Comparison of Emerging Information Visualization Tools for Higher Education

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***Abstract*—Information Visualization online tools have gradually found its way into various contexts of use and Higher Education Institutions are not an exception. The considerable amount of data and information continuously produced in Higher Education Institutions provide Information Visualization professionals an interesting set of challenges which, if looked through a broader perspective all share a common goal: to assist and contribute to decision making. However, tools presently available, or in an ongoing stage, take different approaches regarding interface, interaction and goal design in Higher Education Institutions, Information Visualization tools. This paper presents a review and analysis of some Higher Education Institution Information Visualization online tools, according to an up-to-date theoretical framework. Its conclusions include some final thoughts on what is driving, or not, work and outcomes in this particular context of use.**

Keywords-Information Visualization; Higher Education; emerging tools

I. INTRODUCTION

Information Visualization (IV) is being used in many fields including Education, with the purpose of sharing to a wide range of public related data, conveying information of interest to institutions, general public at a social and political level.

Handling and exchanging information is part of the information and knowledge society, emerging as a pressure from within the knowledge driven economy [1-3]. In many types of works, handling data and processing information in the digital form is part of everyday activity [4]. In Higher Education (HE), the focus of this paper, digital technologies have allowed the handling, access and manipulation of massive data-sets, to benefit research, help to visualize more complex systems and strengthen international communication and collaboration in research [5]. But many international data bases only allow data to be used for the purpose of research and knowledge transfer, preventing wide public to have access [6]. Although there are a great number of online open databases to be used, data available is vast and disperse, making it a time consuming task to access all the data that we want to work with. As Eick [7] states, "with the growth of networking and decreasing cost of storage it has become technically feasible and cost effective to store and access vast sets of information. The academic, business, and government challenge is how to make sense of this information and translate the insights into value producing activities". In a knowledge economy, information is relevant for all the stakeholders of any field, and HE is but one the many fields that are gradually grasping the advantage of the adoption of IV solutions in activities linked to decision making.

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DOI 10.1109/IV.2012.27

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II. STATE OF THE ART

In this paper, IV is broadly defined as computer driven visual representations of data interface [8], although more recent authors call for the need to define IV not only by the technology it involves, but also regarding the relation, with aim and context it wants to reach [9].

In 1957 computer processing was first used for statistical data representation, evolving to interactive statistical applications [10]. Further in 1987 the term visualization was first used by McCornick, to describe how interactive graphs and scientific visualization which began to be understood as valuable for data analysis and to deepen research, as well as a tool that would serve to draw the experiences [11]. IV is an area of interest to anyone who wants to represent data efficiently, among which are researchers and academics [12]. More recently, interest in IV has been growing, integrating artists of programming and design data, scientists interested in art working with the information in the form of digital art with the power to engage users and make their experience more visually interesting [13].

With the widespread use of the web as a work tool, concerns with user friendly interface and interaction design have taken center stage in this powerful medium. It may also be said that the whole web 2.0 phenomena has contributed to the importance of interface and interaction design, alongside issues related with usability and accessibility, due to its focus on the participation and collaboration activities developed by users when they interact, produce and share content and information.

The Web 2.0 phenomena, and its participative nature, has also allowed a huge amount of data to be available and shared online, in multitude forms through an unpredictable number of manners. Several authors however agreed that current challenges within IV involve: finding ways of making sense of that data, converting it into meaningful information and knowledge [7, 14]; making sense of the increasing dimensions and data complexity provided by user pro-consumption; finding patterns and making connections towards a better understanding of the data and information produced [14-16]; and how it may be made available to specialists and non-specialists web users.

The evolution of IV has enabled it to become massive, with IV tools used worldwide by recognized governmental and non-governmental organizations, institutions, services, entities, which have realized the power of this type of communication and understanding of data and information on a large scale. IV is dealing with data and information such as statistical quantitative data (i.e.: Census Bureau data, national and international reports); bibliometric data concerning the quantity of scientific publication, that can help define a research profile of the HE institution or department [6] (i.e.: Web of Science, Scopus and Google Scholar). In both cases some datasets are open and of public use, while others can only to be used for research and knowledge transfer, for particular contexts and environments [6].

In the case of data concerning HE, if the vast majority of data and deriving information is not available from open databases, this means that it will need to be collected directly from institutions, a time consuming task for whomever collects data and for institutions who may be see it as a burden [17].

Over the last few years IV has also gone beyond its focus on individual singled out objects with their own sets of variables, to increasing the number of tasks of comparison of complex data [18]. Complex networks represented in IV can be seen through Manuel Limas' work of aggregation of a set of 772 IV projects[1] of different visualization methods and disciplines, presented in the website 'Visual Complexity' [14]. Within this website, for the context of HE, up to this date, it is possible to find only one link referencing a paper produced by Ortega, et al. [19], which aimed at mapping the web presence of the European Higher Education Area (EHEA), regarding the hyperlinks used by universities towards analyzing the topology of the European academic network. IV contributed towards mapping university linkages, showing visual relationships between themselves, showing the complex networks [20], contributing towards a greater sense of transparency in HE.

European Higher Education Area (EHEA) calls for greater accountability and the need to make European HE diversity transparent, through the development of mechanisms for providing more details about HEI such as: benchmarking exercises, classifying and ranking HEI study programs, creating quality profiles, and offering comparable information on Higher Education Institutions (HEIs)/study programs [21]. Data regarding HE is valuable to decision makers, and its visibility on the web may give institutions prestige, helping them attract students, scholars and financial investment [19, 22]. Relating this to the aim of the TRACER project, presented in the introduction of this paper, the usefulness of an IV tool becomes clear for it may contribute for students decision making. Pratt and Palloff [23] state the knowledge of how wired the HE institutions are, helps students determine which HEI to choose to apply to and attend. This evidences that making this information available, through an IV tool is of interest and may influence decision making by institutions and users.The stated interest and need for transparency, has led the European Comission to support the creation of a set of 4 online IV tools, to map diversity of HE and characterize HEI according to their autonomy, mobility, ranking and classification:

- U-Map 2 , a European classification of HE institutions, a tool active online that calls for the institutions participation in updating information;
- University Autonomy in Europe3, ranking countries according to organizational, financial, staffing and academic autonomy, active online tool;
- U-Multirank4, a global university ranking tool, that calls for the institutions participation in updating the data;

[1] http://www.visualcomplexity.com/vc/ accessed at 21/02/2012
[2] http://www.u-map.eu/
[3] http://www.university-autonomy.eu/dimensions/organisational/

- MAUNIMO[5], a tool aiming to draw attention to various forms and types of academic mobility - this is part of a project which is at the initial development stage, and does not have available the proposed online tool.

In all the IV tools mentioned above, HE institutions were directly contacted in order to obtain the data and information needed for each tool and its particular goal. It was also set that the projects update was and is dependent of their continuous collaboration in order to feed the tool with up-to-date data and information. Collecting this sort of data and information is a time consuming task, usually done through a survey and a coordinated search within existing databases. Besides time consuming it also requires the researcher to: find the data and information in case it is open access and making a careful collection of it taking in consideration its context [24]. So, if that is such a hassle why bother? The Web can hence be used as a way to attract students, scholars and funding from other places, spreading the prestige of these educational institutions nation and worldwide. This raw yet true fact has provoked competition between universities to achieve an advantageous visibility on the Web and to improve their position in search engine results. The following sections of this paper present some additional aspects of the theoretical framework where they are deconstructed according to their direct use in the HE IV tools comparison and analysis.

III. METHODOLOGY FOR THE SELECTION AND COMPARISON OF IV TOOLS FOR HE

To select the IV tools regarding HE information a systematic search was undertaken from September 2011 to February of 2012, using the key words: higher education, Information Visualization, tool, mapping tool. The search was performed on the websites: Information Aesthetics[6], The Chronicle of Higher Education[7], the Google search engine. The search resulted in a total of 4 IV tools representing data regarding HE and aiming to classifying, and rank HE institutions. We have selected only 3 IV tools which have been published online or have a final report detailing the aims, organization, interaction and design of the tool.

To establish a comparison between the set of 3 IV tools, a search was undertaken by searching in the Scopus database, Springer link, and IEEE Xplore digital library using the key words: comparison, Information Visualization, tool, Higher Education. A total of 3 articles where accessed and analyzed in order to structure a comparison of the selected IV tools. The results led us to propose 3 tables to establish the comparison of the set of tools:

- table based on the taxonomy of tools that support the fluent and flexible use of visualizations proposed by Heer and Shneiderman [25];
- table based on the proposal of visual comparison for IV, by Gleicher, et al. [18]. Both the work of these authors focus in a more broad analysis of IV and its design;
- table to allow the comparison at a deeper level of the patterns in the IV tools, according to the compiling of visualization methods by Behrens [26] - see Table1 presented in this paper.

IV. COMPARISON SETTING OF IV TOOLS FOR HE

The aim is to understand how information and data are being visually presented in the 3 selected IV tools for HE.

A. Tools selected

As result of the search performed, there were 3 IV tools regarding HE selected, of which will be made a briefe description: i) U-Map, European Classification of HEIs; ii) University Autonomy in Europe; iii) U-Multirank.

U-Map tool: a classification tool of European HEIs, of an ongoing project (see *Fig. 1* bellow). This tool gives the user a list of HEIs with a description of the profiles through 6 comparable dimensions. Users select the dimensions more relevant for their need of information, visualizing specified profiles of HEIs. The graphical presentation of data is in sunburst charts to illustrate institutional profiles, comparing side-by-side up to three HEIs [17]. The data of U-Map tool through time will be updated by HEIs who will have a registered profile, and reviewed by the administrators of the tool.

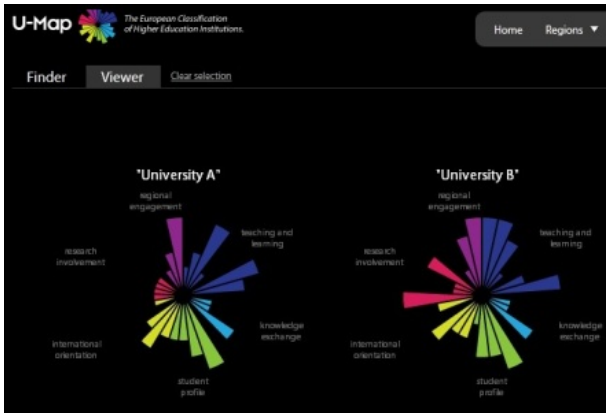

Figure 1. Printscreen of the U-Map tool

U-Multirank tool: a global multi-ranking tool, aiming to allow users to select HEIs performance indicators according to their own preferences and priorities, and define the institutional profile they are interested in and hence the sample of institutions to be comparing, gaining a detailed view of institutional profiles (see *Fig. 2* bellow).

[4] http://www.u-multirank.eu/
[5] http://www.maunimo.eu/
[6] http://infosthetics.com
[7] http://chronicle.com/section/Home/5

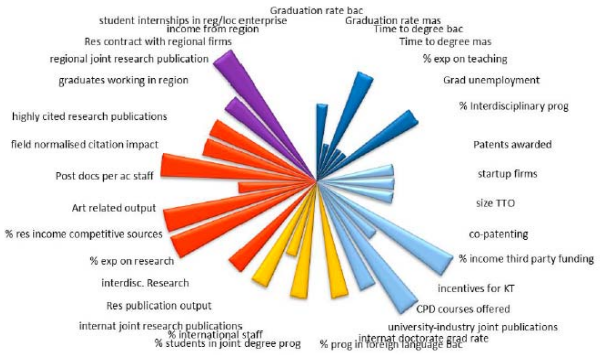

Figure 2 Sunburst representation of an institutional performance profile

The creators of both U-Map and U-Multirank believe these tools offer a new approach to user-driven rankings [17]. The institutional profiles rely on multidimensional rankings, already created in U-Map, adding to the user the possibility of selection of dimensions and of a set of institutions they want to compare in a focused ranking [27]. Regarding the comparison allowed by U-Map, Federkeil et al [27] in a critical perspective over these two tools, state that it does not make sense to allow comparison between institutions with such different profiles.

University Autonomy in Europe tool: lets the user compare 28 HE systems regarding their academic, organizational, financial and staffing autonomy (see *Fig. 3* bellow). The visualization is allowed by a graphical representation in the sunburst-like which represent unique indicators made up by multiple colored squares. The more autonomous the HE system is, the more colored squares there are. A high score on an indicator or autonomy dimension indicates that the relevant regulations provide a legal framework without restricting universities in their freedom of action.

Figure 3 Pintscreen of the University Autonomy in Europe tool

B. *Tools comparison*

We propose three tasks of comparison, focusing on the design and interaction patterns of the tools, sustained on the work of the three authors referred in methodology section of this paper. It is important to take into consideration the two following notes: the U-Multirank tool is not active online, and was analyzed according to the information obtained in the final report published [17]; analysis of the U-Map tool focuses on the online available demonstration mode.

The first comparison task is based on the fluent and flexible use of visualizations proposed by Heer and Shneiderman [25], adopted to understand how the visualization is helping the user to make sense of data. The authors present a taxonomy of interactive dynamics that contribute to successful analytic dialogues, consisting of the group of three high-level categories, with a total of 12 task types [25]:

Category 1: data and view specification (visualize, filter, sort, and derive): in this category the strongest task integrated into all the three tools, is allowing the user to filter out data to focus on relevant items. This means users have a limited data view specification options.

Category 2: view manipulation (select, navigate, coordinate, and organize): the view manipulation is the strongest task allowed by all 3 tools, were the user is enabled to select items to highlight, filter, or manipulate, as well as to organize multiple windows and works paces, although the U-Map offers only two window work spaces, and to coordinate views for linked multi-dimensions. This highlights the visual manipulation as strong quality of these tools. Within this category the only task not made available by any tool, is the navigation to examine high-level patterns and low-level detail, meaning that what the user sees is what the user gets in terms of the patterns produced.

Category 3: analysis process and provenance (record, annotate, share, and guide): the most fragile category, almost non existing integration in the tools. Only one task in tool is included, the University autonomy in Europe, guides their users through the analysis tasks or stories of the data. Sharing or recording is not implemented in any tool, meaning that the user cannot keep its history of interaction within the tools, collaborate or share visualization.

The second task of analysis consisted in comparing the designs of visualizations, core in IV. The proposal of visual comparison by Gleicher, et al. [18] brings us to a brief comparison the tools regarding three categories: Category 1) juxtaposition, the design of each object is separate; Category 2) superposition, multiple designs show multiple objects in the same coordinate system (i.e. on top of one another); Category 3) explicit encodings, represent the relationships that directly visually encodes connections between objects.

The analysis of the tools, done in a checklist like way, revealed that the only visual category used in the design of all the tools was the juxtaposition, and that all have adopted a sunburst layout, implementing a partition layout [28].

Finally the third comparison task was prepared by compiling the visualization methods proposed by Behrens [26], allowing a comparison of the design patterns for interactive IV, providing an overview of methods with elements of the display, behavior and interaction patterns, as shown in the *Table 1* shown below [26]:

TABLE I. COMPARISON TABLE OF VISUALIZATION

Visualization methods		IV tools		
		U-Map	University autonomy in Europe	U-Multirank
Display Patterns	Correlations (Scatter plots and Bubble Charts).	no	no	no
	Continuous quantities (Simple Line Charts and Multiset Line Charts).	no	no	no
	Discrete quantities (Simple Bar Charts, Multiset Bar Charts and Stacked Bar Charts).	yes	yes	yes
	Data proportions (Nightingale's Polar Area Diagrams, Pie Charts and Ring Charts).	yes	yes	yes
	Flow diagrams (Sankey's Diagrams and Thread Arcs).	no	no	no
	Hierarchies (Tree Diagrams and Treemaps).	no	no	no
	Networks (Diagram Maps and Relation Circles).	no	no	no
	Spatial configurations (Topographic Maps and Thematic Maps).	no	no	no
Behaviour Patterns	Navigation (Simple Zoom, Local Zoom, Panning,Timeline, Linked multiples and Overview plus detail).	no	no	no
	Filtering (Layering, Active Objects, Boundary Filters, Facet Browsing and Dynamic Query).	yes	no	yes
	Arrangement (Selective Arrangement, Sortable Columns, Custom Dimensions and Isolated Comparisons).	yes	no	yes
	Exploration ("Details on Demand" and DataTips).	yes	yes	yes
	Animation (transition in element's colour or size and element animation).	no	no	no
Interaction Patterns include:	Boolean selection (usually done with interface elements such as radio buttons, checkboxes, and dropdown menus)	yes	no	yes
	Linear adjust (Sliders and double Sliders).	no	no	no
	Spatial navigation (Drag and Drop and SelectionMasks).	yes	no	n/a

Comparison table adapted from the visualization methods proposed by Behrens (2008)

The results show that the display patterns of discreet quantities and of data proportions are a common option in all the tools. The U-Map and U-Multirank tools, allow the users to have behavior patterns such as filtering the information to access and arranging it facilitate understanding and comparison tasks, and allowing for a deeper exploration of data and information by giving details on demand as well as data tips. The interaction patterns most common in use are the selection of elements by interacting with the checkboxes or dropdown menus of the interface.

In all tools the visual presentation of data is done in a sunburst layout, as it is possible to see figures 1, 2 and 4, and in the U-Multirank final report [17]. Each sunburst line represents a unique indicator, made up by its length, or a multitude of squares. In University Autonomy in Europe the more squares are filled, the more autonomous the higher education system. A high score on an indicator or autonomy dimension indicates that the relevant regulations provide a legal framework without restricting universities in their freedom of action. The main differences between these U-Map and University Autonomy in Europe tools, is that the first allows a comparison between 3 institutions simultaneously, each represented by one independent sunburst for the institutions profiles and characteristics [17]; and in University Autonomy tool, comparison is not allowed by putting the sunburst graphs side by side, arguing that some characteristics do lend themselves to international comparison [29]. The issue of comparison of institutions is also predicted in the U-Multirank tool report, stating "the integration of the already designed and tested U-Map classification tool into U-Multirank enables the creation of the user-selected groups of sufficiently comparable institutions. This two-step approach is completely new in international and national rankings" [17]. Because these tools are recent, there is no timeline behavior.

V. DISCUSSION OF RESULTS

The analysis of the data and view specification revealed that concerning all categories, the three set of tools U-Map, European Autonomy in Europe and U-Multirank, are very similar in the visualization and interactions provided, and that all are result of projects supported by the European Commision. The similarity between both U-Map and U-Multirank is explained as a result of the first tool developed - U-Map - having prepared the ground for the second tool [17]. Nonetheless, all tools have in common the adopted the visual presentation of data in a sunburst layout, and only offer one type of visualization method, what in our opinion, this makes this set of tools limited in what it concerns the exploration of visual displays and interface interactions design.

In such a strong social web context, it is noted that none of the IV tools allow the user to collaborate, annotate or share visualizations. There would be advantages if these tools, created with the aim of contributing towards transparency of HE, would allow the user to save the result of his interaction patterns with the tool: careful interaction by filtering the variables and dimensions of interest, to be able to export that visualization or share it with others on the web.

VI. CONCLUSIONS

The limited number of IV tools for HE can be somewhat justified with the fact that this sort of outcomes are relatively recent in this particular context of use. Pioneer projects, such as U-MAP, have started dealing with these issues in 2008. If considered that rankings and institutional comparisons are still very sensitive issues one may easily understand the need for in-depth thought and much consideration before investing time and resources in the development of such tools. There is much discussion about which should be the appropriate ethical and methodological practices adopted by the network of HEIs. However, the diverse landscape of HEI makes reaching a consensus close to impossible. HEI may agree with comparing themselves to the "big picture", but never to variable based comparison with their peers. This has been a very important issue still under-discussion within the U-MAP project.

Their aim is to promote transparency of the HE area, and not to rank comparatively the HEIs. It is also important to take into account, the fact that all data had to be collected and validated directly with the HEIs, a time consuming task. This may justify the lack of temporal comparison of data in all the tools.

Regarding the layout and interactive patterns of the tools, we can conclude that although the selected IV tools fit under the umbrella of interactive web tools, they offer limited interactive patterns, and sets of variables to compare. The visual layout of the tools are similar, lacking diverse layout exploration. None allow the user to share or export the visualization created as a result of their interaction, filtering and arranging within the tool. Not taking advantage of the knowledge transfer via social web.

One final observation worth making is that, despite the fact that the IV tools present data and information which may help in decision making or future research, none of the tools suggest any improvement aids nor best practices for cases where there is still room for improvement. This could eventually be the next goal for future work on online IV tools proposed for the HE area as an aid for improving current practices through proactive and reactive analysis.

ACKNOWLEDGMENTS

This work was partially supported by the Portuguese Foundation for Science and Technology for financially supporting the project under the reference PTDC/CPE-CED/113368/2009 COMPETE:FCOMP-01-0124-FEDER-014394.

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