Story Telling Aspects in Medical Applications

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Abstract

Although the use of images as well as movies has proven very valuable for presentation purposes in volume visualization, these methods still lack a certain feature, that has become state-of-the-art in other visualization areas, namely interactivity. Giving the consumers of a presentation more interactive freedom would allow them to further investigate the presented visualizations as well as to draw their own conclusions. The approach that we suggest in this paper introduces storytelling to volume visualization as a new form of interactive volume visualization presentation. During story playback a certain amount of interaction possibility is left to the users, while other actions are executed from a pre-recorded story-script. This interactive concept of storytelling for volume visualization has been implemented as addition to the existing RTVR volume visualization library.

Keywords: Volume Visualization, Virtual Storytelling, Interactive Visualization, Focus+Context

1 Introduction

For as long as people have been around, they have used stories to exchange information as well as experience. According to Perlin [14], stories are quite central to our culture. One could even say that cultures define themselves by the stories they tell. The information given in a well-told story is often easier to understand and remember for the consumer, than providing him with a plain list of serial data. With the evolution of new media, e.g. the Internet, people are given new ways to tell stories to a wider audience and over larger distances. Nahum Gershon et al. [5] highlighted the value of a story with a special focus on information visualization. The metaphor of a story seems to be very useful in this area, since data characteristics are often abstract and cannot be visualized in the form of a picture in a satisfying way.

Looking at state-of-the-art applications of volume visualization, the users are, in most cases, confronted with a vast collection of visualization tools. All of these tools allow them to produce different visualizations of the volumetric data. Assuming, that not all users have the expertise to handle these tools or the a priori knowledge what the actual dataset represents, it is difficult for them to produce insightful visualizations. Exploring predefined visualizations of the dataset, that include contextual information on the dataset itself as well as annotational information on the used representations, makes it easier for the users to orient themselves in the dataset. The delivery of this additional information could be done by narratively introducing the users to the dataset, using kind of a story.

This paper explores the usefulness of storytelling in the context of volume visualization. It is organized as follows. In Section 2 we summarize several techniques from the areas of volume visualization as well as virtual storytelling, which we later combine to form a new visualization presentation concept. Section 3 is dedicated to the introduction of the new approach itself. The concept of volumetric storytelling divides into a story authoring and a story telling part, which will be discussed in Sections 4 and 5. In Section 6 we finally present a volumetric storytelling prototype application, which is based on the RTVR Java library for interactive volume rendering [13].

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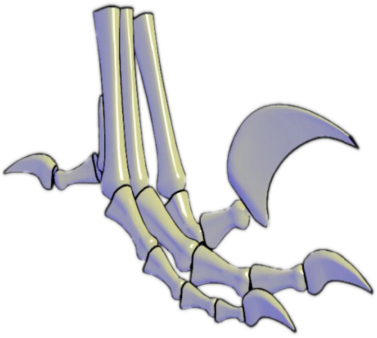
2 Related Work

Although a comparable effort to combine virtual storytelling with volume visualization has not been made so far, there are of course several well researched key techniques, that form the backbone of volumetric storytelling. This chapter gives an overview of the contributing research areas virtual storytelling and volume visualization with a focus on the specific research fields, that are relevant for volumetric storytelling. Additionally the general differences as well as the integrating aspects of the three research areas are highlighted.

2.1 Volume Visualization

From its early beginnings about 40 years ago up until now, the use of computers for scientific visualization has changed the way researchers explore, analyze and present their data. The immense growth of gathered data (e.g. from satellite or medical imagery) on the one hand was faced by an even more tremendous growth in computational power on the other hand. The scientific progress was of course not only limited to the hardware field, a key event was, e.g., the introduction of a general visualization model by Haber and McNabb [7]. The similarities

(a)



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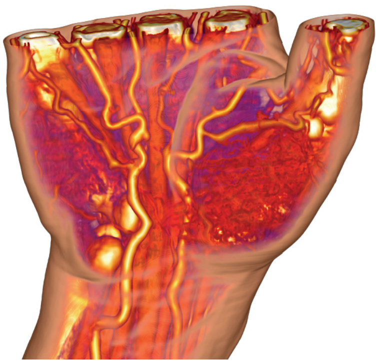
(c)



(d)

Figure 1: **Volume illustrations.** *This figure shows different volume illustrations techniques, that can be used to emphasize or deemphasize specific volumetric story elements. (a) Contour rendering [10] (b) Non-photorealistic color hue shading [6]. (c) Direct volume rendering [18] (d) Illustrative context-preserving rendering [2]*

between traditional volume visualization and our new approach encompass the following research areas:

Interactive Volume Visualization. As Westover et al. [19] already stated in the 1980s, interactivity is a key issue for successful and fast data exploration. With the advent of current PC graphics hardware, interactivity has nearly become a standard in the field of volume visualization (cf. works of Bruckner [3] or Svakhine [16]). Since data exploration is an integral part of volumetric storytelling, interactivity is a primary goal for this new approach.

Volume Classification. In order to emphasize specific parts of the data, a volume classification scheme has to be applied to the raw data. Such a classification scheme can be influenced by function evaluation (e.g., Direct volume rendering [11]), spatial position (e.g., volume clipping, masks), and local properties (e.g., volume segmentation [15]). The discrete classified volume parts form the reference points, that the overlaid story refers to, and therefore a volumetric storytelling approach needs to offer at least simple volume classification techniques (e.g. masking).

Volume Representation & Illustration. Searching for new volume data representations/illustrations has been and still is a very active research area. Initially inspired by classic technical or medical illustration, consequent refinement and research has resulted in a now large pool of useful volume illustrations, which generally can be divided into surface-based and volumetric approaches. Figure 1 shows some examples of visual representation methods, which are of course also very practicable in volumetric storytelling. While all of these methods change the appearance of only one single volume representation, the research field Focus+Context Visualization [9] concentrates on the relations between them by increasing or decreasing the visual prominence of a representation in relation to the others. Since storytelling often alternates between focussing on a specific story part and providing a contextual overview, Focus+Context Visualization is an integral part of our volumetric storytelling approach.

Volume Annotations. The application of labelling for co-referential information is widely used in traditional technical as well as medical illustration. Hartmann et al. [8] analyzed the different classic labelling styles, and introduced a label classification scheme as well as guidelines and metrics for optimal label placement. Providing the users with additional annotational information to their visualizations is a key issue in volumetric storytelling, and the use of labels seems natural in this context.

2.2 Virtual Storytelling

The ancient art of storytelling has long been used by humans to hand over information, education, and experience from one generation to the next. It is clear that storytelling heavily relies on the communication medium that is used to tell the story, and thus a short investigation of the evolution of communication seems useful. According to Donald [4] the evolution of the modern mind and one of its thriving forces, communication, can be separated into three significant transitions leading from primates to the modern human.

The first of these stages is represented by the homo erectus, who developed extraordinary motor as well as mimetic skills in comparison to its predecessor, the primate. Although mime provides a rudimentary way to refer to things or events by using gestures or acting, it is only a very laborious and imprecise medium for communication and we can therefore assume, that it was not used to tell stories. The next step in human evolution led from the homo erectus to the homo sapiens and was marked by the evolution of speech. Donald highlights the intimate connection between spoken language and ”mythic” cultures, which develop and store crucial knowledge in myths (i.e., ancient stories), preserved by an oral tradition. The wish to conserve such stories and the information contained in them led to the replication of events by cave-paintings. These paintings form the beginning of the third stage introduced by Donald, whose integral part is the use of ”external long-term storage” for information. The development of systems of written symbols for concrete as well as abstract ideas finally provided a way to vastly increase the possibility for individuals to draw from and contribute to a stream of knowledge from near and far, contemporary or from the past.

All of these media, when used for storytelling, leave enough room for the imaginative interpretation of the story by the listener. The invention of film marked the next milestone for storytelling. This new medium gives the story authors a powerful tool to visualize their stories but also limits the room for imaginative interpretation by the film consumer. According to Louchart and Aylett [12] the crossing of storytelling with the new, highly interactive media of virtual environments raises some fundamental and critical issues, that need to be addressed.

- *What is the role of the listener in the story?* As the role of the users changes from ”spectators” to ”spect-actors” they get in conflict with the overall story plot. This is called the *narrative paradox* and is one of the main issues that virtual storytelling has to overcome. One possible approach is the application of emergent narrative, as Aylett proposes in her paper [1]. The storytelling for volume visualization approach introduced in this paper exploits this paradox by permitting concurrent scene interaction in a structured way, which is described in Section 5

- *What form does a virtual story have?* In non-interactive storytelling scenarios, an underlying plot that was created by the author of the story, is responsible for the direction in which the story unfolds. Interactive stories cannot rely on such a plot, since a single user interaction could render the whole story plot senseless (e.g., killing a main character, that would've been needed for the story plot). Therefore the whole concept of stories has to be adapted to the new medium.

- *How to manage a non-linear scenario?* If the users are given the freedom to steer the direction of the story into one or the other direction at any time they want, an explosion of possible worlds would be the (at first sight) unavoidable consequence. A possible solution would be the application of a multi-layered interaction approach, which is presented by Perlin [14].

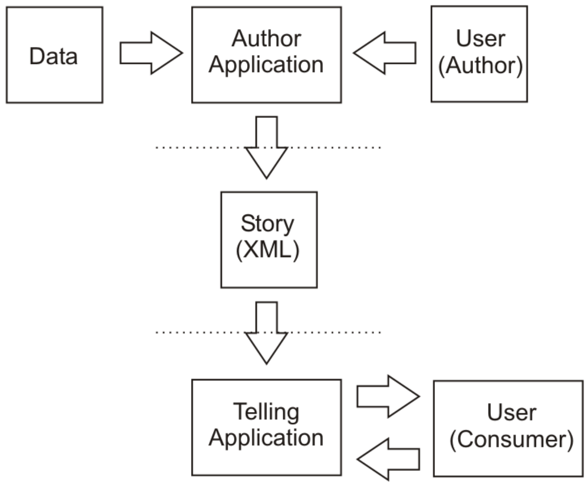


Figure 2: **General storytelling workflow.** *This figure shows the general separation between the story authoring and the story telling process as well as the interaction possibility while consuming a story.*

3 Integrating Storytelling and Volume Visualization

The usual output of a data exploration/analysis session is either a picture containing the visualization or a movie that shows the visualized data as a non-interactive animation. These forms of visualization presentations certainly hold a considerable amount of information, that is quickly grasped by the viewers. But according to Gershon and Page [5], images are also susceptible to uncertainties and might require some declarative statements to clear things up. Additionally, the lack of interactivity in such presentations makes it more difficult to believe the results, while a more interactive approach would allow the consumers to reinvestigate the data. The non-interactive confrontation with a visualization presentation could cause some doubt in the consumer wether the presented findings are credible or not. An interactive reinvestigation could confirm or disprove the presentation's statements, and would definitely resolve the doubt in the consumer himself.

A very interesting though only partly solution to these issues is the use of Quicktime VR (QTVR) objects for visualization presentation (e.g., the works of Tiede et al. [17]). While a certain amount of interaction is possible with such QTVR objects, they still rely on images created by their author and therefore a thorough reinvestigation of the presented objects is not possible.

In order to overcome these issues of traditional data presentation we introduce storytelling to volume visualization as a new form of interactive data presentation. The main pillars of this approach are:

- **Considering story authoring and telling separately** As this new approach is an enhancement to volume data presentation, a division into story authoring and story telling is natural. Story authoring is done by users, who want to present specific points of interest in the dataset to other people, and is described in Section 4. The result of this story authoring process is a story file conforming to a hierarchical story model, which is defined in Section 3.1.

- **Storytelling interaction** While consuming a story, users are allowed to interact with the visualization to a certain degree. This partial user interaction during presentation forms the major difference to other visualization presentation approaches. The amount of possible interaction as well as the handling of concurrent visualization changes due to story action and user interaction are explained in section 5.

- **Open XML story exchange format** For a possible integration into existing volume visualization frameworks as well as inter-application operation, an open XML story scheme is defined. This scheme defines a basic story vocabulary, that has to be understood by all compliant volumetric storytelling applications. Additionally, it leaves the individual applications enough room to also incorporate more application-specific story attributes.

Figure 2 depicts the general process of storytelling for volume visualization, by putting the above-mentioned crucial points of our new approach into a context to each other.

3.1 The Story Model

In order to author and tell stories in a volume visualization context, a satisfying story model has to be defined. The story model, that we propose, is designed in a hierarchical way. This hierarchy leads from the semantics of a story to the syntactic commands and actions, that will be executed to tell the story through volume visualizations and contextual information. It is influenced by the way how scriptwriters are building up their movie scripts. These

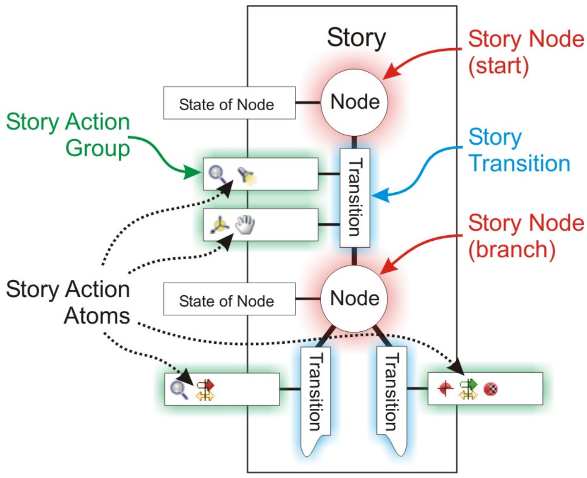


Figure 3: **The story model.** *This figure shows all the elements of our story model and how they are combined to form the final story.*

scripts consist of (among other things) shots and transitions, similar to views of points of interest in the dataset and the transition between those views. The several hierarchy levels, in top-down order, are:

- **Story nodes.** The highest story hierarchy level refers to the key statements, that the story author wants to deliver to the story consumers. In addition to the volume representations, story nodes might contain textual information to tell the actual story as well as annotations to the visualizations of interest visualized by labels.

- **Story transitions.** The second-to-highest story hierarchy level refers to the transitions between story nodes. A story transition consists of one or multiple story action groups, each defining specific changes to the scene. In order to move from one story node to the next, all story action groups contained in a story transition are executed sequentially.

- **Story action groups.** The second-to-lowest story hierarchy level groups several story action atoms together so that scene changes defined by them can be executed simultaneously. Additionally, timing information is used on this level, so that transition times are independent from render times.

- **Story action atoms.** The lowest story hierarchy level is associated to the atomic actions that can be performed on the scene. These story action atoms form the basic vocabulary of Volumetric Stories influencing viewing, representation as well as data parameters.

The equivalent to story plot from traditional storytelling is a particular story line, which is used by the story authors to lead the story consumer from a general overview of the data to the specific message of the story. Although a simple list of story nodes connected by story transitions would be sufficient to model this scenario, we want to give the authors the ability to build branches into their stories. These story branches could be used to add additional information on a side topic of the story. In Figure 3 all story elements defined in the story model are presented in the form of a short sample story. The story nodes form the corner marks of the story and store the state of the whole scene. Story nodes are connected by story transitions, each consisting of one or multiple story action groups. Each story action group stores the scene changes relative to its preceding action group (or story node). Branching is shown at the lower story nodeof Figure 3, which has two outgoing story transitions.

4 The Story Authoring Process

If we take a look at the usage of traditional volume visualization for data exploration, a typical working scenario could be comprised of the following user interactions:

- Import the dataset and apply a direct volume rendering scheme using an arbitrary transfer function to create a visualization.
- Adjust the transfer function's composition. An interesting anomaly becomes visible.
- Segment the anomaly using a suitable segmentation algorithm and visualize it context-preserving.

The result of all of these interactions is an image containing a visualization of a specific data anomaly in the dataset. While this resulting image might hold a certain degree of interesting information for the observer, a significant part of information is lost: The actual user interaction steps that were necessary to create the particular visualization.

4.1 Story Recording

The sequence of user interactions, that led to the final presentation in the example mentioned above, could be interpreted as a data exploration interaction path. The resemblance between this path and a story script inspired the concept of interactive story generation through story recording. The working principle is quite similar to any recorder component.

- **Story recorder disabled.** When the recorder component is disabled, the application should work just like any interactive data exploration tool. This means, that arbitrary user interaction is allowed without any impact on the story.

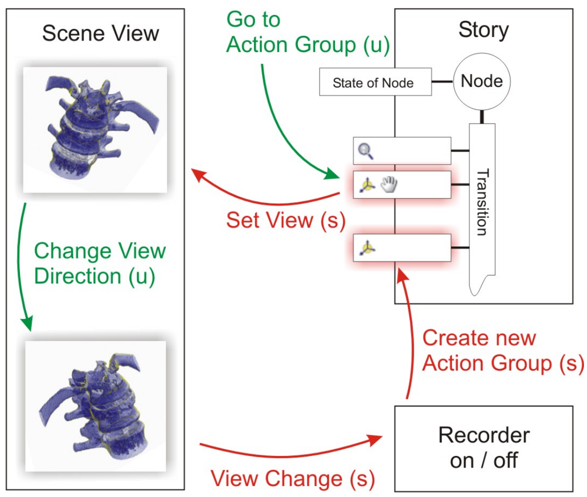


Figure 4: **Story recording.** *This figure shows, how the proposed story recording approach works. Green annotations refer to user interactions (u), red annotations are system internal actions (s), that are triggered through these user interactions.*

- **Story recorder enabled.** As soon as the recorder component gets enabled, a new story will be recorded. From that point on, all user interactions are logged and incorporated into the raw story, until recording gets disabled. Additional story parts can be added in a separate story editing step.

The outcome of this recording process is a raw prototype of a story told through volume visualization. In a following story editing step this raw story is refined until the final story outline is reached.

4.2 Story Editing

After a raw story has been recorded, the story prototype can be refined and improved in several ways in a story editing step. The refinement possibilities are:

- **Record additional story parts.** The story authors are of course not forced to record the story in one coherent recording step. After doing some recording, the users are allowed to look at as well as navigate through the story. If desired, additional recordings can be made, which are incorporated into the story in a way that depends on the current story position. If the current position is a story action group (belonging to a story transition), the recorded story action atoms are inserted at this location. If the current position is a story node, a new story transition (containing the recorded story action atom) is appended to the story node, resulting in a story branch.
- **Adding story text.** As we have already stated, telling stories in volume visualization is not a task that can

be solved through images only. Additional text is needed to explain the visuals, and in the story editing step, this text can be added to the story. Additionally story editors could also add verbal explanations, but for our prototype implementation spoken story text was categorized as future work.

- **Adding annotations.** Apart from the general story text, specific volume visualizations can be annotated by labelling. The annotational information is also added to the story in the story editing step.

- **Combine several story actions to groups.** When recording a story, the user interactions arrive serially at the recording component. In order to parallelize some of these Story Actions, they can be grouped together in the story editing step. Additionally, timing adjustments can be made here on a per-story action group basis.

While editing the story, authors have the ability to navigate through the story, as well as to start and stop story execution for previewing. As soon as the the resulting story is satisfying, it can be stored on disk using the proposed XML story exchange format, and used in the separate story telling step.

5 The Story Telling Process

The second step in our approach to storytelling for volume visualization deals with the story telling itself. The general idea behind the story telling process has many similarities with a state-of-the-art media player application. The users have to be given the abilities to start, pause, etc., the playback of a pre-recorded story. Additional effort has to be put into the handling of story branches, since the users need to make a choice in this case. If the story execution process encounters such a branch, it has to pause and wait for the user's input indicating the story direction.

As we already stated, interactivity is a key feature that needs to be available for reinvestigation and further data exploration through the story consumer. This need for interactivity leads to a concurrent situation between scripted story action and user interaction. In order to solve this concurrent situation, we propose an approach that categorizes all possible actions / interactions affecting the scene, and leaves the control over those categories either to the users or the story telling application. Those interaction categories are:

- **Viewing interaction.** This category contains all viewing parameters like viewing direction, zoom and lighting conditions. The only parameter not affected by this category is the view center since a change of this parameter would disrupt the whole story telling process (i.e., the story text would be torn apart from its context).

- **Representation interaction.** The representation interaction category contains all volume illustration / representation parameters like illustration type, color or opacity.

- **Data interaction.** Data interaction contains all interaction related to the visualized data objects, e.g., a change in the iso-value of a surface representation.

The standard way of consuming a story is, apart from the interaction needed for branching, passive and therefore comparable to watching a volumetric visualization movie. If the users want to further investigate the visualizations as shown in the story, they can enable one of the interaction categories from above. If that happens, story execution is paused until the users restart it. From that point on the user is allowed to interact with the scene according to the state of interaction categories, wether the story is executing or not. This leads to a blending of interactions between the story script and the users and therefore solves the problem of concurrent interactions.

6 The Volumetric Storytelling Prototype based on RTVR

After the technological discussion of the new approach to storytelling for volume visualization, we present an application prototype that is based on the Real-time Volume Rendering Java Library (RTVR). RTVR is a volume visualization library, which was first introduced by Mroz and Hauser [13] and does not rely on any hardware accelleration. Nevertheless it is able to reach interactive framerates by putting a lot of effort into the following fields:

- *Rendering.* The RTVR uses a fast shear-warp based parallel projection rendering algorithm, which is intended to deliver interactive framerates. Due to the limitations to data interpolation caused by the shear-warp algorithm, RTVR's renderer is not able to deliver high-quality images of low-resolution datasets. Its advantages are based on its independency of hardware, which for example makes it possible to realize visualization sessions over the Internet.

- *Data reduction.* Only considering the parts of the dataset, which are really needed in the rendering process forms the second pillar of RTVR's interactive visualization capability. This implies a preceding data extraction step, that separates relevant from irrelevant data.

In order to integrate our story telling approach into the existing RTVR library, a lot of implementation work had to be done, which can be categorized into

- Implementation of the story model

- Improvement and unification of action handling

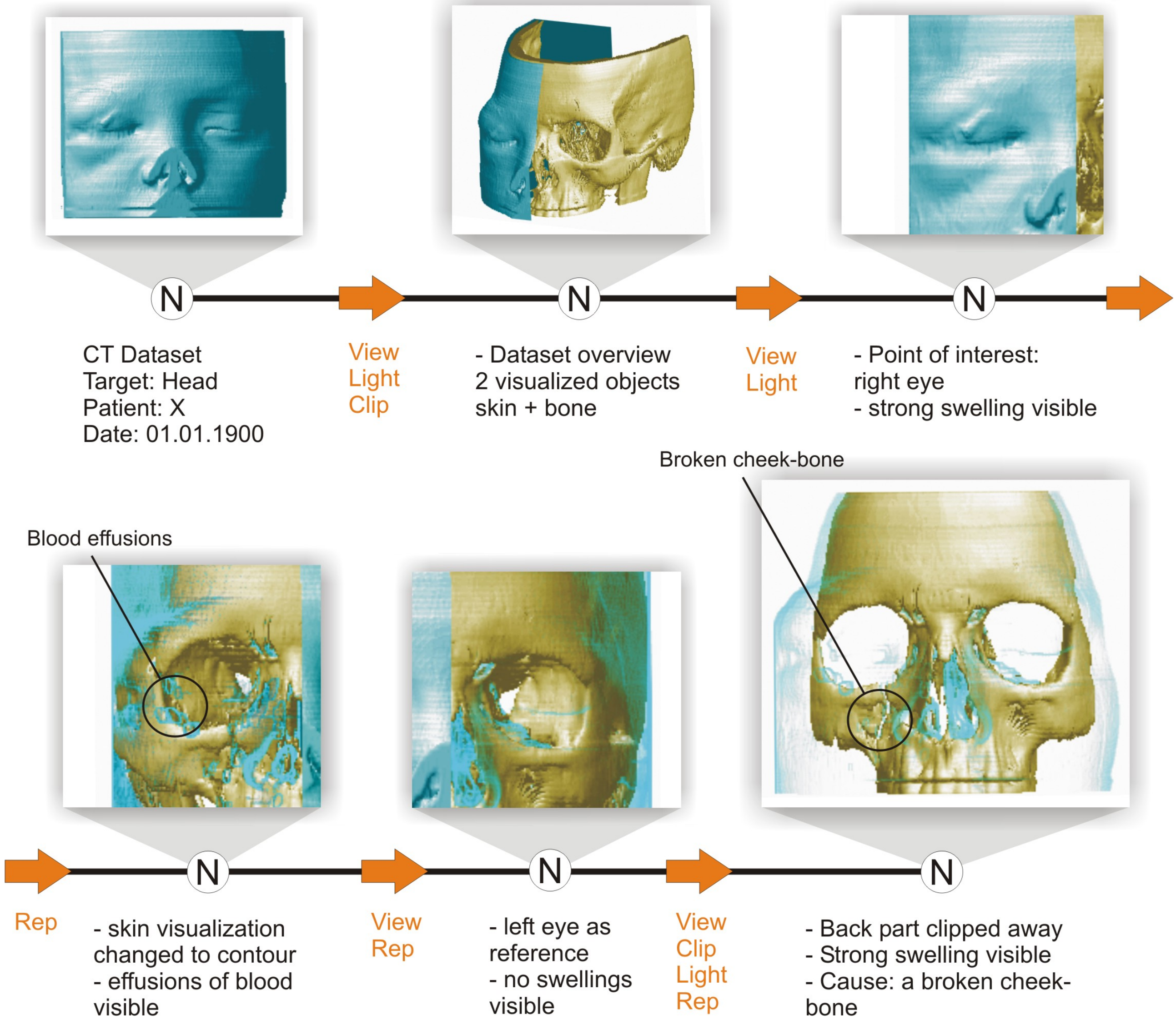


Figure 5: **A sample volumetric story.** *This figure shows an image sequence taken from our prototype implementation. Story nodes are denoted through (N) and story transitions are represented as arrows.*

- Improvement of the scene model
- XML representation of scene and story

Figure 5 shows an image sequence taken from a sample linear volumetric story visualized with our prototype. The distinct story nodes denoted through (N) refer to the key events in the story, which are an overview first, then details on specific features in the dataset, and at the end a conclusion made by the story author. The necessary story transitions are represented as orange arrows from one story node to the next and are animated in the prototype application. The story consumer may take over some story parameters (e.g. camera angle) already during playback or at the end of the story to further investigate the dataset.

7 Conclusions

In this paper, we introduced a new method for volume data presentation, which was inspired by the research fields of volume visualization and virtual storytelling. This new approach proposes the integration of storytelling into data presentation. Therefore a separation into a story authoring and a story telling process is necessary. In the story authoring step, users can explore a dataset, extract interesting information and arrange it in the form of a story. In the story telling step the users can consume the story non-interactively but are also allowed to interact with the story to a certain degree.

We believe, that the application of our new data presentation approach leads to better understanding of the underlying data as well as information. The possibility of interaction, the ability to look at things from different angles and the feeling to still have some control over what is happening could pose a significant improvement to data presentation.

8 Acknowledgements

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