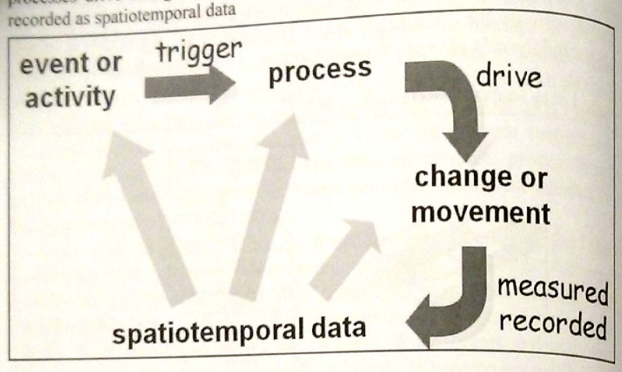
Figure 2. A premise: events and activities trigger processes to initiate or intensify; processes drive change or movement as observables that can be measured and recorded as spatiotemporal data



The proposed premise in Figure 2 goes beyond the cartographic constraints of objects and fields in conventional GIS by enabling connections among events (activities), processes, change and movement, and data (facts, evidence) in space and time. By making proper connections, temporal GIS will be able to construct spatial narratives through historical research exercises of selectivity, simultaneity, and shifting of scale in manipulating space and time to interpret the past (Gaddis, 2002). The proposed premise supports the use of time as an organizing principle and the mutually constitutive relationship between space and time as inherently in the definitions of events, activities, processes, change, and movement as well as their contingent connections.

3. From Temporal GIS to Narrative GIS

The development of temporal GIS by and large parallels to the trend in temporal database management systems with an emphasis on how to store temporal data. Historians and humanity scholars need to embrace space and time in ways to contextualize events and behaviours, based on which they can explore causation and answer questions on "why" (and for them, "why" matters more than "who," "what", and "when") (Bodenhamer, 2013). To this end, the proposed premise in Figure 2 may suggest a brand new way to use both space and time with equal importance in organizing geographical and historical information. The new approach transforms temporal GIS to narrative GIS with spatial narratives as the core concept.

While temporal GIS builds upon layers of snapshots or spatiotemporal objects, narrative GIS uses spatial narratives to geographically contextualize events and interactions in a time-orderly fashion to reveal causation, contingency, and human experiences. Points, lines, and polygons are ingredients to build GIS layers or feature classes. Likewise, events, activities, processes, changes, and movements are all elements available to construct spatial narratives. Even though these narrative-building elements are abstract and use of their spatial and temporal representation schemes for visualization is inevitable, narrative GIS privileges happenings over entities and therefore allows for ambiguity and flexibility with a hierarchy of events (such as wars and battles) associated with multiple spatial and temporal footprints. Selection of narrative-building elements may be based on semantic, spatial, or temporal considerations, or any combination of them. A narrative GIS aims to provide the element pools, frameworks and tools to facilitate selecting relevant elements and assembling them to form narratives that represent meaningful flow of happenings from the chosen perspective.

Events, activities, and processes are incorporeal, not bounded to a particular space and time, but they can be actualized in multiple ways and experienced as such. Movement (or motion) and change result in differences between successive events, activities, or processes, and movement and change inherit distinctive durations. Fraser (2006: 130) synthesized Whitehead's thesis that "duration is the field of the event: points and instances, spatial and temporal divisibility and extensiveness, are the properties of a duration". In other words, movement and change actualize events (and activities and processes) as durations with discrete spatial and temporal extents. Table 1 gives simple definitions of these narrative-building elements. Whitehead (1978: 35) posited that "There is a becoming of continuity, but no continuity of becoming": discrete activities and events lead to a becoming of continuous processes. Events and activities take place, and processes take time. Change and movement denote the differences and effects in space and time. Together, they form spatial narratives to express what happens, how it happened, what the consequences are, and the historical and geographical reasons.

Table 1. Definitions of narrative elements

Term	Oxford English Dictionary	Narrative Elements
Activity	The state or quality of being active; exertion of energy; the degree to which a substance, esp. an enzyme, exhibits its characteristic property.	Action taken by actors (e.g. individuals, agencies, or organization) in space and time. The consequence of activities may generate movement of the actor or other objects. Activities can also cause change to the characteristics of someone or some environment.
Event	The fact of anything happening; the occurrence of; an incident.	An occurrence of something with significance that drives noteworthy motion or change at locations over time. The decision on "significance" and "noteworthy" is situational and problem-dependent.
Process	The fact of going on or being carried out, as an action, or a series of actions or events; progress, course.	A gradual transformation that transcends properties, forms, and patterns over time. The determination of "gradualness" is scale-dependent.
Change	Substitution of one thing for another; succession of one thing in place of another; substitution of other conditions or circumstances, variety.	Substitution of properties in an object, at a location, or conditions in an environment. Changes can occur to population counts, identities, thematic attributes, spatial, or temporal characteristics.
Movement	A change of place or position; a progress, change, development; passage from place to place, or from one situation to another.	Shift in location of an object over time. The object must maintain the same identity during a movement.

Activities and events may be difficult to differentiate. Nevertheless, activities are goal-oriented and contextualization of spatiotemporal patterns reveals routine activities and some purposes. Changes in routine activity patterns suggest event disturbances or progressing to another stage of life. Several GIS projects exploited human activity patterns with Time Geography. Kwam (2004) examined daily journeys with space-time trajectories to project space use in urban area. Shaw and Yu (2009) developed GIS tools to analyse activities and interactions of individuals in physical and cyber spaces. Both projects examine space-time paths at the individual levels as well as at the group levels for interactions. This line of research advances also push studies of accessibility (especially into healthcare facility) and exposure (especially to pollution) that is, moreover, applied to issues related to social and environmental justice. Similar approaches may be helpful to historical investigation of environmental perception or routing analysis by projecting environmental and social characteristics to the pathways of migration or immigration, troop movements, or transportation routing.

Historians and cultural geographers emphasize the singularity of events. Strictly speaking, an event is not just something that happens; it is a happening of significance. Fraser (2006) stressed the importance of singularity to an event on both "the coming together of prehensions" and "their becoming together in a particular way." Furthermore, she argued that event-thinking seeks to apprehend the relations between actual bodies and incorporeal happenings in states of affairs as well as the transformative power of individual events that create the reality of events in themselves. The singularity of an event is relative in nature and is question dependent. Sunrise, payday, and World War II commonly are all singular events that can serve relative time frames at different temporal scales. Yet, birthdays, college graduation, and weddings are personal. The Geospatial Event Model (GEM) offers formalization of events in GIS to support reasoning about events and their states of affairs as settings (Worboys and Hornsby, 2004). Narrative GIS will need to develop data schemes and analytical functions to discern evidence of actors and environmental conditions coming together in a particular way and to facilitate grasp of the interactions when coming together.

Process is at the center of cultural-historical geography as a "retrospective science" that records, illustrates, and synthesizes geographic patterns to explore geographic processes (Sauer, 1956). Apprehension and appreciation of historical landscape can be acquired through projecting processes that are responsible for the forms and patterns as we observe. Indeed, every empirical concepts of space must be reducible by a chain of

definitions to a concept of process (Blaut, 1961). Like event and activity, process is incorporeal and unbounded. Processes proceed continuously, progressively, or eruptively in space and time. An important inquiry about process is to identify distinctive phases and ensuing consequences in process development. A process may promote certain activities or events (such as evolution promoting disruptive events); a process may also be modified by events or activities (such as Licoln's Gettysburg speech energizing emancipation). Narrative GIS will need capabilities to relate processes to forms and patterns as well as relate processes to events and activities to reify incorporeal working of geography into apprehensible contingency to shed light on what may be coming or becoming.

Change and movement are differences resulting from activities, events, or processes. Movement can be considered as change in location, so change is perhaps more fundamental than movement. Persistent identity is critical to change recognition. As mentioned previously, change in administrative boundaries poses the key challenge in historical social science research because the area unit of analysis is no longer constant and so are the spatial representations (i.e. location, size, and geometry) of data assigned to the administrative unit. Many GIS studies on spatial and temporal interpolation methods attempt to handle such issues better. Yet, issues of identity for mobile objects differ from those for area units. From journeys taken by individuals to flows of transactions submitted by multiple agencies, recognizing object identities can be simple or very difficult. Some objects may involve in ontological change, such as a tropical depression becoming a hurricane, and persistent identity may not be possible. With thriving GPS technology, mobile object modelling is a hot research area, but these lines of movement may not fully address the needs of historical research. Narrative GIS will need to ingest useful models and functions from existing developments in change detection, spatio-temporal interpolation, trajectory analysis, and mobile object modelling, and meanwhile develop new conceptual frameworks and functions to relate change and movement to process, event, and activity.

Narrative GIS is intended to respond to historical research needs for temporal GIS. The discussion so far addresses the needs for conceptual frameworks, data schemes, and analytical functions to generate spatial narratives from spatiotemporal data or facts. This is in contrast to geo-narrative research that is being developed under the scope of qualitative and critical GIS (Kwan and Ding, 2008). Oral narration, stories, and diaries are mapped to reveal spatial perception of one's daily activities, spatially referenced ideology or cultural practices, or spatial behaviours and space use on narrative maps with or without multimedia displays

(Caquard, 2013; Mennis, Mason and Cao, 2012; Curtis, 2012; Elwood and Leszczynski, 2012). Both approaches to spatial narratives can bring a spatial dimension to time-centric historical research. Complementarily, geo-narratives spatialize human experiences, whereas spatial narrative generation extracts change and movement from spatio-temporal data to reconstruct process, event, and activities, and through the reconstruction to contextualize these narrative-building elements geographically and historically for rich interpretation on their singularity and contingency. The shift from objects and fields to narrative emphases in both approaches presents a big leap forward in GIS support for historical research.