CogInfoCom Cues, Signals and Ritualization for Adaptive Communication

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Abstract—The merging process occurring between humans and the ICT network surrounding them has led to the emergence of several new paradigms in computing. Cognitive infocommunications (CogInfoCom) aims to investigate how cognitive processes can co-evolve with infocommunications devices, irrespective of whether those processes are entirely natural, entirely artificial, or a combination of the two. An important question in CogInfoCom is how communication signals can emerge and evolve naturally between various natural/artificial systems. In this paper, it is argued that the development of new technologies capable of adapting in their communication with users can be informed by research on animal communication. To elaborate this view, the ethological concepts of cues, signals and ritualization are adapted to CogInfoCom. The technological interpretations of these concepts are discussed in terms of design strategies and application examples.

I. INTRODUCTION

Cognitive Infocommunications (CogInfoCom) is an emerging field at the meeting point of infocommunications and the cognitive sciences [1], [2]. The goal of CogInfoCom is to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices, with special focus on the merging process which is occurring between humans and the ICT network surrounding them [3].

Since the formulation of the definition of CogInfoCom, several aspects have been investigated which could serve as a starting point for providing a common view between infocommunications and the cognitive sciences. The subject of this paper is motivated by research on CogInfoCom channels – structured multi-sensory messages which carry information on high-level concepts [4], [5]. Although the various techniques for conceptual mapping described in the context of CogInfoCom channels are applicable to a large extent in multi-modal collaboration scenarios, it can be argued that communication can and should be richer, both in terms of structure and content, and should serve other purposes as well besides transmitting information on high-level concepts. It has been suggested in the past that ethology should be taken into consideration when designing interaction forms with new technologies [6], [7], [8]. This point of view seems to be especially valid in CogInfoCom applications, where communication can be largely asymmetrical – i.e., between systems with very different cognitive capabilities [9].

The goal of this paper is to provide an overview of some of the key terms which appear in the literature on animal communication (i.e., cues, signals, and ritualization), and to give a brief outline of the relevance of those terms to CogInfoCom. A set of criteria are given which – if fulfilled – can lead to the emergence of signals and channels from cues through ritualization and a process which we refer to as “signal differentiation”. Conclusions drawn these discussions are illustrated in terms of two example application scenarios. In the first scenario, a smartphone learns to adapt to the user’s preferences with respect to the timing of e-mail notifications, while in the second scenario, an augmented/virtual collaboration environment adapts to provide signals which influence the user’s behavior in a way that is beneficial to the task.

The paper is structured as follows. In Section II, an overview is given of some of the key terms in animal communication, which will be relied on later in the paper. In Section III, an outline is provided on which of the introduced terms are relevant to CogInfoCom and how. Section IV contains a brief discussion on a general framework in which the adopted terminology could be applied in CogInfoCom systems, and the two example application scenarios are described.

II. CUES, SIGNALS AND RITUALIZATION IN ANIMAL COMMUNICATION

The question of whether communication can best be described in terms of information theoretical concepts (i.e., in which the task of communication is to transfer information as a ‘commodity’) or in terms of purely adaptationist concepts (i.e., in which only the behavioral effects of communication need to be considered, and a formal definition of information is unnecessary) is the subject of active debate [10]. Nevertheless, a recurring and central component of definitions of communication is that the behaviors of the sender and the receiver
mutually influence each other, and that the given behavior of the sender evolved precisely because of these mutual effects [10], [11], [12].

Through empirical research on animal communication, a number of interesting communication mechanisms have been uncovered, which vary based on the kinds of interaction they rely on, and the explicitness of the content they transmit, including alerting messages, meta-communicational messages (i.e., amplifiers and attenuators), redundancy components, referential, iconic and symbolic communication. Two general mechanisms which enable the emergence of various forms of communication have also been identified [12]. In the case of ritualization, a behavior which at first serves only the individual purpose of an animal is recognized as a cue by other animals, leading to changes in their behavior. The animal producing the original behavior learns to recognize this effect and evolves to exhibit the behavior purely for its behavioral effects in other animals (hence, the cue evolves into a signal through ritualization). In the case of sensory manipulation, a behavior which is originally intended as coercive (i.e., to evoke a certain kind of behavior from other animals) evolves into a signal once the receiver recognizes its own benefit in reacting positively to the coercive behavior; hence, the coercive behavior loses its deceptive character, but at the same time evolves into a form of communication that is amenable to replication.

Scott-Phillips et al. demonstrate convincingly that ritualization is much more common in nature than sensory manipulation [12], due to the fact that the constraints for the success of a ritualization process are more relaxed (whereas an animal may develop defense mechanisms to deceptive behaviors once they are identified as such). In this paper, the possibilities for ritualization are considered between humans and artificially cognitive systems.

III. CogInfoCom cues and signals

Whereas deceptive behaviors might for the most part be considered as alien to artificially intelligent communication systems, from a CogInfoCom perspective it seems natural to design artificial systems in a way that will allow for the emergence of ritualization. As the role of personal informatives devices gains increasing relevance, it is also becoming increasingly important for these devices to be able to adapt in the way they select, filter and present information to users, depending on users’ personal preferences and biases 1. Thus, it is conceivable that the artificial evolution of communication forms other than the high-level transmission of concepts can be beneficial to engineering design, and these new forms of communication could be centered around the concept of ritualization.

Based on the above, we propose the following definitions:

**Definition 1 (CogInfoCom cues).** CogInfoCom cues are sensory signals which cognitive systems are capable of perceiving

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1Research on adaptivity to biases is beginning to become increasingly important for applications in cognitive infocommunications, e.g. [13], [14].
As an increasing number of cues and signals are sent and received, cues can turn into signals through ritualization, and variations in signals can lead to the emergence of CogInfoCom channels through a process referred to as signal differentiation. Differences in the dottedness of signals symbolizes variations which can lead to signal differentiation. The red spirals symbolize the fact that it may take several interactions and exchanges of messages for ritualization and signal differentiation to occur.

necessarily know why the cue occurs). Signals, on the other hand, emerge with a more explicit goal: to evoke a certain behavior on the other end.

- Temporal relevance: In the general case, cues are presented before signals (given the fact that signals emerge through cues), and channels are presented after signals (i.e., unless the explicit meaning of a channel is clear a priori, its presentation may be preceded by a "negotiation" phase in which cognitive systems first try to elicit each others’ attention). During the course of interaction and after the emergence of signals through ritualization, there is a possibility that high-level concepts will be attributed to CogInfoCom signals – as small variations in them are interpreted as being caused by events in the world or changes in internal states. The process of evolution from signals to channels can be referred to as signal differentiation – in reference to the appearance of variations (Figure 2).

IV. DISCUSSION

A. Criteria for ritualization in CogInfoCom

A key point in the definition of cues and signals in both biology and CogInfoCom is that in order for ritualization to occur, the modified behavior of the receiver has to be beneficial to the sender. Hence, the question as to what is beneficial to an artificial cognitive system in CogInfoCom is of key importance.

The idea that artificial systems capable of autonomous development should have an inherent value system is not new, however, the significance of such a value system only becomes apparent once efforts are made to build truly enactive systems in which not even the designer can access and modify the internal state of the artificial agent [15].

Based on the above, the following points can be listed as necessary conditions for ritualization to occur between CogInfoCom systems A and B:

- Behavioral habits should exist which are to be exhibited by communicating system A so that CogInfoCom cues may emerge ("cue criterion 1").
- At least some of these behavioral habits should be attributable by CogInfoCom system B to their source ("cue criterion 2").
- At least some of the above cues should be in correlation with the emotional state or the integrity of CogInfoCom system B, prompting it to change its behavior ("signal criterion").

In biology, a common example of ritualization is the way in which some animals protect their territory by urinating along its periphery. What begins as a behavioral habit (the animal on the defense urinates to relieve the stress of being close to other animals – cf. cue criterion 1) turns into a signal when other animals attribute the habit to a source in the world (i.e., the presence of the animal on defense – cf. cue criterion 2), and when the same cause is in correlation with the emotional state or the integrity of those animals (i.e., the presence of the animal on defense represents a threat – cf. signal criterion).

Following the establishment of the signal, the animal on the defense will urinate along the boundaries of its territory even when it is does not feel stress – in order to elicit the same cautious behavior.

A crucial difference between communication in biology and between CogInfoCom systems is that communication can be more heterogeneous in the latter case, in the sense that CogInfoCom systems are expected to be able to communicate even when their cognitive capabilities are at a different level. This raises the question of interpretability: whether or not two cognitive systems with different levels of cognitive capability can effectively perceive and understand behavioral changes in each other, and whether this perception and understanding occurs in time for meaningful behavioral modifications to take effect. This leads to a further criterion for ritualization to occur between two CogInfoCom systems:

- Changes in the behavior of CogInfoCom system B should be accompanied by behavioral habits (cues, as in cue
**criterion 1** so that CogInfoCom system A may recognize them and learn to continue or discontinue its own habitual behaviors (“interpretability criterion”).

Although in the biological example, the animal on the defence will naturally perceive the disappearance of other animals which likely pose a threat, the relationship between internal states and external behaviors is much more difficult to interpret when there is communication, e.g., between a user and a personal device. Especially when the user wants to influence the behavior of the device, it is important that the device be able to provide cues which help the user ascertain that a change in the anticipation of behaviors has been registered. Hence, the **interpretability criterion** is a key point which guarantees that there will be a closed loop between cause and effect, and that ritualization can occur before cues from the past lose relevance.

**B. Application scenarios**

1) **Scenario 1 – E-mail notifications:** The smartphone notifies its user with a vibration whenever a new e-mail arrives. This is a desirable functionality, however, in many cases one finds that such notifications are too verbose. In particular, relatively few e-mails are important enough to merit explicit notification, while most e-mails (e.g., various newsletters and offers from different companies) are not.

A smartphone equipped with the means for sensing and distributing cues, and for evolving signals through ritualization, would be capable of adapting to the user’s needs. The criteria listed in the previous subsection could be fulfilled by the following properties (assuming that system A is the user and system B is the phone):

- the user naturally behaves differently if the e-mail that has arrived is important (handling the phone for a longer time and reading the message), than if the e-mail that has arrived is unimportant (expressing vocalizations of frustration and putting back the phone in its place). This can be perceived by the phone and attributed to the user, hence **cue criterion 1** and **cue criterion 2** are fulfilled.
- the temporal aspect of the user’s handling of the phone and the user’s vocalizations can be a source of “pleasure” or “displeasure” to the phone: hence, its emotional state correlates with the user’s behavior, and **signal criterion** is fulfilled.
- the ideal way in which the user’s behavior can be reinforced is if the phone makes explicit the fact that the user’s actions caused “pleasure” or “displeasure” (**interpretability criterion**). This way, the user can become accustomed to the fact that certain grunts or certain clicks of the tongue work in affecting the phone’s mood, and ultimately, its behavior.

The combination of these properties can lead to attention-seeking behavior on the part of the smartphone: it should learn when to correctly indicate the arrival of important e-mail, eliciting pleasant feedback (i.e., being handled by the user), and it should also adapt to avert the emission of cues when unimportant e-mail arrives.

The point in this example is not that the phone learns to associate different e-mail contacts with different levels of urgency; such a one-to-one mapping could be provided explicitly by the user. Rather, what is noteworthy is that changes in behavior occur adaptively through longer periods of interaction, and through the (artificial) cognitive functions of the phone, allowing for increasing correspondence to the context. For example, e-mails from a certain contact might be important if the user is spending leisure time, but may be disturbing if the user is actively working or is taking part in a meeting, etc.

2) **Scenario 2 – AR/VR social collaboration:** In our example on the reverse direction, i.e. when system A is an artificially cognitive system, and system B is the user, we consider an augmented/virtual collaboration scenario. It has been remarked before that even complex systems such as virtual reality environments and ambient computing systems – which are not considered to be infocommunication systems in the traditional sense – can be considered as such if they provide an interface for communication in information society technologies [16], [17] (cf. also Sallai’s recent definition of infocommunications, which defines the term as an expression of the integration between IT and telecommunications in terms of ICT [18]).

When ambient technologies, such as an augmented/virtual reality environment serve to communicate between people not only across space, but across time, interesting possibilities can arise. For example, the learning curve associated with the training of complex manufacturing tasks – such as welding, performing lathing operations, etc. – can be reduced if an AR/VR system is used to supervise apprentices and train them based on experience from the past [19], [20], [21]. Outside of manufacturing, it is conceivable that augmented/virtual reality systems can help users perform daily errands and chores more efficiently by suggesting alternative ways of ordering sub-tasks (e.g., based on the availability of resources) or alerting users when they forget to plan or execute steps along the way [22].

The latter type of scenario illustrates well why more subtle forms of communication are needed: users would surely find systems that constantly nag them about performing chores and about forgetting things undesirable. If communication signals and channels evolve from less explicit forms, however, personal devices can become not only more effective, but more likeable as well.

Returning to the criteria for signals to emerge, the following observations can be made regarding such a scenario:

- the system naturally behaves differently if the user is forgetting something – for example, forgetting to buy milk while going home, even though there is none in the refrigerator. This can be perceived by the device and attributed to the user, hence **cue criterion 1** and **cue criterion 2** are fulfilled.
- it is trivial that the system’s behavior correlates with the user’s behavior and emotional state: constant nagging could be the source of negative emotions, while the more effective accomplishment of chores could be the source
of contentment. Thus, signal criterion is fulfilled.

- the system’s behavior is reinforced by the aptitude of the user to heed its advice, among other cues. Thus, interpretability criterion is fulfilled.

V. CONCLUSIONS

Our goal in this paper was to extend the range of possibilities for communication in applications of cognitive infocommunications, by extending the framework for creating CogInfoCom channels based on ideas from studies on animal communication. Accordingly, we have adapted the definitions of cues, signals and ritualization to CogInfoCom, and also defined a process for the emergence of CogInfoCom channels from signals, which we refer to as signal differentiation. We have illustrated these mechanisms in the evolution of more natural forms of communication between users and artificially cognitive devices through two use-case examples.

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