

Chapter 2

Definitions, Concepts and Assumptions

In this chapter, a description of the scope and goals of CogInfoCom is provided. This is followed by an overview of novel concepts—such as those of mode and type of communication, as well as the more general notion of cognitive capability—which have emerged through the field. Further, a set of assumptions, primarily founded on the existence and consequences of the merging process between humans and ICT, are described in terms of their relevance to CogInfoCom research.

2.1 Defining CogInfoCom

Humans and the infocommunications network (ICT in a broader sense) surrounding them are merging together and becoming entangled at various levels, ranging from low-level connectivity at the cellular and electrotechnical level, all the way to the highest level of sensing collective behaviors such as mass movements, mass habits etc. As a result, humans (more generally, living beings) and infocommunications will soon coexist as an entangled web, resulting in an augmentation of both natural and artificial cognitive capabilities.¹ This process is occurring today, and is expected to gain further impact in the near future. By analogy, it also necessitates a merging process between the scientific fields related to natural cognitive systems and the scientific and technological fields related to infocommunications. The above motivations have contributed significantly to the definition of CogInfoCom. A draft proposal of the definition was provided in Baranyi and Csapo (2010), and was later refined by Professors Nick Campbell, Tom Gedeon, Hideki Hashimoto, Toshikazu Kato, Tetsuo Kotoku, Kristiina Jokinen, Joo-Hoo Lee, Gábor Magyar, Helen Meng,

¹As we will see, in many cases this separation between natural and artificial is no longer meaningful.

Géza Németh, Mihoko Niitsuma and Gyula Sallai at the 1st *International Workshop on CogInfoCom*, held in Tokyo, Japan in 2010. The finalized definition is as follows:

Definition 2.1. Cognitive infocommunications (CogInfoCom) investigates the link between the research areas of infocommunications and the cognitive sciences, as well as the various engineering applications which have emerged as a synergic combination of these sciences. The primary goal of CogInfoCom is to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices so that the capabilities of the human brain may not only be extended through these devices, irrespective of geographical distance, but may also interact with the capabilities of any artificially cognitive system. This merging and extension of cognitive capabilities is targeted towards engineering applications in which artificial and/or natural cognitive systems are enabled to work together more effectively.

2.2 Concepts Emerging from CogInfoCom

As will be discussed later in this chapter in further detail, the implicit and explicit assumptions underlying CogInfoCom together form a unique viewpoint. As a result, new notions and concepts capable of leading to new research directions are continuously emerging. In this section, two early concepts central to multi-sensory communication between various levels of cognitive capability are introduced: the mode of communication, and the type of communication. In the future, these concepts may be extended to provide a more detailed qualification (and in the long run: quantification) of cognitive capabilities independent of the exchange of communicational messages.

2.2.1 Mode of Communication

The mode of communication refers to the way in which the relationship between actors at the two endpoints of can be characterized:

- **Intra-cognitive communication:** information transfer occurs between two cognitive entities with equivalent cognitive capabilities (e.g., between two humans, or between two humans in the same social-technological environment—as determined by what is relevant to the application).
- **Inter-cognitive communication:** information transfer occurs between two cognitive entities with different cognitive capabilities (e.g., between a human and an artificially cognitive system, or between two humans in different social or technological environments—as determined by what is relevant to the application).

In accordance with the introductory remarks to this section, future developments are expected to lead to a deeper, perhaps quantified understanding of what is meant by level of cognitive capability. Further discussions on this notion can be found in Sect. 2.3.2.

2.2.2 *Type of Communication*

The type of communication refers to the way meaning is conveyed between the two communication entities:

- **Sensor-sharing communication:** cognitive entities on both ends use the same sensory modality to receive information.
- **Sensor-bridging communication:** sensory information is not only transmitted, but also transformed to a different, more appropriate sensory modality of the receiving cognitive entity.
- **Representation-sharing communication:** the same information representation is used on both ends of communication.
- **Representation-bridging communication:** sensory information is filtered and/or adapted so that a different information representation is used on the two ends of communication.

A sensor-sharing application brings novelty to traditional infocommunications in the sense that it can convey any kind of normally perceptible signal (i.e., a signal that could be perceived if there were no distance to communicate across) to the other end of the communication line. The key determinant of sensor-sharing communication is that the same sensory modality is used to perceive the information on the receiving end of communication as would be if there were no distance between the sending and receiving ends.

Sensor bridging can reflect both the way in which information is conveyed (i.e., by changing sensory modality) as well as the novelty of the information type that is conveyed. Whenever the transmitted information type is imperceptible to the receiving entity due to a lack of appropriate sensory modality, communication will necessarily occur through sensor bridging.

A CogInfoCom application can be regarded as an instance of representation sharing even if it bridges between different sensory modalities. By considering the general characteristics of a representation (e.g., its character-based, icon-based etc. nature) rather than the specific details of its physical or biological manifestation, it becomes possible to describe representations of different modalities in unified ways.

As mentioned in the introductory remarks to this section, aspects encompassed by the concept of type of communication are relevant only when explicit communication occurs in a way that is directed at information sharing. As this is only a small part of what it means to communicate, further extensions can be expected to emerge in future work (see also Sect. 2.3.3).

2.3 Implicit and Explicit Assumptions

The definition of CogInfoCom as well as the discussions on the scope and goals of the field lay emphasis on the merging process between humans and ICT, as well as on different levels of cognitive capabilities and long-term co-evolution of biological and artificial systems (Baranyi and Csapo 2010, 2012). In this section, a brief discussion is provided on these aspects to further highlight the focus of the field. The section is concluded by observations on the new information concept that is implicitly assumed by the CogInfoCom, as well as the transition from operation to emergent functionality that implicitly motivates research within the field.

2.3.1 *Levels of Merging and Entanglement*

As mentioned earlier in Sect. 1, one of the key observations behind CogInfoCom is that there is a merging process between humans and ICT that is resulting in increasingly complex forms of human-ICT entanglement, and is at the same time creating the necessity for an analogous convergence between technology and the human-oriented cognitive sciences. The phenomena of merging and entanglement in the context of ICT are clear not only from everyday experience, but have also been remarked and analyzed to various degrees and in various contexts by many authors, as in e.g. Romportl et al. (2015), Pang (2013), Gripenberg (2011), and Dahlbom (1996).

From the point of view of interaction modes, the merging process between humans and ICT can be observed at three different levels:

1. The first level of entanglement corresponds to low-level, direct relationships, including those that rely on invasive and non-invasive forms of interface (as in e.g. brain-computer interfaces). Entanglement at this low level allows for direct sensing and control, however, it is also relatively cumbersome in that it requires sensors to be implanted or worn and is also difficult to operate at conceptually higher levels of command.
2. A different form of entanglement is possible at the level of personal informatics devices, in which communication and interaction occur through (human—but crucially not only human) sensory modalities. The question of what kind of “communication language” to use (i.e. in terms of message encoding) depending on the semantics of the information, as well as—among others—the modality to be used, the application environment, and the user’s individual cognitive capabilities are strongly relevant to this level of entanglement. It is important to note that the challenge consists not only in providing effective and ergonomic interface design, but also in accommodating the transfer of an expanding set of semantic concepts—relevant at large temporal scales, for instance in co-existent smart home and other augmented virtual reality applications—through the limited possibilities afforded by human sensory modalities.

3. Finally, a third level of entanglement can be seen to occur at the collective level of multi-user interactions. Applications in this layer can have relevance to collective behaviors in two ways: by making use of collective behaviors in order to support individual users' interaction with a system; or alternatively, by supporting the prediction or a posteriori analysis of collective events based on an analysis of past behaviors (both individual and collective). Such applications often rely on the mining and analysis of vast amounts of heterogeneous data sources—including e.g. activity on social communication platforms.

From a general perspective, Hodder defines entanglement as “*the sum of four types of relationships*” in which “*humans depend on things (HT), things depend on other things (TT), things depend on humans (TH) and humans depend on humans (HH)*” (Hodder 2014, 2012). All four of these co-dependence relationships can be equally observed in the particular case of human-ICT entanglement. However, it is important to note that all of them can, and should be interpreted at multiple temporal scales, ranging from episodic interactions that are point-like in time to decades-long periods of co-existence. An important quality of human-ICT entanglement is that co-existence with ICT is becoming an inseparable feature of the everyday experience of children growing up today. This is a new phenomenon that is opening new avenues of research which extend far beyond human-computer interactions; such research must take into consideration the not only the capability to achieve certain functions in comfortable and effective ways, but also the psychological and mental effects of long-term use, and how ICT can evolve together with humans in order to become a natural, ecologically valid part of the everyday human experience.

For example, the psychological effects of ICT can be grasped by considering the effects of ubiquitous e-mail access and connectedness—as suggested by popular notions such as *e-mail apnea*,² *phantom vibrations* or *internet indispensability* (Stone 2011; Drouin et al. 2012; Platzer and Petrovic 2011); as well as the general feeling one experiences when a device or network malfunctions (the feeling that part of oneself is malfunctioning rather than an external technology) as described in Pang (2013). It is also worth considering how the Internet is *physically* closer to users than before: while a decade ago, shutting down the computer for the night meant that access to the Internet was finished for the day, today nothing is easier than checking our e-mail or the weather report one more time on any of the number of mobile devices surrounding us.

Such long-term co-existence in turn raises awareness on the usefulness of applications with long-term goals. Apart from enabling users to perform a specific task in a specific domain, an equally viable goal might be to support, through ICT, the development of a capability to perform an increasingly complex set of tasks (this is the case, for example, in *speechability* and *mathability*, as will be described in Sects. 5.2 and 6.6). It should be noted that long-term interactions are also capable of generating functionalities that are not planned for a priori (see also Sect. 2.3.3). For example, as users continuously interact with, and increasingly

²“A temporary absence or suspension of breathing, or shallow breathing, while doing email” (Stone 2011).

become entangled with systems of ICT components, new use case requirements, and new possibilities for previously unknown functionalities are discovered. The accommodation of such functionalities, in turn, can create new patterns of usage—many of which may then have a recurrent effect on usage patterns, and potentially even on the social organization of the community of users involved in the merging process. This mutual influence between usage patterns and use-case requirements is creating an open-ended evolution of functionality. From a different perspective, long-term co-evolution between humans and ICT is also enabling the “offline” collection of vast amounts of data which can later be instrumental in developing new applications (for example, if those applications rely on machine learning techniques requiring large amounts of data). As a result, the creation of new functionalities is facilitated in more than one way through the implicit knowledge that is generated from past interactions. Based on the above, we introduce the term **tangleface** to be used instead of the word *interface* when characterizing ubiquitous human-ICT relationships. Additionally, we use the term **tangleaction** instead of interaction when such relationships persist through extended periods of time. These notions will be used often and elaborated from a variety of perspectives in later parts of this book.

2.3.2 *Levels of Cognitive Capability*

From a CogInfoCom perspective, any kind of hardware or software component that actively collects/stores/understands/communicates data can be seen as a component with a set of cognitive capabilities. Whenever users become entangled with a system of such capabilities, the border between the natural and artificial gradually becomes vague. In other words, it is often the case that there is no longer any objective border between purely human and purely artificial cognitive capabilities. For example, in a scenario where a user controls an industrial robot with one hand using knowledge obtained from a smartphone held in her other hand, the question immediately arises: should this interaction be characterized from the perspective of communication between three different entities, or is there benefit in viewing the user and the smartphone as one entity that is communicating with the robot? The answer to this question is important, if only for the fact that both the robot and the supporting smartphone application might be designed differently if it is known in advance that they will be used together in this specific scenario, or if the cognitive effects that the smartphone application will have on the user—such as limited dexterity and attention, increased capabilities for information access, etc.—are known in advance. To consider two other examples, the boundary between artificial and human capabilities would be equally blurred in a scenario where a user’s lower arm is augmented through a robot arm that is capable of downloading new “skills” from an ICT network; or in a scenario where a pair of augmented glasses, or an augmented helmet is used to provide an industrial operator with real-time information feeds complementing the task at hand (such technologies are already present in industry, and are on the verge of commercial breakthrough).

The bottom line is not that one would be philosophically inclined to specify a boundary between entities, but that it is also necessary to specify such boundaries from the functional perspective of engineering design. On the one hand, in a domain where difficult problems of synthesis can be effectively tackled only by breaking them down into smaller components and gluing those components together through some form of communication once they are complete, the functional boundaries at which this is done can make or break the tractability and sustainability of an implementation. On the other hand, once it is accepted that the boundaries between artificial and natural are not as clean as they were a few decades ago, unprecedented possibilities emerge for the development of new functionalities—even cognitive capabilities. Such capabilities can be seen as implemented in the dependencies between components in much the same way as lower-level functionalities are created as a result of several different components working appropriately in mutually specified contexts. This hierarchical dependence among capabilities can be seen as leading to a hierarchical organization of cognitive capabilities.

The embodied perspective of cognition that is currently favored in the cognitive sciences adopts the view that human cognitive capabilities and human intelligence are emergent properties which cannot be separated from the physical, biological, neurophysiological and higher-level bases of our mental existence (Deacon 2013). It is also clear that the social and technological context of our interactions with other humans and ICT further influences the kinds of mental and physical work that we are able to perform (Hollan et al. 2000; Deacon 2013). Further, analogous emergent properties can be identified in the functionalities of ICT devices and networks. Although the view that computers are merely symbol processing systems has been implicitly accepted for decades by thinkers and technologists of all backgrounds, an emergentist view of computing is now gaining acceptance. Though fundamentally different from living systems it can be argued that all computational systems (apart from purely theoretical constructs such as the Turing Machine) have some form of embodiment, and that furthermore, computation in general has physical underpinnings and physical ramifications (Heder 2014). As highlighted by several authors, even lexical knowledge such as knowing the derivative of the sine function or knowing the capital of a country is strongly embodied in the sense that without direct experience in working and manipulating functions, or without being able to travel and experience through our bodies what really constitutes a city, our notions would be entirely different (Picard 2003a; Heder 2014).

The extension of such notions to human-ICT entanglement and emergent cognitive capabilities can be seen as a natural development. It can be argued that not only are new functionalities and cognitive capabilities formed through human-ICT entanglement, but that they can also be seen as higher-order in the sense that they are dependent on lower-level foundations. However, this point of view also makes it possible for such higher-order capabilities to be combined into newer ones that are located at still higher levels of hierarchy. This process is illustrated in Fig. 2.1. From a practical point of view, the figure shows that all cognitive capabilities, however trivial in a human-ICT context, can be analyzed in terms of other capabilities on which they depend. This observation can serve as an important

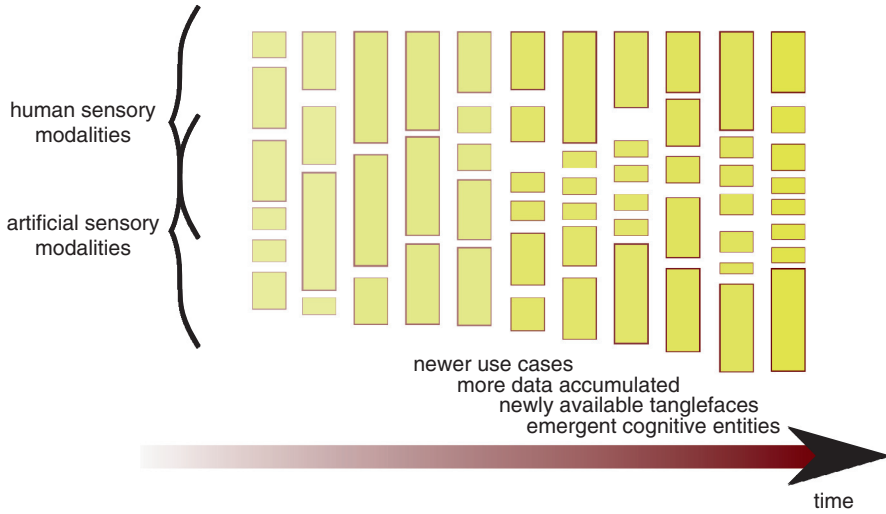


Fig. 2.1 New, higher-level artificial capabilities and emergent cognitive entities are created through time as new use cases are generated through a broadening of artificial sensory modalities and the increasing possibility for users to co-evolve with them through extended periods of time

starting point in the design of CogInfoCom systems, especially when combined with the goal of providing functionality rather than the ability to utilize operational procedures (see also Sect. 2.3.4). In this book, the term **cognitive entity** will be used when describing any synergic combination of humans, devices, infrastructure and environment that is identifiable from the perspective of some (high-level) cognitive capability. Whenever a cognitive capability is considered at a lower, less complex level—and pertains directly to a human or an artificial device, the capability is said to be embodied by a **cognitive being**, or a **cognitive thing**, respectively.³ Based on this terminology, cognitive entities are formed when information on various relationships between cognitive beings, cognitive things and their environment are stored, interpreted and acted upon in identifiable ways. As a result, a new perspective automatically emerges based on which cognitive entities can be analyzed and understood in terms of holistic cognitive capabilities without being broken up into constituent components. At the same time, the emergence of a new generation of users can also be prognosticated, which we refer to as the generation of cognitive entities, or **generation CE** by analogy with the well-known terminology of the generations X, Y and Z. It can be argued that members of generation CE, growing up starting from around the year 2010, are unique in the sense that the maturation of their personality and social life unfolds in an environment that is inseparable from cognitive ICT. The extended cognitive capabilities that ICT provides are merged into

³The analogy with the Internet of Things is clear, when IoT is regarded as a cyberization of the physical world together with humans, as will be detailed Chaps. 3 and 4.

the daily experience of this generation, and become irrevocably intertwined with its expectations and thinking processes, both at a conscious and subconscious level. Expressed more directly, one can say that ICT cannot be ‘taken away’ from this generation without bringing about significant cognitive effects and psychological discomfort.

2.3.3 An Emergent Concept of Information

It is important to clarify that the notions of merging, entanglement and levels of cognitive capability also suggest a unique concept of information that is implicitly present in CogInfoCom. Importantly, rather than being treated as a commodity that can be transmitted from one end of a communication line to another, information is seen as an artifact—a functionally relevant physical by-product—that emerges from embodied patterns of interaction and communication.

In this sense, the design of a CogInfoCom system or application involves not only the identification of various data and information types that are to be sent to various components at certain points in time, but also a broader consideration of how nuanced differences in behavior can lead to functionally relevant by-products, how these by-products cause the communication between cognitive entities to evolve through time, and how this evolution can be directed towards further, novel functionality in flexibly re-usable ways. Thus, a common past—i.e. one that is accumulated in goal-independent ways through a progressive human-ICT co-evolution—can be expected to eventually yield increasingly rich, functional models of how humans are capable of communicating and operating in ICT settings.

While it may be the case that in an information system, a solution to any of these problems will eventually require suitable data structures for representation and manipulation at a more “atomic” level, the CogInfoCom perspective nevertheless suggests that the starting point of design should be the observation and detection of emergent possibilities for novel interpretation leading to novel functionality.

2.3.4 Transitions from Operation to Functionality

As described earlier in Sect. 2.3.1, new human-ICT capabilities are formed based on new kinds of co-dependence relationships among and between humans and ICT. It can also be observed that the details behind these capabilities (i.e., how they are implemented) become gradually less important through time—at least from the

point of view of the user.^{4,5} For instance, a driver using Google Maps or Waze for direction information does not need to know whether and how many other drivers are queried for traffic congestion information before the system recommends a specific route. Similarly, to a user interacting with several social networks at the same time, the route taken by a link before it is shared with the user is unimportant; only its original source is important besides that fact that it eventually reaches the user. Many of the technological services we use on a daily basis we do so unconsciously, while taking for granted that they will be available through the flexible coordination of available devices and software components.

In this way, the emergence of CogInfoCom is implicitly based upon, and also further supports a transition from operation to high-level functionality. This transition is characterized by a decreasing need for explicit specification of use cases and operational details, and an increasing prevalence of high-level and adaptive, transparent functionalities that are seen and treated as tools rather than procedures of operation.

⁴An important characteristic of emergent phenomena is that they cannot be analyzed in a reductionist manner, by separating them into the parts from which they are constituted (Deacon 2013).

⁵Of course, from the perspective of an application designer, implementation details will always be important.



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