Designing a User-Centered Interactive Data-Storytelling Framework

Yangjinbo Zhang[†]
VisLab.
Curtin University
Perth, WA, AUSTRALIA
yangjinbo.zhang@
postgrad.curtin.edu.au

Artur Lugmayr
Edith Cowan University
Perth, WA, AUSTRALIA
Aalto University
FINLAND
www.artur-lugmayr.com
lartur@acm.org

ABSTRACT

Big Data research, and the development of sophisticating data mining methods requires besides algorithm research, also finding better ways to convey information contained in data sources to the end-user. Through improving data visualization methods, we are able to create visual presentations of data sources allowing users to gain a deeper understanding of data. For several millennia, stories where the major medium to communicate complex messages between humans. Within this research work we attempt to converge both, storytelling and data visualization through the development of an interactive data storytelling framework. Our goal is to communicate knowledge contained in data to a general audience and utilize Australia's energy consumption data as an exemplary case for visualizing aspects as energy consumption and production. We describe the essential elements and theories contributing to this framework, and give special attention to user-centered design aspects. We identify end-user requirements, and illustrate the practical application of the overall framework through a prototype implementation.

CCS CONCEPTS

· **Human-centered computing~ Visualization theory, concepts and paradigms** •Human-centered computing~ User studies •Human-centered computing~ Visualization design and evaluation methods •Human-centered computing~ Information visualization

KEYWORDS

Data Storytelling, Data Visualisation, Digital Art, Aesthetics, Design, User Experience, Communication, Visual Media, Information, User-Centered

1 Introduction

Data storytelling can be simply referred to as "telling a story grounded in data". By weaving data into a story, the audience is engaged through both – an objective and subjective perspective. A more convincingly communication of an idea or support for decision making is taking place. One example of data storytelling can be found through the famous Minard's map of Napoleon's Russian campaign in 1812, which is discussed in many research works related to visualisation [34]. Another example for data storytelling is the research of business presentations, such as "storytelling with data" in of Knaflic's works [15]. As we can see, currently most data storytelling studies are building in a utility context and serve a professional purpose such as businesses or science. In simple terms, they refer to a context of 'serious storytelling', as defined in [22]. Therefore, with this paper we try to take a step forward, building a user-centred interactive data storytelling framework. Within this paper, we present an advanced solution of a previous prototype [21].

Figure 1. Sample Screenshot of Our Test-Prototype

The framework is designed to communicate data to a general audience not being acknowledgeable of the actual underlying characteristics of the data. The framework utilizes new digital media technologies into the data storytelling process, by implementing a sample scenario on a 3D platform. Our interactive 3D prototype has been developed to underly our research work, and is combining 3D elements in combination with 2D illustrations. A sample screenshot is presented in Figure 1.

Our framework focuses on interaction design issues, and enables various interactive functions. Our framework merges a user-centred design concept into the structure of the story in order to optimize user-experience and the quality of communicating 'data' in an appropriate way for the end-user. Besides, we also integrated advanced visual design features, and design concepts by evaluating existing theories and adopting these to our use-case to improve the understanding of data. The basic structure of our data storytelling framework in relation to the different adopted theories and disciplines is depicted in Fig. 2.
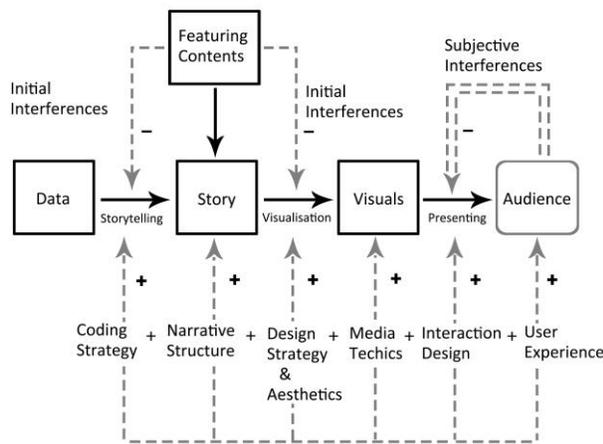

Figure 2. Basic Data Storytelling Framework

In this paper, we brief describe theories and methods that are contributing to our framework, the basic idea of our framework, the considerations in the designing process and some reflect in the implementation of the prototype. The last section concludes with a discussion about our findings, and especially emphasizes aspects in user-cantered interactive data storytelling.

2 Related Works

Much research has been done in the domain of interactive storytelling, as e.g. [1, 2, 7, 8]; more traditional works as e.g. [4, 6]; and the idea of serious storytelling [22] - just to state a few. Nevertheless, our data visualization framework is intersecting multiple disciplines to create user-centered interactive data visualization and adopts methods and theories from different domains [38].

One of the main disciplines we are touching, is the more general domain of '**visualisation**'. Much important research has been done in this domain, and the most significant covering various aspects of visualisation design can be found in [10, 11, 32, 34].

Making data 'understandable', thus cognitive aspects of visualisation are covered by the idea of 'Cognitive Big Data' [20], and visual cognition [20, 36].

We also touch the discipline of '**storytelling**' to develop interactive narrative structure. This is covered by research in the domain of e.g. narrative structure [7], characteristics of storytelling [2], and theories mentioned in the introduction paragraph of this section.

We also integrate methods emerging from '**user-experience**' and '**interaction design**' research, as e.g. user-study development, user behaviour [17, 37], user experience [3, 30, 35], implicit user centred adaptation [18], and basic design principles [9, 23, 28, 29]. To be able to communicate data visualisations more efficiently to the end-user, we also attempt to integrate theories emerging from '**media studies**', as e.g. basic characteristics of media [24, 25] and media communication theories [5, 26, 27, 31].

To develop an appealing user-centred and appealing data storytelling framework, it's obvious that we are also considering works in the domain of art & aesthetics, as e.g. aesthetics response [14], and the structure of art [12, 13]. Within this section we have brief noted theories and methods that are contributing to our overall framework. Table 1 compiles the most significant theories.

Table 1. Key Theories in Consideration

User-Centred Design	Vision movements [37]
	Biology of seeing [17]
	Measuring user experience [3, 35]
	Quantifying user experience [30]
Communication and Media	Communication model [31]
	Information aesthetics [26]
	Communication coding [5, 27]
	Characteristics of new media [24]
	Nature of media & media studies [25]
Narration and Storytelling	Narrative structure [7]
	Characteristics of storytelling [2]
	Serious Storytelling [22]
Data Visualisation	Visualisation design [10, 11, 32, 34]
	Visualisation cognition [20, 36]
	Data storytelling [15]
Design and Aesthetics	Aesthetics response [14]
	Structure of art [12, 13]
	Design principles [9, 23, 28, 29]

3 What is User-Centered Interactive Data Storytelling?

When data visualisation is facing serious and profession users, most theories (e.g. the data-ink ratio [33] – which is the ratio of the un-erasable key visual element) tend to the basic principle of "Occam's razor"[16] In short, the main aim while creating a visualisation is to make it as simple as possible; delete unnecessary details and elements; and attempt to achieve a high communication efficiency to deliver the key data to the viewer.

However, when the visualisation is targeted more towards general audiences - which does not have the essential insights and

understanding of the underlying data (maybe even not the motivation to wanting to understand the data) – a more sophisticating visualisation approach needs to be considered. The approach should be more entertaining, needs to actually catch the attention, and give them a reason to dig into the data. The idea to converge serious utility with creating entertainment, artistic expression, and ways to catch attention comes naturally. Such an approach allows to deliver particular messages and knowledge contained in a particular data set smoothly to an amore general and non-domain expertise audience. In the area of digital art e.g., we utilise animations and video games to create e.g. educational content. Thus, through the integration of animated movement, special effects, and interactive experiences, storytelling gets brought to another level, and becomes more graspable for the viewer. This also relates to adding more different functional parts, which can create more complex story-environments.

Thus, we can consider this data storytelling as a way to 'unpack' the core messages included inside the data into a story by adding narrative, to make dry data understandable in a more natural form. Story telling as channel to transmit message is as a time approved form of sharing information. We use stories to stories to explain the world since thousands of years. A 'story' provides an organic structure to carry information in a more appealing, and encode data in a way which is easier to comprehend and memorisable by humans. When weaving data into stories, we can expect data storytelling to become a method which is smoother and more efficient in communicating data to general audiences.

However, increased complexity also raises the risk of wrong interpretations and story interferences which will blur the focus towards the key data. To prevent this affect, we are trying to improve the overall data storytelling process through a careful process in organising and visualising data and information, visual encoding, and a more thoughtful process in creating narration. In short, all these elements need to be covered by an overall data storytelling framework.

The user's subjective properties will largely affect the communication quality of the data when receiving an encoded message. This is one of the challenges, when communicate data utilizing data storytelling methods. Thus, it is necessary to take a user-centred approach to put the user in the consideration through several phases of the information organisation and communication process. This extends towards several phases in the design process, which all will have to be part of our developed framework.

Thus, a data storytelling framework needs to include an information structure strategy, information units to visual encoding mapping methods, and appropriate user-centred design processes. In order to build up this framework, this research try to bridge data visualisation method with principles from communication, information theories, methods from art and design, and aesthetics studies. Overall the aim is a data storytelling which is attractive, fun and most importantly have high efficiency in deliver the key data.

Our approach of 'data storytelling' try to converge ideas emerging from the fields of data visualisation, digital design, and user-experiences 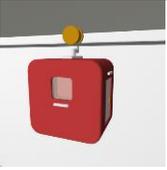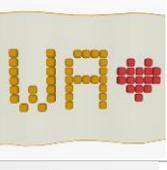to allow a smooth delivery of particular aspects contained in a data source to the viewer. Firstly, we analyse data sources, and pack the data into a story to allow the delivery of the mostly dry core message of the data in a more natural form. As a next step, we apply theories from visualisation to create an appealing visual form based on the raw data set.

4   Designing User-Centered Interactive Data Storytelling Framework

Generally, a user-centered interactive data story is putting the user in the center place. It also organises information based on in a user-centred way, and is optimizing user experience by delivering information efficiently. By weaving information carefully through a careful selection of methods and principles and interaction technics into the visualisation, we are able to ensure an efficient delivery of the key meanings in the data source.

Table 2. Design-Dimensions of our Framework

Scene Element	Description
Interactive Elements	
	In order to draw more attention to the major data related visuals. the major interactive elements are located at the main stage.
	Encouraging users to interactively explore different entries through a reward system: reading entries reveals features of characters
Telling the Data Story in Time	
	Every 30 second, a banner will fly through the scene to attract the attention of users. As the presented information is only secondary, it does not remain constant in the scene.
	As a primary information element, carousels as major information carrier will permanently remain in the front of the scene to showcase essential data elements.
Positioning Elements in the Scene	
	Attracting the focus of user to major data elements, these elements are located at prime positions in the scene.
	Elements containing additional non-diegetic information are located in the scene background

Utilisation of Movement	
	Continuous moving cable cars moving from left side of the scene to the right lead the gaze of the user towards particular focal points. They also act as objects revealing supply-demand dynamics between the fuels and industries.
	The frequency of animated objects (e.g. jellyfishes) depends on entry values which user selected on the interface.
	When a category of data entry is selected. The carousel which showcases the data will move to the front of the stage to draw attention.

Form, Appearance and Shape	
	Utilization of colour as e.g. bright colours for objects that are directly related to the data source, and tones for different categories of data entries for main characters in the visualisation.
	Utilisation of plain colours for objects that are not directly related to the data source as plain colours to not distort user's attention.

Contextualisation through Design Features	
	Integration of local landmarks in the scene to allow easier orientation of the user through the scene, and to visualise geographical information.
	Creating atmosphere and themes to create a 'fun and vivid' atmosphere in the scene, as e.g. cross-stitch-like designs.
	Integration of sea creature features in the design details to render the 'magic undersea park' theme. Enrich the storytelling with creative details.

When communicate data to a user, the biggest challenge in coming from user's subjective perception and understanding. This is especially valid, when facing it is targeted towards a general audience, which is not-context aware, and not involved into the domain where the data is coming from. The subjective aspects of the audience such as interests, attention or habits largely affects the understanding and memory quality of the need-to-delivered data. Thus, it is important to combine different theories to understand the user's perception and understanding of data to support the different phases in the data visualisation process. As noted above, these domains are including visualisation studies, user-experience studies, user-centered methods, narration studies, storytelling, design principles, communication theories aesthetics and media studies.

We identified the following key-elements for our framework: *User analyse and user-experience; Story making and storytelling; Information structuring; Visualisation and visual encoding; Aesthetic and visual design; Media technics; and Interaction design.*

Beside the theory aspects, we also investigated the implementation aspects of data storytelling. Details shows on Table 2. From the implementation perspective, we identified the flowing major design-dimensions for our framework: *Interactive elements; Data storytelling in time; Positioning of elements in the scene; Utilization of movement; Form, appearance, and shape; and Contextualisation through Design Features.*

5 Conclusion and Discussion

This paper can be considered as conceptual work, which introduces different aspects of an interactive data storytelling framework. The framework is composed of key-elements of different disciplines as interaction design and user-experience studies, media communication studies, aesthetics, data visualisation, and storytelling. The goal of this work was to provide insights how data can be visualised in a more appealing and understandable way for humans. Our contribution with this work relates to the following key-elements:

- Information units as fundamental units to convey messages contained in data sources;
- The major design dimensions for interactive data storytelling design;
- Bridging of theories form different discipline into the context of data storytelling;
- Practical approaches to weaving data into a story.

Nevertheless, the overall framework is currently in process, but still requires additional research work, especially it's innovation value (e.g.[19]). We especially are preparing a user-study to evaluate the validity of the framework, and test the prototype in a more practical setting. This work will be conducted as part of a follow-up study.

ACKNOWLEDGMENTS

REFERENCES

[1] Alexander, B. 2011. *The New Digital Storytelling: Creating Narratives with New Media.* Praeger Publishers.

[2] Baker, A. and Greene, E. 1977. *Storytelling : art and technique.* Bowker.

[3] Beasley, M. 2013. *Practical web analytics for user experience : how analytics can help you understand your users / Michael Beasley.* Morgan Kaufmann, an imprint of Elsevier.

[4] Booker, C. 2004. *The Seven Basic Plots: Why We Tell Stories.* Continuum International Publishing Group.

[5] Bossert, M. 1999. *Channel Coding for Telecommunications.* John Wiley & Sons, Inc.

[6] Campbell, J. et al. 1990. *The Hero's Journey: Joseph Campbell on His Life and Work.* New World Library.

[7] Chatman, S.B. 1978. *Story and discourse : narrative structure in fiction and film.* Cornell University Press.

[8] Davenport, G. 2002. Digital Storytelling, Multimedia and Digital Arts. *Multimedia XXI, Eurographics 2002* (Lisbon, Portugal, 2002).

[9] Dreyfuss, H. 1972. *Symbol sourcebook : an authoritative guide to international graphic symbols.* New York : McGraw-Hill.

[10] Iliinsky, N. and Steele, J. 2010. *Beautiful Visualization: Looking at Data through the Eyes of Experts.* O'Reilly Media, Incorporated.

[11] Iliinsky, N. and Steele, J. 2011. *Designing Data Visualizations : Representing Informational Relationships.* O'Reilly Media, Incorporated.

[12] Ingarden, R. 1973. *The cognition of the literary work of art.* Northwestern University Press.

[13] Ingarden, R. 1973. *The literary work of art.* Northwestern University Press.

[14] Iser, W. 1978. *The act of reading : a theory of aesthetic response.* Johns Hopkins University Press.

[15] Knaflic, C.N. 2015. *Storytelling with Data: A Data Visualization Guide for Business Professionals.* Wiley.

[16] Lidwell, W. et al. 2010. *Universal principles of design.* Beverly, Mass. : Rockport Publishers.

[17] Livingstone, M. 2002. *Vision and art : the biology of seeing.* New York : Harry N. Abrams.

[18] Lugmayr, A. et al. 2008. Bits of Personality Everywhere: Implicit User-Generated Content in the Age of Ambient Media. *2008 IEEE International Symposium on Parallel and Distributed Processing with Applications* (2008), 516–521.

[19] Lugmayr, A. et al. 2013. Categorization of ambient media projects on their business models, innovativeness, and characteristics—evaluation of Nokia Ubimedia MindTrek Award Projects of 2010. *Multimedia Tools and Applications.* 66, 1 (Sep. 2013), 33–57.

[20] Lugmayr, A. et al. 2017. Cognitive big data: survey and review on big data research and its implications. What is really "new" in big data? *Journal of Knowledge Management.* 21, 1 (2017), 197–212.

[21] Lugmayr, A. et al. 2018. Financial Data Visualization in 3D on Immersive Virtual Reality Displays: A Case-Study for Data Storytelling and Information Visualization of Financial Data of Australia's Energy Sector. *Enterprise Applications, Markets and Services in the Finance Industry* (2018).

[22] Lugmayr, A. et al. 2017. Serious storytelling - a first definition and review. *Multimedia Tools and Applications.* 76, 14 (2017), 15707–15733.

[23] Maguire, M.C. 1985. A review of human factors guidelines and techniques for the design of graphical human-computer interfaces. *Computers & Graphics.* 9, 3 (1985), 221–235.

[24] Manovich, L. 2001. *The language of new media.* MIT Press.

[25] McLuhan, M. 1964. *Understanding media : the extensions of man.* Routledge & Kegan Paul Limited.

[26] Moles, A.A. 1968. *Information theory and esthetic perception.* Univ. of Illinois Press.

[27] Moreira, J.C. and Farrell, P.G. 2006. *Essentials of Error-Control Coding.* Hoboken : Wiley.

[28] Paivio, A. et al. 1968. Why are pictures easier to recall than words? *Psychonomic Science.* 11, 4 (Apr. 1968), 137–138.

[29] Rogers, Y. 1989. Icons at the interface: their usefulness. *Interacting with Computers.* 1, 1 (1989), 105–117.

[30] Sauro, J. and Lewis, J.R. 2012. *Quantifying the user experience : practical statistics for user research / Jeff Sauro, James R. Lewis.* Elsevier/Morgan Kaufmann.

[31] Shannon, C.E. and Weaver, W. 1964. *Mathematical theory of communication.* Univ. of Illinois Press.

[32] Tufte, E.R. 2006. *Beautiful evidence.* Graphics Press.

[33] Tufte, E.R. 1990. Data-Ink Maximization and Graphical Design. *Oikos.* 58, 2 (1990), 130–144.

[34] Tufte, E.R. 1983. *The visual display of quantitative information.* Graphics Press.

[35] Tullis, T. (Thomas) and Albert, B. (William) 2013. *Measuring the user experience collecting, analyzing, and presenting usability metrics / William Albert, Thomas Tullis.* Elsevier.

[36] Ware, C. 2013. *Information visualization : perception for design.* Elsevier/MK.

[37] Yarbus, A.L. 1967. *Eye Movements and Vision.* Springer US.

[38] Zhang, Y. 2018. Converging Data Storytelling and Visualization. *Proceedings of the International Conference on Entertainment Computation* (Poznan. Poland., 2018).