# Once Upon a Time in a Land Far Away: Guidelines for Spatio-Temporal Narrative Visualization

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***Abstract*—Creating a visualization that conveys a narrative requires choosing the dimensions and features that help tell the story. Time and space are two of these storytelling attributes which are commonly present in the story's structure. Thus, these should be considered in the creation process. Narrative Visualization is still a new field in Information Visualization research, and while there are guidelines for designing visualizations, specific ones for this new area are still lacking. Therefore, supported by previous research on broad recommendations for designing visualizations, we propose a specific set of guidelines to structure effective visual narratives divided into four decision categories: Intent, Spatio-temporal, Interaction, and Narrative Elements.**

## I. Introduction

Over the last decade, the interest in information visualization had a significant increase in different areas, such as business, education, art, and journalism. Information visualization is the "use of computer-supported, interactive, visual representations of data to amplify cognition" [1], and makes data that is not naturally accessible to the bare eye visible and understandable [2]. The large amount of data that is publicly available, combined with sophisticated, easy-to-use toolkits, helped to turn interactive visualizations into a powerful tool to convey information. This information can take different forms, such as talks, animations, and videos. This new context raises new practices and challenges.

Data journalism is one of the fields that embrace these new forms of communication. Visualizations not only help the journalists tell complex and compelling stories but can also assist users to gain insight [3] and make decisions [4]. When one builds a narrative, it is usual to situate the story both in time (when) and space (where). Particularly in journalism, this need for contextualization is assumed as strengths in storytelling and is present in the old axiom on What, Where, When, Who, Why and How as fundamental rules of reporting [5].

Interactivity and its inherent dynamic features provide a solid ground to the visualization of changes over time and space. The visualization of changes within the data and the dynamic properties of the underlying phenomena tend to be the center of attention of a new generation of interactive visualizations [6] because of its potential of engagement.

Including several different dimensions turns the design of visual narratives for data stories [7] a complex process and many visualizations still often fail to communicate properly [8–10]. Broad guidelines to help create the best narrative strategies for different types of visualizations are still lacking. In this paper, we try to fill this gap by proposing general principles to take the most advantage of the potential of time and space dimensions in interactive visual narratives. Towards this goal, we gather and review strategies used when designing a visualization, such as storytelling approaches, insight gaining processes, and interaction techniques.

## II. Background

There is a clear link between storytelling and the dimensions *time* and *space*. "Once upon a time in a land far away" is a stock phrase that has been commonly used (with several variations) since the 1600s in both oral storytelling and literature, but its first use can be traced to as early as 1380 [11].

### A. Storytelling and its relation with time and space

Stories are almost omnipresent in human culture, used to convey information memorably and engagingly [12]. Although modern storytelling has evolved, and now extends itself to more complex media, still maintains some of the characteristics of traditional storytelling. The use of the dimensions *time* and *space* are two of these storytelling attributes.

It is through the observation of objects transformation over time or its movement with one another that we perceive the passage of time [13]. Both dimensions are intuitive and familiar [13], and help us make predictions through this representation of change [14].

Narratives are frequently associated with the classic temporal structure: beginning, middle, and end [15]. This format is usually linear, but non-linear structures that use narrative techniques such as *analepsis* (flashback) and *prolepsis* (flash-forward) are also common. For Herman [16] this is the event sequencing, one of the basic elements of a story. Other basic elements found by Herman [16] include situatedness (discourse context or occasion for telling), world making/world disruption

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(disruption of a state of equilibrium), and what it is like (the feelings of living through the situation and a foregrounding of human experience). Several authors stand by the idea that some narrative elements can be translated to visualization in order to introduce this feeling of storytelling [12, 17–21].

### B. Narrative Visualization

The emerging genre of *Narrative Visualization*, a term coined by Segel and Heer [20] in 2010, concerns visualizations that intend to communicate complex data effectively, in a way that is engaging and promotes the sharing of insights. It emerged as a way to turn visualizations into an independent form of storytelling, not as extra information or supporting evidence, as it has been seen until very recently [20]. The goal is that the visualization can exist by itself, without the backing of other supportive means of storytelling, and that it does not need to depend so much on the audience's ability to interpret the data correctly in order to get the point across in sufficient detail. According to Dove and Jones [3] "one of the distinguishing features of narrative visualization is the use of interactive exploratory techniques to enhance the communication of ideas and promote insight through discovery."

### C. The importance of insights

Providing insights on the data is the primary purpose of information visualization [1, 6, 22] and an aspect that should not be neglected. Insights can be seen as an accurate or deep understanding of something, and according to North [23] is a process that becomes more complex in visualization because of the amount of data, sometimes requiring the exploration of the complete dataset. The insights should be firstly identified in the data modeling step of the process when the conceptual model of how data items relate to each other is established. Nevertheless, there are also paths and procedures that can be used to lead to insight.

Yi, Kang, Stasko, and Jacko [22] identified four distinctive procedures, which can be originated by using particular interaction and presentation techniques, although not exactly being categories of interaction or presentation techniques: provide overview, adjust, detect pattern, and match mental model. When a visualization allows the user to *overview* first, it allows him/her to understand the big picture, and it seems to help in finding portions of the data that he/she needs to investigate more, "thereby promoting further exploration of the dataset" [22]. On the other hand, the process of *adjusting*, which encompasses interaction techniques such as *filtering* and *grouping*, tune the level of abstraction and/or the range of selection in order to enable the user to change his/her perception turning the dataset into more manageable sets. The process *detect pattern* consists of finding specific distributions, trends, frequencies, outliers, structures, or even trade-offs and anomalies in the dataset. The last, *match mental model*, consists of the ability that a visual representation has of decreasing the gap between the actual data and user's mental model, which is one of the known benefits of information visualization.

### D. Interaction

Visual communication of ideas and the process of gaining insight through open-end discovery is considered to be best supported by using interaction [3]. Employing interactive techniques enables users to filter selected queries, reconfigure the dataset, adjust the scale, adjust the pace of animated elements, and many other possibilities. Hence, visualization can be seen as a discovery tool since it facilitates understanding through the analysis of the data.

The conjunction of both inductive and deductive reasoning should be considered to communicate the stories to be discovered in the dataset [24]. On the one hand, deductive reasoning consists of a predetermined and narrow search of what stories are potentially interesting in the given subject matter. It may be a strong starting point when the intention is to create explanatory visualizations. On the other hand, one can use inductive reasoning when he/she does not know exactly what stories hide within the dataset. Interaction techniques can maximize open-end exploration. When wrongly used, they imperil the access to the data by stirring the user experience and consequently, the process of gaining insight [24].

## III. Recommendations

Determining which elements should or not be included in one visualization is not an obvious task [25]. Each project is unique since it always depends (among other constraints) on the purpose, intended audience, context, medium, type of data, taste, and conventions [26]. As in any design project, it is clear that there is not a single best approach towards the optimal final result, and therefore it is not possible to establish a set of rules to assure the effectiveness of a visualization [24]. Nevertheless, due to the shortage of orientation on how to adequately tell stories with interactive maps, combined with the temporal change of data [27], it was noted that there is a need for explicit design guidelines [26]. This need can be lightened by mixing practical knowledge from different areas, such as graphic decisions patterns within best practice examples and empirical evidence on usability, among others.

Aiming to meet the specific challenges that the visualization of temporal and spatial data arise, a compilation of recommendations from different authors was surveyed and analyzed for this research. Following each selected recommendation we introduce key-questions that the author of the visualization may pose throughout the design process.

Foremost, Kirk [24] pinpoints three visualization functions: explanatory, exploratory and exhibition. Explanatory visualizations convey information in a focused narrative with a specific structure. Exploratory visualizations are often interactive, with a more open structure, enabling users to play with the data. Exhibitions, also known as data art, pursue an aesthetic reaction.

- Should the visualization convey an *explanatory* portrayal of data? Allow an open-end *exploration* of data? Or use data as an *exhibition* of self-expression?

Hullman and Diakopoulos [28] propose an analytical framework for visualization rhetoric that crosses editorial layers:

data, visual representation, textual annotation, and interactivity. In addition, they also propose a set of visualization rhetoric techniques as a guide to how much visualization rhetoric should be used on the design of visualizations: Information Access Rhetoric (omission and metonymy), Provenance Rhetoric (data provenance, representing uncertainty, and identification), Mapping Rhetoric (obscuring, contrast, classification, and redundancy), Linguistic-based Rhetoric (typographic emphases, irony, similarity, and individualization), and Procedural Rhetoric (anchoring, and filtering).

- What information is essential for the visualization?
- Does it provide *context* and *background*, trying to be clear and impartial?
- How to translate information into a *visual metaphor*?
- Which *linguistic resources* can be used to convey the intended narrative?
- Which *interactive features* best fit the visualization?

Kirk [24] identifies three groups of analysis that help the author to interpret the data and decide how to visualize it: comparisons and proportions (distribution, ranking, absolute values, averages, standard deviations); trends and patterns (consistent pattern, fluctuation, intersections, overlaps); and relationships and connections (exceptions, correlations, gaps).

- How to convey the interpretation of the data? Through *comparisons* and *proportions*? *Trends* and *patterns*? Or *relationships* and *connections*?

To define the design aspects for time, Aigner, Miksch, Schumann, and Tominski [29] call to mind three types of temporal structures: ordered time, branching time and multiple perspectives. In the ordered time the events occur in a continuous sequence, from the past to the future (linear time) or happen in a set of recurring time values, such as the seasons of the year (cyclic time). Branching time allows the description and comparison of alternative scenarios (e.g., project planning). “This type of time supports decision-making processes where only one of the alternatives will actually happen” [29]. Multiple perspectives, on the contrary, enables simultaneous alternative scenarios actually to happen (e.g., eyewitness reports).

- Which temporal structure shapes the data: *ordered time* (linear or cyclic), *branching time*, or *multiple perspectives*?

To represent time in space, Andrienko, Andrienko, and Gatalsky [30], building on Blok [31], classify spatio-temporal data according to the type of changes that occur to them over time. The three main types are existential changes, changes in spatial properties and changes of thematic properties. In existential changes, objects or/and relationships appear and disappear. Changes of spatial properties can be represented by location, shape, size, orientation, altitude, height, gradient and volume. Changes of thematic are expressed through values of attributes, e.g., in demographic maps.

- How is the spatio-temporal phenomena organized: are there *existential*, *spatial*, and/or *thematic* changes?

Once the spatio-temporal data is properly represented, the user should be able to pose three different kinds of questions about objects (what), location (where) and time (when).

| | |
|---|---|
| Filtering | Hide data that does not interest the user. |
| Selecting | Enable to mark and keep track of items. |
| Abstract / Elaborate | Enable the user to adjust the level of abstraction of the visualization (e.g., zooming and details-on-demand). |
| Overview and Explore | Overview first, zoom and filter, then details-on-demand. |
| Connect / Relate | Show relationships between data items. |
| Reconfigure | Allow the user to rearrange the data (e.g., same representation with another scale). |
| Encode | Enable to change the visual representation. |
| History | Provide ways to undo and replay actions. |
| Extraction of features | Allow to extract data in which the user is interested. |
| Participation / Collaboration | Enable the user to contribute to the visualization. |
| Gamification | Present the data in a more playful way. |

Table I
INTERACTION TASKS [32]

According to Peuquet [13] the first question describes the objects that are present at a given location at a given time; the second describes the location occupied by a given object at a given time; the third describes the times that a given object occupied a given location.

- How is the interpretation-question posed: is the visualization *focusing on one object* at a given location at a given time; is it *highlighting the location* occupied by a given object at a given time; or is it rather *stressing the times* that a given object occupies at a given location?

The choice of what type of thematic map and projection best fit the intended message is crucial. Additionally, the temporal and spatial scales play a very important role, affecting the extent and amount of detail represented in the map [27, 33]. Specifically, the temporal dimension is composed of time points or time intervals. A time point is an instant in time, whilst a time interval is a temporal primitive with a particular extent [27]. In exploratory visualizations, interactivity techniques “allow multiscale analysis and the manipulation of both space and time to help discover an appropriate match” [14].

- At what granularity should *time be scaled*: minutes, hours, years, etc.?
- Is the temporal dimension composed of *time points* or *time intervals*?
- At what granularity should *space be scaled*? Locally, regionally, worldwide?
- Would the analysis be improved by interaction tasks?

Two different types of interaction can be considered: trans-

| | |
|---|---|
| Titles | Should be accurate and compelling. |
| Introductions | Provide context and background. |
| User guides | Recommended for interactive pieces. |
| Labels | Simple but useful devices to help explain. |
| Captions and narrative | Recommended to surface important insights and findings. |
| Visual annotation | Clues to help draw out important insights visually. |
| Legends and keys | Explanation of color schemes and shape size of objects. |
| Units | Details of the units of values to avoid misinterpretation. |
| Data sources | Details about where the data was collected. |
| Attribution | List of contributors to the visualization. |

Table II
NARRATIVE ELEMENTS [24]

formable or manipulable [34]. If the visual representation is transformable by the user, he/she can control the process of modification of data, such as varying parameters of data entry, varying the extremes of the values of some attributes, or choosing different mapping for view creation. If the user can control parameters that influence the view, such as zooming or rotating, the interaction is considered to be manipulable.

Figueiras [32] identifies eleven types of interaction techniques: filtering, selecting, abstract/elaborate, overview and explore, connect/relate, reconfigure, encode, history, extraction of features, participation/collaboration, and gamification. Table I presents a description of each technique.

- What *level of interaction* will the user have in the analysis?
- What *interaction tasks* make sense to provide to the user, according to the data and communication purposes?

Finally, the inclusion of narrative elements in the visualization has a crucial role in enhancing the accessibility, by helping the users navigate. It assures that the audience is taken care of, "recognizing who they are, what they might know already, and what they don't know" [24]. Table II stresses the importance of a set of 10 visual elements identified by Kirk [24].

- What *narrative elements* best fit the interpretation and provide insight?

## IV. RESULTS

According to Cairo [33] "the purpose of your graphics should somehow guide your decision of how to shape the information." Behind the creation of a visualization there is an implicit decision-making process where various steps need to be taken into account. Considering the adequacy of these steps and its articulation is vital for the success of the visualization.

From the compilation of recommendations presented in section III, we propose a set of 10 guidelines: Function, Rhetoric Techniques, Purposive Interpretation, Temporal Structure, Spatio-temporal Phenomena, Representational Framework, Time and Space Scale, Type of Interaction, Interaction Tasks, and Narrative Elements. These guidelines, presented in table III, are then divided according to their type in four main decision categories: Intent, Spatio-temporal, Interaction, and Narrative Elements. We aimed to combine the decision-steps in conformity with their nature, in an intuitive, logical/chronological order, along with the eventual interdependencies.

First and foremost, every visualization depends on the dataset. The data and its properties are primarily the ground feed that determines what can be communicated. Only after being familiarized with what dimensions lay within the data is possible to take off to outlining a broad intent of communication, which is the first proposed decision step shown in figure 1.

The category of *Intent* defines what message is to be communicated and interpreted. This editorial focus that defines the visualization purpose is important for it to be clear and to avoid misinterpretations. Since the *Intent* shapes any further decision, "the greater clarity we achieve now will ultimately help minimize wasted efforts and lead to a more efficient process" [24]. Here, we include the following guidelines: function, rhetoric techniques, and purposive interpretation.

The second category, the *Spatio-temporal* decisions, help to define the structure and understand the impact of the inclusion of temporal and spatial dimensions in the visualization. As identified by Meirelles [14], this step is essential to the process because "given the dynamic nature of spatio-temporal phenomena, the designer faces several challenges in representing the fluidity of time in space." In this main category we include the following guidelines: temporal structure, spatio-temporal phenomena, representational framework, time and space scale. The *Spatio-temporal* decisions are directly connected to the following two steps: *Interaction* and *Narrative Elements*.

The *Interaction* category is substantial to communicate complex data. Interaction "helps users become engaged in the system, and helps them gain more insights" [22]. For instance, by allowing the user to reshape the layout, the visualization is facilitating his/her analysis process [35]. In this category we include decisions about type of interaction and interaction tasks. The choice of *Interaction* is both influenced and influences the *Spatio-temporal* and *Narrative Elements* decision categories, as can be seen in figure 1.

Lastly, the category *Narrative Elements* gathers the features

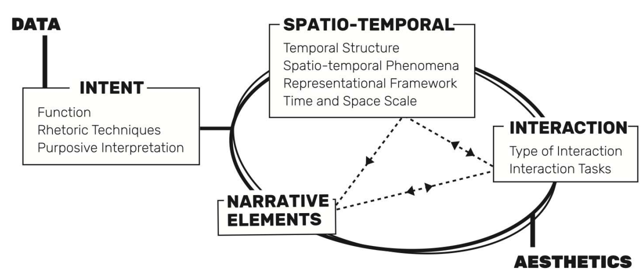


Figure 1. Proposed process flow

| | | |
|---|---|---|
| Function | explanatory; exploratory; exhibition. | [24] |
| Rhetoric Techniques | Information Access Rhetoric; Provenance Rhetoric; Mapping Rhetoric; Linguistic-based Rhetoric; Procedural Rhetoric. | [28] |
| Purposive Interpretation | comparisons and proportions? trends and patterns? relationships and connections? | [24] |
| Temporal Structure | ordered time (linear time or cyclic time); branching time; multiple perspectives. | [29] |
| Spatio-temporal Phenomena | existential changes; spatial changes; thematic changes. | [30] |
| Representational Framework | when + where >what; when + what >where; where + what >when. | [13] |
| Time and Space Scale | minutes; hours; years; centuries; … \| time points, time intervals.<br>locally; regionally; worldwide; … | [27] |
| Type of Interaction | transformable; manipulable. | [34] |
| Interaction Tasks | filtering; selecting; abstract/elaborate; overview and explore; connect/relate; reconfigure; encode; history; extraction of features; participation/collaboration; gamification. | [32] |
| Narrative Elements | title; introduction; user guides; labels; captions and narrative; visual annotation; legends and keys; units; data source; attribution. | [24] |

Table III
RECOMMENDED GUIDELINES COMPILATION

that support the comprehension of the story or the exploration of the visualization. Elements such as labels, visual annotations, guides, and data source, are crucial because the visualization author "shouldn't assume that readers or users are instantly and easily going to be able to navigate their way around" [24]. The *Narrative Elements* decisions may shape the choice of *Interaction*, as well as the *Interaction* is influenced by the first. On the other hand, the *Spatio-temporal* category affects the *Narrative Elements*, while the opposite does not occur.

Naturally, each visualization requires particular choices and consequently unique relationships between its decision-making steps. As in any design project, the creation flow and the fluctuation between the steps are flexible, since "any decisions we make across this process can be revisited and refined" [24].

Alongside these decisions remain the aesthetic concerns (e.g., layout, size, color, iconography, etc.), as seen in figure 1. These define the visual style that better conveys the message.

## V. CONCLUSIONS

Creating an effective visualization is a complex process and the dimensions time and space "raise new challenges in diverse contexts" [14]. In this paper we aimed to present a collection of steps (Function, Rhetoric Techniques, Purposive Interpretation, Temporal Structure, Spatio-temporal Phenomena, Representational Framework, Time and Space Scale, Type of Interaction, Interaction Tasks, and Narrative Elements) to consider when creating an interactive visualization that takes advantage of the potential of the spatio-temporal dimension.

We consider that the four proposed decision categories (Intent, Spatio-temporal, Interaction, and Narrative Elements) can help structure the design process. These may assist professionals who need to communicate a clear message supported by complex data.

Although the recommended guidelines are not recipes for the visualization design process, we believe that these are structuring considerations. We are aware that this is an open and flexible process and admit that other relevant guidelines/steps/recommendations may have been left out. The singularity of each visualization enhances the inadequacy of the idea of universal sets of rules or guidelines. Our proposed process flow is necessary groundwork and future work should include testing within real scenarios.

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