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LETTER

Semantic cross-correlation as a measure of social interaction

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Abstract
Achieving human-level social and emotional intelligence is vital for the integration of future virtual agents and robots into the human society. To solve the challenge, it is necessary to have efficient metrics and criteria that would allow us to measure how close the solution is to the state of the art. In this work, one such potentially useful measure is introduced: semantic cross-correlation computed in addition to semantic trajectories characterizing a dialogue. This measure characterizes social interaction. Two different kinds of dialogues are used: (1) between physicians and schizophrenic patients and (2) between ad hoc participants assigned the roles of a user and a system who cooperatively solve problems. Similar in some aspects and at the same time different patterns of semantic characteristics are observed in the two cases. The new measure is applicable to dialogue transcripts as well as to sequences of actions with known semantic characteristics attributed to them. Therefore, it can be expected to become a useful general metric in evaluation of social-emotional interactions and social intelligence of virtual agents.

Introduction

Achieving human-level social and emotional intelligence in virtual agents and robots is the key for their future integration into the human society (Samsonovich, 2012). To solve this challenge, it is vital to have accurate computational description of human social and emotional intelligence. Computational understanding of complex social phenomena, including the emergence of affective relationships in small groups and social decision making, is also vital for successful control of unexpected situations, team management, policy making, and many other practical needs. This challenge requires the right set of measures and criteria for social interactions among partners, and in particular, measures and criteria for the believability and human-likeness of virtual agents engaged in social interactions. As to the latter, the most widely known and popular criteria such as versions of the Turing test (Turing, 1950) appear to be not sufficient and have been criticized as measures for human-level intelligence (Korukonda, 2003). On the other hand,

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tools borrowed from the experimental psychology lab with minimal modifications are also insufficient or not suitable, since they were designed for humans and focused on limited aspects of human cognition (Mueller, 2010).

Methods of sentiment analysis (Pang & Lee, 2008) are attractive in this context: they have became more and more popular in opinion mining via automated extraction of meaning from text or speech transcripts, and can also be used as metrics for social and emotional intelligence. It is therefore vital to develop basic metrics and scales for semantic characterization of interactions, e.g., documented in a dialogue transcript. The set of measures based on semantic cross-correlograms introduced here is expected to be useful for this purpose.

Materials and methods

Dialogue transcripts

A set of transcripts of 850 conversations between physicians and patients treated for schizophrenia used in this study were provided by Verilogue, Inc. (http://www.verilogue.com). Verilogue maintains a database of audio records and transcripts of in-office physician-patient conversations across more than 50 therapeutic categories. The dialogues included on average 1929 words each (minimum: 160, maximum: 17849), or 152 turns per dialogue. The main two participants are labeled as ''doctor'' and ''patient''. The third and fourth occasional participants are labeled as ''nurse'' and ''caregiver''. Only characteristics of the interactions between ''doctor'' and ''patient'' are studied below.

Also used in this study were 130 TRAINS dialogue transcripts obtained from http://www.cs.rochester.edu/research/cisd/resources/trains.html (Allen et al., 1995). Of these transcripts, 16 were collected in 1991 and 114 in 1993. Further detailed description of the data is available at the above URL and in the reference. All details cannot be explained here due to the limited volume of this letter. The total number of turns in 130 dialogues was approximately 10,000. Each dialogue occurred between two participants playing roles of ''User'' (who has a certain task to accomplish) and ''System'' (who plays the role of a planning assistant) in cooperative problem solving. The problem was to design a strategy for shipping boxes of oranges between cities on a given map. The User had to design a plan, and the System explained options and constraints. Details of the task and its solution are also available in the cited work. Below follows an example of a 1991 dialogue transcript downloaded from the above public URL (some notations and punctuation marks are modified or removed here for clarity; the timing is not included).

USER: okay: I have to ship a boxcar of oranges to Bath by 8 o'clock today...
SYSTEM: okay
USER: um: so: let's see: where are there oranges
SYSTEM: the oranges are in the warehouse at Corning
USER: oh okay: and I see that there's a tanker car there: oh we don't want a tanker car do we: um: I have to get a boxcar: to Corning: and then I have to load it with oranges and eventually I have to get that to Bath by 8 o'clock
SYSTEM: right
USER: um: so what's the cl... okay: we have to get engines to the boxcars
SYSTEM: right
USER: um: are there boxcars anywhere except at Bath
SYSTEM: there's boxcars at Bath Danville and Elmira
USER: oh okay: ... um: and we only need one boxcar: okay: so: aha: I see an engine and a boxcar both at Elmira
SYSTEM: right
USER: this looks like the best thing to do: so we should get the engine to pick up the boxcar and head for Corning's that sound reasonable
SYSTEM: sure: that sounds good
USER: and from Corning we'll pick up the oranges: and um: take them to Bath: will that get me: do you think that I can get ... this all over to Bath by 8 o'clock
SYSTEM: yeah: that gets us to Bath at 5 AM: so it's plenty of time
USER: okay: so: um: do I tell you what to do at this point: [chuckle]
SYSTEM: um: well: we're done
USER: [chuckle]
SYSTEM: we can now ship: we're done with the warmup problem

Weak semantic cognitive maps

Weak semantic cognitive maps are a variety of semantic spaces that provide metrics for universal semantic dimensions. Semantic spaces, or semantic cognitive maps, are continuous manifolds with semantics attributed to their elements and with geometric relations among those elements capturing semantic relations. The majority of approaches in this field are based on the idea of a dissimilarity metric, the idea of which is that the geometric distance can serve as a measure of semantic dissimilarity: the more dissimilar two concepts are, there more distant from each other are their representations allocated on the manifold, with zero distance implying semantic identity. To this category belong such well-known and widely-used techniques as the latent semantic analysis (LSA: Landauer & Dumais, 1997; Landauer, McNamara, Dennis, & Kintsch, 2007); probabilistic topic models, including latent Dirichlet allocation (LDA) and probabilistic latent semantic analysis (pLSA) (Blei, 2012; Blei, Ng, & Jordan, 2003); various methods of multidimensional scaling and manifold learning (e.g., Tenenbaum, de Silva, & Langford, 2000) that cannot be reviewed here. One of the shortcomings of these methods is the difficulty of semantic interpretation of the semantic space dimensions. In contrast, the idea of weak semantic cognitive mapping (Samsonovich, Goldin, & Ascoli, 2010) is to separate representations (e.g. words) along as many as possible clearly identified, mutually independent, universal semantic dimensions that make sense for all domains of knowledge. Weak semantic maps include, but are not limited to models of affective space (e.g., Lövheim, 2012; Osgood, May, & Miron, 1975).

In this work, quantitative lexical semantic analysis of texts was performed using weak semantic maps constructed