Towards a Ubiquitous Model of an Individual in Social Machines *

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ABSTRACT

It is the activities of individuals that lead to formation and changes within any social system. Hence, the "social" component in a social machine (socio-technical machine) can be understood constructively from the conception of an individual as a machine. In this work, we present a stochastic finite state machine model of an individual based on Abhidhamma tradition of Buddhism. The machine models moment to moment states of consciousness of an individual in terms of the Buddhist formal ontology that constitutes an individual. Thus, the key contribution of our research is a ubiquitous framework of an individual which unifies the idea of a human agent across all possible social machines. It is shown that from web data of a particular individual this machine can be populated. We expound how our model solves issues pertaining to varied temporal granules and sparsity of data. We further illustrate through an example as to how our approach can unify the conceptualizations of an individual from the numerous ideologies and definitions of a social machine. As a part of our future work, we hope to align this proposed stochastic machine with social observatories on internet.

CCS Concepts

•Human-centered computing → Social networks;

Keywords

social machine; individual; automaton; formal ontology;

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1. INTRODUCTION

The emergence of personal computing and internet has made everyone in the world potential technological contributors, elevating the ever increasing interaction between humans and technology. There is a multitude of work trying to study systems and interfaces facilitating this interaction. For instance, Human-Computer interaction [3] as an area of applied cognitive science and engineering design is concerned with understanding how people make use of devices and systems that incorporate computation. Social Computing as the area of Computer Science is concerned about examining the intersection of user behavior and computational systems. It finds inspiration in creating or recreating social conventions or contexts with software systems and technology. Personality Mining [6, 12] is a newer domain of computer science which focuses on capturing the psychological processes and dispositions of an individual through the person's publically available data. Encompassing these outlooks into analyzing socio-technical systems is the concept of a social machine. Social machines are typically presented as systems that combine some form of social participation with conventional forms of machine-based computation. There are numerous views on what defines a social machine.

The first attempt at defining the concept was provided by Berners-Lee and Fischetti [2] in their book "Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web":

> "Real life is and must be full of all kinds of social constraint – the very processes from which 'society' arises. Computers can help if we use them to create abstract social machines on the Web: processes in which people do the creative work and the machine does the administration"

Although this characterization is a valuable tool in identifying social machines, it is extensively focused on the design and engineering aspects of the mechanisms that are found in social machines and overlooks the social dynamics that inhabit them. Attempting to rectify these shortcomings, Smart and Shadbolt [14] proposed the following definition which brought a major conceptual shift. It democratically allowed all involved components, animate or inanimate, to have a participatory role in social machinery [15].

> "Social machines are Web-based socio-technical systems in which the human and technological

elements play the role of participant machinery with respect to the mechanistic realization of system-level processes."

In parallel to the above, another tangential conception tends to see social machines as socio-computational systems. This view entails processing social machines as "socially-extended computational systems" in which some aspects of the computational parts are delegated to multiple human individuals. While there is a clear common ground among the above stated definitions, they do harbor significant differences in terms of the scope of conceptualizations entertained by each of these perspectives.

Social Machine, at present is a conjectural notion with various ideas and definitions attempting to elucidate the idea it represents. However, we believe that the convoluted image of the entire system can be simplified by understanding its individual components and would lead to an inductive process of discovering the whole itself. We are, by means of our research, attempting to formalise one such part of this whole. The human agent or individual in a social machine has one of the most complicated participatory roles in terms of their relations, goals, contributions to the system, and is one such facet which is invariant across the diverse perceptions of a social machine. The individual is the building block to the "social" aspect of a socio-technical machine. Thus, understanding one individual is the key to unlocking the social interaction between multiple individuals and finally their interactions with technology in a given interface.

In this work, we present a general framework of any individual who is participatory in a social machine, modelled based on Buddhist psychological tradition, as a stochastic finite state machine. Further, we address the issue of temporal variability of processes in a social machine and how our model of an individual can accommodate visualizing the machine at different temporal granules. By temporal variability, we express the differences between processes that are relatively short-lived, fleeting (for instance in the case of a social machine that supports social coordination with respect to a specific event) and ones that are enduring (for instance a social machine which keeps record of a relatively longer span of time). We also briefly discuss how various other characteristics like sociability, visibility of user contributions, variability in goals and evolving personality of an individual can be captured with the proposed model of an individual. Key contributions of this work are summarized as follows:

- Introduces the development of a unified framework for modeling an individual participating in a social machine. This framework is useful not only for classification purposes of social machines, but will help us in undertaking thorough observation and analysis of the persona of the given individual.
- Solves issues of temporal variability of processes and sparseness of individual data encountered while observing and monitoring social machines.
- Provides evidence of functioning of the model in terms of a lexical ontology through a working example on one social machine - Facebook.

The organization of the rest of the paper is as follows. Section 2 briefs the formal ontology of individual as presented in Abhidhamma meditations and the conception of a stochastic finite state automaton model of individual. Section 3 formally defines the stochastic automaton of an individual and discusses the key granularity function over the automaton to accommodate varied temporality of processes in a social machine. Section 4 demonstrates a case study to illustrate our model fitting into one of the social machines discussed in previous works [2] - Facebook. Finally Section 5 lays out the conclusion of our work so far and sketches a brief map of our future work in this domain.

2. FORMAL ONTOLOGY OF INDIVIDUAL (ABHIDHAMMA MEDITATIONS)

Abhidhamma scholarship in Theravada Buddhism [10] has long deliberated on the mechanisms of reality. In the Abhidhamma both mind and matter, which constitute the complex machinery of man, are microscopically analysed. The analysis provide descriptions of sentient experience as a succession of physical and mental processes that arise and cease subject to various causes and conditions. These sequential processes (mental and physical) formulated as discrete, momentary events are referred to as tropes (defined as *dhammas* in the original text). Tropes are thus seen as psycho-physical events that provide mental cognitive awareness. The doctrine also presents the concept of a moment (khana) which is a kind of synchronic duration of each such event. In this sense, Abhidhamma visualizes the time scale of these mental/physcical processes so they are now seen as operating from moment to moment. The Abhidhamma thus attempts to provide an exhaustive account of every possible type of experience, every type of occurrence that may possibly present itself in one's consciousness in terms of its constituent tropes.[5]

Further, the doctrine provides a taxonomy of tropes and their relational schema whereby each acknowledged experience, phenomenon, or occurrence can be determined and identified by particular definition and function. There are two kinds of tropes that constitute reality according to this doctrine - ultimate tropes (paramattha dhamma) and conventional tropes (samutti dhamma). Conventional tropes are complexes constituted by ultimate tropes and include social and psychological reality. Ultimate tropes are organized into a fourfold categorization. The first three categories include 1) the bare phenomenon of consciousness (citta) that encompasses a single trope type and of which the essential characteristic is the cognizing of an object; 2) associated mental factors (cetasika) that encompasses fifty-two trope types; and 3) materiality or physical phenomena (rupa) that include twenty-eight trope types that make up all physical occurrences . The fourth category that neither arises nor ceases through causal interaction is nibbana.

For our conception of modeling an individual based on Abhidhamma, we build a discrete line of moments, wherein each moment stands for a consciousness trope or citta. An individual is then conceived as a formal arrangement of these conscious tropes on a discrete line. This line of moments compulsively passes to the next moment as a result of previous cognition and action. Each moment has 2 categories of tropes embedded in it. 1) cetasikas or mental factors related to the cognition and 2) rupa or material cognition and actions. This in a nutshell is a basic mechanism of individual for which in the next section we write a stochastic finite

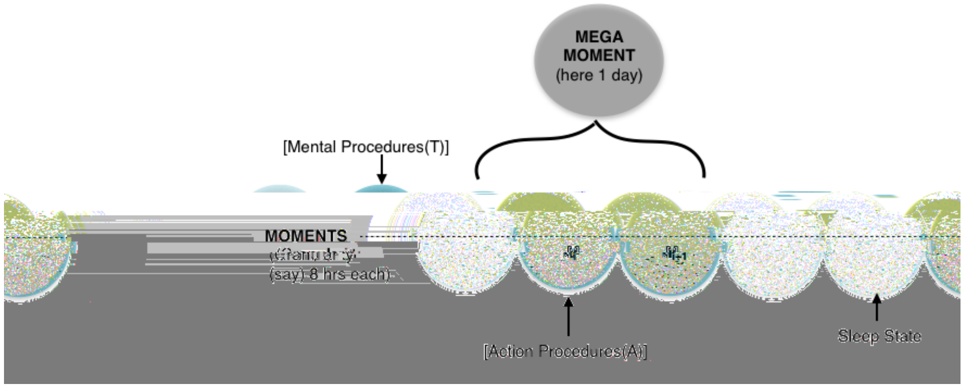

Figure 1: Represents a conceptualization of the model of an individual. It handles the temporal characteristics with the sequencing of subsequent moments one after the other M_{i+1} follows M_i. It also handles the sparsity of data by means of "Sleep States" (Translucent Blue Bubbles) accommodated amongst the populated states (Dark Blue Bubbles). Finally it attempts to illustrate the varied granularity which can be manifested in the respective moments. For instance multiple blue moments make up bigger mega moments (grey). This phenomenon can be witnessed both top-down and bottom-up.

state machine [9, 11] which takes the line from one moment state to the next moment state.

Interesting aspect of the above outlined mechanism is granularity of temporal moments. This idea of moment as "syncronic duration" has several advantages in rectifying certain problems in the realm of social machines as introduced in Section 1. One of them is that it helps in making a static moment that has no temporal parts. This formulation would help in sparse data population of individual's web data as it allows for sleep states for missing data. Another advantage is in context of accommodating real data of an individual from the social machine which occurs at different levels of granularity. This data may be of varied temporal granularity based on the participatory role of individual, characteristics and purpose of social machine etc. Various state descriptions of a life of individual fall in different granularity of time. Date, hour and seconds of clock time can index these granules. We also attempt to capture this idea by means of Figure 1.

We can comprehend the footing that theories of Abhidhamma provide to support the above advantages by means of the following. Theoretically , any granule of moment is divisible until one reaches a granularity level where only ultimate tropes populate it, and not conventional tropes of lesser granularity. Assumption in a machine is that division of moments will terminate into ultimate tropes. The above advantages can be exemplified by (say) a sequence of events such as <"woke up" →"brushed teeth" →"combed hair"> can be a set of 3 moments, the same can be represented by a bigger moment of a similar construct <"got ready">. Thus on our finite state machine we write stochastic probabilistic functions which accommodate the known sparse data of individual and help in establishing a predictive system for the future moments of an individual. We demonstrate this is Section 4 as a working example of how Buddhist mechanism can be aligned with social observatory.

3. STOCHASTIC FINITE STATE AUTOMATON OF AN INDIVIDUAL

In this section we formally define a stochastic automaton of an individual based on the conception of a formal model of individual as described in Section 2. A central concept to this doctrine is that, there is a total ordered temporal sequence of moments that captures the consciousness of an individual. We model this sequence of moments as states of a finite state automaton. Each state is a temporal moment defined in terms of the mental concomitants and actions embedded in it. This embedding of a particular set of mental concomitants and actions in each moment is defined through transition functions of the automata. Upon this basic architecture, to populate each moment as a bag of word representation from individual's web data, we write stochastic processes to help in modeling, predicting and refining rules governing the persona of the individual.

Formally speaking we define our automaton as a finite state machine. Let Q = $\{Q_1, Q_2, Q_3 \dots\}$ be a set of symbols that represent moment states, A = $\{A_1, A_2, A_3 \dots\}$ be a set of symbols that represent actions and material cognition, and T = $\{T_1, T_2, T_3 \dots\}$ be a set of symbols that represent the mental concomitants of an individual. We define our stochastic automaton whose internal state space is Q and whose input and output spaces as a Cartesian product AxT.

$$I(rf\ ) = \{Q, A, T, rf,\ \ (f, r., .\ ), M(f, ., .), AT(r., .\ ), E\}$$

$$r \in [0, 1])^D, f \in [0, 1]$$

$$AT : [0, 1]^D \times Q \times A \times T \to [0, 1]$$

$$AT(r_i, Q_i, A_j \times T_j) :$$

Probability that the output is $A_j \times T_j$ *when the internal state is* Q_i.

It is important to note here that which Q (a moment state) is an embedding of A (action and material cognition) and T (mental concomitants of the social machine), it's structure varies by means of it's temporality and the personality/persona (f, r) of an individual.

$$M : [0, 1] \times (A \times T) \times (A \times T) \times Q \rightarrow [0, 1]$$

$$M(f, A_j \times T_j, A_k \times T_k, Q_l):$$

Probability that the next moment state is Q_l when the input is $A_j \times T_j$ and the output is $A_k \times T_k$

$$E(\in Q): \textit{Halting state}$$

*i.e. when the moment state moves on to *empty state**

$$\pi(f, rQ_i):$$

*Probability that the initial state (after *empty state*) is Q_i*

$$\sum_{j=1}^{n} AT(rQ_i, A_j \times T_j) = 1$$

$$\sum_{l=1}^{m} M(f, A_j \times T_j, A_k \times T_k, Q_l) = 1$$

$$\sum_{l=1}^{m} \pi(f, rQ_l) = 1$$

Here, f represents the personality parameter and r represents the attitude of the given individual towards an object for output.
Let m(t) $\in$ Q be a moment state at any discrete time 't', at_out(t) be any output set of A & T at time 't' and at_in(t) be any input set of A & T at 't'. Then the relation m(t), at_out(t) and at_in(t) share is as follows:

$$Pob(em(0) = Q_i) = \pi(f, rQ_l) \quad (1)$$

$$Pob(em(t+1) = Q_i) = M(f, at\_in(t), at\_out(t), Qi)$$

$$Pob(ac\_out(t) = A_j \times T_j) = AT(rem(t), A_j \times T_j)$$

Let $TRM_k(f, r) \in Mat_m(R)$ be the state transition probability matrix in the case the input is $A_k \times T_k$. From (1), we can get $TRM_k(f, r)$ as follows:

$$TRM_k(f, r) = (tm_k(f, r)_{ij}) \in Mat_m(\mathbb{R})$$

$$tm_k(f, r)_{ij} = Pob(E_i \rightarrow E_j | input = A_k \times T_k) \quad (2)$$
$$= \sum_{l=1}^{m} AT(rf, Q_i, A_j \times T_j).M(f, A_k \times T_k, A_j \times T_j, Q_l)$$

$$\left\{ \begin{array}{c} TRM_k(f, r) = AT(r)M^k(f)(k = 1, 2, 3, \dots), \\ AT(r) \in Mat(\mathbb{R} : m, n), M^k(f) \in Mat(\mathbb{R} : n, m), \\ (AT(r))_(ij) = AT(rM_i, A_j \times T_j), \\ (M^k(f))_(ij) = M(f, A_k \times T_k, A_i \times T_i, M_j) \end{array} \right\}$$

Here Mat_{ij} is the (i,j) component of the matrix Mat.

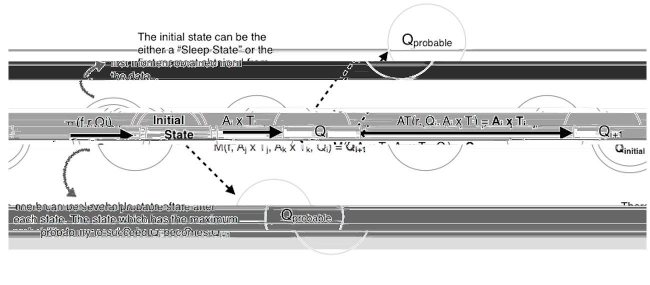

Figure 2: A stochastic finite state machine representation for the model of an individual elaborated in Section 3

4. PROOF OF CONCEPT - WORKING EXAMPLE

To illustrate how our proposed model fits into the mould of an individual in the framework of a social machine we present an example derived from the social media platform Facebook. The model is also a spectacle of thorough insight into the persona of an individual (and thus the kind of society they might spawn). It tackles the varied temporal characteristics of data and handles the sparseness of social media, accommodating them seamlessly into our system. The structure of our unitary moments (or states in the automaton) have the ability to combine, or meld together into bigger moments, thereby combining the dynamic elements and revealing connects beyond the unitary level. These will also help us to observe the motivations and dynamics which are important in multi-individual social machine systems, thus coming in handy for studying individual incentives for socially motivated observations in Web Sciences .

One of the frameworks which attempts to address a definition space for social machine has been covered in paper [2]. Here they discuss 31 constructs clustered according to the main components of social machine: social and machine driven services and the interactions between them. We are by means of the following example trying to expatiate on the social aspect of these constructs. We are not only unraveling the motivation (one of the 6 motivations discussed in the paper) but also the mental procedures concomitant to each of those motivations. This can also be seen as one of the major advantages of the proposed techniques.

As a working example, we consider the case of an online social machine scenario of an individual updating his/her status on Facebook. Here the programmed technological element of posting a status prompts the user with questions such that "X happened today, what do you think", or "what is on your mind", the user in turn participated with the interface, with a motivation to also engage in multi-user status sharing with his/her social network. While the present work deals with the motivations and mental states of one individual, it can by means of its mutability be scaled to a group of individuals. Each moment represented below is in chronological order with the temporal granularity set to a day. Each moment is populated from status update by the individual in consideration who we refer to as Person. The mental procedures and action procedures of this Person might express themselves at a singular moment, or across a combination of several Moments. Thus, preserving the handling of variable granularity in our model.

4.1 Dataset Used

myPersonality [7] is a sample of personality scores and Facebook profile data that has been used in recent years for several different researches [1, 8]. It has been collected by David Stillwell and Michal Kosinski by means of a Facebook application that implements the Big5 test [4], among other psychological tests. The application obtained the consent from its users to record their data and use it for the research purposes. We have used one of the statuses from this dataset, picked randomly to illustrate a proof of concept of our stochastic automaton.

4.2 Illustration

In Table 2 are the sequence of statuses updated by a given user. Following each status is a bag of words representations of mental states captured in the respective moment. We intend to capture these sets of mental states to understand and subsequently predict the individual's participation in a social machine. Here the mental procedure labelled <CF-PIC*A> is a set of 7 cognitive procedures namely : <Initial contact with the object < Feeling or Sensation < Perception < Intention < Concentration < Vitality < Attention or Advertance. "Sleep State" represents the empty states i.e. time-periods (here days) for which we have no data available. These mental procedures are helpful in tracing the motivation that sustains prolonged and continuous participation of human-counterparts in the system. The 6 different types of motivations listed in the study by Shadbolt et al [13] can be easily mapped onto the respective set of mental procedures covered as a part of Abhidhamma meditations. Thus, our model is not only complementary to the work undertaken in the domain so far, it also helps us in carrying out as
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Another idea that we intend to scale our present framework to is ensuring enough ubiquity in the model/definition of a social machine which can help us in maintaining interoperability across various websites. For instance, to get the real sense of an individual engaged with the Web, we would need all his/her activities across various social machines to understand their motivations/mental procedures in their entirety. For instance, a Person could be demonstrating X mental procedures on (say) Facebook while being engaged in an entirely different set of mental procedures Y on (say) Quora. To be able to capture these and infuse them into the profile of a single human agent (at a given moment in time) is what we envision our model to achieve in the near future. Thus, our work paves way for a universal model of a social machine, across a multitude of social media platforms. In conclusion, we not only propose a model to extensively analyse an individual engaging in a social machine, we also introduce the idea of furthering this model to incorporate muti-user scenarios and inter-operability across various social media platforms.

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