Probabilistic Models of Psychological Aspects in Computer-based Social interactions

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Goal

- Development and analysis of appropriate mathematical tool allowing representation and reflection various psychological aspects both human-computer interaction and users interaction during their joint work in a computer network.
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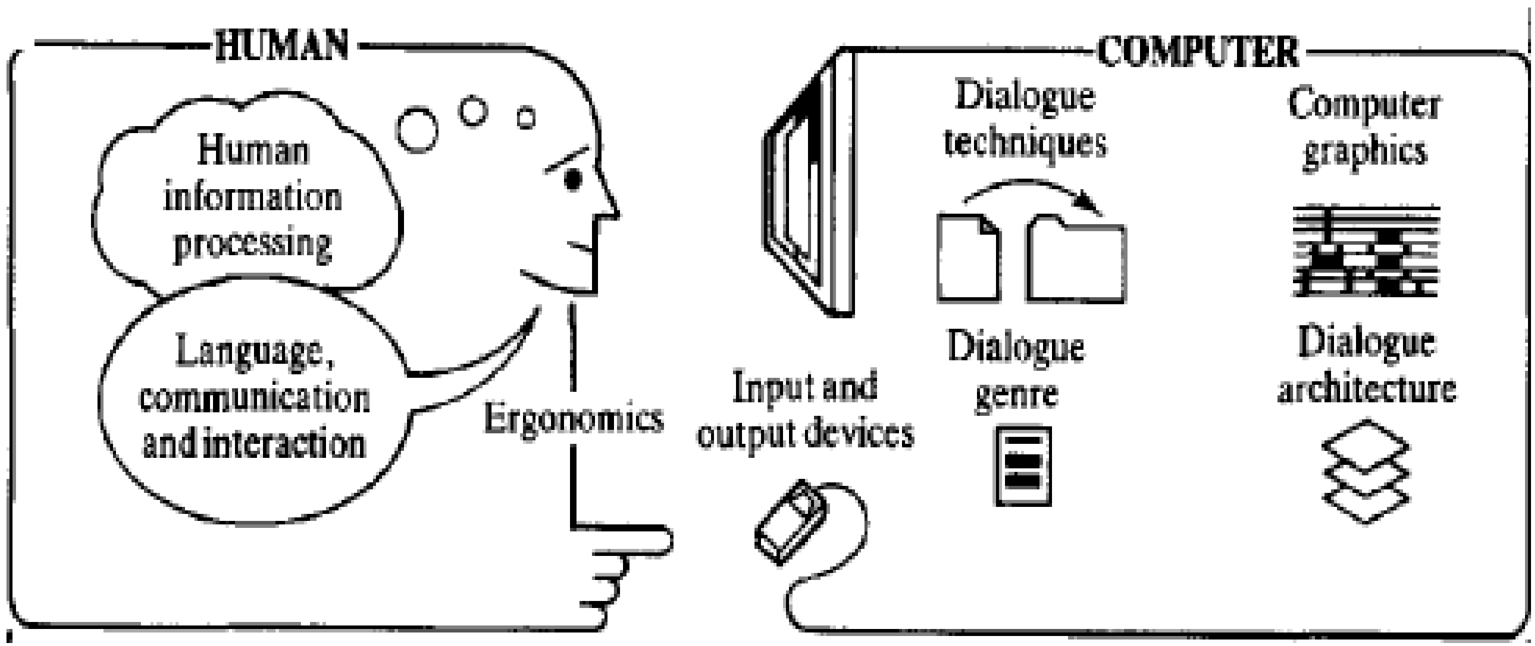
Motivation and contribution

- 1. The security of functioning of a certain network with online interacting communication participants, depends also on their psychological states ("mood" in the system of interacting subjects).
- **The problem:** in addition to technical and information security, one has to also consider the issues of psychological sustainability both of interpersonal communications and human-computer communication.
- **Requirements to the math models and tools:**
- -representation of emotional aspects,

  -main aspects of concentration,etc.

- 2. ***A* stochastic automaton network (SAN) is proposed as a high-level tool for representing the psychological interaction models described by CTMC.**

Human-computer interaction (according to ACM Special Interests Group in HCI)



General aspects of Social Interaction Modeling

- 1.*A state machine is the main form of building a model in a system of discrete events, and it is close to the model of human thinking and emotional behaviour, so it is easy to build and understand.*
- In order to represent a social and emotional actions in a network (network of robots, interacting users of a network resources, etc.) it is desirable to simulate changes in psychological states simultaneously, taking into account transitions durations.

The interaction model must be able:

- to describe events that can occur in several explicitly presented finite state machines associated with several transitions in different automata,
- the automata transitions should correlate with events that can occur in several automata, which means that synchronization occurs between the components, that is, some e_p event is associated with several transitions in different automata, and a numerical characteristic of speed transition should be presented in any good social interaction model.

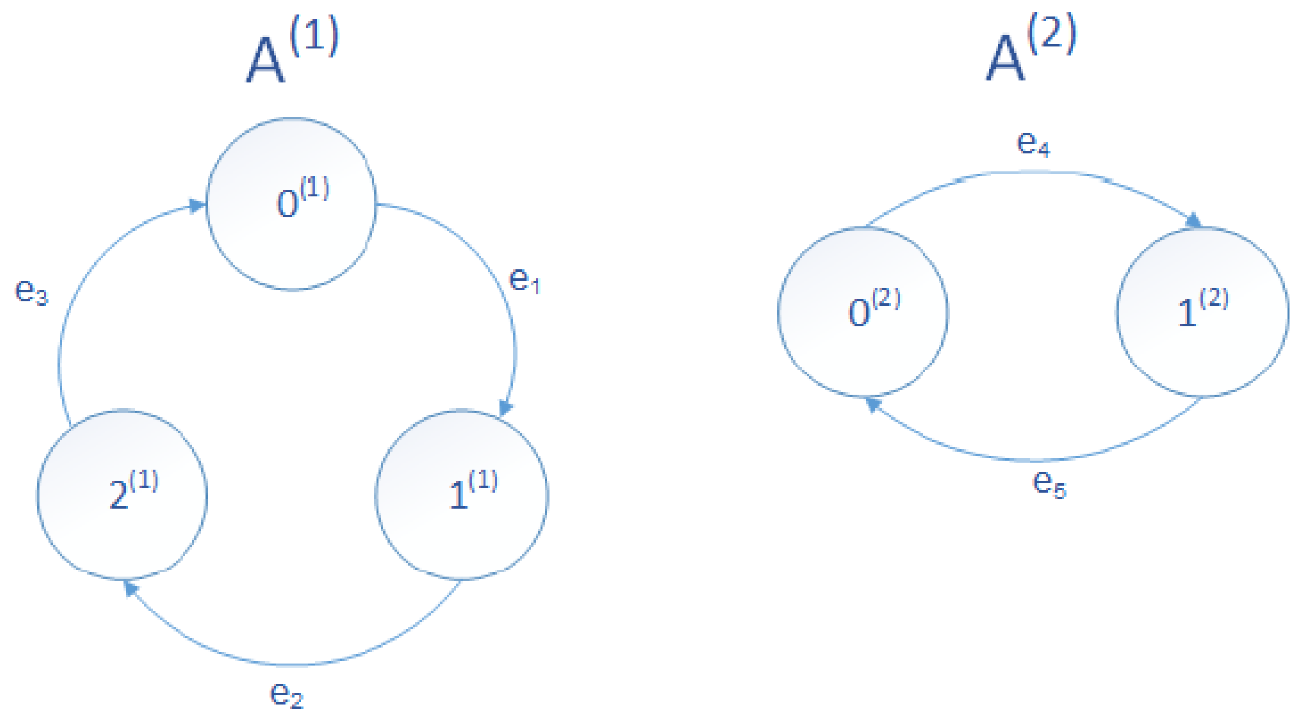
Mathematical aspects

- Each event is connected with a change in psychological/emotional state.
- Events may contain *constant or functional rates*. "Functional" means that the events may depend (as a Boolean function) on the local states of other automata that should be triggered), as happens when synchronizing.
- The mathematical model, which could underlay these conceptual requirements is the Continuous Time Markov Chain (CTMC).
- Definition. A stochastic process $\{X(t) : t \geq 0\}$ with discrete state space S is called a continuous-time Markov chain (CTMC) if for all $t \geq 0$; $s \geq 0$, $i \in S$, $j \in S$,
- $P(X(s + t) = j | X(s) = i, \{X(u) : 0 \leq u < s\} =$
- $P(X(s + t) = j | X(s) = i) = P_{ij}(t)$:

$P_{ij}(t)$ is the probability that the chain will be in state j, t time units from now, given it is in state i now.

Modeling example

- Let interaction of two subjects (human-human, human-somebody's avatar etc) be represented by interaction of two simple automata.



The events e_i, $i=1..5$ can correspond to different behavior aspects, e.g. change of emotional state.

CTMC

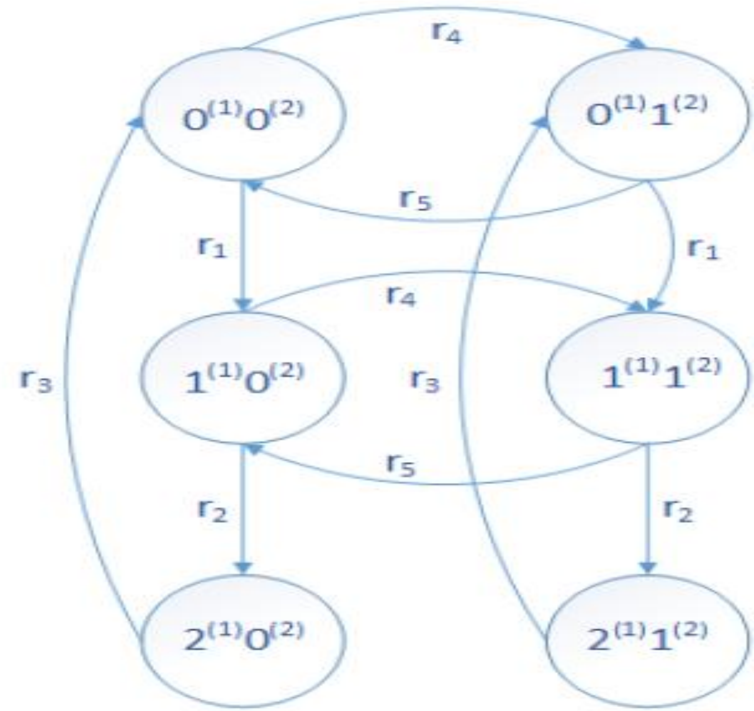
Event	Rate
e_1	r_1
e_2	r_2
e_3	r_3
e_4	f_1
e_5	r_5

where
r_i are the transition rate (characterized, e.g. the emotions intensity), f1 are transition rates

$$f_1 = \begin{cases} \lambda_1 & \text{if automaton } A^{(1)} \text{ is in state } 0^{(1)}; \\ 0 & \text{if automaton } A^{(1)} \text{ is in state } 1^{(1)}; \\ \lambda_2 & \text{if automaton } A^{(1)} \text{ is in state } 2^{(1)}; \end{cases}$$

The firing rate of the transition from state 0(2) to 1(2) is $\lambda 1$ in case automaton A(1) is in state 0(1) or it is $\lambda 2$ in case automaton A(1) is in state 2(1). If the state if automaton A(1) is 1(1), then the transition will never occur.

CTMC corresponding to the interacted automata



Stochastic Automata Networks (SAN)

- Stochastic Automata Networks (SANs) are high-level formalisms for modeling very large and complex CTMCs in a compact and structured manner.

- SAN is defined as a finite automaton (FSM) whose transitions are assigned *random durations*.
- Each automaton is characterized by many states and the rule of transition from state to state.

- SAN can be described as a collection of K stochastic automata A_k, with $k \in [1.., K]$. An internal state of the system collects the information about previous inputs and indicates what is necessary to determine the behavior of the system for the following inputs. The times are treated as a random variable that follows an exponential distribution in the continuous time scale.

SAN…

- SAN model-based description of the interacting automata allows to represent the CTMC with the infinitesimal generator of the Markov process corresponding to the behavior of an N-automaton system
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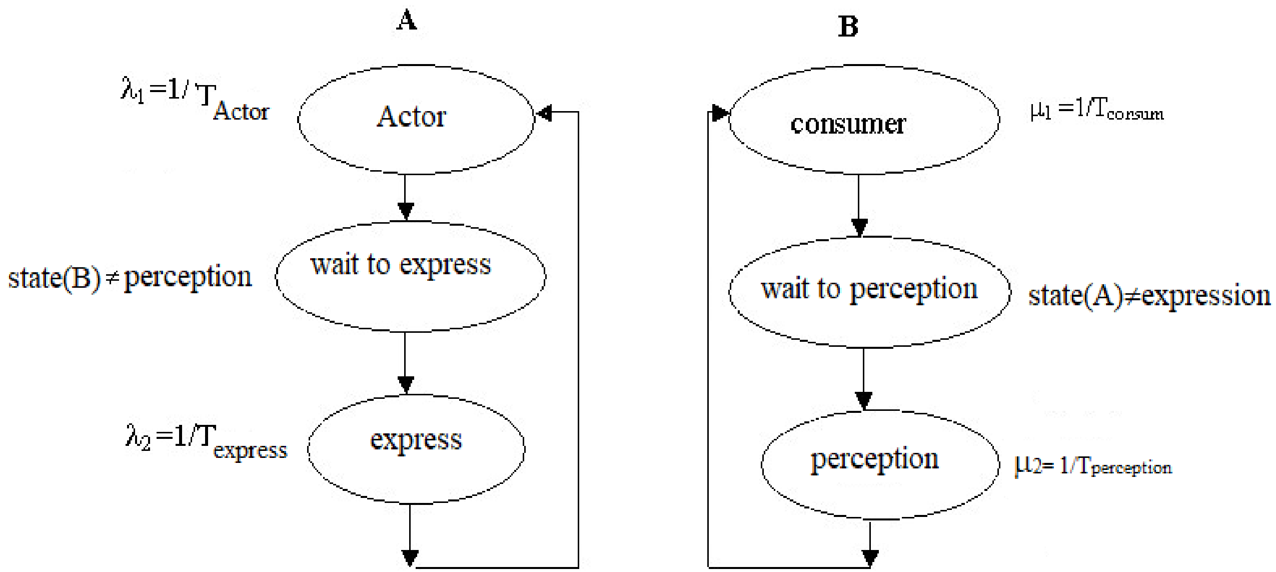
- $$Q = \Sigma_{j=1,2E+N} \otimes_{i=1,N} Q(i,j)$$
- Q (i, j) is the infinitesimal generator (matrix) of the Markov chain describing the behavior of the i-th automaton in the network, E is the number of synchronizing events that can be distinguished (but there are no functional transitions).
- $\otimes$ is the Kronecker product.

An example of SAN-based social interactions description

- An interaction of two individuals (or their avatars), each of the individuals is described by an automaton, corresponding to switching of psychological status.

The model of mood as a result of some emotional combinations (e.g, confusion and tension), modeled as corresponding events, and cognitive states affecting the appearance of these emotions.



A is an Actor (e.g. a dominator of on-line discussion, high-prioritized user of an collective computing network etc.), expressesing some thoughts or emotions which are presented in the perception of the other participant.

B is the Consumer, that is the recipient in relation to the dominant initiator (Actor) of the interaction (discussion, in particular).

An example…

a local transition between *Actor* and *wait_to_express* states; that is, this transition occurs at the fixed rate of 1/*TActor*, where *TActor* is the time required to produce an item. The local part of the global generator (Q_l) can be computed as:

$$Q_l = Q_l^A \otimes I_3 + I_3 \otimes Q_l^B$$

where

$$Q_l^A = \begin{pmatrix} -\lambda 1 & \lambda 1 & 0 \\ 0 & 0 & 0 \\ \lambda 2 & 0 & -\lambda 1 \end{pmatrix}, \quad Q_l^B = \begin{pmatrix} -\mu 1 & \mu 1 & 0 \\ 0 & 0 & 0 \\ -\mu 2 & 0 & \mu 1 \end{pmatrix}$$

I_3 is the unit matrix 3×3

Model parameters

- The fact that the *Actor* expects the recipient's reaction to be complete before he speaks again appears to be the peak of “wait_to_express”.
- Accordingly, another participant waits for the end of activity A before it (“he/she”) accepts (“reads”) the message of the first.

- $T_{produce}$ has a concrete meaning, which can be deduced from a high-level analysis of the mood conceptual model mentioned above.
- The transition from state *wait_to_write* to state *write* is functional and occurs if and only if the condition [$state(B) \neq express$] becomes true.
- Once the *Actor* gets access to the buffer, it transitions to its initial state (with the local transition rate $1/T_{express}$).

PEPS input

- PEPS – Performance Evaluation of Parallel Systems, STOCHASTIC
- AUTOMATA NETWORKS SOFTWARE TOOL.
- Input file structure:
- The average firing rates for all the events in the model are defined with a unique name(identifier). Each firing rate can be assigned either a constant value or a function.
- Events**:** For each event, its type (local or synchronizing) and name are specified, as well as which identifier its firing rate corresponds to. Each event firing rate is associated with the identifier for that specific rate or to a function that represents a functional transition rate.
- Partial Reachability**:** It is a boolean function that returns 1 if the state is reachable and 0 in case it is not. (The word *partial* indicates that the expression used for describing the set of reachable states encompasses only part of states, not all of them).

Not all global states are reachable, the combination of the starting states is specified to be surely reachable. It is guaranteed that at least this global state is known to be a reachable state in the model.

Network**:** names, states, and the transitions associated with their corresponding firing rates for each automaton.

Results and Conclusion

- Discrete time Markov chain based models, which are widely used for tasks of analyzing the optimization of social interaction (including such as interaction with humans and reactions of programs that support web navigation, interaction between humans and bots or bots), do not reflect some aspects of human-computer interactions for which it is necessary to use such concepts as “speed” and “time”.
- CTMC based model is more suitable.
- Stochastic automaton network (SAN) is proposed as a high-level tool for representing the psychological interaction models described by CTMC.

- This tool can be used for such virtual objects as avatars and bots which presently often considered as agents of network interaction.

For example, the detection of “dangerous emotions” may be a sign of the dysfunction of systems of interacting avatars, and the social systems they represent which requires attention of human operators.

The emotions model is strengthened by the analysis of the behavioral reactions in real time in order to adapt the dynamics.

Thank You!