Human-Centric Framework for Perceptually Adaptive Interfaces

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ABSTRACT

Multimodal interfaces have long held the promise of enhanced and effective human machine interaction. The ultimate goal of multimodal interfaces is to facilitate human activity allowing seamless exchange of information. This goal requires a coordinated development effort that incorporates a thorough understanding of human perceptual system in the design of interfaces. In this manner, multimodal interfaces can supplement and expand current paradigms in human computer interaction. A novel framework is, therefore, proposed for design, development and evaluation of perceptual interactions between human and the computer. The proposed framework hopes to enable interfaces that aim to ‘fit’ and ‘adapt’ with the human perceptual system. An empirically driven conceptual approach is used to derive guidelines, create artefacts, and develop models for these perceptually adaptive interfaces.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces; H.1.2 [Models and Principles]: User/Machine Systems -human factors.

General Terms

Perceptually adaptive interfaces, Multimodal Interaction, design framework, Human centric design, multisensory integration.

Keywords

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1. INTRODUCTION

With the advent of new technologies and tools such as computer vision technique based tracking, detection, and recognition and haptic based interaction tools such as Phantom® joystick, multimodal Interaction has started to take on a new meaning. It is no longer synonymous with “communicative” multimodal interfaces. Indeed, several novel interface paradigms such as reality based interfaces[3], perceptual interfaces[5] have been proposed to tackle this

explosion of means of interaction.

Reality based interface, for example, encompasses all existing interfaces that either mimic reality or are situated in reality. On the other hand, perceptual interfaces are defined as “highly interactive, multimodal interfaces that enable rich, natural, and efficient interaction with computers”[5]. These efforts point to the need for novel frameworks that accommodate interaction possibilities that range from simple awareness to multimodal immersion. For example, CoDeIn framework[2] has been proposed in reality based interfaces that attempts to provide a common language of interaction for all types of interfaces ranging from direct manipulation to tangible user interfaces wherein a user moves through a set of knowledge states by manipulating different types of objects.

Systematic investigations are needed that give insights into perceptual basis of the user any successful future paradigm change. The research effort must also allow more empirically driven approaches that enable quantification of these activities. It is argued that traditional cognitive psychology models fail with respect to both situated cognition and perceptual interaction. Instead, a more embodied approach is needed. Another concern in this new paradigm is the compatibility of these interfaces with cognitive and physical capabilities of the human user. Hence, there is now a great demand for biologically plausible (or in some cases biologically compatible) design and models of human computer interaction.

2. CONCEPTUAL FRAMEWORK

Studies in multimodal interaction have long focused on two broad questions [4]: (1) how does the perceiver integrate information about features from sensory modalities? and (2) how does multisensory integration affect performance? Researchers have also specifically addressed these questions in terms of suitability of the format of information that is being presented, recoding of information from one modality to another, and interaction of cues in each modality. Plethora of findings exist to demonstrate the fine tuned interaction that occurs in each context [1]. Thus, when it comes to understanding and application of multimodal interfaces, fields share a common problem space. Development of these novel perceptually adaptive interfaces has six aspects for investigation:

- 1) Choice of the information that is to be conveyed (“content selection”).
- 2) Selection of modalities through which the information will be conveyed (“modality allocation”).
- 3) Selection of the format in which the modalities will be able to perceive that information (“modality realization”).

- 4) Determinations of mechanism(s) that are used combine the modalities (“modality combination”).
- 5) Evaluating the affect of environmental and cognitive factors on user’s perceptual integration (“Situating multimodality”).
- 6) Analysis of performance of the human user in the interface (“Task Analysis”).

The dimensions that must be considered for evaluation are: 1) Spatial 2) Temporal 3) Cognitive 4) Environmental. These dimensions are derived from the architecture of human cognition. The empirical investigation proposed to tackle these factors is shown in Figure 1. These empirical findings provide us with ground truth which can be analyzed in various ways to produce the cognitive basis of human perceptual integration. For example, a Bayesian model will allow us to predict the conditional probability of certain value in one modality given the values in other modalities. Similarly, pattern recognition approaches such as Hidden Markov Models are applicable as well to fit a model over existing data. Although, a typical HCI user model is based on information processing constructs, it is argued that these cognitive constructs will not be able to address the measurement issues in the perceptually adaptive interfaces. This is because human perceptual system is not organized procedurally. A procedural system with defined goal and selection methodologies lends itself to algorithmic analysis of work output. In human perceptual tasks, this is rarely the case.

Experiment	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Cue Combination	Complementary	Concordant	Discrepant	Redundant
Manipulated Variables	Texture (Sinusoidal Gratings)	Hierarchical cue complexity; similar information send via different modalities	Shape (3D)	Shape, time lag, spatial lag, and Signal to Noise Ratio
Modalities	Vision, Touch	Vision, Touch, Audio	Vision, Touch	Vision, Touch
Analysis/ Model Fitting	Psychometric Function Fitting	Psychometric Function Fitting	Psychometric Function Fitting	Psychometric Function Fitting
	Bayesian Modeling/MLE	Bayesian Modeling/MLE	Bayesian Modeling/MLE	Bayesian Modeling/MLE
	ANOVA	ANOVA	ANOVA	ANOVA
Formalism	Weighted equation	Weighted equation	Weighted equation	Weighted equation
Validation	MonteCarlo Method	MonteCarlo Method	MonteCarlo Method	MonteCarlo Method
	Cross-validation with Ground truth	Cross-validation with Ground truth	Cross-validation with Ground truth	Cross-validation with Ground truth

Figure 1 Summary of proposed empirical investigations

Figure 2 summarizes the conceptual framework. It is proposed that given the complexity of aspects that are to be investigated formalism must be derived from computational modeling approach as well as user evaluation in scenarios- both of which contribute towards the final generic framework. In this way, we bring together diverse findings from neuroscience and cognitive psychology to produce a coherent cohesive framework.

3. SUMMARY

Next generation post-WIMP interfaces require us to think of ways and means by which human multimodal output and input can be efficiently coupled with the multimodal environments of the machines. Research shows that outside the bounds of

integration, user’s perceptual experience degrades severely and can result in frustrating error prone environments. Maintaining multimodal coherency, both sensorial and cognitive, is crucial for high level user engagement and efficiency. This coherency can be achieved only if a cognitive model that can cohesively embody empirical results is employed for prediction in a human centric environment. In this proposal, we have identified specific experiments with virtual stimuli that will be used to model the human multisensory integration process. Subsequently, this model will be used to drive the theoretical underpinnings of human computer interaction in multimodal environments. The model will be tested against real-world HCI scenarios and design artefacts for further refinement of the task analysis and work output measurement.

Figure 2 Proposed framework for investigating perceptually adaptive interfaces

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