Using machine learning techniques to enhance expressiveness of computer-based design systems

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expression, emotion, machine learning

Abstract

In face of the huge expansion of computer-mediated interaction among people, current representation-centered CAAD systems do not offer full information spectrum necessary to express all design intentions. Representational structures that those systems use suppress expression of affective information that plays a major role in design process. The paper describes few experiments conducted at the IMS Institute to enhance expressiveness of the CAAD systems.

Introduction

Most recent research in CAAD is concentrated on the problem how to represent design process and resulting artefacts. Drawing inspiration from computer science and artificial intelligence, CAAD researchers have forgotten that traditional use of design process and artefacts is to express designer's intentions, not to represent them. Design is an explorative process during which a designer uses diverse representational media to express and communicate his/her ideas about the intended change and about the artifact realizing that change [1][2]. Design process has a cyclical structure. A person expresses his/her ideas using diverse representational media. Application of the process characteristic for the particular medium uncovers effects of the expressed ideas. Newly generated expressions trigger off the concepts in the designer's mind, generating new ideas that can be further expressed in the design process.

Today, we are witnessing a huge expansion of computer-mediated interaction among people. More and more designers use computers and networks to interchange their ideas, and to present their designs to the audience. In addition, increased number of clients and builders are using computers to access design data. In the future, designers can also face the intelligent computer agents trying to comprehend their designs so they can inform the potential clients or design firms. Using current representation-centered design systems designers can not transmit full information spectrum necessary to express all their intentions.

Representation vs. expression

Common sense definition of representation is a notion of something standing in for something else. More accurately, representation is an entity (i.e. material or energy pattern) that stands for some other physical entity or some abstract concept. Representation plays a crucial role in design process. It enables designer to make a permanent record of his/her idea, thus overcoming the limits of the short-term memory. Also, representation emphasizes some attributes of the artifact and hinders others because it is an imperfect rendering of the represented artifacts. Consequently, by using different representations and by switching among them, designer can comprehend the design situation that he/she is creating, and to reflect on it [3]. Representation also enables the designer to apply formal processes like proof, derivation, or calculation, and to obtain consequences of his/her represented ideas. Further, representations that designers use to unveil their ideas prevent harmful consequences that the direct realization of the change can have on the physical environment. Finally, representation enables communication of the design ideas.

The notion of the expression commonly implies that transmitted message contains more than simple replacement for denoted entity. Picture, for example, can represent some mundane scene from everyday life, but it can express joy of family life, or nostalgia for the childhood days [4]. Architectural design is the subject that traditionally requires expressive talents from participants. Designers should be able to recognize desires of their clients and articulate them in their design. In addition, design is the medium that enables a designer to express himself. Finally, desired change that new artefact embodies conveys cultural settings of the social milieu.

The research on affective computing has started in the last decade, and the research topics include affective communication between people mediated by computers, ability of computers to recognize and express emotions, computer systems having "emotional intelligence", etc. [5]. The field of CAAD offers many topics where affective technology could enhance functionality of computers in the design process:

- *Communication of affective information among the participants in design process.* This technology enables designers to "feel" the needs of participants in the design process. In addition, it enables design teams to establish shared project "mood", which is important in the "virtual design studio" environments that incorporate globally dispersed designers, having different cultural and emotional backgrounds.
- *Design team barometer.* A computer system that could monitor emotional states of all members of the design team could enhance group cohesion. Upon detecting stress or confusion of some team member, it can alert others to offer help to that person. In addition, it can alert the designer if his/her personal goals oppose the intended "mood" of the evolving design.
- *Searching through the databases or case-bases for the designs that evoke particular emotions.*
- *Enhancement of the "creative atmosphere"*. The computer can search multimedia databases to find contents that can either stimulate the designer if he/she is in the good mood, or improve his/her bad temper.
- *Knowing when to interrupt the designer.* Recent CAAD systems often incorporate various knowledge-based technologies that monitor consistency of designer's actions with the design constraints. To be useful, system should know when is the right time to reveal its findings. If the designer is in highly productive mental state, known as "flow" [6], the system should postpone its actions until some calmer, "reflective", state occurs.

Machine learning

Many aspects of the affective expression varies among people, making task of building universal person-independent affective system almost impossible. Fortunately, we can use machine learning mechanisms to build a system that can be trained to recognize, express and communicate expressions of a single designer.

The field of machine learning offers many efficient and theoretically sound-grounded learning mechanisms [7][8]. We can distinguish between four main learning paradigms. Inductive learning algorithms induce general concept description from the set of positive and negative examples of the concept. Analytic learning algorithms use few examples of the past problem solving experience and the rich underlying domain knowledge to improve system's performances. Genetic algorithms accomplish learning by making random mutations to learned concepts and preserve as the "gene pool" those that best fit objective function. The connectionist learning algorithms learn to differentiate patterns from an input domain by adjusting weights on the interconnected network nodes. The choice of the algorithm that is most appropriate to the particular task depends on the type of the training examples, class of the target function to be learned, and representation of the domain task.

Enhancing expressiveness of computer-based design systems

At the IMS Institute, we have conducted few experiments directed toward the enhancement of the expressive abilities of the CAAD systems. The research is directed toward the recognition of emotional content in the representations that designers create during the design process, not from the physiological signals like blood pressure or facial expressions. To accomplish that goal we are using analogies, metaphors and other associative and symbolic contents that have a potential to affect emotions directly [9]. Our intention is not to detect, classify, and explicitly denote particular emotional states. Instead, we are using computational agents to detect affective information in the designer's representations and to transform it to emotionally richer representations.

The EmComm agent enables affective communication among the designers. The program uses connectionist learning algorithms to associate verbal and visual representation [10]. The program consists of two modules. First module is trained to recognize appearances of the analogies and metaphors that designer often uses in his/her writings. Second module learns to associate these verbal representations with images that, according to designer's view, depict them. Both designers who participate in the communication have on their personal computers a copy of EmComm agent. Each copy is trained on the separate set of verbal and pictorial examples representing personal preferences of each designer. On the sender's side EmComm agent scans written text and transforms it to a picture. Because of the nature of the connectionist learning algorithm, resulting picture is not a copy of any image given to the program during the learning state. Instead, it is an abstract image capturing an essence of the exemplar images. This image is transmitted as the annotation to the text. On the receiver's side EmComm agent accepts an image and associates it with a set of strings. Those strings represent analogies and metaphors that the designer who receives a message often uses. Strings which activation exceeds the threshold level are selected as a kind of the "affective keywords" annotating the original message. Received image and "affective keywords" do not explicitly state sender's emotions; instead, they trigger off the affective response of the designer who receives the message.

PromoBot is an intelligent computer agent that uses available computer-based design data and produces the ad-hock design presentation each time someone tries to access the design data. The program learns to create appropriate presentations from the interaction with the guests. It generalizes classes of interesting parties, and patterns of successful intercourse using both inductive and analytic learning mechanisms. To create the appropriate presentation PromoBot uses mechanism that enables analogical inference of the metaphor that is consonant with the current state of design process and the designer's habit [11]. The inferred metaphor is used for the dynamic construction of the design presentation. The metaphor recognition algorithm is implemented as the analytic learning mechanism, while the metaphor synthesizing algorithm employs connectionist learning techniques.

EpAct is the case-based reasoning program that reasons about designer's use of representations during the design process [12]. The program records instances of the designer's actions directed toward design representation creation, modification or transformation, and stores them as cases for later use. A case description includes representation of the design context in terms of the applied representations, and the representational transformation conducted in that context.

Conclusion

The described programs are still in the phase of the laboratory prototype. Few real world experiments have been conducted, so we can not offer any sound proofs that described technology will bring improvement in the design process. We treat the development of programs as the experiment that will reveal true designers' needs. Goal of the project is to develop a computer-based design medium that provides fluid and adaptable processing of expressions comparable with the conversation with another person or discourse within social environment. Only then can we treat a computer as a partner in design process, not because it possesses intelligence, but because its capabilities to flexibly process our external expressions are comparable with the flexibility of the social interaction and the participation in the culture. Experiments have been conducted with the final intent to model the computer-based design systems as the active medium that has expressive powers unachievable in any traditional media.

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