A Framework for Modelling Human Emotion

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ABSTRACT

This paper describes the design of a modular framework, for constructing models of interacting systems. In particular, systems that can adapt and have different objectives; we also consider that these objectives could be of an emotional/hedonistic form. To that end, we introduce Pask's conversation theory, and Boyd's thoughts on decision making under uncertainty. In conclusion we describe modes of studying interacting systems.

CCS CONCEPTS

• **Human-centered computing → HCI theory, concepts and models**; **Interaction design theory, concepts and paradigms**.

KEYWORDS

affective computing, computational modelling, human-computer interaction

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INTRODUCTION

We increasingly use human-computer interfaces and systems that adapt depending of their intended use, such as computers that display context aware menus, or specific configurations to aid the user's activities. These customizations are often intended for a very specific scope of functionality, pre-baked and mostly limited in a few variations of a core, standard theme. Nonetheless, when it comes to day-to-day manual tasks we are quite accustomed to use tools not primarily designed for the problems we end up using them for, such as using a piece of folded paper to balance a wobbly table. Yet, when it comes to software, we often re-map problems into the logic of the application, language or system in use. The versatility of using, say, a screwdriver as a can opener, or a door stop is not encountered easily with computing software.

Moreover, an increasing proportion of machine/computer use is no longer utility/function-based. Vehicles can designed for enjoyment, computer hardware is developed to run games for fun, and smartphones become status and prosperity symbols. Emotional Design [9] and Hedonomics [4], [5] and Kansei Engineeering [8] are fields looking at the benefits of considering the emotional value in objects/technology, with implications in the resulting user-experience (UX). Beyond this primary motivation for considering the emotional properties/values of objects, there is also the potential for using affect as an information channel to aid users in performing tasks; or even as the target of the task. Affective Computing [13] is a field that looks at emotion/affect as the purpose of a system; which can interact with users at an emotional level, and use this information to enhance the system's functionality and effectiveness.

We consider the use of computational models as a form of information exchange and collaborative development. Models move from being tools for generating information, towards actually being part of the lexicon. Instead of advocating a specific model, we suggest a conceptual framework which accepts a diversity of existing models (see:[6][1][2]). The notion of emotion as a consequence of and as a purpose of HCI are combined; and affect is deemed a property of interfaces that should at least be accommodatable within an overarching HCI model.

Our framework has the following characteristics:

- **Generalizable** Sufficiently generic, to allow multiple domains to benefit.
- **Subsuming** Existing models or principles can be expressed within the framework.
- **Modular & Composable** Allows different implementations for elements and multiple systems can be combined to form more complex systems.
- **Comparable** Representation of different systems within the framework should make them easier to compare.
- **Interrogable** In that it is possible to ask the model questions, to posit conditions on modules and observe the consequences.

BACKGROUND & MOTIVATION

Jeon [6] compares various approaches [9][13][8][5][4] that consider the role of emotion within Human-Computer interaction and Human factors. And identifies future work: 'First of all, constructing a robust, generic affect research model is required'[6, p.19] and '... it is also required to form the clear relationship between affect and other core concepts in HF/HCI, such as workload, situation awareness, automation etc.'[6, p.19] Of particular relevance to this paper are: Picard's ideas relating to dynamic affect aware computers and the construction of domain-specific affect dimensions within Kansei Engineering [8] both of which relate to Pask's conversation theory .

Table 1: System in Environment

Element	Description
System of Interest (SoI):	The system currently under investigation (e.g., the user).
Source:	The resources used by the system in order to achieve it's tasks (e.g., energy, air for sound).
Sink:	Drains on resources, waste output and inhibiting factors (e.g. heat, friction, background noise).
Environment:	The surroundings/context within which the S.o.I. must operate.

A system is a collection of parts that in combination can achieve things that individual parts cannot.

Table 2: Feedback System

Element	Description
Sensor	Measures a property of the system that is indicative of the performance/control state (e.g., RPM, blood sugar, mouse position). Performs the **Observation**
Comparator	Allows the comparison of the current value, with a previous value (Long and Short term memory, signal transit time)
Set-point/Goal	The target state of the system (e.g. The desired position of the mouse pointer. Target engine speed) Collects information for **Orientation**.
Controller Model	The method of making decision, a model of the counterpart system (e.g. A Neural Net, Cognitive Model, Statistical Distribution). This can also include a model of the SoI and environment. Creates a **Decision**
Effector	The mechanism for changing the current behaviour of the system, this can be a change internal to the system itself or in the availability of resources (e.g. Fuel Controller, Airflow restriction). Implements the **Action**.

The feedback system is the mechanism for controlling the system (e.g. the decision logic or mind). Sensor and Effector are the boundary between the Feedback System and S.o.I.

THE FEEDBACK CONTROL SYSTEM

We base the design of our framework around two theories, Boyd's cycle of Observation, Orientation, Decision, Action (OODA) [10], and Pask's conversation theory [11][12]. These models are both cybernetic and our discussion is linked to an elaborated representation of a feedback control system Fig:1. Our model, denoted as a Feedback Control System, comprises of two major subcompoments: the System of Interest (SoI) and the Feedback System. We provide an overview of the model in Fig:1 and elaborate on each element below.

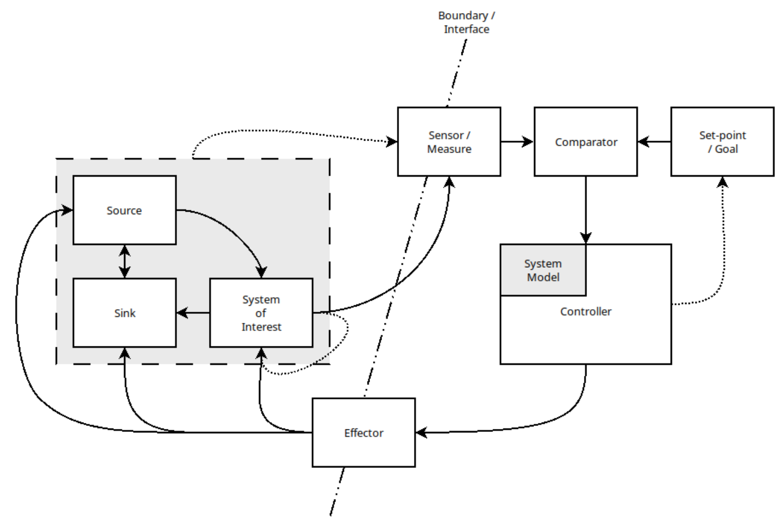

Figure 1: An elaborated model of a Feedback Control System

Whilst Pask represents interacting systems from the perspective of an external observer, Boyd's model covers the stages of interaction from that of an individual. The Block diagram representation of a feedback control system allows a bottom up construction of a simulatable system; it allows definition of elements (e.g. various sensor types, memory/comparator structures etc.) that can be composed into more complex systems. The OODA frame offers a top down/meta representation of the system, allowing description of the system behaviour; which is easier to reason about than the component specifications.

Boyd's cycle of Observation, Orientation, Decision, Action [10] is a model of an individuals decision making process within an uncertain environment. It is a model of learning and adaptation. Whilst

Table 3: Interaction Environment / Boundary

Element	Description
Interface Object	An object which creates a connection between the sensors and effectors of both systems. This can be either synchronous or asynchronous.
Mutual Goal / Stability	Continued interaction between two systems, requires that there exists a mutually desirable objective and that the interaction is stable.
Counterpart System:	The system with which the S.o.I. is interacting, e.g., if a driver is the SoI the counterpart is the car.
Observer System:	The observer is a tertiary system that is connected to interacting systems, but not directly interacting via the boundary (e.g, an experimenter, designer or data logger.

The above elements come into consideration when we go from an independent system, to one that interacts with others.

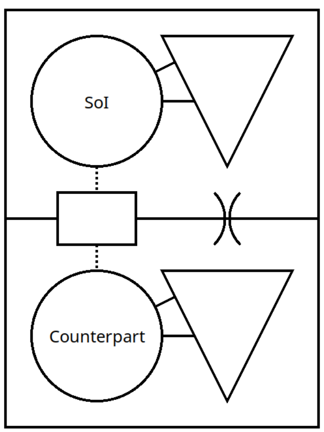

Figure 2: A pair of systems interacting by manipulating an interface object.

Boyd initial motivation was to better understand the factors contributing to aerial combat, his thinking and models have had influence on training, design, operational doctrine and government policy. The OODA loop is often simplified to the point of being equivalent to Demming's Shewhart cycle (Plan, Do, Check, Act) [3] or Kolb's experiential learning [7], with a particular emphasis often being placed on accelerating iteration time and making decisions. Boyd's model in reality is more complicated. There are interconnections, bypasses and elaborations for each stage.

The OODA loop, considers the factors that can contribute to choosing an action. The OODA stages take place within the Feedback System (see Fig:1 and Table:2), and are an elaboration of the kinds of analysis performed by the comparator and controller.

Observation (Sensor behaviour). Awareness is the first requirement for responding to a change in environment. Detecting sooner, more often, at greater distance or with greater resolution; allows orientation to begin sooner with better information.

Orientation (Comparator and Set-point behaviour). Orientation, is the process of identifying the implications of the observations. Contributing factors to orientation are: genetic heritage and physical attributes; past/ongoing experience; their training methods or design philosophy. Even Analysis & Synthesis is a process that differs between parties, in that individuals can be taught different methods/philosophies for analysis. The orientation element is the largest part of the cycle, and together with the Decision stage elaborate on the Comparator behaviour of the Feedback System (Fig:1).

Decision (Controller and Goal behaviour). Whilst orientation provides the information required, there is still a need to make a decision; this shifts the modality from collating and interpreting information available, to determining whether the action suggested should be taken. Are the consequences acceptable; how reliable is the information collected and is the plan achievable. The decision process becomes more complex when there are multiple competing objectives e.g. multiple individuals; requiring some way of weighting factors within the orientation stage, and valuing possible outcomes. This behaviour is the action performed by the controller and goal of the feedback system.

Action (Effector behaviour). Action would appear to be a trivial step; but the predictability of ones own actions is essential; allowing greater effort to be put into reacting to a situation, rather than managing oneself. Evaluation of the appropriate action will take into consideration the energy/effort demanded, as well as the potential accuracy/success of execution.

Framework Application

The model of an individual within an environment becomes more interesting, when that environment is shared with another. Pasks Conversation Theory [11][12] is a cybernetic model of learning conversations, a model of how information is exchanged between two entities. An intelligent entity is

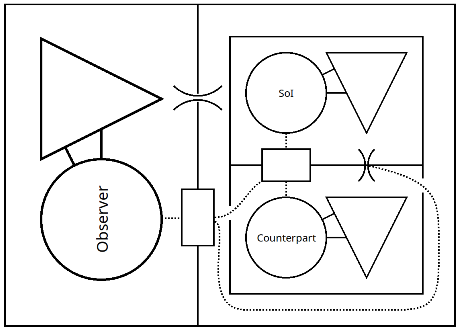

Figure 3: Observing System

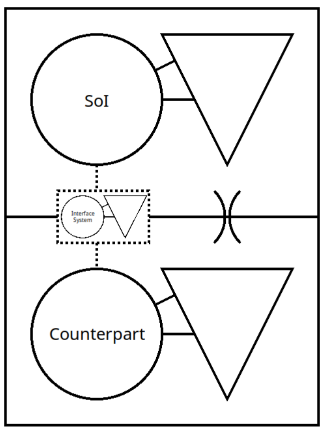

Figure 4: Interface Object replaced by and Interface System

capable of manipulating an object or object meta-language in order to reason about or communicate a topic. To elaborate: a topic is a set of relations between concepts or procedures (which are methods for demonstrating that a relationship exists). An entity will posses a memory of topics, concepts and procedures as well as the ability to self-replicate and manipulate the topic. Pask's work goes further and includes an algebra for defining topics and curricula; teaching machines, with systems to aid in identifying learning styles, learning rates, student knowledge retention.

Two entities of importance are M (Mechanical) and P (Psychological) individuals. M individuals are capable of manipulating and sensing objects in the world to allow exchange over an interface (the physics or biology of a system). The P individuals are capable of instructing M individuals and by extension, of encoding and decoding P-individual knowledge through an interface object; or as Pask calls it, an "Epidemiological Laboratory". This encoding/programming is done in the hope that sensing and decoding of an object by another brings about the formation of a similar set of topic relationships.

Further to being a model of learning between interacting agents, it is also a 2nd order cybernetic model; in that it can be a model of learning about learning, and the process of studying learning systems. In our case, we consider the notion of two systems (with personal goals) interacting with the aim of achieving a mutually desirable outcome, through the continuous exchange or manipulation of an interface object.

INTERACTING SYSTEMS

There are special cases of interacting systems which are of interest.

Observing and Interrogating Systems. Two systems interacting, with a third system having access to the interface object and/or the mutual goal e.g. Human-Computer and HCI researcher (Fig:3). An Interrogating system can additionally manipulate the interface object or the goal.

Teaching Systems. When the SoI is an expert in a domain which is unknown to the counterpart system. A special case of a teaching system occurs when using a data-set i.e. Use of responses collected from past questioning of a system which is not the current counterpart.

Interface, Facilitation and Translation Systems. Replacing the interface object with an intelligent system (Fig:4), allows the message sent from the SoI to be adapted before it is received by the counterpart; influencing the stability or learning rate of the system. If the interface system knows both SoI and counterpart reasoning then the SoI message can be made clearer to the counterpart.

Competing Systems. Connecting the SoI to multiple counterpart systems (Fig:5) and assessing which learns fastest or provides the most accurate response, is a means of evaluating multiple candidates e.g. differing control models and sensor sets.

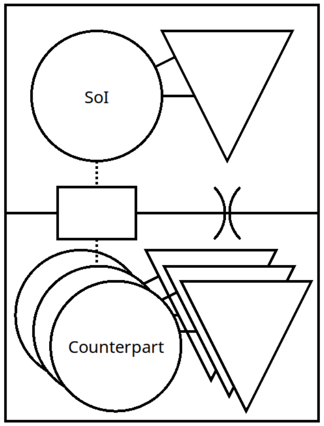

Figure 5: Multiple counterparts connected to a single SoI

CONCLUSIONS

The benefits of using interactive system models is clearer when considering Human-Machine Interaction, a miss-match in response can lead to catastrophic outcomes, the ability to respond at the onset of these conditions can stabilize the situation. For Human-Computer systems, the prime examples would be: Virtual and Augmented reality situations, where incorrect mapping of a physical characteristic can contribute to motion sickness; and Gameplay, where the objective is to adequately challenge the player e.g. Adaptive difficulty. If we take a step back and consider HCI as a design process, then the design theory shaping an interface evolves as designers learn about the problem domain and user behaviour; and past designs influence the use of future designs.

Distinction between algorithmic/predictive models that tell us what will happen and theoretical models explaining why they happened, are equivalent to Pask's M and P individuals. The mechanisms that the algorithms describe exist because of relationships that are being defined. The theory explains the mechanisms, and the algorithms validate the theories.

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