Remarks on the Future of AI: Machines and Communication

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Abstract

Artificial Intelligence will continue to flourish in many ways. In this article, we present a view that centers on communication. Genuine human-computer communication has been an ambitious goal of Artificial Intelligence for decades and bears great potential for its future. Yet, nature still remains the sole successful crafter of systems capable of this art. Observations of natural communication processes suggest a holistic view that unites different means and levels of communication. Patterns from various senses as well as vast amounts of contextual information are integrated to yield an approximate understanding of reality. Instead of focusing on individual aspects of high-level communication techniques, we advocate to trace this holistic approach to communication and to systematically increase algorithmic, integrative communication capabilities.

Keywords: AI future, communication, holistic view, living organisms.

Introduction

Artificial Intelligence will prosper towards many directions, and we have selected a specific perspective for its future in this article. In particular, we are looking at systems of artificial intelligence as genuine collaborators in communication. This is a far-reaching perspective, as it requires machines to be able to make effective use of a broad spectrum of communication methods. It is clear that this goal will not be fully achieved within a short period of time, if at all. But we believe that any step towards it will spawn significant progress in numerous areas in and around Artificial Intelligence.

In the remainder of this text, we sketch out basic aspects of communication, we briefly outline achievements in human-computer communication and we point out the weaknesses of the taken approaches. So far, the functional view, i.e. the effectiveness of communication has been at the center of scientific interest. However, we believe that a holistic view on communication, which has not won acclaim outside of the cognitive sciences yet, will result in greater leaps towards genuine human-machine communication and collaboration. Therefore, we present a deeper investigation into the emergence of successful communication. Our observations reach from low-level techniques of sending and receiving messages to complex, high-level processes in the brain.

For this purpose it seems useful to us to trace the structures and processes of communication that recursively emerge across biological scales, from molecular interaction networks to inter-cellular communication to individuals and societies. We deem this bottom-up view invaluable for investigating and formulating high-level, intelligent communication as it unfolds an important perspective on issues in communication such as contexts and abstraction.

The traditional dominance of mathematics and logic in Artificial Intelligence has borne wonderful fruits that provide a strong foundation for many aspects of thinking. In [1], it was argued that this foundation should be extended to consider approximation techniques in reasoning. In some sense this article expands on this perspective.

We will have an outlook on possible future work that promotes the design and the application of a rigorous mathematical framework to support the ongoing endeavors of the emerging field of Biological Computation and other areas that deal with dynamic, complex systems. We also indicate to make the progress precise.

Communication

Humans can communicate in written form, via the spoken word, through making gestures or by presenting images. All these means of communication rely on various parts of our bodies: our eyes, ears, vocal tract, arms, hands, fingers, face muscles, etc. Without rigorous scientific investigations, we would not be aware of how they actually work. Different mechanisms are involved in acquiring the skills that are necessary for communication. Writing and speaking, for instance, are skills that are taught, whereas the abilities to make noise or to move limbs are innate.

We have to keep in mind that in addition to numerous body parts, large numbers of humans can be involved in a communication process. In fact, the number of participants seems arbitrary, reaching from a single individual in monologues to thousands or millions of people in the mass media and digital communication networks.

Communication is motivated and directed by goals. For instance, one might want to exchange information, to come to an agreement, to entertain, to praise or to offend. In order to achieve the desired goals, some of the tokens of communication relate to the experienced world and create a semantic context.

Accordingly, communication is an integration task that considers syntax to understand the relationships within a statement and semantics to relate the communicated terms to the real world.

Gestures that support the spoken language are an example of the integration of different parts of a conversation: Accompanied by a gesture, a spoken sentence can evoke a radically different meaning. In addition to the concurrent use of several means of communication, syntactical and semantic contexts can further be created and modified by the situation in which the communication takes place, the communication partners' socio-cultural backgrounds and any previously exchanged information.

Understanding and interpreting these contexts is an essential aspect of intelligence, often referred to as Social Intelligence.

In fact, humans judge about their communication partners' intelligence from their ability to build on and to respond to them. Simply uttering a correct statement is not awarded with intellectual credit. On the other hand, incorrect or disputable arguments do not usually result in denial of intellectual abilities either. We conclude that the ability to integrate information is the foundation of understanding and communication.

Communication Networks and Contexts

Syntax determines the relations of words and statements in language, semantics adds references to the real world, thus creating relations of living beings, things and processes. Together syntax and semantics form algorithms that, when processed, reveal a message. Based on this perspective, the given communication contexts provide all the information that words and statements can possibly reference. Therefore, contexts can be seen as the set of all possible inputs for the algorithm of communication

When individuals share their knowledge in groups they create new communication contexts. As individuals can be part of many groups they can carry information from one group to another, enriching the respective groups' communication contexts. Groups can merge or break apart. Intersections of knowledge bases can form specific contexts and unions can result in very broad and general ones, etc. Inevitably, a highly complex and dynamic communication network emerges resulting in innumerable contexts---not even considering the individuals' backgrounds and the multitude of means of communication.

It is impossible to concisely capture all these contexts. Yet, our shared experiences, the standardization of language, and its intrinsic abstraction make it possible to communicate based on a rich contextual foundation. Additionally, quick-witted remarks, wise decisions, intelligent responses, and the formation of new communication contexts in everyday situations require the continuing and approximate integration of all available information.

The Present State of Human-Computer Communication

Communication has always been an important aspect of AI, which makes it impossible to provide a comprehensive overview in the scope of this article. In general, the biggest strides have been made in written, text-based communication---the methods for generating, receiving and understanding written text are fairly advanced. Less progress has been achieved regarding the use of speech, images and gestures. One reason is that the workings of the human perception systems are not sufficiently well understood, in terms of physiological models and also regarding numerous mathematical and statistical problems that still need to be addressed.

The field of Human Computer Interaction (HCI) explores possible hardware and software interfaces for human-computer communication. Mixed-reality devices in combination with digital surfaces and speech processing already offer a rather rich set of possibilities for human-computer communication. Current examples comprise fairly successful approaches of speech synthesis and attempts toward the humanization of digital surfaces [2].

Despite the individual successes of certain AI and HCI approaches to communication, the integration of various levels of communication and connecting them with contexts and intentions is still an unsolved challenge. In fact, this lack of integration has been a major obstacle for establishing genuine human-computer communication. Systems for answering questions and for conducting advanced dialogues work well in confined laboratory environments that pose isolated, well-defined problems. In our everyday lives, however, we cope with multifaceted, ill-defined and inexact communication.

There is an analogy between computers receiving messages that refer to stored contents and the stimulus-triggered activation of neural patterns in the brain. Beyond mere storage/retrieval tasks, however, humans have at least one fundamental advantage: They are able to adjust their knowledge by using common sense and informal concepts. Modeling common sense and the frame problem have been attacked for decades. The most ambitious approach is the Cyc project that has been building an impressively large knowledge base of logically phrased facts [3]. Regardless of a number of interesting results, its overall goal, i.e. to recreate human-like reasoning, has still not been achieved after more than 25 years. To some extent, Cyc has been floundering because of the high degree of precision captured by its knowledge representation.

All the outlined approaches are being actively pursued. However, instead of addressing local problems, new initiatives have to be taken to integrate the solutions and approaches that we have already. As a guideline, we suggest a holistic view on communication that is oriented towards biology and evolution, because, to this day, nature provides the sole example of successful emergence of genuine, intelligent communication. Although we can neither computationally nor otherwise retrace evolution in its entirety, we should still learn from it. For this purpose, we suggest an investigation from very simple communication to complex information.

Bottom-Up Communication

In this section, we retrace the physical underpinning of communication and we emphasize the increase in communication complexity in accordance with the emergence of abstraction in communication.

Since cellular behavior is driven by molecules, and since cells absorb and secrete molecules, they can establish two-way communication, not unlike signal processing in computers. Seeing molecules as both the medium and the message reduces communication to a physical, mechanical process. Obviously, interpreting patterns in the physical environment is invaluable for any kind of organism. Bacteria, for instance, use physical information to optimize their foraging strategy: They pursue a random walk until they discover an improvement in their food supply. They follow the rewarding direction until the food supply drops, triggering an exploratory random walk, or 'wobbling', again. Obviously, the differences in food supply provide important patterns to inform the bacteria's behavior [4].

An extension of the senses, an increase in memory and progress in putting two and two together lead to advances in communication and to higher levels of abstraction.

Social insects, for example, realize increasingly abstract, powerful ways of communication. (1) They inform each other about trails or territories through depositing pheromones [5]. (2) They coordinate nest construction work by reacting to and changing the built environment [6]. (3) While cutting leaves, ants cause vibrations from which their mates estimate the quality of the leaves' flesh. (4) Honey bees perform a wiggle dance to convey direction and distance of food sources---it is especially interesting that the dancer poses in relation to the sun, reflecting the spatial context of the message [7].

Over the course of time, powerful tools and mechanisms for communication have evolved from the bottom-up. Computers are programmed bottom-up, too, starting with individual bits. However, humans and animals can rely on complex, co-evolved and inter-connected communication systems like the vocal tract and the ear. From a technical perspective, these systems bring about an increase in sensory information gain and extended and adapted memory. As a consequence, they provide the vast sets of distinguishable signals one requires to effectively learn abstractions and, in turn, to apply them to incoming information.

Insights and Challenges

Nature has not only come up with solutions for genuine communication but also provides us with the opportunity to seek inspirations from the various degrees of communication capabilities exhibited by organisms around us. We observe an increase of sensory information in tandem with an augmentation of abstraction and pattern matching processes.

In this context, we naïvely define progress as a partial order of communication abilities over sets of organisms. In order to render this naïve definition more precisely, we propose a series of specialized Turing tests. Unlike the Turing test, however, we suggest unrestricted testing scenarios, in which, for instance, the successful mapping from spoken words to gestures could indicate progress in communication abilities.

Progress in communication has been achieved by extending the capabilities of perception and interpretation of patterns. The greatest leaps toward genuine communication, however, have been accomplished through the integration of existing capabilities. The ability of abstraction increases when senses and actuators are utilized in novel ways, when patterns merge and meta-patterns form, when interaction cycles and complex networks emerge---metabolically, system-wide, between individuals and the environment, among individuals, and between groups. This realization prompts us to systematically push toward the unification and integration of established approaches in AI. It is not local improvements but holism that currently poses the greatest and most important challenge in Artificial Intelligence.

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