An Approach to Information Presentation Employing Game Principles and Physics Based Interaction

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Abstract. In this paper we propose a novel approach optimized towards the presentation of general sets of information entities that employs game-like features and social context to engage its users to explore the presented data and streamlines the navigation and overall usability in terms of several constraints that we established. The presentation environment is embedded within a physical engine that controls the movement of visualized entities, resolves user's interaction and takes part in the overall information throughput.

Keywords: web information entities visualization, exploratory navigation, game-like, physics based interaction.

1 Introduction

The times when the web contained overwhelming amounts of information that were interesting for the widest audience and besides it was composed mostly of textual HTML-based websites are long gone. With some popular portals like youtube.com spreading the browser plug-ins that render an interactive graphics the web has become a highly visual medium.

The mere fact that the information is communicated by a visual presentation does not solve any of the major problems of those crowded and boring 1.0 websites. On the contrary, the enhanced possibilities that the web developers nowadays wield have the potential to break more usability and HCI guidelines than ever before.

One of the common principles that has become ever more apparent in this era of Rich Internet Applications is the separation of the content and its presentation known as the MVC software design pattern. In this paper we devise an intelligent and uniform way to present almost any set of information entities so that the parties that provide actual content can do so without any burden imposed by the presentation itself. Our major interest lays in exploratory-based navigation, where the user does not know what exactly he is looking for in advance.

The proposed approach strives to fulfill the following general requirements for information front-end:

- *Strong first impression* – if the presentation fails to catch the attention of the target audience, every other quality may have gone unnoticed. Additionally, it sets the mind of the user for the rest of the interaction.

- *Sustained attraction* – the information is communicated after the user becomes familiar with the presentation, but only if he does not walk away in the meantime.
- *Presentation clarity* **–** the process has to be streamlined to the point, where there is no presentation anymore, only the user and his comprehension of the data
- *Personalization* **–** the presentation adapts to the user, not the other way round. Novel visualization approaches cannot rely on the established standard, they have to guide the user to find their own way.
- *Socialization* – our attention is affected by our peers, we prefer to accept the information from the people we know or like and pass it along to somebody else.

Every presentation idea is derived from the characteristics of the presented data and so we define the basic constraints for the data-set. Firstly, it is comprised of a variable number of objects that carry various multimedia. Secondly, these objects have a variable number of attributes, values of which can be compared and provide a basis for object grouping and filtering. Finally, the relations between objects can be modeled by the configurations of their attributes and by their dynamics.

The key idea of our approach is to portrait these objects as visual entities in 3D space and to apply several methods to fulfill the requirements and follow the constraints mentioned above. To position the entities and meet the navigating, filtering and grouping requirements, we embedded the presentation space with a physical engine. The engine allows the presentation to be more natural and intuitive, contributing to the attraction requirements as well.

We exploit the psychology of human mind to engage the users through the game-like aspects of the presentation that drive them to explore and understand the presented data and to challenge their friends. The game mechanism is comprised of two intertwined parts. The action centered part where the user's attention is stimulated and the navigational skills practiced, and an information centered part where the user demonstrates the amount of the information obtained from the presentation. We use an underlying graph to define certain formal aspects of our method e.g. traversal order. In these definitions, the information entities are mapped on the nodes of a simple undirected graph and the similarity in the context of object attributes is modeled with graph edges.

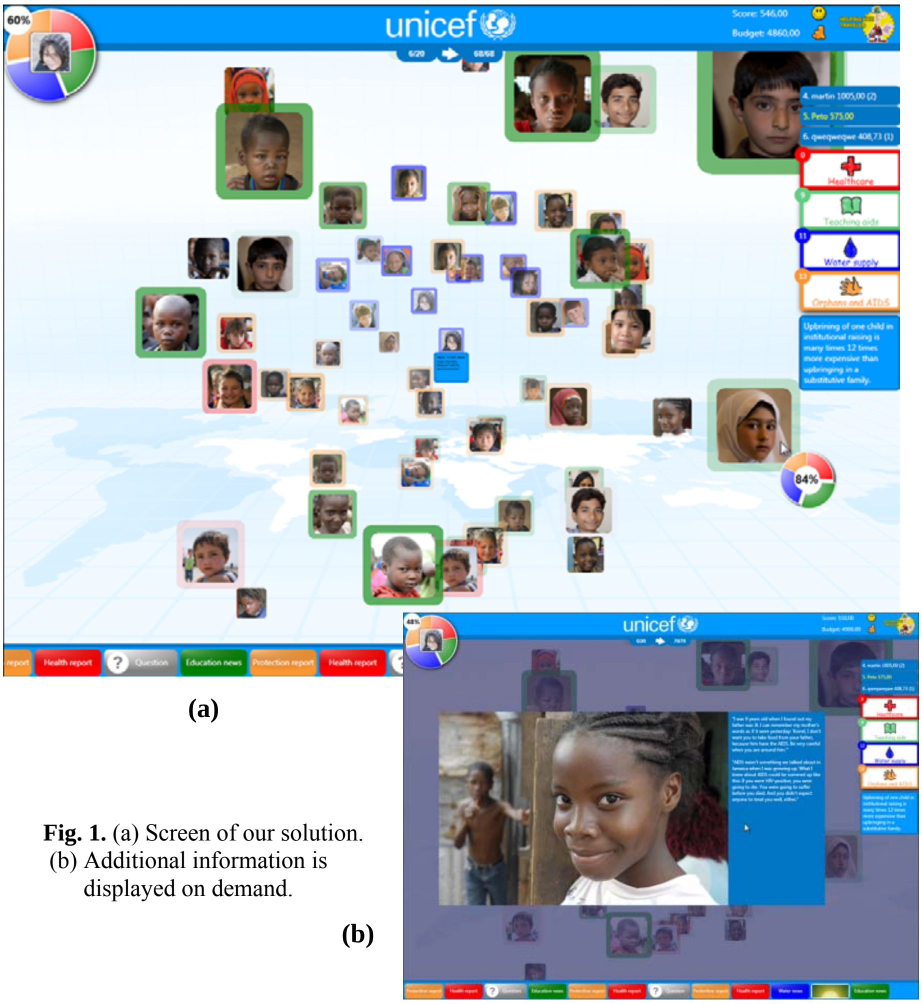
2 Related Work

There are many data and information visualization tools. Plenty of them are mostly focused on comparing the exact measured values e.g. different kinds of charts. Several of those can be easily transformed into presentation of multimedia with given attributes, but they mostly fail to visualize relations.

The visualization of ontology is more related to our work. There are three major ways of ontology visualization. The first way is tree based [1], also known as hierarchical navigation. The second one is based on the graph visualization (not limited to tree) [2], which is more general, but also less transparent and more complicated for the user. These two visualizations are not so intuitive for the user and are mostly oriented on relations between entities. The third one is based on creating clusters of entities, where hierarchically same entities are clustered together and clusters hierarchically on lower level are contained in the clusters which are hierarchically above [1]. This is more intuitive approach to tree based visualization, but it can visualize fewer entities. These techniques are unfortunately closely bound to the structure of ontology.

There is also another way how the information can be visualized. The informational space can be seen from various aspects [3]. More aspects ease the navigation through the space, but the mechanisms (usages of matrixes, lists, etc.) are not so effective on the visualization of large numbers of entities.

Our solution is designed to be more intuitive for the user and our base idea was to create the best user experience. The user does not need to know exactly all the relations and the whole domain structure. It is enough to see the domain overview and the rest of information should be visible on demand. Our solution is based on 3D lightweight graph visualization where the entities are stressed instead of relations (see Fig. 1). To increase the user experience we use game-like features [4]. We have realized that many visualization techniques do not emphasize the user's interaction with the domain space, but we have made it a part of the method itself.



(a)

Fig. 1. (a) Screen of our solution. (b) Additional information is displayed on demand.

(b)

3 Requirements for Dynamic 3D Information Presentation

The basic requirement of the dynamic information presentation is to simplify exploration of complex informational structures like tons of documents to achieve the best user experience. To improve the clarity, you can either extract and present only the most important information or devise a presentation technique that is easier to understand. An ideal solution employs both principles. It is important to create an abstract generic environment for data visualization and not to create concrete environment like animated villages etc. Abstract environments are more serious and force user's imagination to improve the domain space in a user's personal way.

Our idea is to visualize multimedia with attributes, where the focus lies on the most important attribute, leading to the reduced complexity of domain space. We adapt the object oriented programming principles (everything is an object with attributes) in a new user friendly way. The basic data entity has to be designed according to this idea.

The next requirement is to visualize approximately 50-100 data entities at once in a way where there is a good visibility of multimedia content on a majority of entities. It follows that the entities have to overlap and thus the visualization has to be sufficiently flexible to deal with it. This complication can be solved by properly designed user interaction based on easy to use structure that allows intuitive navigation through the object space. The additional requirement is to visualize mutual relations between objects, list values of all attributes on demand, categorize objects and list all information about object on demand. The object categorization has to meet the requirement for easy creation of related components (e.g. button which is easily understood as a control component of given category).

Amongst the navigation requirements, the *horizontal navigation* allows the user to move from one piece of the information to the other, staying roughly at the same level of abstraction. After the user embraced the dataset on certain level of detail, he needs the ability to *filter* certain specific points of interest. This is done by allowing the user to highlight some interesting entities or to suppress or even completely remove the uninteresting entities out of the view. The next logical step is to learn more about the rest. To achieve this, he needs to engage the *vertical navigation* to access more detailed information associated with any given entity. The navigation is therefore vertical in the sense of the immersion in the level of detail.

4 Principles of proposed visualization

Preattentive visual patterns [5] are basic principles which we use in our visualization. They clearly determine the techniques to distinguish objects that we want to emphasize. The patterns are very important for users to identify significant objects as fast and as easily as possible. Such an approach creates a pleasant user interface that allows the user to understand the content effortlessly. There are five basic patterns to distinguish and highlight objects like colour, size, rotation, movement and shape. They reduce the visual noise and thus the combined usage is allowed.

According to the requirements the best solution is to use colour as an element to distinguish entities and movement to attract user and to navigate through space. The size, rotation and change of shape are suitable for highlighting the entities.

The combination of these three patterns creates various possibilities how the entity can be highlighted so the user is alerted on different actions in different way.

Considering *depth of presentation space* there are three possibilities that fit the requirements: the visualisation made via *2D*, *2.5D* or *3D space*. The 2D space is the easiest one to understand. Visualization of multimedia content implicitly requires a 2D surface or a 3D object with the multimedia displayed on its surface. The 3D object view requires an additional content, which is not primary necessary for visualization of multimedia. Therefore the visualization of multimedia on an ordinary 2D surface is clearer than visualization on 3D surface. The 2.5D space is 2D space augmented by features of 3D space like shading, bumping textures or the usage of lights and reflections. This all raises the attractiveness and preserves the clarity of 2D space [6].

The third dimension can be confusing and decrease the clarity of the content for some users, but in this decade most users using the Internet are identified with 3D space and consider it more attractive. On the other hand, the third dimension can be easily used to increase the clarity of visualization of a big amount of entities.

It is important to display the content in 3D space to make the environment look as real as possible what ensures that the user feels comfortable while interacting with domain space. The techniques [7] to emphasize the content are *perspective*, *kinetic depth*, *face-tracking* and *binocular vision*. Perspective is natural way how some objects can be highlighted without additional features. When the perspective is properly used, some objects are bigger than others, letting the user to focus on the stressed ones but still observe the whole domain space at the same time.

A large number of visualized objects requires smaller objects or objects which are overlaid. The usage of intuitive object movement (kinetic depth) solves the problem of overlaid objects, because the user can easily see behind the objects.

Face-tracking is natural and attractive usage of kinetic depth based on the position of user's head in front of the screen, creating an immersive 3D effect observable only from the user's view-angle. Giving good light conditions, it does not burden the user and so it is a good additional feature.

Binocular vision is the best way how to achieve clarity and simplicity of complex domain space [7]. A disadvantage of this solution is the necessity to own quite expensive polarized glasses and so it is inappropriate for an ordinary usage.

Our solution is based on a combination of 2D and 3D space visualization. We have employed the clarity of 2D visualization and attractiveness and advantages of 3D. The data entities are in 3D space but multimedia content remains two dimensional. The media content is displayed on billboards that are perpendicular to the camera. To create an illusion of 3D space we made the back entities darker to look like dipped in shadow together with kinetic depth and natural perspective (front objects are about 3 times bigger than rear). The face-tracking was used as a bonus to add attractiveness.

4.2 Constructs of the Presentation Space

With all the advantages of 3D space there are also some inherent complications caused by the projection of 3D space onto a 2D computer screen. To set the foundations of the entity visualization, we evaluated two basic constructs of the presentation space that are the most accessible for the user.

The first option is to fix the data entities in the presentation space and let the user (i.e. the camera) to move in this space with certain degrees of freedom. The more arbitrary the camera movement is, the more confusion and disorientation of the user it causes. Also with every axis or direction of the movement, the complexity of the control system increases. We found that it is not very user friendly to navigate in unbound 3D space using only a mouse so the logical step was to let the camera move only in 2 axis system or on the surface of a sphere that would enclose the data.

We also evaluated a setup with fixed camera and user enabled to move the data entities around. We have concluded that this option is more comfortable for the user, as he is aware that he is sitting statically in front of the computer.

Furthermore, the data have to be positioned in the space and there has to be a mechanism allowing the user to change this position and fulfill all the navigation needs listed above. We considered four options regarding the data entity distribution in the space together with the ways users can navigate through the data set. The simplest and most accessible option is to position all the objects on a 2D plane in the 3D space right next to the camera. Then you can let the user to move the plane in all the available dimensions and/or rotate it. Due to its simplicity, this option does not really exploit the advantages of 3D presentation space and we have found its use mildly redundant as opposed to a simple planar distribution in 2D presentation space.

A slightly more 3D insight can be achieved by distributing the objects on a surface of a 3D body like a sphere. The navigation is getting more complex but the objects are still bound to a planar surface that cannot carry much of information itself. The user can browse the data set by manipulating the position of the body. This is still within the reach of an average user sharing similar complexity with the first option.

The first configuration that embraces the potential of 3D distributes the objects in the full volume of a 3D body. This configuration exploits the expressiveness of the space yet the navigation controls share the complexity with the first mentioned option. This creates the desired balance of visual power and user friendliness.

The last option we evaluated was to distribute the object in the whole unbound space and let the user move individual/or user selected groups of objects. The problem with this configuration is the same as with the unbound camera movement - it is difficult to move in full three axis system using only a mouse, especially with the limited insight given by the PC screen. Fulfilling the navigation requirements listed above was concluded too difficult and awkward and so we abandoned this option.

5 Visualization made by a 3D Graph

In terms of the requirements, the 3D graph structure is the best choice for bearing the data entities. Centre based 3D graph offers easy navigation and attractive interaction. The graph as an abstract structure does not help with the identification of the presented domain. We have solved this problem by creating a box surrounding the graph with thematically designed walls. These walls contain characteristic domain elements, that remain visually suppressed compared to the graph.

Nodes bear the basic data entities. The primary purpose of the nodes is to visualize the multimedia content of the data entities and provide proper navigation in a way that there is no additional effort to understand the domain content and the most important information. It is critical to display proper number of nodes. We have identified three boundary cases. The first is to visualize 7±2 nodes, which creates enough space to list all attributes and visualize additional information of entities. An advantage of this kind of visualization is the full concentration on the all screened entities.

The visualization made by 10-40 nodes forces the user to care of basic information entities. It is possible to visualize values of attributes of entities in a more complex structure like economical graph or colourful border of multimedia data where the quantity of each colour mirrors the value of the given attribute.

Our requirements lead us to use visualization of more than 40 nodes, where the user is focused on the most important attribute of the entity. Visualization of single attribute is used to suppress the visual noise and to ease the complexity of domain space. More information is screened after the request of the user. More nodes and simple visualization render a complex structure with areas of entities with similar attributes (using preattentive visual patterns) immersing the user in aspects of the domain space.

The edges of the graph represent relations between presented information entities. To ease the complexity of the edge visualisation we use complete undirected graph with no need to visualize an edge between two nodes because there are edges between all nodes (the absence of relation is modelled with zero weight). The problem of weight visualisation has been solved by easy understandable mutual relation visualization based on distances of nodes in 3D space. This kind of visualization is more intuitive for an ordinary user than the usage of exact numbers, because ordinary user does not know the graph structure.

6 Graph user interaction

We have established that the most plausible solution to information entities visualization and navigation in 3D is to distribute the information entities in the full volume of a 3D body and then let a user to change the position of the body, navigating himself through the data set.

We have identified two suitable coordinate systems for the body movement. Due to its general familiarity, the first option is to use standard orthogonal Euclidean coordinate system. The use of billboards that are kept rotated orthogonally to the camera voids the need to spin the whole body. The lack of spinning makes the movement in the Euclidean space user-friendly. The only problem is that the layout can be observed only along the two camera-orthogonal axes. The axis parallel to the camera cannot communicate its data unless the camera enters the body and the entities that are 'behind' it disappear. we still could not achieve the full information throughput.

The second option is the polar coordinate system. We placed the center of the sphere at the origin and also positioned the camera at the ray in the certain distance from the origin. At the center of the sphere we placed an exchangeable data entity to highlight the point of rotation and consequently the entity itself. This allows the user to look at the data set from any point of view and also from any distance along the ray. For the perception of stationary camera the relative position of the enclosing box to the camera was constant.

There are two main approaches to the axes rotation management in the polar system control realization. Firstly, the planetary model keeps the axes relatively fixed in relation to the inner objects because they rotate together. This broadens the possibilities yet it burdens the visualization or the user, because we need to help the user keep track of the position of axes. Secondly, the simplier model keeps the axes static relatively to the position of the camera, taking care of the biggest flaw in the planetary approach. Even though the interaction possibilities are reduced, we have decided that this model is much more suitable for the 3D data visualization given the inherent complexity of the remaining factors (see Fig. 2).

Fig. 2. Counterclockwise rotation around the blue node and its vertical axis.

6.1 Selection of the data entities

In order to be able to interact with the specific visualized entities, the user needs to be able to pick the ones intended for the interaction. The position of the entities visualizes relation of the data, so it makes sense to select groups clustered together.

Computer mouse is used for selection due to the accessibility. Starting with the simplest option, the user can be allowed to draw a rectangle onto a 2D plane perpendicular to the camera ray with parallel selection volume. This option does not require the user to consider the full 3D space but the selected entities are not spatially related. The second option overcomes this problem by letting the user to draw a complete 3D box, the first drawing of the base side as a rectangle parallel to the bottom of the graph enclosing box extending it in the second step, delaying the whole action. Finally, the third option exploits the spatial relation of the data. This selection exploits a traversal of the under-laying graph structure that we employ in many aspects of the proposed model. For this specific task we use the breadth-first traversal, which pertains a distance uniform spread. To be more specific, we allow the user to select a single entity and then until he does not let go of the mouse button, we gradually add the traversed nodes into the selected set. This option does not require the user to draw complicated 3D shapes and use an excessive amount of time or different controls as it allows selecting any spatially related subset of nodes.

6.2 Force based layout

We have established that the optimal way to position the visualized entities is to distribute them in the full volume of a 3D body. We evaluated two kinds of distributions, the first positioning the entities at points fixed relatively to the enclosing body. While it is possible to achieve a uniform initial distribution, the layout itself is static and inflexible in later operations. The second distribution is an interactive adaptation of force-based graph drawing algorithms.

Heuristics for the NP-hard problem of graph drawing tend to converge quickly. Even a simple implementation of the force based principles discovers a suitable layout. The challenge is to transform the user interactions into meaningful actions in the context of the model. The force-based model overcomes challenges of the dynamic node count by itself, given the fact that the piece-wise distances between nodes are adjusted in each iteration and so when we add or remove a node, the model adapts naturally. We suggest the dynamically adjusting the formulas used to calculate the piece-wise force interaction. The attraction forces of related nodes in this way can dynamically increase clustering the entire data set demonstrating the chosen relation.

The scene of the model can also be augmented with so called virtual objects that help to take control of certain aspects of the movement of visualized entities. For example, we can insert an invisible and highly repulsive object in front of a node we want to highlight to repel nodes that block the view. Other advantage is the impression of a living, playful “organism” that the model creates with the entities behaving like a swarm of fish. The "viscosity" needs to be controlled to accommodate the various users. We gather user input statistics as e.g. click rate, engagement in the game aspects of the presentation and feeding them to a Fuzzy controller system that is able to devise the desired speed settings.

As discussed above, we need to rotate the body around two perpendicular axes and change the middle node. While the body can be rotated and moved directly, we discovered that this reduces the effects mentioned in the previous paragraph and so there is a significant advantage in embedding these manipulations into the model itself. This is achieved by adding the virtual forces during certain amounts of iterations of the layout algorithm, allowing the whole system to compensate for the change of the middle node by shifting the nearby nodes and also creating naturally looking effects caused by inertia of the nodes apparent during the rotation, which shapes the normally spherically distributed data set into a disc-like object.

The virtual force augmentation brings new challenges. If we are to transform the user input to the respective forces directly, we need to keep in mind the behavior of the force-based layout model in the extremes like inserting excessive amount of force into the system, pushing visualized nodes too close to each other etc, because the repelling force increases exponentially while the distance decreases. A severe distance reduction can therefore destabilize the whole model.

On the other hand, if the rotational forces exceed a certain threshold, the attracting forces begin to be too weak to hold the entities together and they spread away from the axis of rotation creating unsuitably large gaps between the nodes harming the convenience of the navigation. We suggest combating this by dynamic addition of attraction forces pointing from each given node to the center of the coordinate system. The power of these forces needs to be controlled to prevent the implosion. We simulate the inertia of the body rotation so when the user rotates the body enclosing the entities and he lets go of the mouse, the body rotates slowing down naturally. The force-based rotation is coupled with the direct rotation of the body to compensate for the lower inertia forces.

7 Information Presentation as a Game

We have been forced to transform the ordinary mostly boring web pages into the interesting and attractive web presentations. There are always two actors in information presentation, those who present and those who listen to. The keystone of the relation between the presenter and the listener is motivation. The motivation can be achieved by information itself or by the way of presentation. We have identified that the best way of presentation is employed by games. The games are mostly based on presentation, where the insignificant information are wrapped by interesting visualization, interaction etc. This kind of presentation creates a large amount of motivation without the necessity to present interesting information. Therefore, we have decided to use the game definition to abstract game-like features and use them in generic none-game information presentation.

7.1 Applying Game Definition

A game represents a formal system based on four elements. The users play games because the *goals* of the game that they want to achieve are strictly defined. The achievement of the goal usually ends the game. This is called the long term goal, but in games there are also short term goals, which are necessary for playing long games. The user has to feel that he is within the reach from the goal permanently.

The number of nodes in the graph is dynamically changing accordingly to the users' interaction and it defines the long term goal. Users reduce the number of nodes to zero or increase it above a given level. The short term goals are effectiveness of interaction during a short period and achieving ranks. This is a way to guide the users to navigate properly through the domain space and increase their motivation.

Rules clearly define the means to achieve goals. We use dynamic attributes of data entities which decide whether the entity will be presented in the graph or not. The user can operate the tools (thematically designed according to a domain theme) to change values of the dynamic attributes indirectly affect the number of nodes in the graph. The tools and dynamic attributes are also elements which supplement the domain space and informational value. *Challenges* make the user's motivation better and better in achieving the goals sustainable. It is not enough to achieve a goal, the way it is achieved is important as well. We use score and budget to quantify this. Every tool application costs some resources which is not the primary part of presentation so the user is subconsciously motivated to do his best. Each action is evaluated and reflected into the change of score and therefore the users can be easily compared to each other.

We are concentrated to compare scores among friends, because the user is mostly interested in actions of friends and there are also short term goals like: "I have to beat Johnny, who is right above me." It is really important to implement proper *interaction*, where each action causes a reaction. A good example is shooting in action games. Each shot has to cause spreading blood, not just standing man saying: "Ouch". The next aspect of causing reactions is the use of physical forces to make the user feel like it is real and natural. To achieve this we use physics-based model and sufficient visualization of the domain processes.

The game-like principles not only increase users' motivation, but also create many possibilities to implement wide variety of features. For example, we have designed a way to embed the application with domain-related advertisement which is highly welcome, because it increases the user's budget.

8 Evaluation and Conclusions

We have suggested a general presentation approach that can be used uniformly across a large number of domains imposing only certain well defined constraints on the presented data. The careful usage of the discussed HCI principles, the use of 3D space and the physical engine to keep the presentation clear and to-the-point resulted in a fact that we can present more data at once without the increase of the information noise and overload with sustained user-friendliness and intuitiveness which is a tremendous advantage in the explorative navigation in unknown information spaces.

To evaluate the described concepts, we have implemented a presentation system called WOWI (World of Web Information). To achieve a balance between the rendering and processing power and accessibility, we have chosen the Windows Presentation Foundation framework that enabled us to visualize cca 100 entities in 3D physics enabled space and still be able to deploy the application into the web browser via XBAP. WOWI can take any data that follow the discussed constraints and produce a presentation with all the qualities described in this paper.

To illustrate the vast possibilities, we have created two WOWI presentations, one for the UNICEF charity organization and one for the Faculty of Informatics and Information Technologies, our faculty (http://mirai.fiit.stuba.sk/wowi/) [8].

The reception of WOWI throughout the various phases of its development was improving as we incorporated more features obtained from the feedback. These improvements were projected back onto the overall method in several iterations. We found that to really understand the theoretically designed techniques, one must prototype and frequently consult with various types of audience starting with people involved in the project and then spreading to related fields and to the actual desired user audience as soon as possible.

Based on the analysis of a wide range of visualization techniques and presentation approaches we came to the conclusion that the most important factor that determines the quality and success of the presentation is the amount of the motivation and the user involvement the presentation can generate. This is often almost unrelated to the actual information that is being communicated.

In this context, our contribution came from the unique combination of generic game principles catering on basic human instincts and the open presentation platform that is able to take a wide range of various types of data and transform it to a presentation appealing to broad audiences. Our method

- catches the attention of the user and sustains it,
- creates challenging and social environment that makes the user enthusiastic about learning and comprehending the presented information and
- creates a wide range of possibilities for further augmentation of this space with business plans of "welcome-advertisement".

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