THE SPATIO – TEMPORAL PROCESS MODEL
FOR CONCURRENT PROCESSES AND MESSAGE TRANSMISSION

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ABSTRACT: Spatio-temporal models are crucial for performing assumption and predictions for physical, environmental, space and biological science. Typical application examples include traffic monitoring, regional ozone monitoring, disease mapping and analysis of satellite data. This paper discusses the construction of a conceptual model for spatio – temporal processes based on the concepts of concurrent processes and message transmission. Spatial, Temporal as well as Spatio – temporal domains combine together with proposed STPM. The spatial nature (domain) of this model is also captured in the concepts of a process. Syntax and semantics of \( \pi \) – Calculus are also incorporate with processes in this model to furtherance the potential of messages transmission among each domain. The paper considers a real world example as a case study to show the working of the model and emphasize its sustainability over several situations and transitions of processes.

1. INTRODUCTION

Space and time are intrinsically tied to every aspect of the real world. Therefore spatio - temporal model have gained widespread of popularity since last few decades. One may observe the statues of entities before and after a change occurs, these are facts and consequences. Providing an efficient system to operate simultaneously on absolute and relative views of space and time implies that geographical [where] and temporal [when] components are implemented using a homogeneous data models (Armstrong 1988; Langran 1988; Peuquet 1995). However, those models do not provide mechanisms to explicitly describe events and processes and relate changes of one specific entity to actions of other known entities. The three domain model (Yuan 1996) is also the process oriented data model, which can be classified under this category. Three domains define as semantical, temporal and spatial in this model each domain has location and semantic oriented dynamic links. The major advantage of this model is that there are no pre defined data schemata, unless the dynamic links. Those kinds of models are not much popular as its modeling complexity than data model.

Process is an essential component in dynamic mechanism. A process is a concept developed by scientists to understand and relate changes occurring in nature (e.g., soil erosion, organic, growing processes). Process is not an isolated term in the dynamic perspective. It has widespread ontological arguments for its individual behaviors. Process is one of the ontological arguments among them. Recognize of the spatio – temporal world is a crucial fact in defining the term “Process”. The entities which stand to Process termed as Processuals entities. Processuals are occurrents or happenings which depend upon their participants and located both in spatio – temporal and temporal regions. The self connected Processual entities together, define as a Process. Events are the instantaneous boundaries of processes and instantaneous transitions within processes (Grenon &
Smith 2004). Action is a different kind of occurrents than Process and Events which is initiated and sometimes terminated by human or non–human agents (Worboys 2005).

In this paper, we propose a different spatio temporal model called Spatio Temporal Process Model (STPM) which has high correlations with the concepts of where, when, process and action. Unlike other models, STPM is highly compatible for concurrent process modeling via $\pi$–Calculus (Milner 1999). It is capable to model the spatio- temporal changes with the context of either location or process.

The rest of the paper is organized as follows. Section 2 the architecture of STPM with its concepts and in Section 3 modeling behavior of the real world phenomena through STPM as case study. Finally, section 4 expresses the conclusion of the STPM model.

2. ARCHITECTURE OF SPATIO–TEMPORAL PROCESS MODEL

The architecture of STPM is not much complex. It consists with three domains, two channels and two links as shown in Figure 1. While, Domains and channels are essentials for a complete model and links are optional for it.

![Figure 1. Spatio–Temporal Process Model (STPM)](image)

2.1. Domains and Channels

While the temporal domain represents time as a Process, the spatial domain represents the space also as a Process. Though, the notion of time as a process is not quite unfamiliar since time already represent as an event, the notion of a space as a process will be quite complicated. Space can represents as two different Process methodologies termed either “Locations” (Worboys 2005) or “Attributes”. In “Locations”, represents each location as a Process that handshake with its neighbor locations through its adjacency relations which are act as an Actions. “Attributes” process concerns only the Attribute changes of a particular location (single location) when “Action” happens on. Status of Attribute represent as a Process and anything which cause to change the statues of attributes declare as an Action in “Attribute” process. Meanwhile Spatio – Temporal domain represents the process of Spatio – temporal phenomena. This phenomenon may be “Even” process, which means no Actions happen during the Process or “Uneven” process.

TC and SC are channels termed as Temporal Channel and Spatial Channel respectively. So, it is understood that each Process in Temporal domain should at least link with one Process in Spatio –
Temporal Entity domain through channel TC and each Process in Spatial domain also should at least link with one Process in Spatio – Temporal Entity domain through channel SC conversely.

2.2. Links

Spatio Temporal Link (STL) is an optional link which can present the link between Temporal domain, Spatial domain and Spatio – Temporal Entity domain. When defining a predetermined trajectories or activities, this STL₁, which is between Temporal domain and Spatial domain will helpful to present the relation in between time and locations or time and Attribute statues. Similarly, STL₂ also an optional link in between STL₁ and Spatio – Temporal domain, when defines a predetermined activity of a Spatio – Temporal Entity. It necessary to understand that, STL₂ bounds only with the “Uneven” process of Spatio – Temporal Entity. If the trajectory or activity is not predetermined, then no more further use with this STL. It is essential to keep in mind that this link can make 1:1 relations only. Modeler’s privilege to determines either STL is applicable or not to the model. If it is applicable then it should make with broken lines, similarly in figure 1, in the model. Otherwise, ignore it.

3. CASE STUDY – BEHAVIOR OF LANDSPOUT (DUST-TUBE TORNADO)

As we explained in previous section, there are four (4) different applications in STPM, such as “Location” process applications for “Even” and “Uneven” processes of Spatio – Temporal Entities and “Attribute” process applications also for “Even” and “Uneven” processes of Spatio – Temporal Entities. In this section we wish to discuss the behavior of Waterspout as a combination of an “Even” and an “Attribute” process among them. The optional STLs also utilize in this model.

As a presumption, it can considers as no actions can effects to the process of Landspout when considering instance and during that period Spatio – Temporal domain has as an “Even” process. Figure 2 shows a STPM for case study of Landspout.

3.1. Process Advancement and Message Transmission

3.1.1. Temporal Domain

Process Advancement C₁,

\[ C₁ = \text{tick}.C₂ \] \hspace{1cm} (1)
\[ C₂ = \text{tick}.C₃ \] \hspace{1cm} (2)
\[ C₃ = \text{tick}.C₄ \] \hspace{1cm} (3)

Message Transmission Process T₁,

\[ T₁(t) = \overline{TC}(t₁)C₁ \] \hspace{1cm} (4)
\[ T₂(t) = \overline{TC}(t₂)C₂ \] \hspace{1cm} (5)
\[ T₃(t) = \overline{TC}(t₃)C₃ \] \hspace{1cm} (6)
Where $t_1$, $t_2$ and $t_3$, times are referring to instances of Clock process $Cl_1$, $Cl_2$ and $Cl_3$ respectively.

3.1.2. Spatio – Temporal domain

No process advancement happens in this domain since it’s an “Even” process.

Message Receiving Process $E$,

$$E(t, a) = TC(t)SC(a)ST$$  \hspace{1cm} (7)

3.1.3. Spatial Domain

Process Advancement $At$,

$$At_1 = ac_1. At_2$$  \hspace{1cm} (8)
$$At_2 = ac_2. At_3$$  \hspace{1cm} (9)
$$At_3 = ac_3. At_4$$  \hspace{1cm} (10)

Message Transmission Process $S$,

$$S_1(a) = SC\langle a_1 \rangle. At_1$$  \hspace{1cm} (11)
$$S_2(a) = SC\langle a_2 \rangle. At_2$$  \hspace{1cm} (12)
$$S_3(a) = SC\langle a_3 \rangle. At_3$$  \hspace{1cm} (13)

Where $ac_1$, $ac_2$ and $ac_3$ are actions and $a_1$, $a_2$ and $a_3$, attributes are referring to instances of Attribute process $At_1$, $At_2$ and $At_3$ respectively.

3.2. Overall Mechanism


$$(4), (7) \text{ and } (11) \quad T \mid E \mid S$$
\[TC(t_1)Cl_1 | TC(t)SC(a)ST | SC(t_1)At_1\] (14)

\[Cl_1 | \left\{ \begin{array}{l} t_1 \\ t \end{array} \right\} \left\{ \begin{array}{l} a_1 \\ a \end{array} \right\}ST | At_1\] (R1)

At Processes \(Cl_1\) and \(At_1\) Spatio – Temporal Entity, Landspout occupies the time \(t_1\) and Attribute \(a_1\). Now, Signal Receiving Process E form (7),
\[E(t, a) = TC(t_1)SC(a_1)ST\] (15).

Similarly (5), (12) and (15),
\[Cl_2 | \left\{ \begin{array}{l} t_2 \\ t_1 \end{array} \right\} \left\{ \begin{array}{l} a_2 \\ a_1 \end{array} \right\}ST | At_2\] (R2)

Likewise, at time instance of \(t_3\) and Attribute \(a_3\),
\[Cl_3 | \left\{ \begin{array}{l} t_3 \\ t_2 \end{array} \right\} \left\{ \begin{array}{l} a_3 \\ a_2 \end{array} \right\}ST | At_3\] (R3)

Parallel Compositions of Processes: Advancement of processes, Clock, Spatio – temporal and Attribute happens parallely with Reations

(1), (7) and (8) \[Cl_1 | ST | At_1 \rightarrow Cl_2 | ST | At_2\] (P1)

(2), (7) and (9) \[Cl_2 | ST | At_2 \rightarrow Cl_3 | ST | At_3\] (P2)

(3), (7) and (10) \[Cl_3 | ST | At_3 \rightarrow Cl_4 | ST | At_4\] (P3)

Mechanism of STPM: By amalgamating (R1) to (R3) and (P1) to (P3), the entire mechanism of STPM express as follows. Equation order presents the sequence of STPM mechanism from (M1) to (M6).

\[Cl_1 | \left\{ \begin{array}{l} t_1 \\ t \end{array} \right\} \left\{ \begin{array}{l} t_1 \\ l_1 \end{array} \right\}ST | At_1\] (M1)

\[Cl_1 | ST | At_1 \rightarrow Cl_2 | ST | At_2\] (M2)

\[Cl_2 | \left\{ \begin{array}{l} t_2 \\ t_1 \end{array} \right\} \left\{ \begin{array}{l} t_2 \\ l_2 \end{array} \right\}ST | At_2\] (M3)

\[Cl_2 | ST | At_2 \rightarrow Cl_3 | ST | At_3\] (M4)

\[Cl_3 | \left\{ \begin{array}{l} t_3 \\ t_2 \end{array} \right\} \left\{ \begin{array}{l} t_3 \\ l_3 \end{array} \right\}ST | At_3\] (M5)

\[Cl_3 | ST | At_3 \rightarrow Cl_4 | ST | At_4\] (M6)

4. CONCLUSION

Even though \(\pi\) – Calculus has an extensive coverage of Signal transmission, few of them can only applicable to spatio – temporal modeling. But we believe this few amount would make grate changes in process modeling. STPM is a newly design model which is totally depends on \(\pi\) –
Calculus and concurrent processing. This case study retrieves following five (5) different situations among the model’s full competence which is eight (8) different situations due to user requirements.

- Temporal situation
- Attribute situation
- Process situation
- Temporal transition
- Attribute transition

As our suggestions this model is ideal for synchronous domains, which are all temporally referenced entities handshake with processes in the same clock, and syntopic domains, which can share the same habits within the same geographic range.

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