Understanding Subjectivity:
An Interactionist View

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Abstract. User modeling is traditionally about constructing an explicit representation of the user. We argue against such approach because it overlooks the real nature of the human brain: plasticity and absence of monolithic control. Instead, we suggest to focus not on the modeling of the primary mechanism that explains a user's response but on the mechanisms through which technology can mediate as complex information as subjective responses. Indeed the only way two persons can reach mutual understanding over such responses is social interaction.

We propose a novel architecture based on three main components: (1) an elaborate sensory(-motor) apparatus, (2) a dynamical memory and (3) an active interface with turn-taking capability. It supports the interactive emergence of a common symbolic language through which user and system can share subjective responses over visual perceptions. We assert that while the "user model" is not explicitly constructed, it reveals in the interactive dialog between the user and the machine.

1 Introduction

Technologically-mediated information retrieval has been extensively studied recently and several systems have been made available that can successfully retrieve information based on its content (Niblack et al., 1996; Li et al., 1998; Del-Bimbo et al., 1998). The retrieval of information based on subjective requests (Kato, 1996a) has also been addressed, mainly using psychological profiles or other user models (Lee and Harada, 1998; Kitajima and Don-Han, 1998). Indeed, it is commonly accepted that modeling a user can help optimizing the coupling "user-machine", by eliminating the dissonance between natural human capability and the demands of technologically mediated activity (Gorayska et al., 1997). This is all the more relevant if one is to deal with as complex and non-explicit information as subjective or emotive response (e.g. retrieving a sad image). However, it is important to specify the nature of such user-model.

As defined by the call for paper of this conference, a user model would be an *explicit representation* of *properties* of a particular user. In this paper, we wish to argue against this definition. Our discussion is two-fold: about the *explicit* nature of the user model and about its target.

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Explicit nature of the user model: We argue that such characteristic implies an *explicit* human cognition as a basis for the design and, hence overlooks the main characteristic of the brain, namely, its continuous adaptation through processes both physical and cognitive[1]. Our claim is supported by evidence (also reported in Brooks et al. (1998)) from cognitive science and neuroscience which we summarize next.

- Human cognition doesn't rely on monolithic internal models: Such models only derive from naive models based on subjective observation and introspection and biases from common computational metaphors (Brooks, 1991). Modern understanding of cognitive science and neuroscience refutes those assumptions. Not only humans tend to minimize their internal representation of the world but those representations can even be not mutually consistent (Ballard et al., 1995). For example, in the phenomena of blind sight, cortically blind patients can discriminate different visual stimuli, but report seeing nothing (Weiskrantz, 1986). This inconsistency would not be a feature of a single central model of visual space. Humans tend to only represent what is immediately relevant from the environment, and those representations do not have full access to one another.
- Human cognition doesn't have monolithic control... but instead relies on competitive processes. Studies of split brain patients, such as the one of Gazzaniga and Ledoux (1978) show the existence of multiple independent control systems (separate halves of the subject's brain independently act appropriately even if one side falsely explained the choice of the other).
- Human cognition is not a general purpose processing system: It can be proficient in a particular set of skills, at the expense of other skills. A good example is the Stroop effect (Stroop, 1935). When presented with a list of words written in a variety of colors, performance in a color recognition and articulation task is dependent on the semantic content of the words. The task is very difficult if names of colors are printed in non corresponding colors. This experiment demonstrates the specialized nature of human computational processes and interactions.

Such evidences force us to look for alternative attributes of human cognition when attempting to construct user models. We will suggest in this paper that (social) interaction, embodiment and multi-modal integration form a valid set, if only the right target is chosen for the user model.

Target of the user model: When dealing with emotive/subjective responses, which *properties* of the user should be modeled ? The (embodied) ability to have subjective experience ? i.e. an explicit user model would then consist in modeling the full sensorimotor apparatus of the subject. Or the cognitive process by which the user makes use of concepts like "emotion" ? But that would not be possible if one considers our previous arguments on the absence of monolithic internal models and control. In this paper, we fully subscribe to the view of Frijda and Swagerman (1987) which suggest to undertake a functionalist approach to emotion/subjectivity (and hence to its possible model). *What is important in the phenomena that make one use concepts like "emotion" is not primarily subjective experience*. We shall not model the properties of the user's subjectivity because *subjective experience is not what invests those concepts with relevance, either for the*

[1] Designing a technology that feels good and is comfortable to use is not user modeling but merely facilitating the user adaptation to the designed system, and not his/her adaptation to the task at hand

experiencing subject or for others who make emotion ascriptions. What counts is action or, more generally, the relationship between subject and environment and the subject's readiness to modify or not to modify that relationship. The same holds for the relationship between the subject and his internal objects, his thoughts, goals [...]. Who cares about this own feelings when they have no consequence, of wanting to approach or avoid or get rid of, be it with regard to external objects or objects of thought ? What is interesting in emotion is some relationship to behavior or behavioral intent.

If this is accepted, it is then appropriate to consider that *emotive response* and subjectivity might exist and be functional in an artificial system and *it is not meaningless to disregard the question of whether that disposition does or does not have the shape of "experience", for the presence of which, criteria have yet to be devised* (Frijda and Swagerman, 1987).

User model as emergent structure of interaction: To summarize our stance, let's suppose now a system endowed with some sensorimotor apparatus, not necessarily anthropomorphic but sufficiently complex, and capable of recalling such experience, then, such system would be able of having its own "emotive/subjective response", although not necessarily the same as the user might experience or even desire. Our definition of "user model" relies on the existence of a mechanism through which the system is able to share emotional responses with the user, in such a way that both actors could reach mutual understanding. It is in this "mutual understanding" that lays our user model, though in a purely implicit form.

2 The Proposed Architecture

The above discussion casts strong constraints on the design of the architecture in term of interactive process. Human-human interaction however proves valuable as an example of interactive dynamics for sharing as complex information as emotive responses. The support of interaction include symbols (words) naturally but also postures, joint visual attention, use of metaphors or examples... Importantly, there is no explicit mapping from one actor to the other one of what one or another symbol might "mean" because the meaning of which, is grounded in the experience of the subject, sensorimotor (multisensorial body experience) on the one hand and shaped by other factors such as cultural background, character, state of mind (Saracevic et al., 1997) on the other hand.

Hence we suggest that user and system develop their own symbolic language, where a symbol ("pearl" for example) is understood as an instantiation by the subject (user or system) of his/her/its sensorimotor experience associated with the *qualia* of this symbol, i.e. (in the case of "pearl") the coldness of the material, the brightness of light reflexions, etc... This development of a specific language can also be found in humans, who tend to develop vocabulary/interactive patterns specifically suited to their counterpart (mother-child, husband-wife, nurse-elderly patient interaction ...). In human-human communication though, both actors generally share similar sensorimotor experience by virtue of their similar body. Such similarity is difficult to simulate in computer systems because they are generally disembodied, unless a Virtual Reality based system is considered (Biocca, 1997) or unless they are embedded in some physical body (Sato, 1996; Maetama et al., 1998). Fortunately human visual perception provides us with the possibility to embed motoric activity in a disembodied system by modeling human ability to shift gaze when perceiving its environment. In the next paragraphs, we describe our experimental framework and its three main components : (1) a sensorimotor apparatus, (2) a dynamical memory and (3) an active interface (see main blocks in Figure 1). We will discuss the structure of each component along with the overall integration.

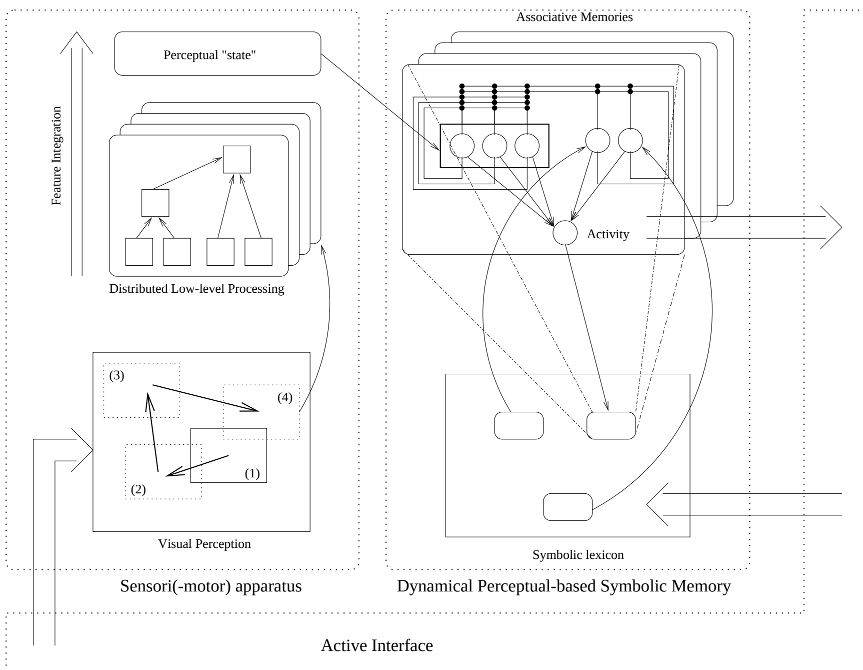

Figure 1. The proposed architecture: It shows the three main components of the system: (1) A sensorimotor apparatus performing distributed low-level processing and integrating it into a "perceptual state", (2) a distributed network of dynamical associative memories, each of which storing various sensorimotor experiences associated to a symbol of the lexicon and (3) an active interface which externalizes the internal states to the user and reciprocally allows the user to externalize his/her own internal states.

2.1 Sensori(-motor) apparatus

Observations made on human visual perception show that eyes move and successively fixate at the most informative parts of the image. It is a visuo-motor behavior that provides us with a sensorimotor basis on which to anchor the symbols that will be used by the system and the user to interact.

The sensori(-motor) apparatus runs as follows. Suppose the system attends to a specific area of an image. Our algorithm first performs a primary transformation of the image into a "retinal image" at the fixation point. The transformation provides a decrease in resolution from the center to the periphery, that simulates the decrease in resolution from the fovea to the retinal periphery in the cortical map of the retina. The retinal image is then fed to two parallel processing modules:

– A module for primary feature detection which performs a function similar to the primary visual cortex. Proposed by Rybak et al. (1998), this module is a dedicated neural architecture

based on interacting neurons with orientationally selective receptive fields that extracts two types of edges, *basic edges* located at the fixation point and *context edges* located at specific positions in the retinal image. Those *context edges* are used to determine the next point of fixation (details are available in the paper mentioned above).
– An array of low-level operators processes the retinal image, after transformation in HSB (Hue, Saturation and Brightness) color coordinate system, and characterizes information such as color distribution, brightness, edges orientation (Kirsh, 1971), homogeneity (i.e. number of dominant gray-tone transitions), contrast (i.e.a mount of local variations) following algorithms proposed by Haralick et al. (1973). This information, combined with the motoric activity corresponding to the current scan-path, is used to incrementally construct the "perceptual state" (a sensorimotor pattern).

2.2 Symbolic lexicon and dynamical memory

The lexicon is interactively constructed and updated, each new symbol being initially given by the user at run-time, when labeling his/her emotive response to an image. A symbol is characterized by its label (which can be, as in our example of Figure 2, an ordinary "word" but taken as a string and not as a meaning) and by the associative memory which is associated to it as shown in Figure 1. Symbols do not have explicit connections to each other, as we discussed in (Bianchi-Berthouze et al., 1998). Instead, we suggest with this architecture that dynamical relations be constructed that would reflect apparent (externalized) relations while not making hypothesis on their real existence.

The associative memory is constructed on the basis of a Hopfield network (Hopfield, 1982). Before describing our specific implementation, we will briefly introduce the rationale for using such network. Hopfield networks are a class of neural networks fully connected, based on Hebbian rule (Hebb, 1991) which follow a stochastic dynamics of the state. The justifying fundamental principle is that nervous systems tend to look for stable states, attractors in their state space. Neighbor states tend to get close to a stable state so that (1) errors can be corrected and (2) states can be recalled even with incomplete stimulation. In other words, such network is like a memory which can be addressed by its content: a state that has been memorized can be retrieved by stabilization of the network, if it has been stimulated by a suitable part of this state. During the network's evolution towards a stable state, an energy function tends to a local minimum. In term of dynamics, this means a fixed point corresponding to one of the stored patterns is recalled by one input stimulus in a steady state. For our application though, it is desirable that more than *one* fixed point be recalled if the system is to be capable of giving examples for example or provide the user with views on his internal states. In classical Hopfield networks, this is not possible because of the lack of a mechanism erasing a fixed point once it is reached, and the lack of a mechanism that would enable the system to leave a fixed point by climbing the potential wall [2]. Tsuda et al. (1987) suggested that enlarging the basin of attraction (by an algorithm of unlearning) would increase the accessibility of attractors. In other words, it is possible, by breaking the stability of a recalled state, to reach successive recall of stored memories.

Our implementation is as follows: a single layer of neurons, with connections as described in Figure 1. The left group of neurons is corresponds to the "perceptual state" described in the

[2] The purpose of a Hopfield network is not to find the optimum but reasonable solutions.

previous section. This left group is fully connected. The aim of this structure is to categorize perceptual states associated to the current symbol into stable states (or attractors). The effective recognition of a perceptual state by the memory (i.e. the energy function falling into a local minimum) is fed to an *activity* neuron. The right group of neurons in each memory correspond to the activity of all other symbols of the lexicon, as evaluated at the current computing cycle. This provides us with the mechanism for dynamical learning/adapting/recalling of apparent connections between symbols.

2.3 Active interface

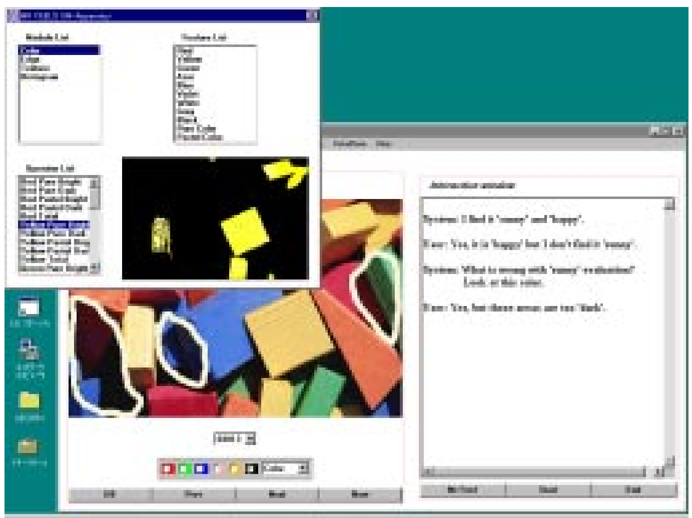

Figure 2. Snapshot of the system: The system utilizes its sensory-motor system to externalize its perception and provide the user with a view on its internal processes. The user can use this view (selecting areas on the image (in white in the image)) to externalize why his/her emotive response conflicts with the one of the system.

The main obstacle to the interactivist view is and has been the rigidity and the predominance of the machine as an actor in the user-machine dialogue. Even when human interaction is required, *the intrusion of human knowledge is somewhat peripheral: systems are still machine-centered* (Tanguy, 1997). Instead the focus should be put on user-centered design (Bianchi et al., 1996) where the user is at the center of a supportive systems, i.e. sensitive to (and actively using) the cognitive abilities as well as the affective characteristics of the user. Lee and Harada (1998) identify three cognitive processes through which humans respond to visual perceptions: shape (which we generalize in this paper to visual characteristics), metaphor and memory. Those processes, the implementation of which has been described earlier in the paper, must be fully embedded in the interface so that the user can intervene, both functionally and structurally in the system.

At the current stage of implementation, this activity of monitoring and evaluation typically involves three patterns of interaction, triggered either by a user input given in the form of a sentence in natural language or a visual example, or by the system self externalization. In the next paragraphs, we describe these interaction patterns.

Creation of a new symbol: It follows a sketch similar to the one shown in Figure 3. It doesn't simply consist in adding a new symbol but also in evaluating the instantaneous relationships of the symbol to be created with existing symbols by stimulating all memories and retrieving activated symbols. It is a mean to close the loop with the user by sharing information, turn-taking initiative etc... The user might agree/disagree with the system's evaluation and, if he wishes so, engages in another interactive pattern (as described in next paragraph). Note that he might as well ignore the system's evaluation and instead provides the system with other images for which his emotive response best matches the newly created symbol.

User: This is a *happy* image !
System: *Happy* ?
(1. processes the picture with his sensori-motor apparatus,
(2a. feds the perceptual state into all associative memories and let the networks relax. If one (at least) network stabilizes, takes the initiative to tell the user about corresponding symbols (see ??th interactive pattern).
System: I find it *light* and *refreshing*.
(2b. looks for *happy* in symbolic lexicon and doesn't find it.
(3. creates symbol *happy*, its associated memory and starts learning with current image as learning set.
System: I've never heard of *happy* images. Why don't you show me other *happy* images ?

Figure 3. The system selects and displays an image in the workspace. The user introduces a new *symbol*.

Reinforcement and specialization of existing symbols: Whereas the reinforcement of positively evaluated response is straightforward, the specialization of existing symbols is delicate because it raises the issue of how the system should handle what might be considered as inconsistencies from the user side whereas it is simply that the user, because of external factors, unconsciously focussed on another aspect of his/her perception. Handling such inconsistency in a rigorous manner would break the ability of the system to handle the variability issue we have evocated in introduction. Instead, we suggest user and system rely on a process of *externalization*. In daily life, such process can take various forms, from conversation, written texts, sketch and memos, to simply physical "records" of actions taken in the world. As mentioned by Miyake (1997), *externalized records are useful because they serve as sharable and concretely manipulable objects for constructive collaboration*. So, instead of simply reflecting in the internal process the overall evaluation by the user, the system should help the user keep record of such externalization, reflect upon them for making changes and restore them when necessary. Hence, the active interface provides the user with a view on its internal processes so that the user can projects his own internal processes onto them (or conversely, projects his response onto the system's internal process).

Even though an externalized record sheds light on the system internal processes, it does not necessarily pertain to the user's previous evaluation. Hence, previous evaluations should not necessarily be unlearned. Rather, we must reflect instantaneous inconsistency as local perturbation and let the dynamics of the system finds its own stable states. This dynamical systems view is reflected by the fourth point of Figure 4. The inconsistency is only reflected by the inhibition of the activity neuron corresponding to the symbol relevant to the externalized perceptual state. A previous evaluation is not unlearned. However, it is likely that in further interaction, as described in the next paragraph, the system would come up with its own internal inconsistency or variability: two symbols being excited while mutually excluded.

System: I find it *light* and *refreshing*.
User: Yes, it is *refreshing* but I don't find it *light*.
(1. Reinforces current perceptual state in memory associated to *refreshing*.
(2. Recalls other perceptual states associated with *light* symbol. Browses the database of images, processes them and selects a set of images whose properties match *light* symbol. Calls for user evaluation.
System: What is wrong with *light* evaluation ? This image is similar to those ones, isn't it ?
User (who selects an area in the image): Yes, but this area is too *dense* and ....
(3. Processes the area selected by user and extracts perceptual state.
(4. Creates a symbol *dense* and start memory learning on extracted perceptual state, inhibiting activity neuron corresponding to symbol *light*.

Figure 4. User and system's evaluation of the image differs (continuation of previous dialog). The user tries to externalize his/her perception.

User: How about this picture ?
(1. processes the picture with his sensori-motor apparatus,
(2. feds the perceptual state into all associative memories and let the networks relax. For all networks in a stable state, list associated symbol and related symbols (i.e. symbols for which the corresponding activity neuron, in the recalled state is excited).
(3. Checks possible inconsistencies such as inhibition of symbol otherwise excited.
(4. For each inhibitory connection, processes image, in a top-down fashion, to detect area best matching associated recalled perceptual state. Attempts to externalize internal processes to user.
System: This image is *refreshing*. Don't you think so ?
System: But I'm confused about something. Do you find this image *dense* ? or do you find it *light* ?

Figure 5. System came up with seemingly internal inconsistency. It asks for user guidance.

Externalization of the system's internal processes: We view internal inconsistencies, such as shown in Figure 5, as branching points in the interactive dynamics: the user might ignore, correct or propose alternatives. It makes the existence of "fixed point" or "trivial attractor" in the interactive dynamics unlikely. In further work, we wish to formally study the importance of this mechanism in the overall dynamics.

3 Conclusion

Retrieving information based on its content has been quite successfully investigated because computer systems are well suited to extensive search in database of explicit information. However, when retrieval involves the subjectivity of the user, the system needs to construct a model of the user so that both actors share a common support of interaction. We argued that, in light of evidences in neuroscience and cognitive science, the user model to be constructed cannot be explicit because human brain doesn't have monolithic control and internal models. What might be a *sad* image at a given time might not be so in a different context. Or content might be influencing the user's emotive response by way of *unconscious learning* (Kato, 1996b). Instead, the constructed model should mainly rely on **interaction** because what matters is not the primary subjective experience but *action*, i.e. the relationship between subject and environment and the subject's readiness to modify or not to modify that relationship. If we assume a system with a sufficiently complex **sensorimotor apparatus**, such system will be capable of own emotive responses if it is provided with mechanisms to share such information with a user. Those two elements (in bold in the text) ground our experimental framework. We propose a novel architecture endowed with (1) a sensori-motor apparatus constituted (at this stage) by the ability of the system to change its focus of attention and extracts information about the nature of the image; (2) a set of dynamical sensorimotor memories that associate symbols (one support of the interaction) with the sensorimotor experiences and supports the successive recall of past experience) and (3) an active interface allowing multi-modal interaction with the user through the use of symbols, example or processus of externalization of the system's internal processes.

A true cooperation (an interactive process) can emerge, not necessarily achieving a flawless performance but effectively supporting the transmission between each actor of complex, non-explicit information. We believe this approach provides an alternative to classical understanding of user modeling as well as human-machine interaction in general. It integrates true dialog and each actor of the dialog is re-centered based on his/her/its particular cognitive and physical properties and let adapt through interaction.

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