Understanding Effects of the Algorithm Visualized with AR Techniques

Lázaro V. O. Lima
Centro ALGORITMI, Departamento de Informática,
University of Minho, Campus Gualtar, Braga, Portugal

Manuel Sousa
University of Minho, Braga, Portugal

Luis Gonzaga Magalhães
Centro ALGORITMI, University of Minho, Braga, Portugal

Pedro Rangel Henriques
Centro ALGORITMI, Departamento de Informática,
University of Minho, Campus Gualtar, Braga, Portugal

Abstract

We create analogies to understand and visualize complex concepts. Such approach, based on analogies are presentation of software, is also effective when it concerns software comprehension. Many visualization techniques for data structures have been developed in 2D and 3D to improve the visual representation of large structures. A common challenge faced by developers that want to implement these techniques is to increase the amount of information to be displayed in each node seeking a balance between quantity and visibility. To overcome these challenges, this article presents a visualization technique using Augmented Reality to display hierarchical structures and understand the effects of the algorithm in data structures. The visualization system based on AR, proposed and discussed along the paper, allows the user to interact and navigate through the structure, enabling him to explore information in depth.

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1 Introduction

To start, we quote the authors [5] who say "The use of computer-supported, interactive, visual representations of abstract data to simplify cognition" – in other words, we create analogies to understand complex concepts and this relationship is a cognitive process of information transfer.

For this, another author [4] says: "Visualization holds great promise for computational science and engineering, provided we can meet the immediate and long-term needs of both toolmaker and tool users." According to [7], our cognitive system takes about 15 to 20 different psychological stimuli into account to perceive the spatial relationships between 3D objects. These so-called depth tips can be divided into monocular (use of one eye) and binocular (use of both eyes). This information is usually classified into 3 categories: one-dimensional, two-dimensional and three-dimensional [6].

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The form of representation of certain information must be carefully chosen since misrepresentations can cause errors of interpretation [14]. Based on these categories, several metaphors were created, such as bar graphs, hierarchical structures (*Information Cube* [11], indented lists [13], hierarchical graphs [3], *TreeMaps* [8], *ConeTree* [1]) and maps to represent the different categories of information.

Indented lists, the items (nodes) belonging to the hierarchy are organized one below the other, linearly, with the indentation corresponding to the level occupied by the element in the hierarchy [13]. A hierarchical graph can be defined as a graph where each node is composed by a simple element or, in turn, a new hierarchical graph [10]. When a graph has the purpose of visualizing hierarchical data, it is called a hierarchical graph, and can be presented in different ways (horizontal and radial). The horizontal hierarchical graph, as shown in Figure 1, has the level lines drawn horizontally, parallel to each other.

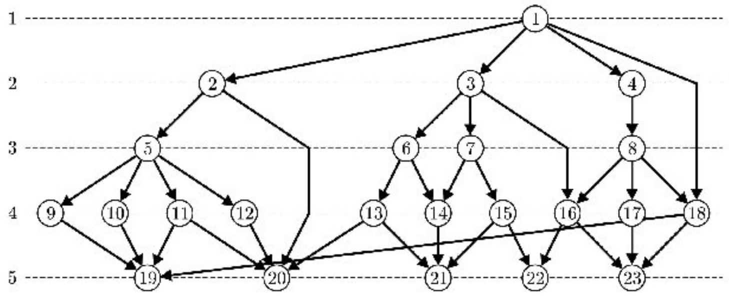

Figure 1 Horizontal hierarchical graph [3].

To solve this problem, the radial hierarchical graph presented in Figure 2 was proposed and created by Bachmaier [3], having the level lines represented by concentric circles. One disadvantage of radial hierarchical graphs is that for large volumes of nodes, clarity in the visualization of the information presented is lost.

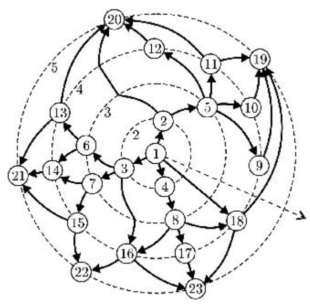

Figure 2 Radial hierarchical graph [3].

The *TreeMaps* presented by Figures 3 and 4, constitute a structured information visualization technique, which maps a given hierarchy in a rectangular area, using 100% of the available space for the presentation of data [8]. With the efficient use of available space, it becomes possible to view large hierarchies, facilitating the presentation of the information in question.

Even though this technique is a good option for viewing large hierarchies, it becomes limited when displaying a single type of information throughout the structure (viewing in two dimensions limits the ability to present complementary information).

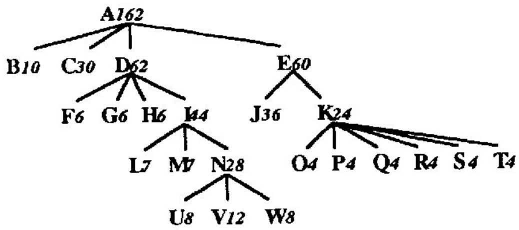

Figure 3 *TreeMap* equivalent to the structure of Figure 4 [8].

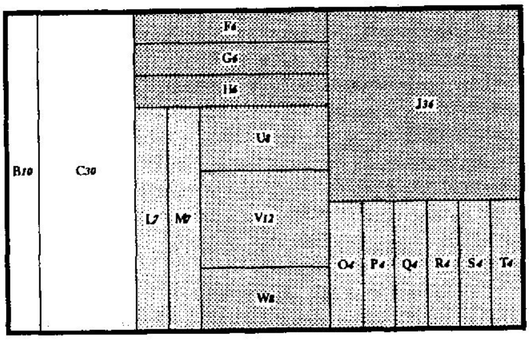

Figure 4 Example of *TreeMap* [8].

ConeTrees are a technique for visualizing hierarchical structures, through the connection of sub-trees, in the form of 3D cones, as shown in Figure 5. The main disadvantage of *ConeTrees* is the occlusion of some nodes, which increases significantly as larger hierarchies are viewed. To work around this problem, *ConeTrees* are designed to be interactive, allowing the user to navigate through the presented structure and, consequently, the visualization of occluded nodes [1].

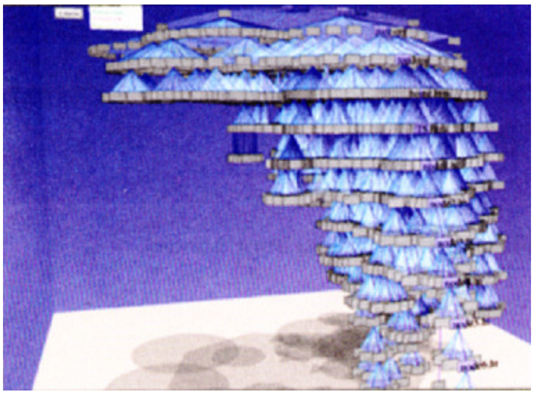

Figure 5 Example of *ConeTree* [1].

The techniques described above have some limitations, such as:

- Presentation of a single type of information throughout the structure;
- High degree of disorder in the presentation of different types of information;
- Does not allow interaction with the hierarchical structure presented.

Therefore, we need to present new techniques for visualizing information with Augmented Reality. We understand that the AR allows the observation of a data structure in three dimensions, in addition to allowing the observation of changes that occur in the data structure knowing that the AR inserts increased information in real time. Augmented Reality is defined by Azuma [2] as the overlapping of virtual information in the real world through technology. This information can be simple textual images or 3D objects. AR increases information in the real world, the user maintains a sense of presence in the real world and requires mechanisms to combine the real world with the virtual one.

The prototype proposed in this article addresses a different use of the visualization technique of data structures, in which the user interacts with the information presented at different levels of depth through a Virtual Environment. The goal is to allow the representation of arbitrary information and data.

Taking advantage of the best practices of Augmented Reality, one can align the objectives of teaching Algorithms and their different data structures with 3D visualization in which the teacher can perform an operation and instantly visualize the structure in Augmented Reality. Besides this introduction, this paper is divided into five sections: the section 1 covering the importance of using technologies that impact students' motivation to understand complex concepts and thereby make the abstract better; another one documenting the construction and presentation of tree information; a third one presenting the application of the prototype built with a case study and a last one to show some concept prototypes, conclusions and work in progress.

2 Understanding Software with Visualization of Effects in AR

There is a lot of research underway on 3D data visualization in AR, especially in the field of Immersive Analysis and analysis of medical volume, such as Sielhorst [12]. Luboschik [9] claims that among the fundamental aspects to be considered in Augmented Reality are linear perspective, relative sizes, parallax of movement, binocular disparity. It is also important to show here that AR allows us to understand how a program works, that is, the effect of an algorithm on a data structure. To illustrate the visualization technique presented in this work, the visualization of family trees in 3D was chosen as a case study. In times of pandemic, a tool that shows medical information can prove to be useful for relating, for example, hereditary and relational diseases.

The purpose of the proposed visualization technique is to allow the user to understand the effects of an algorithm on a visualization structure and / or database, reducing the degree of visual disturbance. Unlike a two-dimensional presentation, in which a greater amount of information, colors and shapes tend to negatively influence the abstraction of information by the user, the three-dimensional system allow a amount of data, colors and shapes, without leaving the environment overloaded with secondary information.

Once the developed prototype is executed from the *browser*, it is possible to add external content to the hierarchy, presented as web links, images, complementary texts, among others. We will present in the next topics the tools used to validate the prototype proposed here.

3 Construction and presentation of the tree

With the prototype, the user can build a tree containing different types of information. The library *AR.js* is a lightweight open-source library for Augmented Reality on the Web, which supports features such as Image Tracking. It is essentially a JavaScript framework acting as a port of ARToolkit. Their goal is to be able to use AR on web browsers without losing

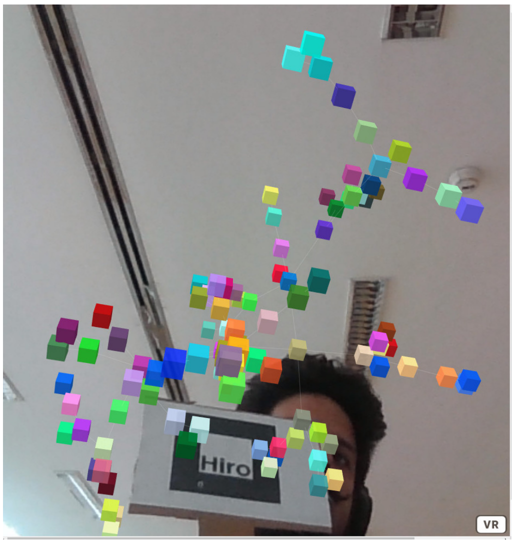

Figure 6 Example of Graph with links in Augmented Reality.

performance. One of the advantages of using this type of technology is that it can run on old hardware, such as old smartphones, enhancing user accessibility. The library is web-based, using components such as **Three.js** + **A-Frame** + **jsartoolkit5**.

The prototype is using 3D Force-Directed Graph in AR, which is a web component to represent a graph data structure in Augmented Reality using a force-directed iterative layout. This makes use of *AR.js* with A-Frame for rendering and *d3-force-3d* for the layout physics engine.

Each node in the hierarchy can represent any type of data. This information is distributed in volumes. Moreover, in the case of two nodes being more closely connected, we created a type of relation named "marriage", which also has the literal meaning in a use case of a family tree. This relation is represented by a node with a color red as seen in Figure 7.

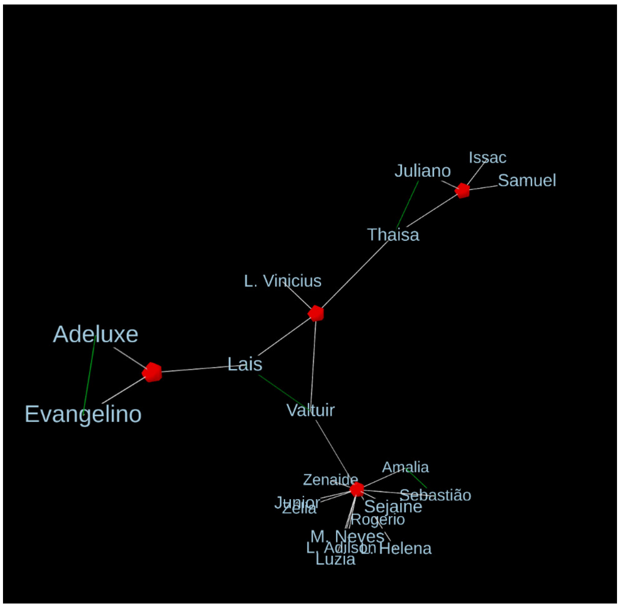

Figure 7 Example of Family tree in Virtual Reality.

After the tree is generated, the user can interact with the nodes and said information by accessing different context menus. Within these menus, it is possible to search the information of each node as well as insert a new node. The system is also capable of saving or loading a tree in a specific *JSON* format see in Figure 8.

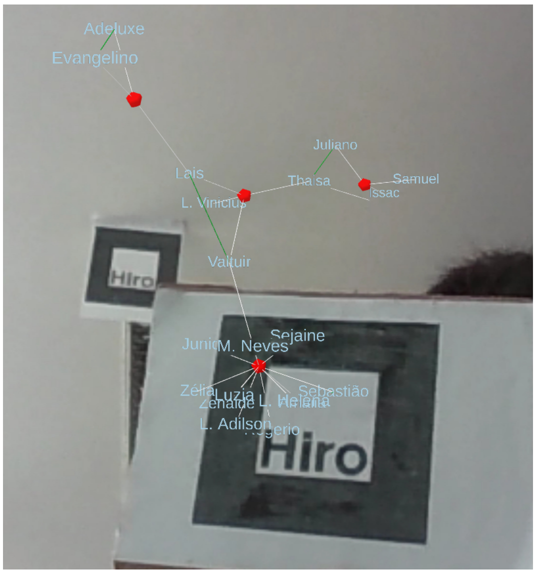

Figure 8 Example of Family tree with Augmented Reality.

It is important to emphasize that the prototype allows the addition of a new element, the visualization of the addition of that element is animated and happens in real time. Taking advantage of the best practices of AR, it turns out that the effects can be used to teach structures such as Lists, Stacks and Queues. This concepts are better understood by students if we use appropriate analogies created by AR.

An important attribute of virtual systems is their navigation and interaction with the user. Once the family tree is built, the user can access, within each node, the complementary information, for example, personal data, professional data, or medical data. Each node has a *JSON* object representing the information that it contains. To view and edit the node information, a text area is available for the user, as seen in Figure 9. After saving new data, it is verified if the input of the user has a correct *JSON* format.

Using the tool, detach the nuances of using Augmented Reality to the usual one used to increase and decrease the scale of the graph. Navigation allows the user to identify connection points, thus locating family members. The Figure 9 presents one of the chosen family nodes and the personal data area. When the hierarchical structure has a large number of nodes, and even with the existing interaction resources inherited from the applied AR techniques, it was created an easy and understandable way for the user to visualize a specific node – a filter (Figure 10) using a search term and evaluating said term with a value.

Using a search term that corresponds to a key in the information object, an expression that can evaluate the filter as “Equals”, “Not Equals”, “Greater than” and “Less than”, and finally a search value, the user can search for specific nodes that match the previous created filter.

After presenting the example described for the construction of the visualization of connected structures and with the possibility of adding information on each element, in the next session, we will present the representation of a tree of visual syntax analysis in AR.

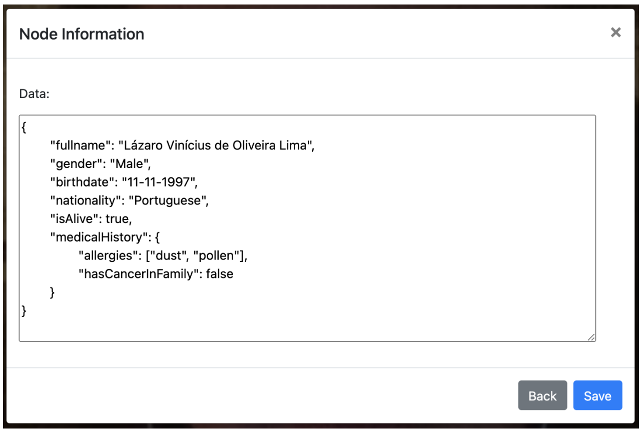

Figure 9 Visualization of one of the nodes in the tree and personal data form.

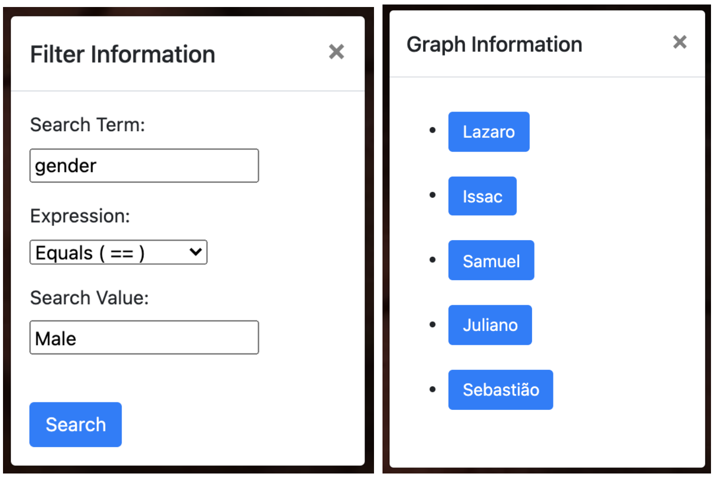

Figure 10 Nodes information of Nodes and Filter Information Panel.

4 Lyntax – Use Case

In order to show the representation of information in depth, one of the use cases of the idea presented in this paper is a tool named **Lyntax**. **Lyntax** is a compiler for a domain specific language which intends to enable the teacher to specify different kinds of sentence structures, and then, ask the student to test his own sentences against those structures. It generates *ANTLR* instructions that correspond to a specific natural language sentence based on a previously created specification. When processed, an *ANTLR* file is generated, which is then processed in order to create a visual syntax parse tree of the input (in 2D), allowing for a better understanding of the sentence. The syntax tree generated can then be post-processed and used to create an AR graph, allowing a even more visual and interactive way of envision the syntax tree.

With **Lyntax** it was possible to verify the application of the ideas presented in which they are successful in explaining the effect of an algorithm on the visualized structure. The results of the tree generated by the **Lyntax** tool using Augmented Reality can be seen in the figure 11 For more information, the tool can be access at `https://lyntax.epl.di.uminho.pt`.

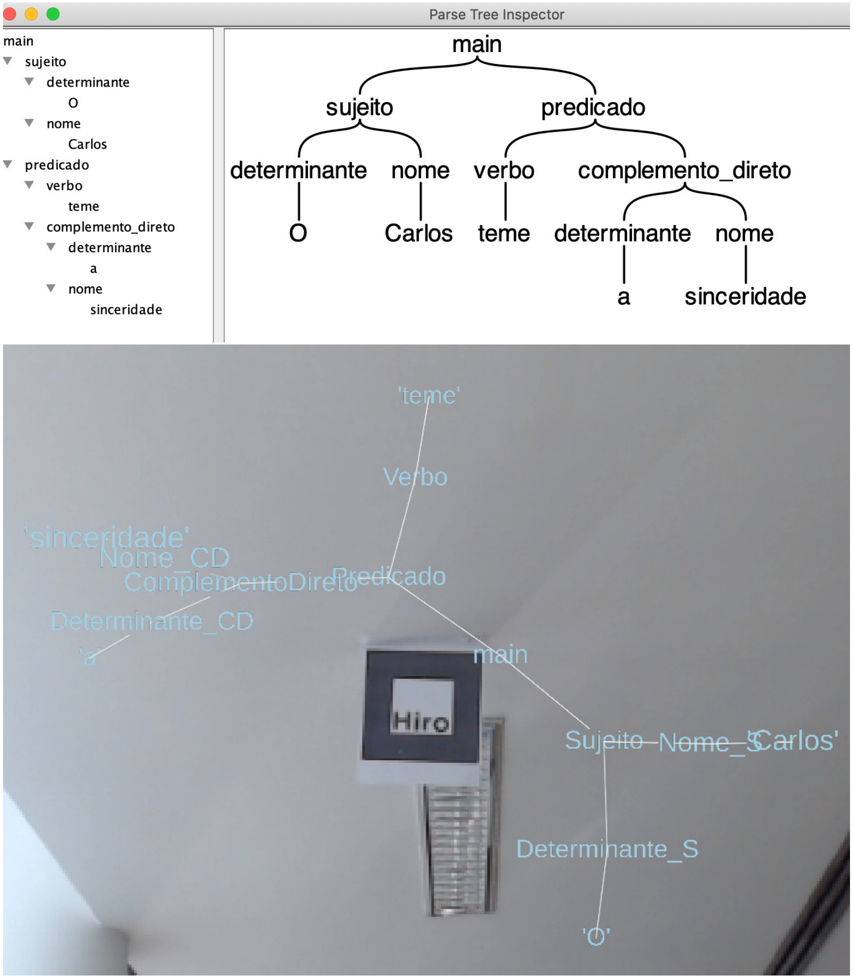

Figure 11 Example of Lyntax in AR.

Each component of the sentence can have different types of attributes in order to have a more enhanced analysis. For example, Figure 12 has a sentence written in Portuguese, in which two of the components (*sujeito* – subject and *verbo* – verbo) have a common attribute, *tipo* (type). This type can be both "animated" or "inanimated". All of the different information that guides each node within **Lyntax** is also ported for the AR graph.

Figure 12 Example of Lyntax component attribute.

The prototype enhances **Lyntax**'s syntax tree, as it allows the user to view each component attributes in real-time. The user is able to analyze the sentence while visualizing the attributes that flow within the syntax tree. This takes advantage of the best practices of Augmented Reality and explores the depth of information in the tree.

5 Conclusions

The prototypes developed in the context of the project here reported, for building trees of words in Augmented Reality, made it possible to apply and evaluate the proposed visualization technique. It should be emphasized the importance of a valid strategy to show a solution to a problem in 3D. The information is presented to users in a simple and objective way, to favor the abstraction of relevant information. For many years we have demanded for appropriate educational tools and now we have the possibility of select and use visualization/animation tools that use 3D and AR to understand complex concepts.

With the referred prototypes, it was possible to corroborate the improvements resulting from the use of the third dimension (depth) to visualize hierarchical structures. Besides, the use of hyper-textual interfaces contributes significantly to the reduction of visual disorder with a large volume of information to be presented. Thus, the proposed AR system allows the user to navigate, interact and search for information within the structure, is an important alternative to traditional methods providing an effective way ti comprehend the effect of the algorithms on a data structure. As suggestions for future work, we intend to discuss the adaptation of the proposed technique to the visualization of different kinds of structures, such as *ConeTree*, computer networks or networking systems, complex chemical molecules, or other type of hierarchical structure. Another idea for future work is the integration of this tool with systems that manipulate knowledge bases. With AR it is possible to create better analogies in order to visualize complex hierarchical structures, such as a list of geographic and temporal information. In addition, the efficiency of visualization of the proposed technique will be investigated,as well as the scalability of the approach. At last, it is intended to explore the Learning Resource in an educational environment to verify its impact when compared to traditional methods.

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