**A conceptual framework for studying reactions to events in location-based social media**  
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**Keywords**: event, reaction, spatial-temporal, social, semantic, information-spread

**Abstract:**

* (250 words)

Events are a core concept of spatial information (Kuhn, 2012), and location-based social media (LBSM) provide information on reactions to events. Individuals have varied degrees of agency in initiating, reacting to or modifying the course of events and reactions can take the form of observations of occurrence, expressions containing sentiment or emotions or a call to action. Key characteristics of reactions in LBSM include a referent event and information about who reacted, when, where and how, as well as information relating one reaction to others. Collective reactions are composed of multiple individual reactions sharing common referents. They can be characterized according to the following dimensions: spatial, temporal, social, semantic, interlinkage. Our conceptual framework allows us to characterize and compare reactions. For instance, for a thematically well defined class of event such as cherry blossoming we can explore differences and similarities in space and time in different towns, countries and even cultures. Other events may have very complex spatio-temporal signatures (e.g. political processes such as Brexit or elections) which may be decomposed into a series of individual events (e.g. a temporal window around the result of a vote) whereby reactions can be characterised and compared with respect to this event. The purpose of our framework is twofold: firstly we explore ways in which reactions to events in LBSM can be usefully described and secondly, we use the framework to underpin the development of methods for analyzing and understanding collective reactions to events.

1. Intro and motivation

Ross

* Application of framework by: Planners & journalists, decision makers, sociologists
* Introduce Objectives (audience: researchers)

1. Examples

As a means to demonstrate implementation and validate fitness of the proposed framework, we chose a sample of events from the following social and natural phenomena:

* Brexit (an ongoing opinion formation process)
* Cherry Blossoming (a natural event class)
* St. Jude storm (a natural event)

All of these phenomena relate to change with possibly significant impact and, at the same time, portray quite different challenges for studying event reactions on social media. For example, in case of the Brexit, it is difficult to speak of any single event. Rather, ‘Brexit’ can be seen as an umbrella term for a complex and ongoing process of voter opinion formation, encompassing many individual events which once may (or may not) lead to the UK’s separation from the European Union. In this context, the referendum held on June 23, 2016 represents a singular event of particular importance. While a high volatility of opinion is typical for such referendums (Leduc, 2002), the observed reverse in sentiment was both unexpected as well as affected by intense campaigning, misinformation and highly emotional expression of attitudes and feelings on social media and elsewhere (Bianchetti, Ricci, & Salvatori, 2016). A framework that helps studying these reactions, sentiments and their interlinkage may lead to a better understanding of the particular effects that determine final outcomes of similar referendums.

The subject of investigation in the example of cherry blossoming are collective reactions to a *class* of events, with many different manifestations as instances of cherry blossoming and related events around the world. Due to their quite regular, predictable pattern, these annual events became an almost worldwide recognized icon of spring, influencing many people’s appreciation of seasonality and transience. Their local experience can be conceived as a puzzle piece in the bigger picture for cultural identity formation and collective attribution of meaning. Questions of relevance include but are not limited to identifying hierarchical patterns of similarity and interrelatedness in different reactions across event instances, across different cultures and between annual trends in amplitude and spatial distribution. In this context, a specific application example for interrelated dependency of event reactions is presented by Fontugne, Cho, Won, & Fukuda (2011), who showed that amplitude in reactions to cherry blossoming (among other phenomena) on social media varies depending on concurrent events, such as natural disasters, and may therefore be used as cross-event impact indicators.

Finally, St. Jude storm is a specific and well delineated event which caused major human, environmental and economic consequences while sweeping across the UK, mainland Europe and other countries on and after October 27, 2013 (Hickey, 2014). Here, specific knowledge is available on the temporal and spatial unfolding of events, including particular sub-events. This allows for precise modelling and comparison of people’s reactions and reaction-interlinkage on social media. In a related application example, Shelton, Poorthuis, Graham, & Zook (2014) used Twitter tweets to evaluate impact and information distribution and distortion of Hurricane Sandy on social media. Our choice for St. Jude storm also resulted from the fact that this storm was given many names: originating from Low ‘Burkhard’ and the remnants of ex-tropical storm ‘Lorenzo’, it was first coined ‘St. Jude’, based on the feast of Saint Jude the Apostle and the storm’s coinciding day of landfall. Whilst crossing several country borders, other references emerged such as Cyclone and Orkan Christian, Höststormen Simone, Oktoberstormen 2013, or more personalized names such as ‘Carmen’ and ‘Allan’. This cross-cultural difference in references affects spatio-temporal patterns and causal relationships of reactions on social media, and therefore poses formal difficulties for a framework as it is presented here.

1. Literature review
   1. Brief discussion of event literature: distinction between ontologically based and data/ methods driven definitions

Dirk, Alexander

Space and time fundamentally influence how humans perceive the world. Not surprisingly, events play an important role in many areas. Literature on event definition can be categorized in either ontologically motivated or method driven. From a general perspective, consensus exists in the core notion of an event as an *identifier* for change. In other words, an event is considered a segment of time that is “carved out of processes” (Kuhn, 2012) such that it can be distinguished, referenced and memorized. This is also in accordance with the common-sense notion of events. Similar to how ‘mind maps’ are constructed for the spatial world, retrospectively, humans perceive, structure and memorize their lives as a sequence of discrete events of varying importance (Zacks & Tversky, 2001, p.58). In this vein, many authors argue that events function as the temporal counterpart of objects in the spatial domain and, therefore, should be treated similar or of equal rank (Chen, 2003; A Galton, 2006; Worboys, 2005; Zacks & Tversky, 2001). The current paradigm is that both events and objects are mutually interdependent but ontologically distinct (Galton & Mizoguchi, 2009; Liu et al., 2008; Worboys & Hornsby, 2004).

The exact ontologically definition of events in an application-oriented GIScience framework, however, remains a matter of controversy (Galton, 2015; Polous, Krisp, & Meng, 2013). [add terminological issues/overview of definitions]\* Unlike processes and objects, events do not ‘persist’ as a whole throughout their existence, they simply occur (Galton, 2006). This means that start and end are a core component of events, often referred to as the *boundary* or *frame* (Zacks, Speer, Swallow, Braver, & Reynolds, 2007; Zacks & Tversky, 2001). Each part of an event may itself consist of processes and events, arranged in a particular sequence. These sub-structures can be broken down further, which forms a unique pattern and taxonomic hierarchy (Beard, Deese, & Pettigrew, 2008; Quine, 1985). Here, Beard et al. (2008) propose a two dimensional event categorization between primitive and composite and expected and unexpected events. The most primitive events consist of simple physical changes which are conceived almost instantaneous. This means that, in some cases, both start and end may coincide (Zacks & Tversky, 2001). At other times, composite events can become so complex that they are only retrospectively perceived as an event. Frequently, these composite events will have fuzzy temporal and spatial boundaries, which is a difficulty in event detection (Westermann & Jain, 2007) but usually presents no challenge to the human observer (Zacks et al., 2007). This uncertainty is an important characteristic for the everyday-connotation of events, and is expressed in the second distinction from Beard et al. (2008), expected versus unexpected. Expecting an event or becoming aware of it while it is happening requires knowledge (Zacks & Tversky, 2001). Sometimes, it is easy to spot events because their temporal sequence is very familiar to us. At other times, events are unexpected just because we have not experienced them before (Bell, 2012). In other words, some people may perceive an event while it passes unnoticed for others (Worboys, 2005). This intangible nature of events poses difficulties for research dealing with events, because events require both a physical manifestation and an explicit cognitive labelling (Ref!). A further challenge is seen in the granularity of events (Ref!). Zacks & Tversky (2001) argue that humans possess a pre-conditioned range of scales where they are particular sensitive to events. Finally, Polous et al. (2013) categorize events in three basic types, natural, social and artificial. In this view, events can occupy a continuum of granularity scales from the micro-level (artificial events such as computer clicks) to human-scale events (the social/human-centered view, e.g. someone’s vacation) to the macro-scale in the case of some nature events (e.g. astronomers consider a merger of two galaxies, spanning millions of years, as an event).

\* Overview of event definitions in literature:

* “Quine described events as units that can be localized in space and time, broken into sub-parts, and arranged in a taxonomic hierarchy.” (Quine, 1985)
* “Peuquet describes an event as a change in some location(s) or object(s).” (Peuquet, 1994)
* “Claramunt and Jiang define an event as an application-driven concept that supports a cognitive interpretation of a significant pattern of change.”(Claramunt & Jiang, 2000)
* Guralnik and Srivastava describe an event as a qualitatively significant change in the behavior of some dynamic phenomena. (Guralnik & Srivastava, 1999)
* “Event[s] can be viewed as objects with time and space as their primary attributes” (Jain, 2003, p.52).”
* Event: “a segment of time at a given location that is conceived by an observer to have a beginning and an end” (Zacks & Tversky, 2001, p. 17).
* “Define an event to be a semantically meaningful human activity, taking place within a selected environment and containing a number of necessary objects.” (Li & Fei-Fei, 2007)
* Antony Galton (2015, p. 7) defines events as “synoptic summaries of salient aggregates of processes as they are recorded in the memory” and also as “an intrinsically bounded, discrete occurrence” (p.8)
* Yuan “regards an event as ‘ a spatial and temporal aggregate of its associated processes’” 🡪 ‘process is measured by its footprints in space and time’.
* Langran and Chrisman conceive “events as marking points of discontinuity in an otherwise smooth course of history”
* Events can be seen from two perspectives: ‘historical’ = objective and ‘experiential’ = subjective (Antony Galton, 2008)
  1. Literature exploring works on reactions to events

Eva

Beside a definition of reactions in a chemical or physical sense, the Oxford English Dictionary[[1]](#footnote-1) defines a reaction as “something done, felt, or thought in response to a situation or event”. This definition is specified in three aspects:

1. a reaction can be a human’s ability of mental and physical response to external stimuli
2. a reaction can be a physiological response in the form of a side effect to an inhaled, ingested or touched substance
3. a reaction can be a way of thought or behaviour that differs intentionally from earlier ways of thinking or behaving

In order to exclude reaction-related work that is non-relevant for this paper, the conducted literature review has been restricted to reactions to events which are expressed social media. However the diversity of domains investigating this topic is rich (see Figure 1), likewise the intensions behind.

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Figure 1: Domains investigating reactions to events in social media  
(classification of scientific fields based on Universal Decimal Classification[[2]](#footnote-2))

In the majority of the reviewed publications, the terms reaction and response are used synonymously, which conforms to the definition of the Oxford English Dictionary.

In all analysed studies, a message or post published on a social media platform related to a certain event is considered to be a reaction to this event. The most commonly examined social media platform is the microblogging service Twitter, but also Facebook or the Chinese microblogging service Sina Weibo are regarded amongst others. The reference to a certain event is identified by particular keywords or hyperlinks contained in the message/post and by temporally limiting the data collection to the issue attention cycle around the event (Downs, 1972), i.e. the period in which public attention to an event arises and drops off.

Some studies analyse reactions to newspaper articles in order to determine the life cycle of news articles posted online (Castillo, El-Haddad, Pfeffer, & Stempeck, 2014) or to correlate news events with crucial changes in user sentiment (Tsytsarau, Palpanas, & Castellanos, 2014) which corresponds with definition c) of the English Oxford Dictionary. Tsytsarau et al. (2014) declare that it is essential to not only look at news from news media or news agencies but also at the publication dynamics of people in social media for the purpose of understanding the significance and impact of news. McEnery, McGlashan, & Love (2015) argue the other way around, that when analysing social media reactions to news events, the press needs to be taken into account since it is influencing the discourse; thus McEnery et al. (2015) focus on the contrast between reactions to a terrorist event in the press and in social media. Criminal events, including terrorist events, are another kind of events causing reactions in social media. Kounadi, Lampoltshammer, Groff, Sitko, & Leitner (2015) investigate the public perception of homicides and how the concern about them is influenced by the spatial proximity of the crime. He, Hong, Frias-Martinez, & Torrens (2015) utilise social media reactions to the Ferguson unrest to spatiotemporally study protest dynamics since social media provide users more possibilities than merely receiving news. However Burnap et al. (2014) are rather interested in the diffusion of reactions to terrorist events in social media and can distinguish between supportive and disruptive reactions.

Hashimoto, Aramvith, Chauksuvanit, & Shirota (2013) explore social media reactions from different Asian countries related to the East Japan Great Earthquake for understanding Asian social context. With this in view, different addressed topics are identified and regarded as reactions (e.g. concerns about damages), whereas Amanatullah, Barish, Michelson, & Minton (2013) differentiate reactions referring to a speech by their topical (referring to the same subject) and temporal (occurrence within same short time interval) reference.

Also reactions to health-related events are investigated in different aspects, for instance for determining which kinds of information are triggering social media reactions concerning infectious diseases (Fung et al., 2015), to understand the perception of a cluster of perinatal deaths in Ireland (Meaney, Cussen, Greene, & O’Donoghue, 2016) or to identify trusted online sources by analysing social media reactions to reported swine flu (Szomszor, Kostkova, & St Louis, 2011). Nikfarjam, Sarker, O’Connor, Ginn, & Gonzalez (2015) utilise social media for pharmacovigilance and thus for public health monitoring tasks by extracting adverse drug reactions and thus refer to definition b) of the English Oxford Dictionary.

Rodrigues (2016) investigates how ‘femvertising’ (an advertisement strategy applied by brands using pro-female messages in order to promote their products) is perceived by consumers, how they react and relate to it in social media. Three categories of reactions could be identified: users thanking, complimenting or criticising the brand for the campaign. Lipizzi, Iandoli, & Marquez (2016) analyse social media reactions to newly launched movies focussing rather on traffic metrics than on sentiment with the aim to predict box-office sales.

In summary, the introduced investigations are either conducted to interrelate social media reactions in some way to news articles from the press (e.g. in a comparative way) or to find out in which way social media users reacted to an event (e.g. supporting or disrupting). Within all the mentioned studies, merely He et al. (2015) and Kounadi et al. (2015) are regarding space. Our own work intends to broaden these approaches by considering also the social background of the reacting people as well as the interlinkage of reactions beside the spatial, temporal and semantic component.

* 1. Data mining and data dimensions (methods)

(Who?)

* G.Klir. Architecture of Systems Problem Solving: <http://www.springer.com/us/book/9780306473579>
* Temporal & spatial, interlinkage, social (==”population”, or a set of discrete objects in G.Klir’s terms, see Klir, 2012), thematic & character/type/kind of reaction

1. Conceptual model
   1. Events

Alexander

An *event* can be represented as a tuple *e* = (*te*, *se*, *Pe*, *ae*), where

* *te* is the time when the event happened (instance or interval);
* *se* is the spatial location of the event. It may be a point, a continuous area, or a set of disjoint points or areas, or *s* may be empty;
* *Pe* is the set of people involved in the event, which may be empty;
* *ae* is a combination of thematic attributes characterizing the event.

These elements comprise the temporal, spatial, social and thematic attributes of the event, which can also be called its ‘facets’ (see Purves & Derungs, 2015, for details about the origin of this four-parted notion). Perhaps the most directly recognizable attribute of events is their temporal facet *te*. The Brexit referendum, for instance, can be reduced to a single point in time when the final count of votes was available and announced at Manchester Town Hall on June 24, 2016, at 7.20am (Rayner & Dominiczak, 2016). In case of the St. Jude Storm, *te* takes the form of an interval of time. While the exact start and end times may be the subject of some degree of uncertainty, the events peak impact can relatively unambiguously be assigned to the time between October 27 and 28, 2013 (Hickey, 2014). A formal difficulty in temporal characterization of events is present in the example of cherry blossoming. Here, it seems natural to speak of a cherry blossoming event as *repeating* or occurring *regularly*. Periodicity is a fundamental characteristic of many events (Beard et al., 2008). However, as Galton (2015) points out, each event is unique and can only occur once. What is perceived as repeating is nothing else than a very similar pattern of regularly occurring instances (i.e. tokens) of events (e.g. in spring each year) of the *class* cherry blossoming.

While this distinction between event class and event instance is important for many applications, it depends on the context of analysis and its intended granularity. In the example of St. Jude storm, the subject of analysis can be seen as both a unique event or as an instance of more general, universal classes such as “cyclones”, “UK storms”, or “extreme weather events” etc. It appears equally reasonable that St. Jude storm itself consists of many sub-events and event classes with similarities among their facets, which finally formed a specific pattern that was perceived as St. Jude storm. Theoretically, this also works the other way round: if the same pattern of events would occur on a regular basis, the ‘yearly return of St. Jude storm’ may justify denoting it as a new class of reoccurring events. This is mainly seen as a problem of communication and language and means that, for the analyst, in the context of studying reactions, it will frequently make sense to treat similar, reoccurring events as a single subject of analysis, or separate events into many sub-classes if need arises. Consequently, linking collective reactions to the right event granularity poses a significant difficulty in practice (see 4.2.2).

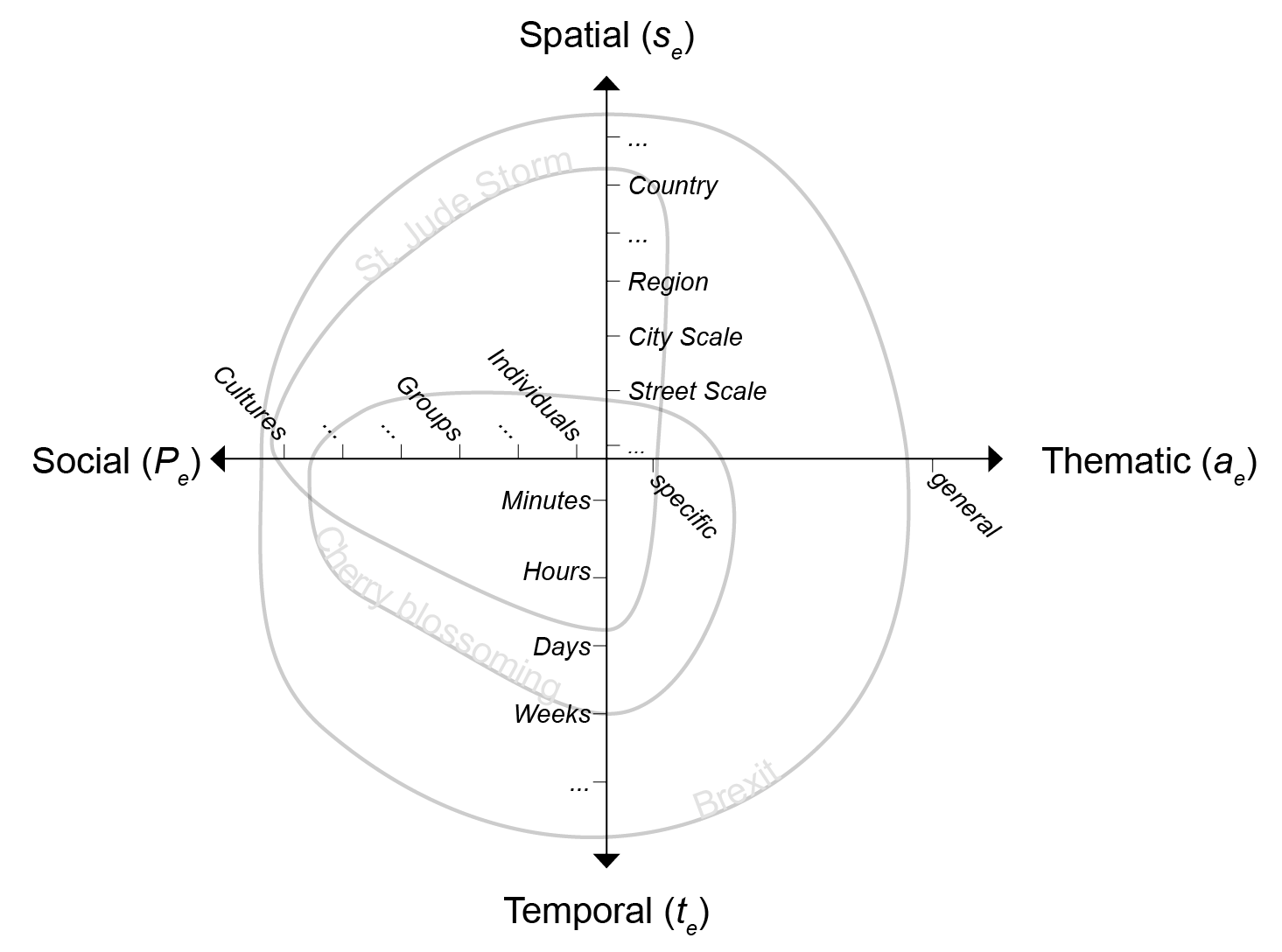


Figure 2: event granularities across facets for typical contexts of investigation illustrated for 3 examples.   
[graphic is a bit problematic to interpret but I left it in for now]

This granularity (or *hierarchical*) aspect similarly applies to other facets and is particularly obvious in the spatial facet of the cherry blossoming event example. Here, the class of events can be grouped in many different sub-classes and sub-events. From the outset, all cherry blossoming events are characterized by a base of common attributes, which is why they are collectively referenced as such. These attributes may slightly vary across different countries (e.g. Japan, USA), across regions (e.g. US East and West coast) and among different parks (e.g. cherry trees in High Park in Toronto and around Washington’s Tidal Basin), and for different trees (e.g. the ‘Miharu Takizakura’ is a particularly impressive tree and a national treasure of Japan in Fukushima Prefecture), or even when comparing individual blossoms on a single tree. Therefore, in the example of cherry blossoming, *se* may be a continuous area (a boundary of a park), a set of disjoint points or areas (multiple parks or several regions and countries), or *s* may be empty (all cherry blossoming events), depending on the respective context of investigation. Likewise, the spatial footprint of St. Jude may be defined as either a continuous area or a collection of areas representing the moving trail of the storm. In the example of the Brexit referendum, defining a spatial location appears not productive at all. While the event is obviously related to the UK, it is mostly irrelevant where exactly the final result was announced or where people cast their ballot. Granularity distributions across facets for typical contexts of related investigations are illustrated in Figure 2.

The social facet *Pe* is directly related to *agency*, a concept that denotes people’s involvement in an event. For some natural events, such as St. Jude storm, people are mere passive observers (or possibly victims, in this particular example), whereas other events only exist because of people actively participating (e.g. this is apparent in the many cherry blossoming festivals). A more complex picture is present in the Brexit referendum. As a specific group of people, the UK’s population directly participated in this event, and therefore had at least some agency in the referendum final outcome. Another group, the population of the European Union, had limited to no agency in the referendum, but is, to some degree, affected by its outcome. Other groups outside Europe were neither involved nor perhaps directly affected by the referendum and its consequences. This means that the degree of agency must be seen as a continuum, representing many nuances of people’s (perceived) ability to change an event (for a more thorough discussion on this topic, see Davidson, 1980). In this context, as a somewhat paradoxical example, consider the situation of cherry trees in Japan, where the yearly event recently reached a cultural (and financial) importance that the government “commissioned scientists to ‘programme’ the cherry bloom at the ‘appropriate time’ by experimenting with sprays and plant hormone injections” in the context of earlier than typical peak bloom times as a result of climate change (Scott et al., 2008, p. 185).

Finally, a certain degree of uncertainty for delimiting many of the everyday events remains. Facets may not be completely available upon the time of analysis, or difficult to define. For example, in the case of Cyclone St. Jude, many people’s perception will differ as to the storm’s peak impact time, and even more so on its start and end. Meteorologists may likewise not be able to point to a single point in time when the storm came into existence. This difficulty is sometimes referred to as the *experiential* aspect of events (Galton, 2008; Westermann & Jain, 2007; Lyons, 1977) and used to emphasize the subjective experiences of events and what they actually mean to the people. If the distinction between different people’s perception is important for the analyst, one may define *te* as a set of times *T* corresponding to an array P*e*, encompassing, for instance, a collection of start and end times. The collective summarization of all perceived impact times may then be used as an approximate for its ‘true’ value.

* 1. Reactions to events
     1. Individual reactions

Alexander, Natalya

An *individual reaction* is a single reaction of one person to one event. It can be represented as a tuple *r* = (*e, p, t, s, a*):

* *e* is the event that motivated the reaction;
* *p* is the person who reacted;
* *t* is the time of the reaction;
* *s* is the spatial location of the reaction;
* *a* is a combination of thematic attributes characterizing the reaction (how specifically did the person react?)

An individual reaction may also be called *elementary* reaction. Individual reactions are themselves events, but of a specific type: they require a conscious entity, such as a person, who reacts (under specific circumstances, reactions from *bots* may also be considered). The type of reaction of a person not only depends on the referent event but also on past experiences, knowledge, expectations, beliefs and goals etc. This means that whereas one event may trigger a direct call to action, another may merely lead to a slight change in sentiment. Conversely, many small events may not provoke any action from a person until their perceived importance reaches a certain significance threshold. This situation was observable in the aftermath of the Brexit referendum. Many people initially rejected to take part in the referendum because its outcome was perceived as ‘set in stone’ (Ref!). Finally, once the results were announced, sudden awareness of the referendum consequences led to protest marches worldwide. For some supporters, the event outcome meant a complete reverse of sentiment, which was later coined the ‘Bregret’ movement (Dearden, 2016), a portmanteau of “Brexit” and “regret”.

Despite the fact that events and reaction to events consist of similar facets, the differences in values are of fundamental importance. These differences can be summarized as the event-reaction relationships. In the example of St. Jude storm, for instance, many plausible relationships are imaginable for the spatial facet. Reactions from persons where *se* ∋ *s* are likely to differ from those where *se* ∌ *s.* In the former case, we are talking of reactions from persons who are directly affected by the storm (or at least were direct observers). In the latter, possible reactions may include expression of sympathy or surprise. However, it is important to note that a reaction to an event can happen at any later time. Therefore, even reactions with a spatial location outside that of the storm’s impact area *se* oroutside its impact timespan *te* may come from people who were directly affected. For instance, this would be the case if someone was a direct witness on his or her vacation, but only after returning home (e.g. to some not affected region) decided to report on the incident on social media (an exploration of the spatial relationship for reactions on Twitter is presented by Hahmann, Purves, & Burghardt, 2014). Another example that only initially appears odd is that of a reaction preceding its referent event (*t < te*). This will be the case when an event is *expected* or *anticipated*. For example, someone might book a flight to Japan in January (the reaction), just to see the cherry blossoms in late April to early May (the referent event).

* + 1. Collective reactions

Alexander, Natalya

A *collective reaction* is a set of individual reactions to the same event, i.e., a set of tuples R(*e*) = {*ri* = (*e, pi, ti, si, ai*) | 1 ≤ *i* ≤ N} with a common *e*.

Collective reactions are composed of many elementary reactions. In contrast to single reactions, collective reactions are therefore not homogeneous in terms of their facets. A common referent event may provoke any type of action or expression of sentiment in different observers, depending on the observers’ respective circumstances. This subjectivity and homogeneity must be considered across all facets, space, time, social, thematic and character of reaction.

For a given collective reaction R(*e*) = {(*e, pi, ti, si, ai*) | 1 ≤ *i* ≤ N}, let P(R(*e*)) = {*pi* | 1 ≤ *i* ≤ N}, T(R(*e*)) = {*ti* | 1 ≤ *i* ≤ N}, S(R(*e*)) = {*si* | 1 ≤ *i* ≤ N}, and A(R(*e*)) = {*ai* | 1 ≤ *i* ≤ N}. Here, P(R(*e*)) is the set of people who reacted to the event *e*, T(R(*e*)) is the set of time moments when the reactions happened, S(R(*e*)) is the set of spatial locations where the reactions occurred, and A(R(*e*)) is the set of ways of reacting, i.e., all combinations of values of the thematic attributes that occurred in R(*e*). The sets P(R(*e*)), T(R(*e*)), S(R(*e*)), and A(R(*e*)) can be called *facets* of R(*e*): social, spatial, temporal, and thematic, respectively.

Some individual reactions may come in response to or be motivated by some other individual reactions. Let *l*(*ri*, *rk*) represents a directed link between individual reactions *ri* and *rk* such that *ri* appeared in response to *rk*. A case when *ri* appeared in response to multiple reactions {*rk*, *rm*, …} can be represented by a set of binary links {*l*(*ri*, *rk*), *l*(*ri*, *rm*), …}. We shall use the notation L(R(*e*)) to denote the set of all known links between individual reactions within R(*e*). The links L(R(*e*)) can be considered as an additional facet of R(*e*), which can also be termed *event* *information spread*. This information spread is a sophisticated process of interaction and encompasses many phenomena such as feedback loops, change of options and values during the process, and biasing effects of the network.

In the context of information spread, an important aspect to consider is *relatedness*. Some reactions may directly relate to the referent event. This is the case for example for reactions from direct observers or witnesses. Others may be influenced or triggered by information that was added or removed after the event happened. This is particularly important when studying event reactions on social media. Here, firsthand accounts are often stripped of relevant information, or supplemented based on personal motives and goals (see, for example, He et al., 2015). Sometimes, the interface itself distorts information spread in such a way that renders a part of the data useless for evaluating the original event’s importance. In this context, a simple example are the photo view counts recorded on Flickr. Because view counts highly depend on net-visibility factors, exhibiting particular photos on frequented sites such as the Flickr front page and other sites affects information spread. These effects may provoke reactions that are not directly related anymore to the original photographed event (e.g. a heated discussion of controversial attitudes, triggered by a particular photo), which further distorts information spread. This means that *relatedness* may be seen as a continuum of ties reaching from strong to weak to nonexistent.

* 1. Context of reactions (maybe shift to the discussion)

Natalya

Let S be the entire area under study, P be the whole population of the studied area, and T be the whole time period under study; S(R(*e*)) ⊆ S, P(R(*e*)) ⊆ P, and T(R(*e*)) ⊆ T.

Let E be the set of all events that ever happened or are going to happen (although all events may not be known, such a set can be theoretically conceived); *e* ∈ E. Some of the events may be related to others, e.g., an event *ep* may be a consequence of an event *eq* or be a part of a larger event *ex*. Let L(E) denote the existing links between the events in E.

Let E′ = E – {*e*}, i.e., E′ denotes the set of all events excluding *e*. Some of the events in E′ might also provoke people’s reactions. Let R(E′) denote the set of people’s collective reactions to some events from E′: R(E′) = {R(*ej*) | ∃*ej* ∈ E′}.

The combination (P, S, T, E, L(E), R(E′)) is the ***context*** of the collective reaction R(*e*). The combination (P, S, T) can be called *socio-spatio-temporal* *context*, and the combination (E, L(E), R(E′)) can be called *event context*.

* “Examining a holistic picture of a situation is more productive than examining silos of related data”(Jain, 2003, p.50).

1. Analysis tasks

Natalya

In studying a collective reaction, two main foci are possible:

* Presence of reactions irrespective of their character. Not all people not always react, and not any event provokes reactions. The analyst may be interested how many people reacted, when, where, etc., but not how specifically they reacted.
* Thematic characteristics, which refer to the specific ways of reacting. Analysts usually wish to study the thematic characteristics in relation to the social, spatial, and temporal ones.

According to these two aspects, we can define two major types of analysis tasks:

* Tasks on studying the reaction *presence*. These tasks focus on the set of tuples {(*pi, si, ti*)} reflecting the social, spatial, and temporal characteristics of a collective reaction.
* Tasks on studying the reaction *character*. These tasks focus on the set of tuples {(*ai*, *pi, si, ti*)} reflecting the thematic characteristics along with the social, spatial, and temporal ones.

From another perspective, the set of possible tasks may be divided into

* tasks on studying the *properties* (social, spatial, temporal, and, possibly, thematic) of R(*e*),

and

* tasks on studying the *links* L(R(*e*)) with respect to the properties of the linked reactions.

Based on the two dimensions presence – character and properties – links, we can define four classes of analysis tasks:

|  |  |  |
| --- | --- | --- |
|  | Presence | Character |
| Properties | {(*pi, ti*, *si*)} | {(*ai*, *pi, ti, si*)} |
| Links | {*l*((*pi, ti*, *si*), (*pk, tk*, *sk*))} | {*l*((*ai*, *pi, ti, si*), (*ak*, *pk, tk, sk*))} |

These tasks are very complex since they address multiple facets of R(*e*), social P(R(*e*)), temporal T(R(*e*)), spatial S(R(*e*)), thematic A(R(*e*)), links L(R(*e*)), and their interrelationships. The analysis process is usually decomposed into simpler subtasks. The level of task complexity can be defined based on the number of facets considered together.

1. Level 1: study of a single facet P(R(*e*)), T(R(*e*)), S(R(*e*)), A(R(*e*)), or L(R(*e*)).
2. Level 2: study of interrelationships between two aspects. In particular:
   * T(R(*e*)) + one of P(R(*e*)), S(R(*e*)), A(R(*e*)), or L(R(*e*)): study of the temporal dynamics of the facet P(R(*e*)), S(R(*e*)), A(R(*e*)), or L(R(*e*)), i.e., how the social, spatial, or thematic characteristics of R(*e*) evolve over time, or how the responses to previous reactions emerge over time.
   * S(R(*e*)) + one of P(R(*e*)), A(R(*e*)), or L(R(*e*)): study of the spatial distribution and spatial variation of the facet P(R(*e*)), A(R(*e*)), or L(R(*e*)).
   * P(R(*e*)) + A(R(*e*)) or L(R(*e*)): study of the variation of the facet A(R(*e*)) or L(R(*e*)) across the population P(R(*e*)).
   * A(R(*e*)) + L(R(*e*)): study of the relationships between the ways of reacting in linked reactions, i.e., across all links {*l*((*ai*, *pi, si, ti*), (*ak*, *pk, sk, tk*))}, how *ai* is related to *ak*.

Although it is theoretically imaginable to define also tasks on studying interrelationships between three and more facets, such tasks are practically very difficult. We thus posit that interrelationships among three or more facets F1, F2, F3, … can be adequately represented by a combination of all pairwise interrelationships (F1, F2), (F1, F3), (F2, F3), … Hence, analysis tasks of levels 3 and higher can be decomposed into sets of analysis tasks of level 2.

One more aspect of task characterization is accounting for the context, in particular:

* How P(R(*e*)) relates to P: what part of the whole population reacted, what are the properties of the reacting sub-population with respect to the properties of the whole population.
* How T(R(*e*)) relates to T: how the moments of the reactions are distributed over T, what are the specific properties of the reaction times (e.g., most of them were on the weekend).
* How S(R(*e*)) relates to S: how the locations where people reacted are distributed over S, what are the specific properties of the locations where people reacted (e.g., most of them are in big cities).
* How the facets of R(*e*) relate to events in E, including the event *e* itself, *e* = (*te*, *se*, *Pe*, *ae*). In particular, how T(R(*e*)) relates to *te*, S(R(*e*)) to *se*, P(R(*e*)) to *Pe*, and A(R(*e*)) to *ae*. The same may refer also to other events in E, in particular, those events that are linked to *e* by the links defined in L(E).
* How R(*e*) relates to R(E′), i.e., the reactions to other events, in particular,
  + events that are linked to *e* by the links defined in L(E);
  + events that are similar to *e* by some or all of the characteristics (*te*, *se*, *Pe*, *ae*).

To summarize, the possible analysis tasks can be described using the following features:

* Reaction presence or reaction character;
* Properties or links;
* Single facet or interrelationships between two (or more) facets;
* Reaction alone or relationships to the context.

More specific tasks are defined according to which facets are addressed and which components of the context are taken into account.

1. Implications / Discussion and conclusions

* (to be written later)
* Explain how framework is going to be used in event analysis in regard to audience: planners

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(Who?)

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1. https://en.oxforddictionaries.com/definition/reaction [↑](#footnote-ref-1)
2. http://udcdata.info/ [↑](#footnote-ref-2)