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V. Scarano, R. De Chiara, and U. Erra (Editors)

MightyMind3D.
A 3D Mindmapping Software Using Glove Interaction

F. Turchet[1]

[1]Computer Science Department, University of Verona

Abstract

Nowadays there are several companies offering many different kinds of mindmapping and visual learning software. These products are used every day by a lot people because they are certainly tools that can improve productivity as well as creativity and learning. But all the existing mindmapping programs have something in common: they create maps and diagrams in 2D only. Purpose of this paper is showing the idea of applying the impressive power of 3D graphics to this particular field together with an unusual but suitable way of interaction through a P5 glove: this idea was developed and became MightyMind3D. One of the main goals of this study was to find a good way to show the same information of a 2D MindMap in a 3D space, paying attention to all the possible advantages that could be gained compared to 2D programs. The results achieved are satisfying and the project has many aspects that can be matter of future development.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism

1. Introduction

Nowadays many commercial and non-commercial tools are available to the people who choose every day MindMaps as their favourite way of organizing information.
It's maybe surprisingly enough knowing that more and more people and companies discover every day the power of this tools showing this way that MindMaps can be a very useful tool in everyday life, increasing the productivity both in the personal and working area.
The key to this success is that they reproduce the way of our thinking organizing it in an organic picture containing all the information we desire and in a way that stimulates our brain to recall it.

But the softwares available don't exploit completely the power of the brain. In fact they provide an interface to produce MindMaps in 2D only, while our brain would recognize as more real (and so more effective) a map where concepts and ideas are in 3 dimensions ready to be grasped and created with our hands.
The key idea of MightyMind3D is this indeed: creating the first WYSIWYG editor with which you can create 3D MindMaps with your hands, considering the act of thinking and organizing the knowledge active, fun and effective.
But this idea is not limited only to the possibility of creating MindMaps in 3D: extending maps to the 3rd dimension and using some of the possibilities offered by CG it was possible to add a whole new set of features and value in

comparison with the traditional 2D approach. Impressive visual effects, immersive environment, concepts expressed by 3D models could lead to a new experience of knowledge, going beyond the traditional way of making MindMaps.
A more real and intuitive experience we can say.

2. Main goals

MightyMind3D is the first tool in its genre. Its novelty meant spending a consisting amount of time in the concept and thinking of something that is, actually, new.
No similar references existing meant also proceeding in a design process step by step, often by trials and errors and always in contact with the precious user feedback that lead to improve functionalities in the most useful way.
The conceptual phase started from questions about the main issues of the problem:

- How to render the same information of 2D mind maps in 3D ?
- How to explore and visit the 3D map ?
- Which devices will be used and which ones are the most suitable for our purpose ?
- How to structure a map in a clear way in 3D ?
- Which kind of features should this software have ?
- For which applications could be used ?
- What is the target of this software ?
- Which are the most important implementation details to consider ?

The answers to the questions above lead to the definition of the main goals of this study and can be summarized as follows:

- designing a scene suitable to display information as a 3D MindMap
- design and study of the best way of interaction using a P5 glove
- providing a new kind of interactive environment in which exploring the knowledge
- providing a semi-immersive experience

3. Applications

MightyMind3D is designed to realize tasks that are generally performed with MindMaps : meetings, planning, problem resolution, enhanced creativity, presentations, learning, teaching.
Imagine a lesson or a presentation where you use a 3D MindMap to help your audience focusing on the ideas you are speaking of and providing such an impressive way to help them retain informations you want. Or think of the fun a child or a student could have in learning difficult or boring concepts in such a colorful, creative, stimulating environment. All this is possible with MightyMind3D.

4. MindMaps as tools for Knowledge Visualization

4.1. Information Visualization (IV)

Graphical tools for visualizing data or knowledge are very useful for human perception [CMS99]. In fact, by using *graphical aids*, the human is able to overcome the natural challenges that are involved in the cognitive process [Nor93]. Moreover, the use of computer is crucial in order to increase the automation and improve the user interaction. Therefore, Shneiderman [CMS99] defines the term *visualization* as: *"The use of computer supported, interactive, visual representations of data to amplify cognition"*. In order to design and develop an effective IV application, the *visualization process* needs to be carefully defined. It involves the stages from *raw data* to visual and interactive *representation*. In particular, the visualization process is defined by *Data transformation*, *Visual mapping* and *View transformation*.
Data transformation. Raw data are transformed into data tables by carrying out some data processing techniques such as data set reduction, parameters computation, feature extraction, and so on. It is important to distinguish between *physical* and *non physical* data. The first ones are spatially and temporally well defined. The latter ones are more general and need to be visualized through more complex representations.
Visual mapping. Transformed data need to be represented by effective visual structures. This phase is called *visual mapping*. Visual structures are characterized by the following components:
- spatial substrate: it defines how the space is organized into the visual representation. The space is described in terms of *axes* and their properties. Some elementary types of axes are: unstructured axis, nominal axis, ordinal axis and quantitative axis [CMS99].
- graphical objects or marks: they are the basic components of visual structures such as points, lines, areas, volumes. Marks are characterized by the *marks properties* which influence the human perception. A typical example of such properties are the so called *retina properties*: position, dimension, orientation, color, texture and shape.
- connection and enclosure: they are visual components representing the relationship among the data appearing in the visual representation. They can evidence dynamic flows, trees or graph connections, logical sequences,

and so on. A particular case of data relationship is given by the temporal connection.

An effective visual mapping consists of defining appropriate visual structures according to a specific case study. In particular, data must be preserved and the visual representation must not lead to ambiguous interpretation.

View transformations. View transformations interactively modify and augment visual structures by introducing graphical parameters in order to improve the perception of the analyzed data. Some typical view transformations are:

- **location probes**: it allows the visualization of additional information by using location in the visual structure.

Typically, a *details on demand* approach is defined by displaying *popup windows* or *hierarchical menu.* An effective example of location probe is *linked brushing*, i.e., the cursor passing over one location creates visual effects to other markers. In more details, a selection done in one view should be visible in another view, regardless the different dimensions which may be shown.

- **viewpoint controls**: it allows the changing of the viewpoint aiming at magnifying visual structures and making details more visible. Commonly, affne transformations are introduced such as zooming, pan and clipping the viewpoint.
- **distortion**: it allows one to modify the physical properties of visual struc tures by creating focus-and-context views. Overview and details are combined into a single visual structure.

4.2. What MindMaps are

A MindMap is a powerful graphic technique which provides a universal key to unlock your brain's potential. It harnesses the full range of cortical skills - word, image, number, logic, rhythm, color and spatial awareness - in a single, uniquely powerful manner. In so doing, it gives you the freedom to roam the infinite expanses of your brain. Mind Maps can be applied to every aspect of life where improved learning and clearer thinking will enhance your performance.

A mind map is a diagram used to represent words, ideas, tasks or other items linked to and arranged radially around a central key word or idea. It is used to generate, visualize, structure and classify ideas, and as an aid in study, organization, problem solving, and decision making.

It represents semantic or other connections between portions of information. By presenting these connections in a radial, non-linear graphical manner, it encourages a brainstorming approach to any given organizational task, forming a structure that is easy to understand and remember.

A mind map is similar to a semantic network or cognitive map but there are no formal restrictions on the kinds of links used.

The elements are arranged intuitively according to the importance of the concepts and they are organized into groupings, branches, or areas.

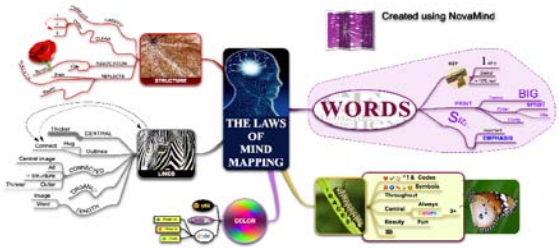

Figure 1: *2D MindMap example*

4.3. Uses

Mind maps have many applications in personal, family, educational, and business situations, including notetaking, brainstorming (wherein ideas are inserted into the map radially around the center node, without the implicit prioritization that comes from hierarchy or sequential arrangements, and wherein grouping and organizing is reserved for later stages), summarizing, revising and general clarifying of thoughts. For example, one could listen to a lecture and take down notes using mind maps for the most important points or keywords. One can also use mind maps as a mnemonic technique or to sort out a complicated idea. Mind maps are also promoted as a way to collaborate in colour pen creativity sessions.

4.4. Origins

Mind maps (or similar concepts) have been used for centuries, for learning, brainstorming, memory, visual thinking, and problem solving by educators, engineers, psychologists and people in general. Some of the earliest examples of mind maps were developed by Porphyry of Tyros, a noted thinker of the 3rd century as he graphically visualized the concept categories of Aristotle.

More recently the semantic network was developed as a theory to understand human learning, and developed into mind maps by Dr Allan Collins, and the noted researcher M. Ross Quillian during the early 1960s. As such, due to his commitment and published research, and his work with learning, creativity, and graphical thinking, Dr Allan Collins can be considered the father of the modern mind map.

Popularized from the 1970s on by Tony Buzan, Mind Maps are now used by millions of people around the world - from the very young to the very old - whenever they wish to use their brains more effectively. Similar to a road map, a Mind Map will:

- Give you an overview of a large subject/area.
- Enable you to plan routes/make choices and let you know where you are going and where you have been.
- Gather and hold large amounts of data.
- Encourage problem solving by seeing new creative pathways.
- Enable you to be extremely efficient.
- Be enjoyable to look at, read, muse over and remember.
- Attract and hold the eye/brain.

As Tony Buzan said by using an explanatory metaphor: MindMaps are “the Swiss army knife of the brain”.

4.5. Why MightyMind3D is good for mindmapping

MightyMind3D complies with the main rules established to obtain a good map.
The development took into account both graphics aspects and mindmapping rules proposed by Tony Buzan, the inventor of Mind Maps.
The majority of rules were accomplished and some of them had to be adapted because conceived for a 2D space and not applicable to 3D. Indeed 3D perspective causes the redefinition of some of the rules as discussed below.

Tony Buzan put together a number of guidelines for creating effective Mind Maps - he calls these the "Laws of Mind Mapping":

1. *Start in the centre with an image of the topic, using at least three colors.*
   The program starts with a root node in the centre of 3D space with the camera looking to it. You can select it, thumb down and add easily an image.
2. *Use images, symbols, codes and dimension throughout.*
   Every node can be an image, just add it. In addition every image can be scaled as you want.
3. *Select key words and print, using upper or lower case letters.*
   Text is displayed in 3D along the branch. But of course it cannot stay along the branch and be readable in a 3D space from every point of view (as happens in 2D); for this reason was developed a system that make the text of the branch you are currently exploring facing the camera and being readable. The program controls the text length and adapt its size for more clear reading.
4. *Each word/image must be alone and sitting on its own line.*
   This happens in MindMap3D.
5. *The lines must be connected, starting from the central image. The center lines are thicker, organic and flowing, becoming thinner as they radiate out. The lines should be curved.*
   Every node is a concept thus becoming a root for sub concepts. Branches are connected to the central node/image. An automatic control rules the thicknesss of branches depending on their hierarchy in the Map. Branches are fully editable, and control points permit to change the degree of curvature easily.
6. *Make the lines the same length as the word/image.*
   This is possible, but only when text is along the branch. When you are exploring its branch, it must be facing you so it's perpendicular to the branch. This is not a limitation, just the only way to render readable text in a 3D space.
7. *Use colors - your own code - throughout.*
   Changing colours is easy. You can colour your map giving hue to text, labels, branches and nodes.
8. *Develop your own style of Mind Mapping.*
   The program offers the tools, and leave the user to express freely his imagination .
9. *Use emphasis and show associations.*
   Even if not yet implemented, many visual effects can be used to enphasize parts of the map.
10. *Keep the MindMap clear by using Radiant hierarchy, numerical order or outlines to embrace your branches.*
    Hyerarchy is achieved by a control system that scale automatically both branch and node dimensions. The final result is a map that radiates from the central node, but in 3D.

5. Implementation

5.1. Interaction devices

The most intuitive way of interaction in an editor such as

MightyMind3D is a glove, because the mouse only would give a poor spatial experience. For this reason a P5 glove by EssentialReality was chosen as primary input device (coupled with the keyboard).
The P5 (which production has stopped a few years ago) is an innovative, glove-like peripheral device, based upon proprietary bend sensor and remote tracking technologies, that provides users total intuitive interaction with 3D and virtual environments, such as games, websites and educational software.
This device revealed as a good way of interaction in the 3D scene although showing also its limitations such as limited angle of the receiver tower and lack of a good rotation and position precision.
For this reason a filtering was needed and an implementation of a Kalman filter was used, adapted to the Linux driver.

Because of the unusual device a new interaction language was developed. We can say it is part of the main family called in general "gestures".
This language is as close as possible to natural and intuitive movements and was developed mainly to substitute actions normally performed with the mouse, that was completely removed as a way of interaction. Many key bindings were substituted too.
So glove movements have taken place as primary way of interaction and this has brought to imagine all the possibilities the new device could offer in terms of number of single, non ambiguous movements.
All the "glove bindings" were duscussed and experimented together with the users who tested the program.
This was one of the most difficult parts because some movements well suitable to a user hand could be not easy for another user, due to different hand conformation and finger coordination.
However easy combinations of finger flexions and hand movements were found, as users reported. For example the branch action is activated by a movement that resembles that of the Marvell hero Spiderman, being in this way much more easy to learn.
In particular a good idea was to reuse same movements (the most easy ones) in different modes: this solution avoided the introduction of too many finger combinations to remember.
The GUI is very simple: the right part of the screen contains a vertical menu that adapts to the current mode, while in the botton left corner are shown finger bending values and other useful information like the length of the branch currently being drawed.
Vertical menus contain a clear image of each possible action you can perform in the current mode. Both colorful icons and text were used to express the action.
An important note to underline is that every edit you can do is done in WYSIWYG mode : for example you can edit colour properties and see the changes applied in real time.

5.2. Rendering Engine used

MightyMind3D is written in C++ and is based on OGRE graphics engine for the rendering part.
OGRE was chosen for several reasons such as : it's cross platform; it has well documented APIs; it benefits of a large community support; it's for sure one of the best opensource engines available.
The program was developed on a Linux box using libp5glove driver.

5.3. Creation of a Map

The program operates mainly in two modes: Editing Mode (by default) and Explore Mode.
In the first mode the user can add nodes, branches, and multimedia data to the map while in the second she can explore the map controlling the camera with the glove.
In MightyMind3D you can easily link different types of information: text, images, audio, video.
The elements containing this information are nodes and branches.

The creation of the Map is the phase in which all the usefulness of the glove can be expressed.
This part of the program was developed keeping always in mind the importance of a good usability and the enjoiment the user could have in using his hands for creating the map.
Creating the map is possible switching to **Editing Mode** (button A).
In this mode the user can create/edit all map elements:

- select a node
- draw a branch from the selected node an edit its curvature
- move around with the glove to position the new node: branch orientates and follows movements
- editing of the position of the node grasped: branch follows movements
- walk through nodes in an easy way
- save the map (XML format)
- load a map (XML format)
- edit all node information
- edit branch text
- edit branch text colour

- edit branch colour
- edit label text
- edit label colour
- add a long text note
- add Image or Image Set
- add Video
- scale node
- change node mesh (i.e. adding 3D models expressing concepts)

Especially with operations such as the movement of the nodes (grasping) the glove showed as the best device could be used for this kind of software , making the tasks pretty intuitive, enjoyable and easy to learn.

5.4. Exploration of a map

Using the glove made it possible to stress the spatial relation between concepts, one of the information our brain uses for memorizing and remembering.
The 3rd dimension offers indeed an easy way to find information because paths to ideas are similar to every day life experience: you can remember easier a way from your house to a destination if you made it personally. The same happens in MightyMind3D where you can run through concepts as they were roads.
This is obtained by mantaining a first person view and by binding glove movements to camera animations. The idea of exploring the 3D Map this way didn't appear clear at first when was preferred giving full freedom to the user in the movements; but soon this freedom turned out in a drawback because of the energy-expensive movements to change from a node to another.
Moreover it took quite a lot of time learning how to freely move the camera without any help.
So it was necessary to search for an easy way of exploring the map without getting tired soon and the animation sistem was a good, eye-candy solution.
Exploring the Map is possible switching to **Assisted Explore Mode** (button A). In explore mode the user can walk through the nodes, zooming in and out , watching to videos, moving back and forward through image slideshows, reading the branch text. For each action a camera animation is activated to assist the user and put contents under his view and not viceversa; all nodes always face the camera direction in fact.
The user can move through the nodes along these directions:

- from father to a child
- from a child to the father
- from a node to the next brother on the left or on the right

In this mode the user can:

- walk through nodes in an easy way
- zoom in and out
- move back and forward through image set
- watch to a video

In addition to the assisted mode, the user is able to use a **Free Explore Mode** in wich is possible to move completely freely the camera with the glove.
Finally, a **Relax Camera mode** can be activated when the user wants to pause the glove : in this mode none of the glove signals is received and you can relax your hand while watching to a video without worrying about movements.

6. Results and examples

Below is shown the result of the conversion of a branch taken from a 2D MindMap using MightyMindMap3D.

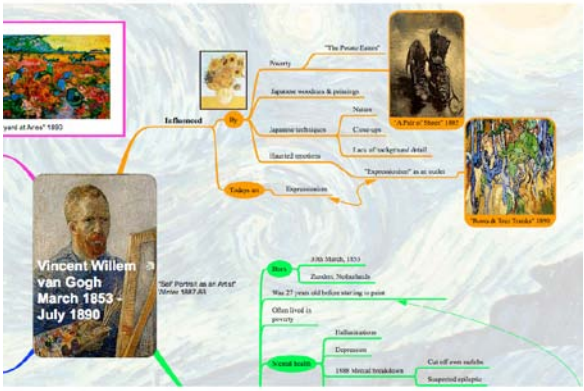

Figure 2: *"Influenced" branch of 2D MindMap on Van Gogh*

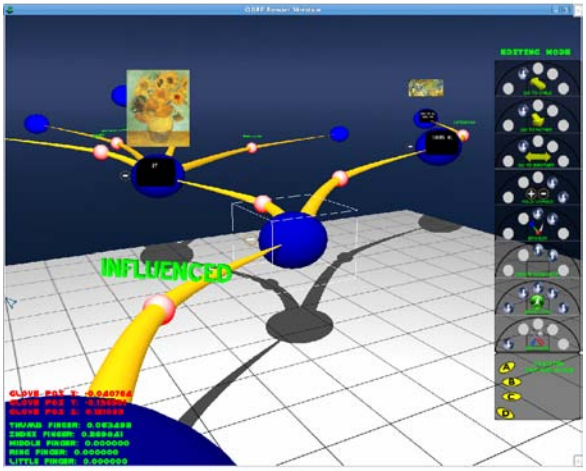

Figure 3: *"Influenced" branch in 3D*

One can always have the overview of the whole map from

different fixed positions of the camera. Below is the front view:

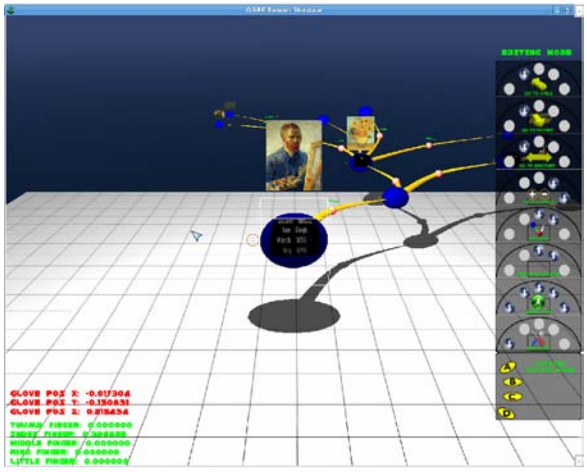

Figure 4: *overview of the map from front camera*

During the navigation the text of the current node enlarges, while the text of its brothers becames small. This is useful because gives attention to the current information you are exploring. Red points are control points for the editing of branch curvature : grabbing them and moving the glove around causes the redrawing of the branch mesh in real time.

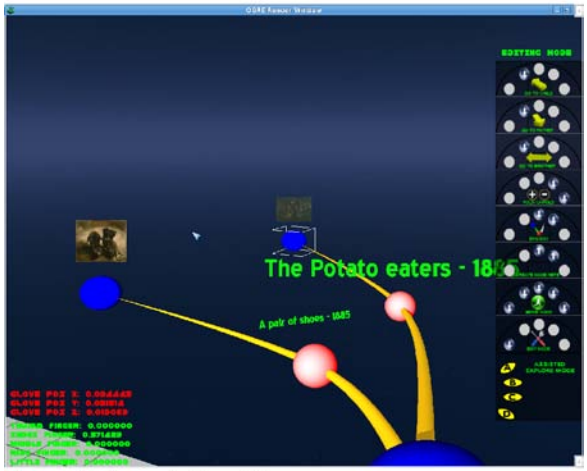

Figure 5: *A particular of the map*

The figure below shows the gui used to edit node characteristics including text, images, video and aspect:

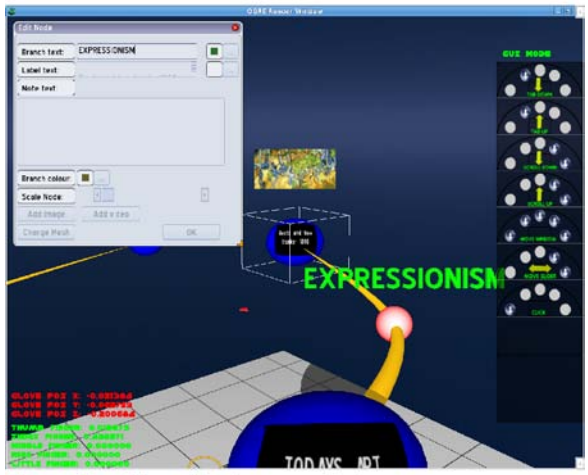

Figure 6: *editing of node properties/aspect*

7. Conclusions and future works

7.1. Main advantages of a 3D MindMapping environment

Using a 3D MindMapping software provides several advantages over a normal 2D tool.
The main advantage is of course the spatial information.
Spatial information helps brain in the memorizing process because the world is in 3D: this kind of information is everyday experience so the result is a much more natural approach to the use of the map.

We can say we think in 3 dimensions, not in 2 only. Even if the scene is virtual, the active action of exploring helps in fixing information making the mindmapping an immersive multisensorial tour : the more we are involved in an action, the more our brain is stimulated and therefore the learning process takes benefit.
A glove was chosen indeed as main channel of interaction keeping in mind that to achieve a more natural approach in a 3D space we need to use different devices from the usual ones.
With MightyMind3D you can grasp concepts with your hand and move them where you want : actually you are moving concepts in your mind.

A 3D scene can offer a more powerful graphic impact and this is another reason why this approach works. You can edit the scene as you want creating the right environment suitable for the map you are creating. You can edit the sky, the terrain, the light, the shadows, add particle and highly-impressive visual effects, add models. Personalizing is very important in mindmapping and visual

effects nowadays available (just think to last 3D videogames) can really make mind maps even more powerful.

Summarizing, main strengths of 3D mindmapping are:

- huge choose of visual effects
- spatial environment, 3rd dimension information
- highly customizable scene
- much more freedom in creating the map
- much more natural experience
- much more fun and involvement
- much more stimuli for the brain

7.2. Future works

The program can be improved in several ways. According also to the testing phase made with users, the following features should be added :

- Use of speech recognition to replace keyboard text input
- Use of gesture recognition systems to replace the glove and enhance hand freedom
- a library containing icons, pictures, 3D models categorized by topics to help the user in the creation of the map
- visual and graphic effects useful to emphasize mind map concepts (nodes) : clouds, animations, light effects and movements to attract the attention on a particular part
- more customization options like the choice of Font type and size
- algorythms which arrange automatically nodes in a clear organic way
- algorythms which arranges neighbours after the movement of a node
- use of glove rotations : a Kalman filter for rotations is necessary
- import maps from existing 2D programs
- internal utility for glove calibration

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