Geometric Representations for Subjective Time in Digital Narratives

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Abstract. Subjective time refers to our living experience of time. We develop subjective timescapes i.e., spatial representations for time as experienced by story characters. Each such timescape describes how a character perceives and shapes story time. We show how these spatial constructions are compatible with relevant psychological and phenomenological studies on subjective time. Timescapes allow us to model characters as operating from particular temporal perspectives mediated by memory and anticipation at various points in a story and to provide geometric mappings of these concepts. We apply these ideas in a visualization environment for digital narrative plot structures.

Keywords: Time, Narrative, Visualization, Experiential aspects

1 Introduction

Most of the current research and applications of time focus on representing and managing "clock" time, i.e. fixed periodic structures such as the 24-hour standard or the calendar system. However, there is another equally important notion of time, that we call "subjective" time, and describes our awareness of precedence or succession, duration, simultaneity and tempo of events, the feeling of presence, and the establishment of temporal perspectives on events and behaviour. In contrast to its clock counterpart, subjective time is qualitative in nature [1], different for each individual and with no rigid linear structure. Subjective time exerts considerable influence on motivation, planning and execution of purposeful activity [4]. We describe the construction of subjective timescapes, i.e., spatial representations for the experience of time in story characters. We develop geometric perspectives for representing the flow of time, temporal dilation and segmentation in episodes. We provide geometric mappings that make these phenomena examinable and allow the creation of alternative character-centric micro-narratives describing how characters experience time. Current narrative systems focus on supporting inferential aspects of stories by reasoning about plans and actions from character goals using variants of plan-based AI methods [3]. They seek to formalize the notion of clock time and to provide means for reasoning about the temporal aspects of knowledge. Time in their stories is something external and disassociated from what is happening in the story. In contrast to these systems our approach seeks to represent how story events interact with the experience of time in characters.

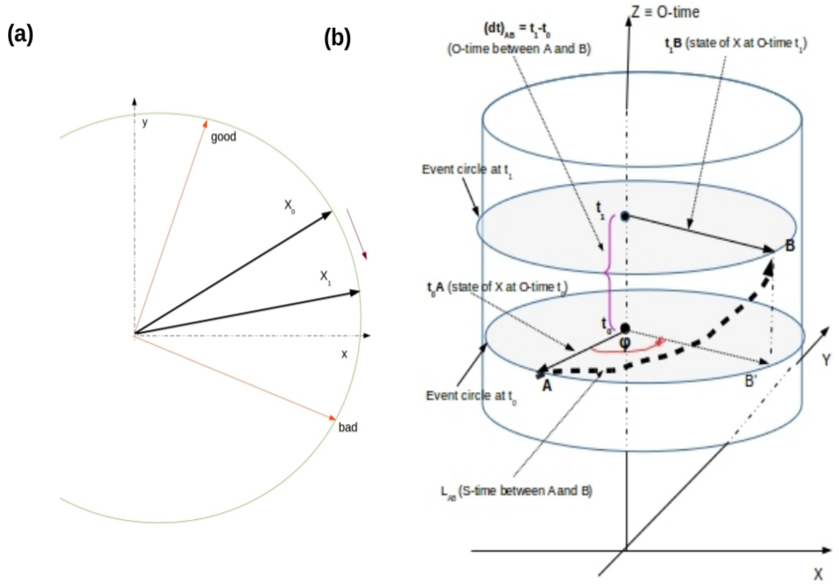

Fig. 1. (a) Atemporal representation for the state of character X on the unit circle (b) C-time interval $(dt)_{AB}$ and S-time segment AB for X corresponding to events at C-times t_0 and t_1. X's state follows the helical trajectory of the S-time curve from A to B by simultaneously rotating with an angle ϕ and translating by $(dt)_{AB}$ on the z-axis.

2 Character state and subjective time

A narrative can be analysed as a sequence of events describing the goals and actions of a set of characters and the complications arising from them. Given such a goal-oriented structure we represent character state in terms of his current disposition towards various goals, i.e. his perception of how near or far he currently is towards their adoption and/or attainment and of how interrelated these goals are. We model character state as a unit vector in a 2-D real vector space lying on an horizontal unit circle centered on the character (see Fig. 1(a)). Thus, character state and goals are mapped to particular directions of motion in space. This configuration reflects the character's perception of goal-driven behavior as motion in a particular direction. Pairs of goals that are opposite to each other and, therefore, pose a dilemma for a story character, are mapped to orthogonal vectors in this space and define a basis for this vector space. The configuration of such a basis encodes the semantic opposition of its goals as a left-right antithesis that reflects a common story metaphor of a dilemma as a forking path of two orthogonal directions forward. As an example, Figure 1(a) depicts the state and goals for a character X. X is confronted with two possible and contrasting goals (becoming either good or bad). We represent such a moral viewpoint with a basis M consisting of two orthogonal unit vectors (vectors are written in bold) **good** and **bad** denoted in red in Fig. 1(a). A state $\mathbf{X_0}$ of X is a vector which can be described in terms of M as a linear combination of the vectors **good** and **bad**. Such a combination indicates that X has two potential goals of being either "good" or "bad" while also describing his current disposition towards them. By disposition we refer to the distance of his current state from either of the goal vectors in M, which reflects how close he is towards adopting or achieving that particular goal. This distance is captured by the dot product between his current state vector and the particular goal vector. X can change his disposition towards his goals. Such change is represented as a rotation of his state vector. Rotation can be instantaneous, as in the case of character decisions, or gradual, as a result of action execution. For example, by reneging on a promise X can change his state from $\mathbf{X_0}$ to $\mathbf{X_1}$, thus rotating his state vector closer to the **bad** goal (see Fig. 1(a)) and increasing his disposition of achieving this goal. We model the perception of state change from the perspective of the character involved as being proportional to the angle of rotation between his initial and resulting state.

We develop two main structures for representing subjective time. The first one, which we call clock time (**C-time**), refers to the temporal placing of events by an external observer using a clock. We represent the C-time for such an event as a point on the z-axis of a 3-D coordinate system (see Fig. 1(b)). We use C-time to signify that an outside uninvolved observer experiences E as preceding all events with higher z-coordinates and succeeding all events with lower ones. Also important is the difference between the C-times of successive events as this indicates the amount of time such an observer perceives as having expired between two successive events in relation to the time intervals between the other pairs of successive events in the sequence. Consequently, C-time exhibits the linearity of clock time. The second structure of time, which we call subjective time (**S-time**), is different for each character involved in the event sequence and corresponds to his perception of the temporal features (placing, duration, simultaneity) between successive events at each point in the sequence. More specifically, we represent each event by the effects it has on the states of the characters. Therefore, each event is a slice of C-time represented as a unit circle (such as the one in Fig. 1(a)) centered on the C-time axis and vertical to it. Each such circle contains the character states that result from the event actualization. The representations of all events are stacked on a cylinder of unit radius and height h, where h is equal to the difference between the C-times of the last and the first event in the story. We model the trajectory of S-time for character X by the sequence of the geodesics (shortest paths) on the surface of this cylinder formed by connecting the endpoints of successive state vectors of X. The duration of the S-time for X between any two successive events E1 and E2 is equal to the length of the geodesic connecting the endpoints of his state vector at events E1 and E2. Let A and B be the endpoints of the state vector for X at successive C-times t_0 and t_1, respectively, where $t_1 > t_0$ (see Fig. 1(b)). The length L_{AB} of the geodesic between A and B represents the duration of the S-time interval separating successive events at clock times t_0 and t_1 according to X. In order to compute L_{AB} let us assume that B at t_1 results by an event that forces X's state at t_0 to transform to the one at t_1 following a helical trajectory with a rotation angle of ϕ radians ($0 \leq \phi < 2\pi$) around the z-axis and a simultaneous translation of $(dt)_{AB}$ units on the z-axis where $(dt)_{AB} = t_1$-t_0 is the C-time interval between A and B. If we then flatten our event cylinder to a square we compute L_{AB} as: $L_{AB} = \sqrt{(dt)_{AB}^2 + \phi^2}$. According to this relation S-time maintains the phenomenology of the flow of time in which events seem to constantly approach an agent from the future, are actualized in the present and recede to the past because S-time duration between two events is proportional to the duration of the C-time $(dt)_{AB}$ separating them. Furthermore, S-time duration between successive events for X is proportional to the rotation angle ϕ separating X's state vectors in these events. Because we model X's perceived amount of state change among these events as being proportional to this angle ϕ, the duration of the S-time between them is also proportional to the change in X's state. Consequently, between two pairs of successive events separated with equal C-time intervals, X will perceive the pair in which his state rotates more as lasting longer than the other one. This allows us to embed in a character an experience of duration compatible with the one posited by the contextual change model in the psychology of time in which estimates of duration of an event in which a person does not need to estimate its duration is proportional to the number of changes observed during an interval [5]. We are not interested in the absolute value of S-time, only in the qualitative relations (comparisons and proportionality) between various S-times. Our ability to generate and process temporal experiences presupposes our ability to apprehend event sequences as episodes (i.e. coherent event sequences that are extended in time). We adopt the phenomenological notion of temporality in which coherency refers to the meaning established by the character for the events in question [2]. We use the notion of distance between the state of a character X and a goal in his goal space, as captured by the dot product between these two vectors, to establish our notion of temporal coherency. In particular, during each event X experiences his state as staying invariant, moving closer or away from a goal **G**. We capture this experience by comparing the value of the dot product between **G** and the agent state vector at the current C-time point t_i with its corresponding value at the previous C-time point t_{i-1} in the event sequence. If the value at t_i is greater-than, less-than or equal to the previous one at t_{i-1} then the agent experiences his state to converge, diverge or stay invariant, respectively, with respect to **G**. A sequence of events in which the agent experiences his state to only converge, diverge or remain stable with respect to a goal forms an episode.

3 An Example

Our story example involves three characters; Joe, Bob and Ann. This story plot has been automatically produced by QuNE, a narrative generation system based on spatial representations of purpose and quantum theory [6]. The goal structure (see Fig. 2(a)) motivating their behaviour consists of five bases. The first one is Morality (which is common to all three characters with two vectors **good** and

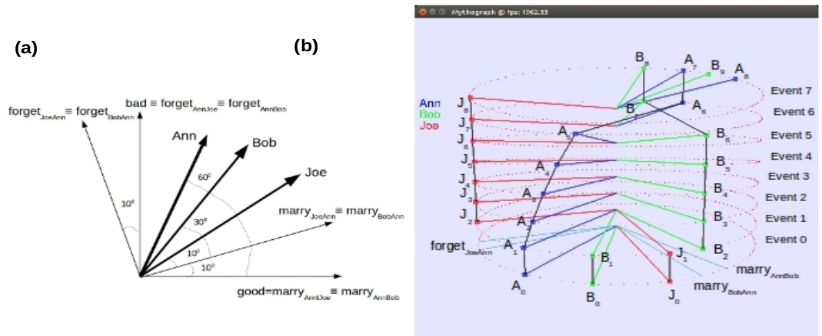

Fig. 2. (a) Initial configuration for the example love story ('≡" denotes coincident vectors) (b) Subjective timescapes for the characters in the example love story.

bad). We also use two bases describing what it means for Ann to try to marry or to forget any of the other characters (bases AnnJoe with **marryAnnJoe** and **forgetAnnJoe** and AnnBob with **marryAnnBob** and **forgetAnnBob** for Joe and Bob respectively), and two bases describing such an involvement for Joe (bases JoeAnn with **marryJoeAnn** and **forgetJoeAnn**) and for Bob (basis BobAnn with **marryBobAnn** and **forgetBobAnn**). The orientation of these bases indicate that for both Joe and Bob trying to marry Ann is regarded as primarily 'good' while forgetting her as primarily 'bad'. Ann has a positive view for marriage since for her trying to marry either Joe or Bob is definitely 'good' and forgetting either of them is definitely 'bad'. Initially both Joe and Bob are more prone to decide to try marrying Ann. Ann seems more likely not to try marrying either one of them. There are four possible story developments: Date, Serenade, Duel and Marriage. Date involves Ann and one of the other guys causing each one of the state vectors involved to rotate by a random angle (dating is unpredictable). Serenade results in increasing the probability for Ann to decide and marry her serenader. Duel implicates two guys resulting in the winner trying to marry Ann and in the loser deciding to forget her. Finally, Marriage occurs when both characters decide to do so. Fig. 2(b) depicts the S-time structure of this story based on the configuration of Fig. 2(a) that is reproduced as the Event 0 (E0) circle in Fig. 2(b). Fig. 2(b) depicts the trajectory of Ann's state by the sequence A_0A_8, the one for Bob with the sequence B_0B_9 and the one for Joe as J_0J_8. Most of these pairs of successive points (e.g. A_4A_5) are connected with line segments whose length indicates the duration of the S-time interval between successive events for the character involved. The ones not connected (e.g. B_1, B_2) describe instantaneous character decisions and therefore lie on the same event circle. Fig. 2(b) assumes equal C-time intervals between the story events. E1 corresponds to Joe and Bob contesting for Ann. Bob wins and decides to try marrying Ann (goal G). This is represented as the instantaneous rotation of his state at E1 from B_1 to B_2 where at B_2 it becomes parallel with **marryBobAnn**. Bob seeks to persuade Ann to marry him therefore he seeks through his actions to make her state parallel with **marryAnnBob**. At E1 Joe (the loser) decides to forget her. This is indicated by the rotation of his state from J_1 to J_2 which becomes parallel with **forgetJoeAnn** (trajectory J_2J_8). Bob serenades Ann four times (E2-5, trajectory B_2B_6) and this arouses Ann's interest for Bob by rotating Ann's state gradually closer to goal **marryAnnBob** (trajectory A_1A_5). In E6 Bob and Ann go on a date which makes Bob waver on whether he should try to marry Ann (in B_6B_7 his state vector rotates away from **marryBobAnn**), even though Ann seems to like him more (in A_5A_6 her state rotates closer to **marryAnnBob**). In E7 both characters decide to marry. This is indicated by the rotation of Bob's state from B_8 to B_9 becoming parallel to **marryBobAnn** and Ann's from A_7 to A_8 becoming parallel to **marryAnnBob**. Each character experiences a different micro-narrative stemming from his partitioning of time into episodes during the event sequence. In particular, at the end of the story Joe divides his experience into two episodes. The first one consists of the sequence J_0J_1 and the second one of J_2J_8. This is the case because between J_1 and J_2 Joe reaches the goal of forgetting Ann. Ann partitions her experience in three episodes. The first one consists of the sequence A_0A_6, the second one of A_6A_7, and the third one of point A_8. This is the case because in A_6 Ann's state changes from converging towards **marryAnnBob** to becoming invariant with respect to it, while in A_8 Ann decides to marry Bob. Analogously, Bob partitions his experience in five episodes, B_0B_1, B_2B_6, B_6B_7, B_7B_8 and B_9. Other micro-narratives also emerge. For example, during E1-7 Joe perceives Ann's state to rotate away from his and vice versa signifying a growing rift between the two, while on the other hand the states of Bob and Ann move close to one another signifying a gradual rapprochement. In general, subjective duration for Ann and Bob is greater than Bob, since the length for J_0J_8 is less than either A_0A_8 or B_0B_9 indicating greater effort for Ann and Bob than Joe.

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