Event-Based Data Analysis and Visualization for Mediation Tracking using TDR System

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Motivation

Meditation, defined as “the attention inwards towards the subtler levels of thought until the mind transcends the experience of the slightest state of the thought and arrives at the source of the thought”, has been proven to have positive effects on social skills, feeling of compassion, self-management, somatic awareness and mental flexibility.

Nowadays, many people are learning meditation. However there are still no adequate meditation monitoring systems to take continuous measurements from various sensors when a person is in meditation and to track its progress.

We built an experimental TDR system with continuous data input from devices such as smart phones and sensors such as brain wave headsets. We developed event-based data analysis and visualization techniques in order to analyze input data and track progress of meditation.

The system architecture

The super-components interact with one another through the SIS server. Based on requests from the administrator, the super-components process input data and upload them to the Chronobot database.

Event-Based Data Modeling

- **Definition 1**: Given a relation \( R(T, A_1, L, A_n) \), for a pair of tuples \( v_i \) and \( v_j \) corresponding to any two moments \( \tau \) of \( T \), we say that \( v_j \) is similar to \( v_j \) with respect to \( \tau \) at the moments \( t_i \) and \( t_j \), denoted with

  \[ v_i[A_k] \equiv (d, \tau, t_i, t_j) \iff d(v_i[A_k], v_j[A_k]) \leq \tau, \text{ where } \tau \text{ is the threshold.} \]

- **Definition 2**: Given a relation \( R(T, A_1, L, A_n) \), and \( X, Y \subseteq U \), we say the type-M function dependency during the time of \( T \): \( X \leadsto Y \) holds, iff a pair of tuples \( v_i \) and \( v_j \) corresponding to any two moments \( t_i \) and \( t_j \) of \( T \), whenever \( v_i[X] \equiv (d, \tau', t_i, t_j) \) \( v_j[X] \), then \( v_i[Y] \equiv (d, \tau', t_i, t_j) \) \( v_j[Y] \), where \( d_1 \in D[X], d_2 \in D[Y], \tau', \tau \in [0,1] \) are thresholds.

- **Definition 3**: Given a relation \( R(T, A_1, L, A_n) \), and \( X, Y \subseteq U \), if \( v_i[X] \equiv (d, \tau, t_i, t_j) v_j[X] \) holds. Whereas \( v_i[X] \equiv (d, \tau, t_i, t_j) v_j[X] \) doesn’t hold, we say \( v_i, v_j \) at the moment \( t_i \) and \( t_j \) with respect to \( X, Y \) constitute a dependency violation of \( T \).

- **Definition 4**: Given a relation \( R(T, A_1, L, A_n) \), and \( X, Y \subseteq U \), we define the dependency violation rate (DVR) of \( X, Y \) during the time of \( T \) as: \( \psi(T, X, Y) = \frac{k}{\tau} \), where \( r, r_1 \in \mathbb{R} \) denote the combinatorial number of any pair of attributes in \( X \) or \( Y \) during the time of \( T \).

- **Definition 5**: Given a relation \( R(T, A_1, L, A_n) \), and \( X, Y \subseteq U \), we say that relaxed type-M function dependency during the time of \( T \):

  \[ X \leadsto Y \text{ holds, iff a pair of tuples } v_i \text{ and } v_j \text{ corresponding to any two moments } t_i \text{ and } t_j \text{ of } T \text{, whenever } v_i[X] \equiv (d, \tau, t_i, t_j) v_j[X], \text{ then almost} \]

  \[ v_i[Y] \equiv (d, \tau, t_i, t_j) v_j[Y] \] holds, and \( \psi(T, X, Y) \leq \epsilon \), where \( \psi(T, X, Y) \) is the T-DVR-XY, \( d_1 \in D[X], d_2 \in D[Y], \tau', \tau \in [0,1] \) are thresholds.

- **Definition 8**: Given a relation \( R(T, A_1, L, A_n) \), and \( X, Y \subseteq U \), for a pair of tuples \( v_i \) and \( v_j \) corresponding to any two moments \( t_i \) and \( t_j \) during \( \Delta T(\eta) \), if there’s one of the following cases happening, we say \( v_i, v_j \) at the moment \( t_i \) and \( t_j \) with respect to \( X, Y \) constitute a dependency violation event during \( \Delta T(\eta) \):

  1. \( |t_i - t_j| > \eta \)

  2. \( v_i[X] \equiv (d, \tau, t_i, t_j) v_j[X] \) holds, whereas \( v_i[Y] \equiv (d, \tau, t_i, t_j) v_j[Y] \) doesn’t hold.

- **Definition 11**: Given a relation \( R(T, A_1, L, A_n) \), and \( X, Y \subseteq U \), for three consecutive tuples \( v_i, v_{i+1}, v_{i+2} \) corresponding to some moments \( t_i, t_{i+1}, t_{i+2} \) during \( \Delta T(\eta) \), if \( \psi(\Delta T(\eta), X(v_i), Y(v_i), \Delta T(\eta), X(v_{i+1}), Y(v_{i+1}), \Delta T(\eta), X(v_{i+2}), Y(v_{i+2}), \Delta T(\eta)) > \epsilon \), we say those tuples \( v_i, v_{i+1}, v_{i+2} \) constitute an abnormal event1 during \( \Delta T(\eta) \).

Figure 1: TDR system with super-components and Chronobot database. Relations in the database.

Figure 2: GUI for normal or abnormal event.

Figure 3: GUI for dependent event.