiences of the young are much more like one another, teaching them what they need to know socially. What they learn may be communicated via posture, "body language," herd behavior, behavioral imprinting (e.g., ducklings imprinting on their mother), pheromones, and many other means. Indirect interaction also may occur via persistent signals deposited on inanimate features of the environment, a phenomenon known as stigmergy [25]. Stigmergy is best understood in social insects where signals deposited on physical structures, e.g., termite mounds, honeycombs, or ant trails, affect and partially organize the behavior of the insects. Any modification of the environment by an individual that can influence the behavior of others of its kind can also produce stigmergy. Nearly all higher animals, including humans, make extensive use of such indirect communication channels. Humans create especially rich stigmergy structures: clothes, jewelry, pottery, tools, dwellings, roads, cities, art, writing, video and audio recordings, and most recently the Internet.

Social animals necessarily have larger and more complex ontologies than asocial animals because, *in addition* to what a comparable asocial animal must learn, social animals must learn how to communicate with others of their species. That requires concepts and ontological categories for the communicative signals themselves (body postures, chemical signals such as urine as a territorial marker, sounds, touch, facial expressions and many others) as well as the ability to associate them to specific behaviors that the learner can interpret or mimic.

The human version of such primitive social behavior includes social dominance and submission signals, group membership awareness, predator awareness and warnings. These cognitive skills are crucial to successful cooperation and perhaps to forming primitive morals, such as those that minimize fratricide or incest.

Cultural ontologies – The most intelligent social species *actively teach* their young. Examples include elephants, primates, corvids (ravens, crows, magpies, etc.), parrots, dolphins, whales and wolves. Many of these explicitly pass on information via structured and emotive utterances that lack the syntactic structure necessary to qualify as a language – call them proto-languages.

Elephant groups in the wild communicate with each other using "... more than 70 kinds of vocal sounds and 160 different visual and tactile signals, expressions, and gestures in their day-to-day interactions" [26]. Wild elephants exhibit behaviors associated with grief, allomothering (non-maternal infant care), mimicry, a sense of humor, altruism, use of tools, compassion, and self recognition in a mirror [27]. Parrots develop and use individual unique names for each other that also encode their family and close knit "clan" relationships [28]. Crows even recognize and remember individual human faces and warn each other about humans that have been observed mistreating crows. These warnings spread quickly throughout the flock [29]. Aided by theory-of-mind insights into the juvenile learner's forming mind, these species purposefully teach about what foods are safe, what predators to flee, the meaning of group signals such as postures and vocalization, the best places to hunt or find water, cooperative behaviors when hunting, and who's who in the social structure of the group.

Ontologies needed to support animal social cultures must be rich enough to allow for learning the vocal and non-vocal signals used to organize cooperative behavior such as group hunting or defense. The ontology must also support recognition of individuals, placement of those individuals in family and clan relationships, and meta-cognitive (Theory of Mind) models of individuals.

Human versions of the animal cultural rung are quite similar to the animal version when the knowledge to be transferred is not well suited to verbal description. Non-verbal examples might include playing musical instruments, dancing, fishing, athletic activities such as skiing, and perhaps the art of cooking. We are, however, so skilled at developing vocabulary to teach verbally that completely non-verbal human teaching is relatively uncommon. Building a non-verbal cultural AGI beginning with a primitive social AGI may be a difficult step because it will require non-verbal theory-of-mind.

It may be strategically important for AGI researchers to first learn to build a primitive social AGI before attempting to address human culture because it is very difficult to determine whether a given human juvenile behavior has been learned by passive proximity (i.e., social mimicry) rather than by active teaching by adults or siblings (i.e., culture). That distinction is nonetheless important because humans tend to be less conscious of behavior learned by passive mimicry than behavior actively taught. And some behaviors, such as empathy, are very difficult, if not impossible, to teach. A common example is epitomized by a parent saying, "I just don't know how Mary learned that," when everyone else recognizes that Mary learned it by mimicking the parent. Moreover, an AGI that did not learn important primitive human social skills, skipping instead to the cultural learning rung may turn out to be an AGI sociopath: a completely asocial, completely selfish predator with an overlaid set of behavioral rules taught without the necessary social grounding.

Oral linguistic ontologies – Human language (including fully syntactic sign language) facilitates an explosion of concepts which at this level are more appropriately called memes [30]. Meme, as we use the term here, approximates the notion of a concept, often but not necessarily expressible in words. Language both supports and reflects a richer and more complex meme structure than is possible without language. Oral cultures are not "dumbed-down" literate cultures (a common misconception). Primary oral cultures – those that have never had writing – are *qualitatively different* from literate cultures [31].

Language in primary oral societies uses a more complex and idiosyncratic syntax than written language, with rules and customs for combining prefixes, suffixes, and compound words that are more flexible than those used in writing. The rules of oral language have to do with the sound, intonation and tempo of the language as spoken throughout prehistory and in the many non-literate societies that still exist. Such rules define allowable vowel and consonant harmonies, or restrict allowable phoneme usage such as two phonemes that may not occur in the same word [32]. Oral cultures use constructs such as rhyme and rhythm, alliteration and other oratorical patterns to aid in the memorability of utterances without the aid of a written record. Oral cultures also aid memorability via rituals, chanting, poetry, singing, storytelling, and much repetition. And they employ physical tokens and other stigmergy structures such as ritual masks and costumes, notched sticks for recording counts, decorations on pottery or cave walls, clothing and decorations symbolic of status, astrology (used for anticipating and marking seasons, e.g., Stonehenge) and the like.

AGI researchers will need to be exceedingly careful to properly develop an oral-language human-level AGI because academics are so thoroughly steeped in literate intelligence that they may find it difficult to put that experience aside. For example, literate people find it very difficult to grasp that the notion of a "word" is not necessarily well defined and hence it is not necessarily the atomic base of language nor the fundamental ontological concept for a primary oral language (or sign language) [33].

Literate ontologies – Writing emerged from spoken language in complicated ways that vary with the specific language and culture [34]. Writing and other forms of long-term recorded thought allow generations and populations far removed from each other, temporally or physically, to share verbal knowledge, reasoning, experience of events (history), literature, styles of thought, philosophy, religion and technologies. Caravans and ships that once transmitted verbal gossip, tall tales, and rumors, began also to carry scrolls and letters which communicated more authoritative information. Literacy exposes people to a wider variety of memes than does an oral culture. As literacy became more common, the memes transmitted via writing grew in number and importance.

The specificity and permanence of a written work also allows more formal and longer-range relationships between the parts of the written "argument" than can be accomplished solely with real-time verbal communication. The development in the last century of recorded audio and video has similarly and dramatically changed the way we learn and reason. And now that these kinds of media are globally available over the Internet, we can expect further changes in human reasoning and ontology.

Since AGI researchers are familiar with the relationship between language and intelligence, little more need be said here. But that familiarity does not necessarily tell us what must be added to the ontology or the reasoning skills of an oral-language AGI to support literacy. It took a millennium after the invention of writing for humans to widely adopt literacy. We suspect that there are some mysteries hidden in the transition that will surface only when AGI researchers attempt to add literacy to an oral-only system. Understanding written material and writing original material are not simple modifications of conversation. Writing does not provide for immediate feedback between the writer and the reader to signal understanding or disagreement, nor a clear context in which the information exchange is embedded. The reader cannot interrupt to ask what the writer really means, or why the author even bothered to write the material in the first place. What would AGI researchers need to add to an orally competent conversational AGI for it to pick up a book on its own and read it? Or sequester itself in some upper room to write a book, or even a prosaic email, or a tweet? We simply don't know.

Civilization-scale ontologies – Over the longer term and wider geography, literacy and other persistent forms of human knowledge can affect large numbers of people who combine and recombine ideas (memes) in new ways to form new memes. These memes spread throughout and across cultures to be further combined and recombined and accepted or forgotten by large portions of the population. Ideas like money, capitalism, democracy, orchestral music, science, agriculture, or Artificial Intelligence can gain or lose momentum as they travel from mind to mind across generations, centuries, and cultures. Cultural memes of this sort are not phenomena that operate at the level of individuals, or even small groups of individuals. They do not run their course in only a few months or years. For example, the idea of humans landing on the moon played out over a century (from Jules Verne, a French author writing in the early 1860's, by way of German rocket scientists in the 1940s, to the American Apollo 11 landing in 1969). At no time did any human mind encompass more than a tiny portion of the knowledge required for Neil Armstrong to make his “one giant leap for mankind.”

Humanity collectively reasons about the world in slow, subtle and unobservable ways, and not necessarily with the help of literacy. Some ancient civilizations appear not to have relied on writing, e.g., the Indus Valley civilization [35]. Modern civilizations are continually being changed by audio and video shared over radio, television, mobile phones, and the Internet. Live television broadcasts allowed people worldwide to share the experience of the Apollo-11 moon landing, the 2001 destruction of the World Trade Towers, the recent Arab-spring events, and disasters such as floods, earthquakes and tsunamis. Widely shared events or manifestations of ideas directly affect civilization-level reasoning that is seldom observable in any individual human, yet is increasingly easy to observe in the Internet [36]. The ontological requirements for supporting intelligence at this level are largely unexplored.

The civilization-level may turn out to be where researchers first succeed in building an AGI that can surpass some of the abilities of humans on the basis of orders of magnitude more memory and search speed. IBM’s WATSON [37] seemed to do so, but WATSON isn’t even an AGI, let alone a human-level AGI. Time will tell. First, the AGI needs to be competent in all the other rungs simply to make any sense of what it reads, sees, and hears in the libraries of civilization, or their digital equivalents on the Internet.

4.6 Conclusion

The octopus is clearly quite clever. Building an AGI with intelligence roughly equivalent to that of an octopus would be quite a challenge, and perhaps an unwise one if it were allowed to act autonomously. A human-level AGI is far more challenging and, we believe, quite hopeless if one attempts to start at the higher rungs of the intelligence ladder and somehow finesse the lower rungs or fill them in later.

From the beginning of ancient philosophical discourse through the recent decades of AI and now AGI research, mankind’s quest to understand and eventually emulate the human mind in a machine has borne fruit in the ever-increasing understanding of our own intelligence and behavior as well as the sometimes daunting limitations of our machines. The human mind does not exist in splendid isolation. It depends on other minds in other times and places interacting in multiple ways that we characterize in terms of a metaphorical ladder. Mapping out the journey ahead and acknowledging the challenges before us, we must begin at the base of the ladder and climb one rung at a time.

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