A Brief History of Virtual Reality in Brazil

A survey over the publications in the "Symposium on Virtual and Augmented Reality"

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Abstract— **Virtual Reality (VR) is becoming a mature technology field. To understand its origins and foresee strategies, a study on the last decade of papers published in the Brazilians´ most prominent symposium (the SVR – Symposium on Virtual and Augmented Reality) has been carried out. Papers were classified according to subject of study (including application domains, sub-areas and technologies, among others) as well as research structure (including authorship counts and geographical distribution, research approaches, among others). The study shows that health related applications have received most of the attention although techniques and tools proposal have raised the most recently which could be related to the low-level programming languages and frameworks preferences found to this community. The number of Augmented Reality (AR) papers has grown steadily and a great variety of underlying knowledge fields (such as 3D interaction and real-time simulation) is a persistent aspect of SVR. Data also show that expected shift from VRML to other 3D Web technologies have already happened. Although oversees participation has been not constant, papers published in English has proven stable in SVR editions. Few institutions from Southeast have dominated the research area but another few from Northeast have just surpassed them. Regarding the research, a lack of higher-level maturity research approaches has been noticed. In addition, it was found difficult to assess the relevance of papers to other researches due to poor abstracts and no centralized database of papers. The analysis of 262 papers suggest that (i) by improving the research budget to the area could impact productivity; (ii) a centralized database would facilitate recovering past contributions and; (iii) that enforcing more scientifically rigorous papers with better abstracts and written in English could raise the visibility of Brazilians´ research in VR/AR.**

Keywords—Virtual Reality; Augmented Reality; Brazil; History

I. INTRODUCTION

The Brazilian Computer Society - SBC - is a scientific association composed by researchers, students, professors and professionals dedicated to education, research and technology development of computing area. Established in 1978, SBC is composed by several forums according to specific areas of computing science. The Special Commission on Virtual Reality – CERV - is one of those forums which is focused to knowledge transfer among Virtual Reality (VR), Augmented Reality (AR) and related areas practitioners in Brazil. Annually CERV promotes two scientific events as a result of its strategy for VR/AR research improvement and knowledge widespread: First, is an international event called Symposium on Virtual and Augmented Reality (SVR) which accepts English publications and has foreigners as reviewers; The second one is called Workshop on Virtual and Augmented Reality (WRVA) and is still restricted to Brazilian community and strong influence from locals.

The SVR is the biggest conference on Virtual and Augmented Reality in Brazil sponsored by SBC. It is distinguished from WRVA since it presents base research where the main contribution resides in new technology developments and on the improvement of VR/AR area. The WRVA, on the other hand, is mainly focused on applied research solving problems from different areas [1].

Established since 1997 the SVR aims to promote technology advance and knowledge dissemination over Virtual and Augmented Reality. Therefore, SVR is considered to account for the history of the field in Brazil. Recent hype from the computing community indicates the benefits that VR/AR is capable to bring to other areas.

The SVR has been established as a Brazilian traditional scientific event but regardless the effort for internationalization it has not received many international submissions [2]. This means that the symposium has plenty of opportunities to grow and expand its contribution on VR research. One of the best ways to improve such event is understanding its weakness and strengths by means of a study (such as [2] that performed an evaluation of 124 papers from 2004 to 2008).

Surveying representative publications is a way to analyze a certain subject area of research. Such approach was conducted by [3] for the Brazilian Informatics in Education (IE) area where papers from SBIE[1][1] , WIE[2][2] events and RBIE[3][3] journal of the year 2011 have been surveyed. The study presented a panorama of IE research community and have shown that 97,8% of authors choose Portuguese as written language. It also indicated that the majority of published papers came from southern-area of the country.

Since SVR is the most prominent Brazilian forum regarding Virtual and Augmented Reality, the analysis of SVR publications over the years brings glimpses of the historical evolution of the area and related research in Brazil and enables to identify preferences and tendencies for the near future.

[1] SBIE stands for Brazilian Symposium on Informatics in Education.
[2] WIE stands for Workshop of Informatics in the School
[3] RBIE stands for Brazilian Journal on Informatics in Education

The objective of this paper is to present a survey of the latest 10 years of SVR. This paper is an extended version of the paper presented at the latest SVR, in 2014 [10]. The survey will cover two main aspects of the papers:

- Contents, which include the analysis of subjects, application areas, software and hardware technologies used, among others, and;
- Research Structure, which include the analysis of authors′ affiliations, number of authors per paper, their geographical distribution, research approach, quality of papers′ presentation, among others.

Such panorama is expected to help overview the development of VR/AR area to foresee its next moves.

This paper is organized as follows: section II presents related work that shows that the VR/AR scientific community is concerned to understand and evaluate the directions the area of knowledge is taking over the time; section III explains the methodology used in order to analyze the last 10 years of SVR; section IV presents our findings regarding papers′ contents while section V presents our findings regarding papers′ research structure. Section VI presents a discussion on what was found, and; section V presents the conclusions drawn from the data.

II. Virtual Reality – Origins and tendencies

The area has been expanding the number of publications at a fast pace [4]. According to this bibliometric evaluation on world′s publications, a sustainable growth of published papers was identified in the area in the last 25 years. Some expressive increase took place [4]: from 2001 to 2006, the area exceeded ACM publications growth as a whole; from 2007 to 2010, it exceeded IEEE data base growth; Augmented Reality grew over 250% from 2002 to 2006 while Mixed Reality presented 550% from 2001 to 2006. This study pointed out that although Virtual Environment is considered to be a better terminology by many researchers and scholars, Virtual Reality should be the preferred term used by the scientific community in order to avoid misconceptions. The reason for this is that Virtual Environment has been used by other areas to identify a completely different application. However, the study did not differentiate national scientific production against other nations. Thus, it is difficult to see how Brazilians' publications relate to others′.

Some studies focused on specific VR subjects. For instance, [5] evaluated most used RV tools to identify which are preferred by researchers for their projects as well as to identify most used tools to improve the efficiency of the development process. Evaluated tools were categorized according to modeling, rendering, development suites and; specialized tools. Such work is very specialized and did not include the Brazilian context.

In the Brazilian context, some previous surveys show that national VR scientific community is always keen to understand the past in order to plan the future.

Raposo et al. [2] performed a wide and in depth evaluation from 2004 to 2008 according to the following criteria: themes, technology and research approach. This work did not indicate any strong shift in the Brazilian panorama over that period. Although the number of publications improved for some years, no significant growth has been noted. However, a preference towards open source software was identified. Particular development for certain sub areas was also identified as well a preference for Developmental research approach. The final evaluation alerted the community in order to produce more descriptive and evaluative researches.

Kirner [6] gathered historical data of Virtual Reality in Brazil based on the SVR and WRVA events. First Brazilian VR events date back to the 90s although CERV was only recognized by SBC in 2000. The author argues that VR has been consolidated during the 90s while AR did the same in the 2000s. This study brings organizational aspects but does not present details regarding application areas neither includes technology analyses. Moreover, it has been limited to events organized up to the end of 2007 when SVR had celebrated a decade of existence.

A more recent study [1] evaluated SVR and WRVA until 2010 and concluded that the majority of research is focused, from the application′s point of view, on training and education regardless if it uses VR or AR. In the base research, the main focus is the user interaction [1]. Regarding research point-of-view, 3D user interaction is the major focus of interest. This work evaluated 3 years of SVR and 2 years of WRVA using a qualitative approach of few aspects but highlighted AR evolution.

III. Methodology

We consider the work of Raposo et al. [2] the paper which best characterize Brazilian production on VR/AR. The paper was structured by well-known scholars of distinguished production from several universities in Brazil in many areas and sub areas or VR/AR which indicates that such work gives a mature survey of VR/AR scientific community as a whole. Thus, we choose the same approach since it would also provide an opportunity for a longer historical analysis which also allows an evaluation of evolution or involution of certain topics. Therefore, the present survey applied the same classifications and tables published in [2] to complement it (which evaluated 124 papers from 2004 to 2008) with the latest 5 years of SVR data (138 papers from 2009 to 2013). All papers were fully read and classified accordingly but only full papers were included, as did the former survey [2].

A few classifications (and tables) required to include new categories or split existing ones. It was done carefully in order to allow the comparison with historical information: inclusions posed no problems but splitting was done in two steps – one for straightforward comparison and other for specialized analysis.

In order to perform an unbiased analysis over all papers the following methodology was adopted:

1 – The tables were divided according to a number of master´s degree students; every table was completed by, at least, two students individually;

2 – Each student surveyed (read) all papers to fill out the categories in the tables, and; each student categorized a max of three tables only;

3 – The information gathered was discussed among all students in order to spot conflicts and/or misconceptions, to identify eventual individual and subjective interpretations that lead to standardize concepts and understandings;

4 – Each table was evaluated once more for each category aiming to spot the consensus among the group. In case of divergence a complete analysis was performed once more by one of the last four co-author of this paper;

5 – In case of doubts or any further conflict, the VR/AR more experienced co-author (the first one) performed a final evaluation.

Following, the data will be presented. To every aspect, a table and a corresponding figure will be shown. The tables will present raw absolute number of papers covering from 2004 to 2013. The figures will show the same information but as a graph of percentages to the total of papers published in that corresponding year. For instance, Figure 14 shows a graph of the percentage of publications published in Portuguese or English, which corresponds to Table XIV data.

All table´s items/categories were kept as they were in the previous survey. Tables that refer to papers use an "YYpNNN" pattern: the first two digits identify the year when the paper was published while the last three digits identify the page number where the paper starts at the referring proceedings.

The order of the tables and figures were altered in order to better organize the text into two halves: The first half is concerned with the contents of the papers, which includes the following data gathering:

- Specific Application Domains;
- Papers in Augmented and Mixed Reality;
- Papers discussing interaction issues;
- Papers about Avatars, Artificial Life and Distributed/Collaborative areas;
- Papers in Real-time Simulations, Visualization and pure Computer Graphic areas;
- Papers related to other Subjects;
- Papers related to 3D web based technologies;
- Papers about graphics Rendering and Physics Simulation engines and libraries ;
- Papers focused on AR technologies;
- Papers related to other technologies for AR;
- Papers using specific Programming Languages;
- Papers related to technologies for hardware systems development;
- Papers presenting technologies developed by the authors.

The second half of the paper is concerned with the research structure of the papers, which includes the following data gathering:

- The language of the paper;
- Authorship nationality;
- Worldwide contribution by continent;
- International contribution by countries;
- Brazilian contribution by region;
- Number of publications by state;
- Top 10 contributors distribution;
- Average number of authors per paper and number of institutions co-authoring a paper;
- Paper x Average authors/institutions;
- Papers classified according to their research approach;
- Percentage of papers containing which abstract component;
- Percentage of papers per number of abstract component;
- The number of abstract components, over the years.

IV. Research Content analyses

A. Main SVR Published Themes

Since SVR receives papers from different domains, it is possible to categorize such work according to specific areas. Table I and Figure 1 show such distribution where all training related virtual environments were categorized as education except when it is explicitly related to medicine or industry.

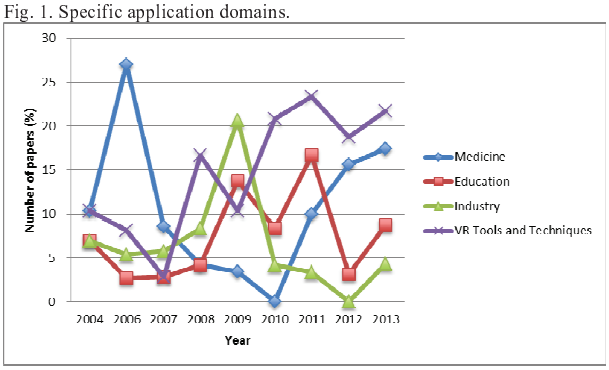
TABLE I. Papers related to specific application domains

Area	Year and page reference
Medicine	04p171; 04p183; 04p195; 06p03; 06p15; 06p27; 06p39; 06p51; 06p387; 06p397; 06p421; 06p433; 06p445; 07p44; 07p100; 07p253; 08p233; 09p278; 11p18; 11p48; 11p73; 12p66; 12p182; 12p191; 12p201; 12p219; 13p17; 13p63; 13p107; 13p117;
Education	04p231; 04p265; 06p409; 07p246; 08p322; 09p119; 09p141; 09p189; 09p199; 10p14; 10p113; 11p28; 11p89; 11p128; 11p197; 11p217; 12p254; 13p01; 13p185
Industry	04p88; 04p327; 06p147; 06p285; 07p278; 07p286; 08p81; 08p143; 09p29; 09p61; 09p93; 09p103; 09p161; 09p168; 10p22; 11p09; 13p97
VR Tools and Techniques	04p03; 04p15; 04p51; 06p65; 06p171; 06p271; 07p162; 08p61; 08p251; 08p307; 08p313; 09p210; 09p229; 09p245; 10p06; 10p50; 10p68; 10p194; 10p212; 11p56; 11p66; 11p102; 11p134; 11p144; 11p178; 11p225; 12p10; 12p26; 12p100; 12p108; 12p116; 12p210; 13p142; 13p152; 13p159; 13p175; 13p191

Traditional areas such as medicine, education and industry remained the most prominent areas in SVR as they were from 2004 to 2008 [2]. However, the analysis from 2009 to 2013 indicates a bit more homogeneous distribution among them subjects.

VR Tools and Techniques represents 35,9%, Medicine 29,1%, Education 18,4% and, Industry applications 16,5% of total published papers. Previous study identified medicine predominance with 56% of papers. Games or entertainment-oriented applications have emerged sparsely and were included into the educational category.

Fig. 1. Specific application domains.



An increase of research on the development of tools and techniques proposals is noticeable from 2009 to 2013. However, such studies are not related to a specific area. These findings reinforce [2] that remarked that the scientific community gives more attention to conceive tools and frameworks in order to help applications development. This suggests that researchers wish to conceive tools that improve code reuse and reduce rework.

B. Main SVR Addressed Subjects

Table II and Figure 2 present information regarding how AR and Mixed Reality (MR) have been appearing since 2004. The difference of these two can be gathered from [12]. Two points are remarkable regarding Table II and Figure 2: first, is the fact that MR has nothing published since 2008, and; second, the volume of AR papers from 2008 to 2012 is much greater than the previous period.

TABLE II. PAPERS IN AUGMENTED REALITY OR MIXED REALITY AREAS

Area	Year and page reference
Augmented Reality (AR)	04p113; 04p149; 04p161; 06p89; 06p121; 06p221; 06p337; 07p51; 07p92; 07p106; 07p207; 07p217; 07p271; 08p28; 08p185; 08p196; 09p29; 09p48; 09p37; 09p114; 09p210; 10p06; 10p14; 10p22; 10p32; 10p42; 10p50; 10p59; 10p68; 10p113; 11p28; 11p48; 11p96; 11p112; 11p128; 11p144; 11p178; 11p225; 12p36; 12p46; 12p84; 12p100; 12p116; 12p125; 12p131; 12p141; 12p155; 12p174; 13p01; 13p117; 13p159; 13p185; 13p191; 13p224
Mixed Reality (MR)	04p124; 07p152; 08p36

Fig. 2. Percentage of papers in AR and MR areas.

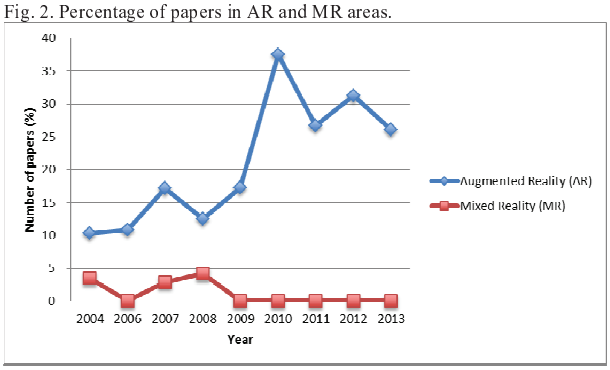


Table III and Figure 3 categorize SVR papers according to 3D Software Interaction; VR Input Devices, VR Output Devices and; Haptic Devices. The first and second items appear well distributed on SVR events while the latest ones appear less.

TABLE III. PAPERS DISCUSSING INTERACTION ISSUES

Technology	Year and page reference
3D Software interaction	04p76; 06p77; 06p233; 06p349; 07p30; 07p77; 07p143; 07p197; 08p212; 08p115; 09p210; 09p268; 10p42; 10p123; 10p153; 11p38; 1p66; 11p79; 12p10; 13p10; 13p90
VR Input Devices	06p259; 06p309; 06p323; 07p17; 07p68; 08p204; 09p278; 10p113; 11p112; 12p18; 12p108; 13p167; 13p200; 13p175
VR Output Devices	06p51; 07p03; 07p60; 07p68; |12p108; 12p261; 13p200
Haptic Devices	04p65; 06p135; 07p36; 11p242; 12p210; 13p63; 13p46; 13p288;

Fig. 3. Percentage of papers discussing interaction issues.

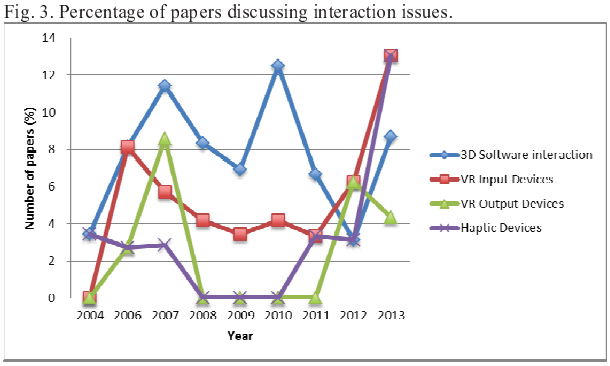


Table IV and Figure 4 categorize papers according to the main focus such as avatars, artificial life and, collaborative/distributed systems. Table IV indicates an absence of artificial life in the last 4 years of SVR.

It is possible to see an increase of researches regarding collaborative systems while avatars is also losing presence - SVR 2013 had not even a single paper categorized under the avatar category.

TABLE IV. PAPERS ABOUT AVATARS, ARTIFICIAL LIFE AND DISTRIBUTED//COLLABORATIVE AREAS

Technology	Year and page reference
Avatar	04p27; 04p243; 04p315; 06p197; 06p209; 07p84; 07p170; 07p180; 08p348; 09p199; 11p66; 11p134; 11p197; 12p227;
Artificial Life	04p39; 04p217; 06p245; 07p187; 07p236; 08p337; 09p229;
Distributted / Collaborative	04p255; 04p303; 06p373; 06p397; 07p263; 08p143; 09p69; 09p114; 09p210; 09p273; 10p133; 11p09; 11p28; 11p188; 11p198; 11p252; 12p84; 12p125; 12p147; 12p155; 12p165; 13p17;

Fig. 4. Percentage of papers about Avatars, Artificial Life and Distributed/Collaborative areas.

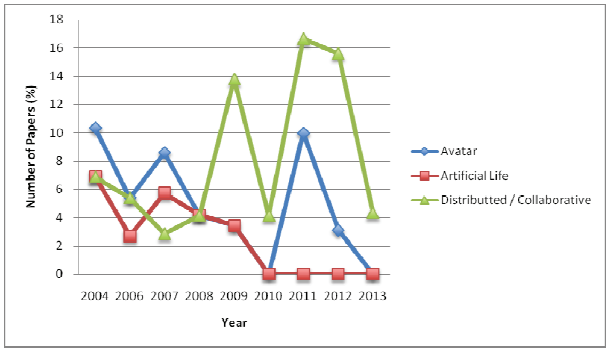


Table V and Figure 5 depict the most alive areas of SVR: real-time simulation/visualization and pure computer graphics. It is possible to see a high volume of papers mainly in 2010 and 2012.

TABLE V. PAPERS IN REAL-TIME SIMULATIONS, VISUALIZATION AND PURE COMPUTER GRAPHIC AREAS.

Technology	Year and page reference
Real-Time Simulations and Visualization	04p100; 06p297; 06p361; 07p116; 07p123; 07p133; 07p227; 08p21; 08p105; 08p233; 08p241; 09p37; 09p48; 09p61; 09p93; 09p103; 09p146; 09p161; 09p189; 09p268; 10p32; 10p222; 10p14; 10p212; 10p68; 10p50; 10p59; 10p42; 10p222; 10p06; 11p73; 11p79; 11p112; 11p128; 11p161; 11p217; 11p232; 11p242; 12p246; 12p254; 12p271; 12p66; 12p108; 12p116; 12p131; 12p182; 12p191; 12p201; 13p36; 13p63; 13p107; 13p117; 13p125; 13p159;
Pure Computer Graphics	04p137; 04p207; 06p147; 08p223; 09p79; 09p245; 09p255; 09p278; 10p93; 10p143; 10p174; 10p204; 10p113; 10p77; 10p102; 10p84; 10p184; 10p123; 11p01; 11p96; 11p102; 11p153; 11p169; 11p178; 11p207; 12p262; 12p01; 12p10; 12p18; 12p36; 12p46; 12p56; 12p74; 12p141; 12p210; 13p27; 13p46;

Table VI and Figure 6 list all papers that did not fit in the main focus of Table V. Among such works are specific application research and other domains, which are not related to Table IV such as digital TV technology.

Fig. 5. Percentage of papers in Real-time Simulations, Visualization and pure Computer Graphics

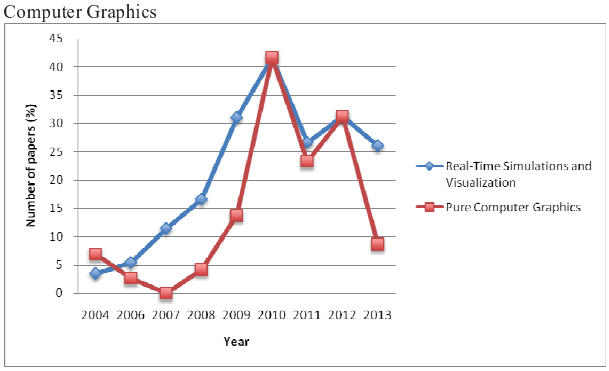
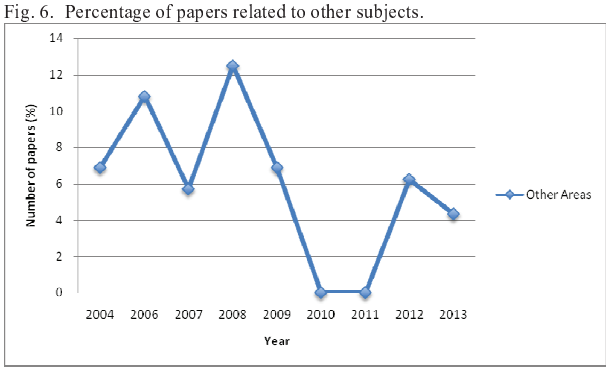


TABLE VI. PAPERS RELATED TO OTHER SUBJECTS

Area	Year and page reference
Other areas	04p279; 04p291; 06p101; 06p113; 06p159; 06p183; 07p24; 07p10; 08p70; 08p151; 08p359; 09p01; 09p221; 12p91; 12p174; 13p83

Fig. 6. Percentage of papers related to other subjects.



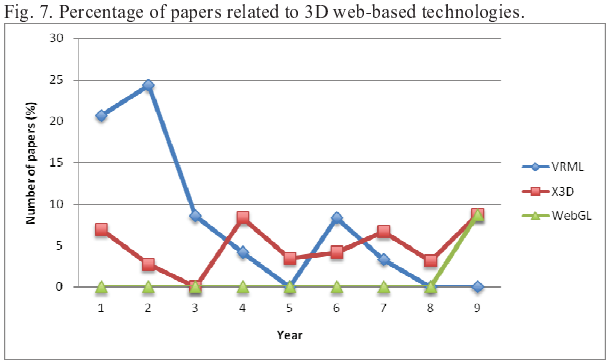
C. Most Important Technologies Used

This section discusses the technologies used for the development of the applications presented in SVR papers. Table VII and Figure 7 present papers that used *Web 3D* technologies.

TABLE VII. PAPERS RELATED TO 3D WEB BASED TECHNOLOGIES

Technology	Year and page reference
VRML (Virtual Reality Modeling Language)	04p03; 04p195; 04p231; 04p255; 04p279; 04p303; 06p03; 06p15; 06p147; 06p159; 06p233; 06p397; 06p409; 06p421; 06p445; 07p100; 07p271; 07p278; 08p185; 10p143; 10p222; 11p144;
X3D (Extensible 3D)	04p27; 04p291; 06p27; 08p61; 08p115; 09p255; 10p143; 11p73; 11p134; 12p108; 13p46; 13p212;
WebGL (Web Graphics Library)	13p46; 13p191;

Fig. 7. Percentage of papers related to 3D web-based technologies.



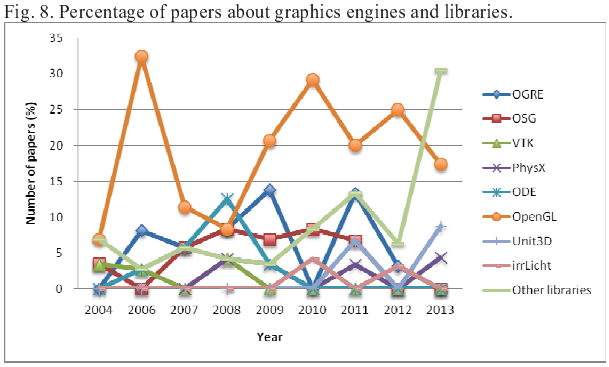
For the latest papers, the predominance of the X3D standard over the old VRML was identified. The adoption of X3D as a standard in *Web 3D* application had already been verified by Raposo and colleagues [2] back in 2008 and remained so for the new period analyzed. In addition, from 2013 on, WebGL has also entered the arena.

Table VIII and Figure 8 show the technologies already consolidated in computer graphics and in games research, which includes libraries for graphics rendering and physics simulation engines. OpenGL is the most popular technology in use followed by OGRE and OSG. All these tools are open source, which facilitates researchers' access to them.

TABLE VIII. PAPERS ABOUT GRAPHICS RENDERING AND PHYSICS SIMULATION ENGINES AND LIBRARIES

Technology	Year and paper reference
OGRE – Open Source 3D Graphics Engine	06p65; 06p271; 06p285; 07p68; 07p77; 08p223; 08p251; 09p93; 09p146; 09p189; 09p245; 11p79; 11p102; 11p112; 11p178; 12p26;
OSG – Open Scene Graph	04p327; 07p152; 07p236; 08p307; 08p337; 09p210; 09p229; 10p22; 10p123; 11p134; 11p232;
VTK – Visualization Tool Kit	04p88; 06p147; 08p233;
PhysX	08p251; 09p61; 11p102; 13p125;
ODE – Open Dynamics Engine	06p197; 07p187; 07p227; 08p241; 08p337; 08p251; 09p29;
OpenGL – Open Graphics Language	04p100; 04p183; 06p03; 06p51; 06p77; 06p101; 06p121; 06p197; 06p271; 06p285; 06p297; 06p337; 06p387; 06p445; 07p17; 07p30; 07p123; 07p207; 08p36; 08p241; 09p37; 09p48; 09p103; 09p119; 09p229; 09p273; 10p06; 10p14; 10p50; 10p77; 10p143; 10p174; 10p184; 11p01; 11p09; 11p48; 11p89; 11p96; 11p225; 12p01; 12p26; 12p36; 12p66; 12p100; 12p116; 12p210; 12p219; 13p17; 13p36; 13p142; 13p175
Unity3D	11p66; 11p217; 13p90; 13p97
irrLicht	10p42; 12p254
Other libraries	04p15; 04p39; 06p361; 07p36; 07p278; 08p81; 09p146; 10p113; 10p143; 11p18; 11p56; 11p207; 11p242; 12p182; 12p191; 13p01; 13p10; 13p63; 13p73; 13p107; 13p152; 13p168

Fig. 8. Percentage of papers about graphics engines and libraries.



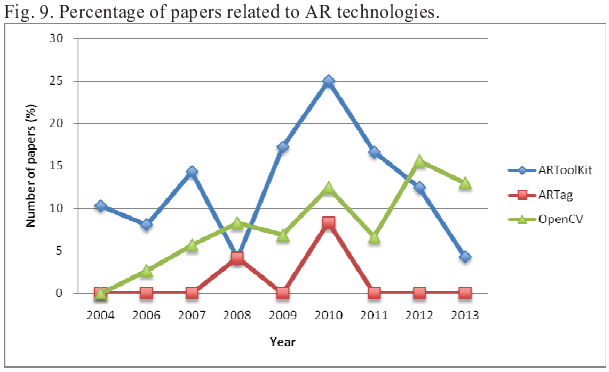
Regarding technologies for developing AR applications, the most used tools in SVR papers were ARToolKit and, secondly OpenCV. Table IX and Figure 9 show how AR-based technologies appeared in SVR.

TABLE IX. PAPERS FOCUSED ON AR TECHNOLOGIES

Technology	Year and page reference
ARToolKit (AR Tool Kit)	04p113; 04p149; 04p161; 06p89; 06p121; 06p221; 07p17; 07p24; 07p123; 07p207; 07p271; 08p36; 09p69; 09p114; 09p210; 09p229; 09p273; 10p14; 10p22; 10p32; 10p42; 10p59; 10p153; 11p48; 11p96; 11p128; 11p144; 11p178; 12p36; 12p100; 12p131; 12p174; 13p185
ARTag	08p185; 10p06; 10p113
OpenCV (Open Source Computer Vision Library)	06p259; 07p92; 07p116; 08p105; 08p212; 09p29; 09p69; 10p06; 10p22; 10p50; 11p28; 11p48; 12p91; 12p125; 12p131; 12p174; 12p182; 13p01; 13p97; 13p191

However, a diversity of frameworks based on ARToolKit, such as ARToolKitPlus, OSGART, irrAR, AndAR, BasAR and FLARToolKit, were identified. These tools were all included in the ARToolKit category of Table IX to keep similarity to the previous survey.

Fig. 9. Percentage of papers related to AR technologies.



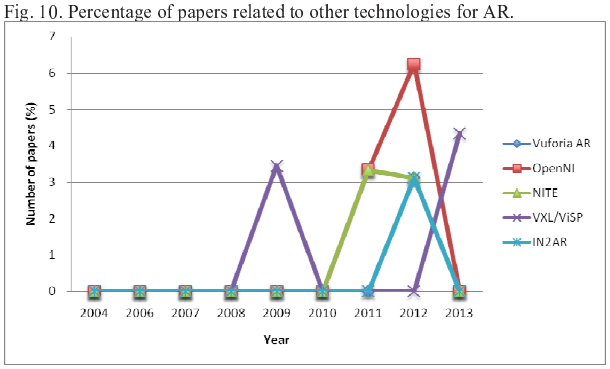
Many papers quote the use of more than one technology. - In these cases the paper has been inserted into two or more categories.

In addition to the technologies shown in Table IX, it was possible to identify the use of other frameworks for AR-like applications although just a few of them appeared. Table X and Figure 10 present the papers found in these tools.

TABLE X. PAPERS RELATED TO OTHER TECHNOLOGIES FOR AR

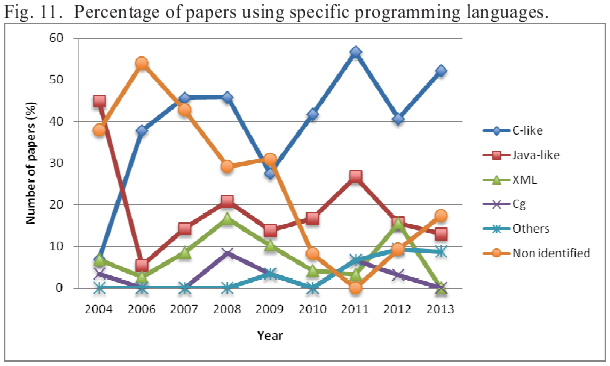
Technology	Year and page reference
Vuforia AR	12p36;
OpenNI – Open Natural Interaction	11p112; 12p182; 12p191;
NITE – Natural Interaction Engine	11p112; 12p182;
VXL + ViSP (Vision-something-Library and Visual Servoing Platform)	09p37; 13p01;
IN2AR (Into AR)	12p155;

Fig. 10. Percentage of papers related to other technologies for AR.



As shown in Table XI and Figure 11, low-level languages such as C, C++ and C#, were the primary choice for a considerable number of papers published in the last three years.

Fig. 11. Percentage of papers using specific programming languages.



These languages were used because they were claimed to be powerful, flexible and multiplatform. The Java language made an honorable presence in 2011 but it was a one-off exception of a modest presence history. CUDA (Compute Unified Device Architecture) was used in just a few papers and many remaining papers do not make it clear the language and/or framework it has used.

TABLE XI. PAPERS USING SPECIFIC PROGRAMMING LANGUAGES

Technology	Year and page reference
C-like	04p88; 04p183; 06p03; 06p65; 06p77; 06p101; 06p147; 06p159; 06p197; 06p271; 06p285; 06p297; 06p361; 06p387; 06p421; 06p445; 07p03; 07p10; 07p17; 07p30; 07p44; 07p68; 07p77; 07p92; 07p100; 07p106; 07p116; 07p123; 07p180; 07p187; 07p197; 07p227; 08p21; 08p81; 08p185; 08p204; 08p212; 08p223; 08p233; 08p241; 08p251; 08p313; 08p337; 09p61; 09p69; 09p93; 09p103; 09p189; 09p210; 09p229; 09p273; 10p14; 10p42; 10p50; 10p77; 10p113; 10p153; 10p174; 10p184; 10p194; 10p212; 11p01; 11p28; 11p48; 11p66; 11p79; 11p96; 11p102; 11p112; 11p128; 11p144; 11p161; 11p178; 11p188; 11p207; 11p217; 11p232; 11p242; 12p01; 12p10; 12p26; 12p36; 12p66; 12p84; 12p108; 12p141; 12p165; 12p182; 12p191; 12p201; 12p219; 13p01; 13p36; 13p46; 13p97; 13p117; 13p142; 13p152; 13p191; 13p220; 13p224; 13p260; 13p264
Java-like	04p03; 04p27; 04p76; 04p124; 04p171; 04p195; 04p217; 04p231; 04p243; 04p255; 04p265; 04p303; 04p315; 06p397; 06p433; 07p03; 07p51; 07p106; 07p162; 07p253; 08p61; 08p70; 08p185; 08p322; 08p359; 09p61; 09p141; 09p221; 09p245; 10p143; 10p153; 10p194; 10p222; 11p09; 11p18; 11p56; 11p73; 11p102; 11p225; 11p242; 11p252; 12p91; 12p100; 12p131; 12p155; 12p210; 13p46; 13p90; 13p63
XML	04p27; 04p291; 06p27; 07p03; 07p180; 07p286; 08p61; 08p70; 08p143; 08p307; 09p189; 09p245; 09p255; 10p68; 11p134; 12p84; 12p116; 12p131; 12p227; 12p261
Cg	04p100; 08p185; 08p223; 09p48; 11p56; 11p178; 12p74
Others	09p168; 11p89; 11p128; 12p14; 12p227; 12p261; 13p46; 13p175
Non identified	04p15; 04p39; 04p51; 04p65; 04p113; 04p137; 04p149; 04p161; 04p207; 04p279; 04p327; 06p15; 06p39; 06p51; 06p89; 06p113; 06p121; 06p135; 06p171; 06p183; 06p209; 06p221; 06p233; 06p245; 06p259; 06p309; 06p323; 06p337; 06p349; 06p373; 06p409; 07p24; 07p36; 07p60; 07p84; 07p133; 07p143; 07p152; 07p170; 07p207; 07p217; 07p236; 07p246; 07p263; 07p271; 07p278; 08p28; 08p36; 08p105; 08p115; 08p151; 08p196; 08p348; 09p29; 09p114; 09p119; 09p133; 09p146; 09p161; 09p199; 09p263; 09p278; 10p32; 10p59; 12p125; 12p246; 12p254; 13p17; 13p27; 13p107; 13p134

A handful of papers has been devoted to the development and application of specialized hardware systems as shown in Table XII and Figure 12. The great majority of them focused on the use of stereoscopic hardware. In 2012 and 2013 there were some papers that used haptic interaction devices in education and therapeutic area. A few papers on immersive systems based on hardware could also be found.

TABLE XII. PAPERS RELATED TO TECHNOLOGIES FOR HARDWARE SYSTEMS DEVELOPMENT

Technology	Year and page reference
Stereoscopic hardware / software based	04p124; 04p183; 04p217; 04p265; 06p03; 06p77; 06p183; 07p10; 07p36; 07p68; 07p77; 07p143; 07p152; 07p236; 07p278; 08p70; 08p21; 08p81; 08p185; 08p204; 08p212; 08p223; 08p233; 08p241; 08p251; 08p313; 08p337; 09p119; 09p133; 10p212; 11p252; 11p134; 12p01; 12p108; 12p182; 12p261
Haptics	04p65; 06p135; 06p309; 06p445; 12p66; 12p165; 12p210; 13p63
Hardware-based	04p113; 06p51; 06p323; 07p17; 07p24; 07p36; 07p68; 07p92; 07p106; 08p70; 08p185; 09p263; 10p59; 11p134; 11p242; 13p167

Fig. 12. Percentage of papers related to hardware systems development.

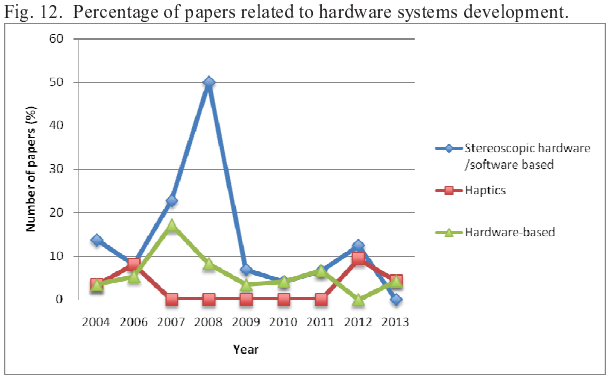
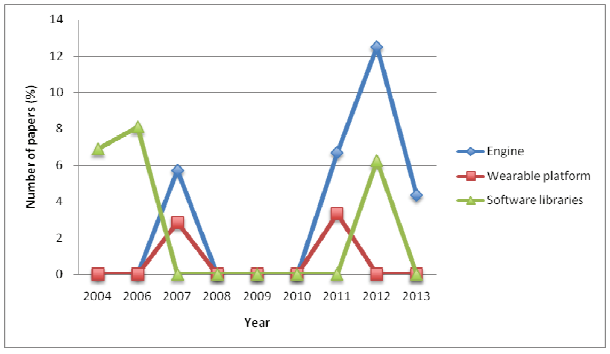


Table XIII and Figure 13 show new technologies produced and presented by the authors. The quantity of new technologies is very small but for engine proposals recently.

TABLE XIII. PAPERS PRESENTING TECHNOLOGIES DEVELOPED BY THE AUTHORS

Technology	Year and page reference
Engine	07p51; 07p92; 11p102; 11p178; 12p36; 12p116; 12p227; 12p262; 13p134;
Wearable platform	07p77; 11p242;
Software libraries	04p149; 04p327; 06p171; 06p245; 06p373; 12p10; 12p210;

Fig. 13. Percentage of papers presenting technologies developed by the authors.



V. RESEARCH STRUCTURE ANALYSES

A. *Language of the paper and authorship nationality*

Since 2001, SVR committees have been encouraging international participation and papers written in English [2]. Table XIV and Figure 14 survey the number of papers published in each language. Statistics collected by previous survey indicated a stable increase in English written papers in percentages. However the updated view indicates an oscillation between English and Portuguese predominance.

During the latest decade there was a significant oscillation regarding the amount of published papers. For instance, 2006 event accepted 37 papers but only 23 in 2013. It is possible to identify a small tendency of reducing the number of accepted papers along the time.

TABLE XIV. LANGUAGE OF PUBLISHED PAPERS

Year	Portuguese	English
2004	22	6
2006	19	18
2007	17	18
2008	9	15
2009	9	20
2010	15	9
2011	16	14
2012	14	18
2013	13	10

Fig. 14. Percentage of papers published in English or Portuguese.

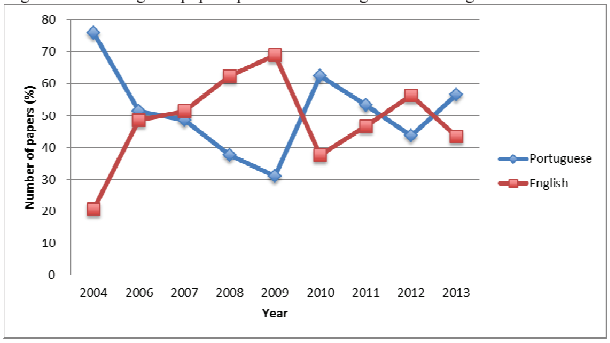
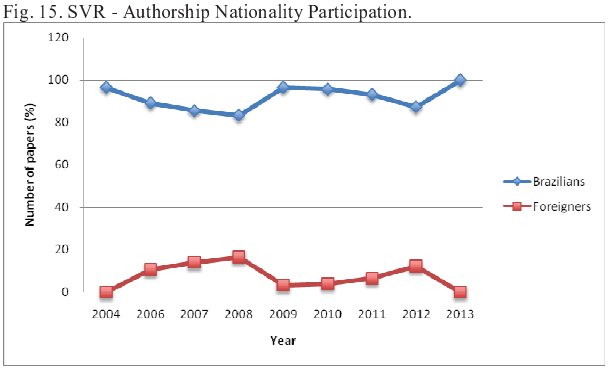


Table XV and Figure 15 show the contribution of Brazilians´ and Foreigners´ research from 2004 to 2013.

TABLE XV. AUTHORSHIP NATIONALITY PARTICIPATION

Year	Brazilians	Foreigners
2004	28	0
2006	33	4
2007	30	5
2008	20	4
2009	28	1
2010	23	1
2011	28	2
2012	28	4
2013	23	0

Fig. 15. SVR - Authorship Nationality Participation.



B. *Worldwide and international contribution*

Europe has been an important oversees contributor exceeding Brazilian´s North and Midwest regions altogether. Germany is, by far, the most present oversee contributor

accounting for 7 papers (more than the North region alone) – see Figure 16 and Figure 17.

Fig. 16. Worldwide contribution by continent

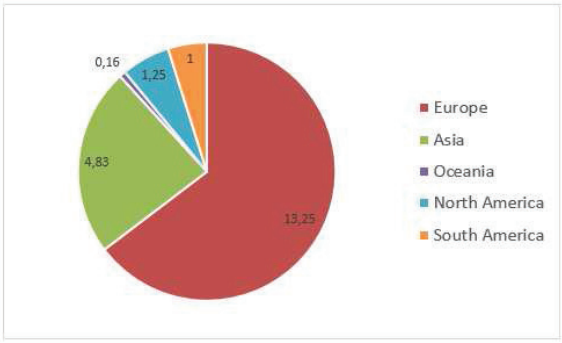
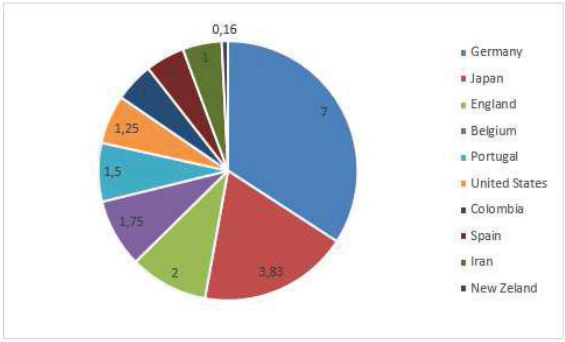


Fig. 17: International contribution by countries



C. *Brazilian contribution*

Over the last decade, 105 institutions attended SVR from 12 different countries: Federal and State Universities, Research Centers, Colleges, Private Universities, Public and Private Companies. In order to measure this participation, and find out which one contributed the most by publishing papers the following measurement was adopted:

- Each paper accounts for 1 (one) point;
- Points are divided equally among co-authors;
- In case a co-author is affiliated to two institutions, her/his points are divided equally once more;
- Afterwards, the contribution per Institution is summed up.

For instance, for the paper titled "X-Libras: Um Ambiente Virtual para a Língua Brasileira de Sinais", by Fusco and Brega in SVR 2004, Fusco is affiliated to UNIVEM while Brega is affiliated to UNIVEM and UNESP. In this case, UNIVEM accounts for 0,75 points and UNESP to 0,25.

After summing up contributions per Institution and assigning it to their specific region in Brazil it was found that the major contributing regions are (in brackets the number of points/full papers over the nine editions): Southeast (107); Northeast (80,97); South (42,28); North (6,32) and; Midwest (5,81) as shown on Figure 18. It can be seen that Southeast has topped all others most of the years but the last two. Also, it should be noticed that South's and Southeast's contributions have been declining at the same time that Northeast's has been growing.

Fig. 18. Brazilian contribution by region

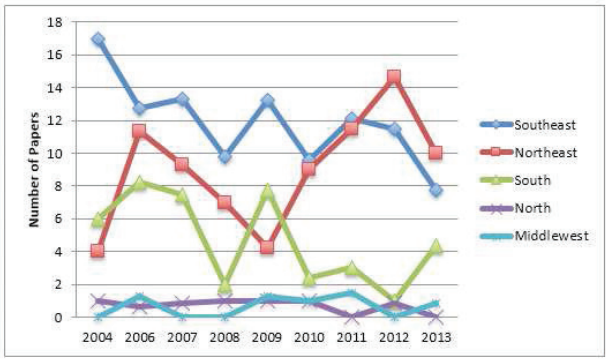


Table XVI and Figure 19 show the diversity of participation by state. These data detail those of Figure 18 but for Brazilian's regions. The state that contributed most was São Paulo (SP), with a peak in in 2004. It is seconded by Rio de Janeiro (RJ), Rio Grande do Sul (RS), Pernanbuco (PE) and, Ceará (CE).

TABLE XVI. NUMBER OF PUBLICATIONS BY STATE

State	Acronym	Number of Papers
São Paulo	SP	54
Rio de Janeiro	RJ	45
Rio Grande do Sul	RS	38
Pernambuco	PE	34
Ceará	CE	22
Paraíba	PB	16
Minas Gerais	MG	11
Rio Grande do Norte	RN	8
Pará	PA	7
Goiás	GO	6
Santa Catarina	SC	6
Bahia	BA	3
Paraná	PR	3
Alagoas	AL	2
Mato Grosso do Sul	MS	2
Mato Grosso	MT	1

Fig. 19. Diversity of participation by state

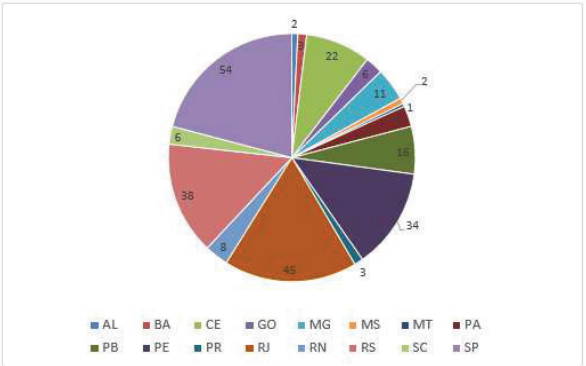
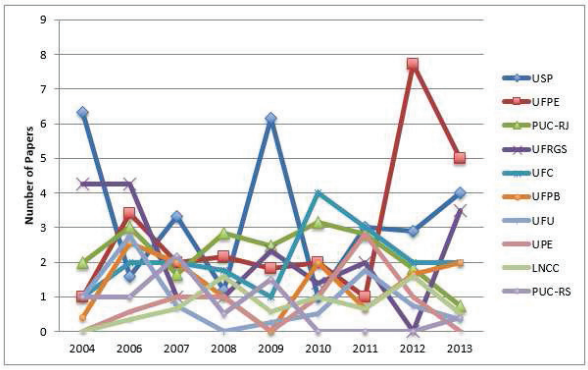


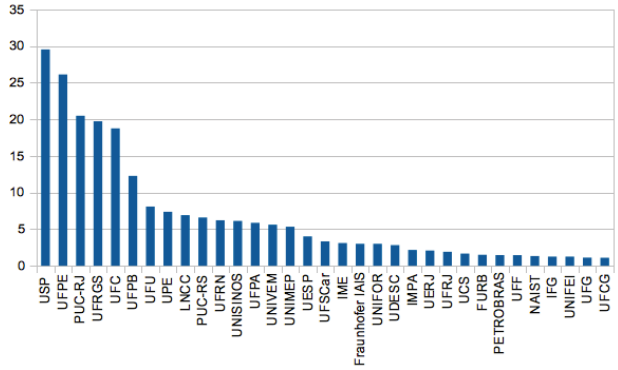
Figure 20 shows that Universidade de São Paulo (USP), Rio Grande do Sul (RS) and Pernambuco (PE) have made major contributions in 2013.

Fig. 20. Top 10 contributor's distribution



Figures 21 shows the contributions from all institutions using the same metrics presented before accumulated over the decade. The institutions are ordered from the most contributing to the less ones.

Fig. 20: Top contributors to SVR



The Top 10 institutions to contribute to SVR are all Brazilians (in brackets the number of points/papers accumulated over the years): USP (29,53), UFPE (26.10), PUC-RJ (20,48), UFRGS (19,73), UFC (18,75), UFPB (12,27), UFU (8,08), UPE (7,37), LNCC (6,91) and PUC-RS(6,59). USP has contributed more than 29 full papers to SVR, which means that more than three papers are expected from USP every single year (of all nine editions). UFU contributed a bit over eight full papers along the time, which means that at least one paper is expected to be seen in SVR every year.

Computing the contribution of all institutions over the last 10 years (shown in Figure 20), it was realized that it is unfeasible to show all contributions along the way because there are so many of them and, for some, so little contribution. Instead, a set of the Top 10 institutions are show in Figure 21.

D. Paper authoring groups

Table XVII and Figure 22 show the average number of authors per paper and number of institutions co-authoring a paper. The average varied a bit with a peak in 2008 and a valley in 2010 but it average around four (3,928) co-authors. There was also a peak in 2008 and a valley in 2010 but an average of 1,4 institutions per paper could be found.

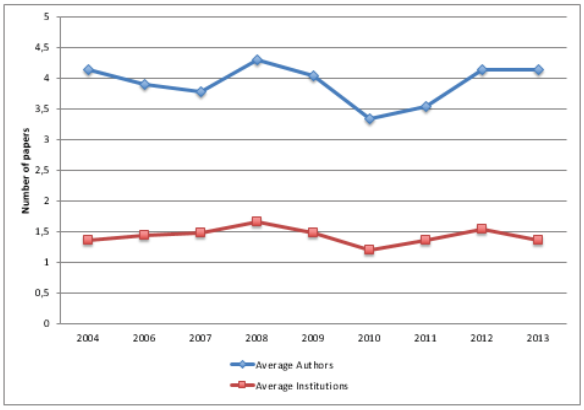
E. Research Approach

As reported by Raposo and colleagues [2], the goal of analyzing research approaches is to identify the maturity of research papers published in SVR. As well as in the survey by those authors, the research approach classification described by Morrison and George [7] was adopted. The papers were read in full and categorized as formulative, descriptive, evaluative or developmental type of research. Table XVIII and Figure 23 show the papers classified according to their research approach.

TABLE XVII. PAPER X AVERAGE AUTHORS/INSTITUTIONS

Year	Average Authors	Average Institutions
2004	4,14	1,36
2006	3,89	1,43
2007	3,77	1,48
2008	4,3	1,66
2009	4,03	1,48
2010	3,33	1,2
2011	3,53	1,36
2012	4,15	1,53
2013	4,15	1,35

Fig. 21. Average number of authors per paper and number of institutions co-authoring a paper



Similar to the last survey, we could not identify any formulative paper that represents original contributions to the body of knowledge, by means of the development and refinement of theories, models, or frameworks that govern research activities and support scientific progress through a paradigm change [7]. Papers of this class represent studies of the highest maturity level.

Descriptive papers involve literatures, surveys, mappings and systematic reviews, in other words, are papers that summarize the main concepts or results of others relevant papers to a particular topic. This approach still has little presence, as analyzed by Raposo and colleagues [2] as well as for the latest period, where only two papers were published.

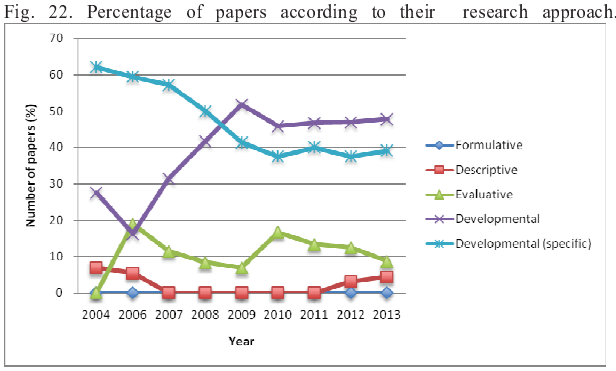
TABLE XVIII. PAPERS CLASSIFIED ACCORDING TO THEIR RESEARCH APPROACH.

Research Approach	Year and page reference
Formulative	(None)
Descriptive	04p65; 04p207; 06p183; 06p409; 12p141; 13p53
Evaluative	06p39; 06p77; 06p89; 06p135; 06p233; 06p323; 06p349; 07p30; 07p143; 07p246; 07p263; 08p196; 08p359; 09p37; 09p114; 10p50; 10p77; 10p133; 10p163; 11p01; 11p38; 11p122; 11p188; 12p18; 12p46; 12p56; 12p74; 13p27; 13p83
Developmental (generalizable)	04p15; 04p51; 04p100; 04p137; 04p161; 04p217; 04p279; 04p315; 06p65; 06p171; 06p197; 06p209; 06p271; 06p361; 07p03; 07p10; 07p84; 07p116; 07p123; 07p133; 07p162; 07p170; 07p197; 07p207; 07p217; 08p36; 08p61; 08p105; 08p151; 08p223; 08p241; 08p251; 08p307; 08p313; 08p348; 09p01; 09p48; 09p79; 09p119; 09p133; 09p146; 09p175; 09p210; 09p221; 09p229; 09p234; 09p245; 09p263; 09p268; 09p273; 10p06; 10p32; 10p68; 10p84; 10p93; 10p102; 10p143; 10p174; 10p184; 10p194; 10p212; 11p56; 11p66; 11p79; 11p144; 11p153; 11p169; 11p178; 11p207; 11p225; 11p232; 11p242; 11p96; 11p102; 11p161; 12p01; 12p10; 12p26; 12p36; 12p84; 12p100; 12p116; 12p131; 12p165; 12p210; 12p227; 12p237; 12p246; 12p261; 12p271; 13p17; 13p36; 13p63; 13p90; 13p134; 13p142; 13p152; 13p159; 13p167; 13p175; 13p191
Developmental (specific)	04p03; 04p27; 04p39; 04p76; 04p88; 04p113; 04p124; 04p149; 04p171; 04p183; 04p195; 04p231; 04p243; 04p255; 04p265; 04p291; 04p303; 04p327; 06p03; 06p15; 06p27; 06p51; 06p101; 06p113; 06p121; 06p147; 06p159; 06p221; 06p245; 06p259; 06p285; 06p297; 06p309; 06p337; 06p373; 06p387; 06p397; 06p421; 06p433; 06p445; 07p17; 07p24; 07p36; 07p44; 07p51; 07p60; 07p68; 07p77; 07p92; 07p100; 07p106; 07p152; 07p180; 07p187; 07p207; 07p236; 07p253; 07p271; 07p278; 07p286; 08p21; 08p28; 08p70; 08p81; 08p115; 08p143; 08p185; 08p204; 08p212; 08p233; 08p322; 08p337; 09p29; 09p61; 09p69; 09p93; 09p103; 09p141; 09p161; 09p168; 09p189; 09p199; 09p255; 09p278; 10p14; 10p22; 10p42; 10p59; 10p113; 10p123; 10p153; 10p204; 10p222; 11p09; 11p18; 11p28; 11p48; 11p73; 11p89; 11p112; 11p128; 11p134; 11p197; 11p217; 11p252; 12p66; 12p91; 12p108; 12p125; 12p147; 12p155; 12p174; 12p182; 12p191; 12p201; 12p219; 12p254; 13p01; 13p10; 13p46; 13p73; 13p97; 13p107; 13p117; 13p125; 13p185

Evaluative research papers are those that perform empirical experiments, apply scientific methods, or test and compare results from different tools or techniques. These papers were found to represent less than 10% of all papers. Papers that performed a test on a specific application to evaluate its efficiency or performance were disregarded in this category.

Developmental researches were divided into two subcategories: generalizable and specific. The former are those that aim to support the development of tools or methodologies for building VR or AR applications. The latter shows VR or AR application for educational or medical areas, for instance.

Fig. 22. Percentage of papers according to their research approach.



F. *Abstract evaluation*

An important aspect of getting a research message across the research community is publishing papers. However, literature reviews rely on searches that take titles and abstracts as the major (and sometimes the only) source. Poor abstracts compromise the analysis of the paper relevance. Structured abstracts have been proved to increase clarity and completeness of information [11]. Therefore, constructing instructive abstracts is an important step in the research process.

In order to evaluate completeness, the abstracts of all articles were analyzed to identify the following structure components [11]:

- Background: The rationale or context of the main subject of study;
- Aim: The hypotheses to be tested or the main purpose of the paper, even when only stated as “presenting a new tool", for example;
- Method: The description of the experiment, details about development or validation;
- Results: The main findings or statistical information about them;
- Conclusions: Any conclusions drawn, limitations or discussions about future research.

Papers were classified as containing one of these components, even when briefly mentioned.

Interested readers can refer to the Table XIX in order to identify which components were found in each paper. A study might be present in more than one category when it contains two or more of the abstract components.

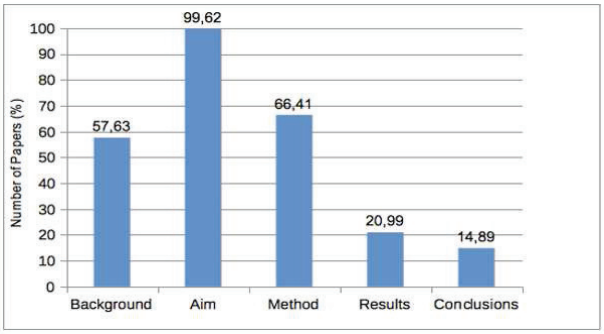
It could be found that almost all abstracts stated the main purpose of the paper, which indicates a consensus among the community that the goal of study should be a minimum component of an abstract. Despite this fact, most often abstracts only described what is presented in the paper, whether it is a new tool, case of study or framework, rather than explaining the hypotheses to be tested or the benefits this new approach could provide. As shown in Figure 24, fewer abstracts mention methods and the background and, around

20% of the abstracts states some results while even less papers brings conclusions in the abstract.

TABLE XIX. PAPERS CLASSIFIED ACCORDING TO ABSTRACT COMPONENT.

Abstract component	Year and page reference
Background	04p279; 04p303; 04p039; 04p149; 04p161; 04p231; 04p243; 04p265; 04p015; 04p027; 04p171; 04p207; 04p065; 04p100; 06p003; 06p015; 06p039; 06p089; 06p183; 06p221; 06p297; 06p323; 06p249; 06p421; 06p387; 06p397; 06p001; 07p003; 07p024; 07p036; 07p036; 07p077; 07p106; 07p044; 07p084; 07p143; 07p152; 07p170; 07p207; 07p236; 07p263; 07p271; 07p162; 08p021; 08p028; 08p036; 08p061; 08p115; 08p151; 08p196; 08p204; 08p233; 08p241; 08p251; 08p307; 08p348; 09p029; 09p061; 09p069; 09p093; 09p133; 09p146; 09p161; 09p168; 09p175; 09p189; 09p199; 09p229; 09p234; 09p245; 09p268; 09p273; 09p001; 10p014; 10p194; 10p133; 10p093; 10p143; 10p068; 10p174; 10p204; 10p113; 10p077; 10p102; 10p084; 10p059; 10p163; 10p042; 10p184; 10p022; 10p123; 11p001; 11p009; 11p018; 11p038; 11p056; 11p066; 11p073; 11p079; 11p089; 11p096; 11p102; 11p144; 11p153; 11p161; 11p169; 11p188; 11p197; 11p207; 11p217; 11p232; 11p242; 12p219; 12p227; 12p237; 12p246; 12p254; 12p271; 12p010; 12p026; 12p046; 12p056; 12p074; 12p084; 12p091; 12p100; 12p108; 12p125; 12p131; 12p141; 12p147; 12p155; 12p165; 12p174; 12p182; 12p191; 13p017; 13p027; 13p036; 13p046; 13p053; 13p073; 13p083; 13p090; 13p097; 13p117; 13p134; 13p142; 13p159; 13p167; 13p185;
Aim	04p279; 04p291; 04p303; 04p039; 04p327; 04p113; 04p124; 04p137; 04p149; 04p161; 04p231; 04p243; 04p255; 04p265; 04p003; 04p015; 04p027; 04p039; 04p051; 04p171; 04p183; 04p195; 04p207; 04p217; 04p065; 04p076; 04p088; 04p100; 06p003; 06p015; 06p027; 06p039; 06p051; 06p065; 06p077; 06p089; 06p101; 06p121; 06p391; 06p135; 06p157; 06p183; 06p147; 06p171; 06p221; 06p197; 06p245; 06p209; 06p233; 06p259; 06p271; 06p309; 06p285; 06p297; 06p323; 06p337; 06p249; 06p361; 06p109; 06p421; 06p387; 06p445; 06p397; 06p001; 06p431; 07p003; 07p010; 07p017; 07p024; 07p030; 07p036; 07p036; 07p060; 07p068; 07p077; 07p106; 07p116; 07p044; 07p051; 07p084; 07p092; 07p123; 07p133; 07p143; 07p152; 07p170; 07p180; 07p197; 07p207; 07p227; 07p236; 07p246; 07p253; 07p263; 07p271; 07p278; 07p286; 07p187; 07p162; 07p217; 08p021; 08p028; 08p036; 08p070; 08p081; 08p105; 08p115; 08p143; 08p151; 08p185; 08p196; 08p204; 08p212; 08p223; 08p233; 08p241; 08p251; 08p307; 08p313; 08p322; 08p337; 08p348; 08p359; 09p029; 09p037; 09p048; 09p061; 09p069; 09p079; 09p093; 09p103; 09p114; 09p119; 09p133; 09p141; 09p146; 09p161; 09p168; 09p175; 09p189; 09p199; 09p210; 09p221; 09p229; 09p234; 09p245; 09p255; 09p263; 09p268; 09p273; 09p001; 09p278; 10p032; 10p222; 10p014; 10p194; 10p133; 10p212; 10p093; 10p143; 10p068; 10p174; 10p204; 10p113; 10p077; 10p102; 10p084; 10p050; 10p059; 10p163; 10p042; 10p184; 10p022; 10p153; 10p123; 10p006; 11p001; 11p009; 11p018; 11p028; 11p038; 11p048; 11p056; 11p066; 11p073; 11p079; 11p096; 11p102; 11p112; 11p122; 11p128; 11p134; 11p144; 11p153; 11p161; 11p169; 11p178; 11p188; 11p197; 11p207; 11p217; 11p225; 11p232; 11p242; 11p252; 12p219; 12p227; 12p237; 12p246; 12p254; 12p261; 12p271; 12p001; 12p010; 12p018; 12p026; 12p036; 12p046; 12p056; 12p066; 12p074; 12p084;
Method	04p279; 04p291; 04p039; 04p327; 04p124; 04p137; 04p039; 04p195; 04p076; 04p088; 06p039; 06p051; 06p065; 06p077; 06p089; 06p101; 06p391; 06p135; 06p157; 06p147; 06p171; 06p245; 06p233; 06p271; 06p323; 06p337; 06p249; 06p361; 06p431; 07p003; 07p010; 07p017; 07p030; 07p036; 07p036; 07p060; 07p068; 07p106; 07p044; 07p051; 07p084; 07p092; 07p123; 07p143; 07p152; 07p170; 07p180; 07p197; 07p207; 07p227; 07p263; 07p278; 07p286; 07p187; 07p162; 07p217; 08p021; 08p028; 08p036; 08p070; 08p105; 08p115; 08p143; 08p151; 08p185; 08p204; 08p212; 08p223; 08p241; 08p251; 08p313; 08p322; 08p337; 08p348; 08p359; 09p037; 09p048; 09p069; 09p079; 09p093; 09p103; 09p114; 09p133; 09p141; 09p146; 09p175; 09p189; 09p199; 09p210; 09p234; 09p245; 09p263; 09p268; 09p273; 09p001; 09p278; 10p032; 10p222; 10p194; 10p133; 10p212; 10p093; 10p143; 10p174; 10p204; 10p77; 10p102; 10p084; 10p050; 10p059; 10p163; 10p184; 10p022; 10p153; 10p123; 10p006; 11p001; 11p009; 11p038; 11p056; 11p079; 11p096; 11p112; 11p122; 11p134; 11p144; 11p153; 11p161; 11p169; 11p178; 11p197; 11p207; 11p217; 11p225; 11p242; 11p252; 12p219; 12p227; 12p246; 12p254; 12p271; 12p001; 12p018; 12p026; 12p036; 12p056; 12p066; 12p074; 12p084; 12p108; 12p125; 12p131; 12p141; 12p147; 12p174; 12p191; 12p201; 12p210; 13p001; 13p010; 13p036; 13p053; 13p063; 13p083; 13p097; 13p107; 13p117; 13p125; 13p152; 13p159; 13p167; 13p175;
Results	04p137; 06p077; 06p089; 06p135; 06p221; 06p245; 06p233; 06p323; 06p001; 07p003; 07p030; 07p084; 07p123; 07p143; 07p236; 07p246; 07p286; 08p021; 08p223; 08p241; 08p337; 09p048; 09p199; 09p001; 09p278; 10p077; 10p050; 10p059; 10p042; 11p028; 11p079; 11p096; 11p161; 11p169; 11p178; 11p207; 12p261; 12p018; 12p026; 12p116; 12p131; 12p174; 13p010; 13p036; 13p053; 13p117; 13p125; 13p134; 13p152; 13p167; 13p191;
Conclusions	06p51; 06p89; 06p121; 06p183; 06p297; 06p323; 06p361; 06p431; 07p10; 07p30; 07p77; 07p253; 07p263; 08p21; 08p115; 08p204; 08p223; 08p251; 08p337; 08p359; 09p273; 10p59; 10p163; 11p1; 11p144; 11p207; 12p261; 12p1; 12p26; 12p74; 12p91; 12p182; 13p46; 13p107; 13p117; 13p167; 13p175;

Fig. 23. Percentage of papers containing which abstract component



Most papers present only two (41%) or three (35%) while only 3% of abstracts contains all five abstract component as shown in Figure 25. In some cases, abstracts just mention what will be presented within the paper instead of giving any detail about what was achieved concluded or statistical data obtained.

Although most papers still does not present all five components, it has been noticed an improvement within abstracts providing a much more detailed description. Also, it can be seen from Figure 26 that the number of abstracts that present three components has been growing while the number of abstracts with one and two components has been falling. Unfortunately, the number of abstracts with four or five components remains steady low.

Fig. 24. Percentage of papers per number of abstract components

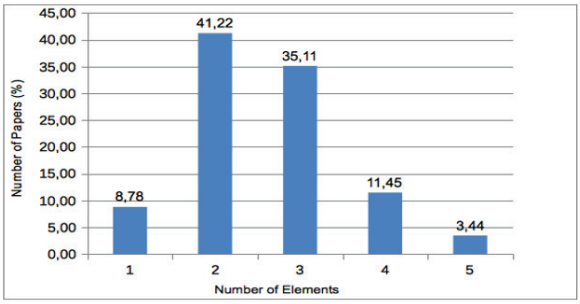
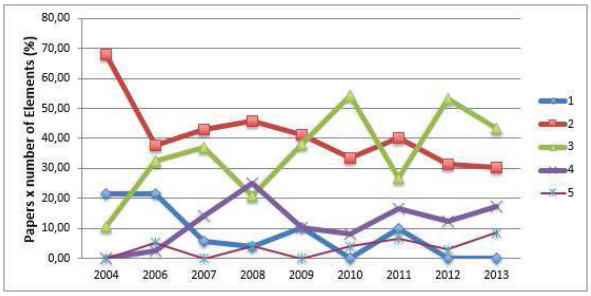


Fig. 25. The number of abstract components over the years.



VI. Discussion

The main application areas remain Medicine with a slightly increase on Education and Virtual Reality (VR) Tools. At the same time, VR presents a persistent and stable increase in sub/related areas such as, and particularly, Augmented Reality (AR). Future surveys should however, include other sub/related areas such as Diminished Reality [8] and Cross Reality [9], as they have already appeared in SVR (see 11p252). This specialization would help identify how the community is keeping up with state-of-the-art in the field.

Subjects like 3D software interaction, VR devices, collaborative systems and real-time visualization/simulation have a stable presence on SVR editions. However, it is important to be aware of researches regarding haptic devices, avatars and pure computer graphics since the subject diversity is very healthy to development of the field.

An expected shift has been verified regarding web technologies like VRML to newer options like X3D. The community also shows preference to use low level, low (no) cost tools like OpenGL. The same applies to AR which shows an increase of ARToolKit usage.

The programming language panorama does not differ from what was previously identified when low level tools were preferred. It seems that C-like languages have been preferred due to the fact that it is generally considered by programmers that these languages provide flexibility, high performance, low cost and lots of libraries support.

The number of papers that did not make explicit the programming language used has dropped over the years, which is a good sign from the completeness of information point-of-view. Future surveys should go into detailing the "others" category to highlight newer technologies.

Stereoscopic-related research declined significantly, in the same way it happened for 3D commercial TV sets. Such shift might be explained by the development of new products replacing stereoscopic need.

The increase in the development of new engines is also noted which shows a bit of researchers' audacity. The commercial cost of existing engines and the general applicability that engines offer to other areas (such as animation and games) are possible motivations that might drive such effort.

Comparing Figure 14 to Figure 15 it is possible to identify that the number of English-written papers do not follow suit international participation in SVR. Thus, foreigner presence does not determine the amount of English-written papers. This means that the amount of English-written papers depend mainly on the national community effort to submit papers written in English.

It is possible to identify that English-written papers are getting consolidated in the late 10 years and such tendency is not affected by foreigners participation however. This suggests that the event might adopt English-written papers as a requirement in order to get international attention with no much fear of publication deflection. It seems also important to promote foreigners participation as reviewers and authors as well as apply efforts to increase the event size since it has been decreasing slowly but steadily.

In 2009, there was an expressive percentage of English papers comparing to Portuguese publications. The following year however, the opposite was observed: Portuguese-written papers increased almost twice while English-written papers dropped significantly. Such oscillation is observed in other intervals: 2007 – 2008 and; 2012 – 2013. Nevertheless, a trend of fifth-to-fifth percent ratio could be observed.

On average, 4 co-authors and 1,4 institutions per paper, it could be said that VR research community seems to work well in groups but within the same institution, mostly. These institutions are mainly Universities from the public sector. Five states accounted for more than 74% of all papers ever published in SVR: SP, RJ, RS, PE and CE.

From Figure 20 and considering the contribution of papers along all nine previous editions of SVR, it can be said that it is expected at least three papers from USP and about one from UFU. In total, there is a strong indication that next SVR edition might expect at least 17 full papers from major players among the average 29 full papers every single edition.

From Figure 18, it can be inferred that Southeast, South and Northeast are the major players in terms of regions contributing to SVR. But, a shift in the leaderboard is slowly happening where the first two places are declining and the last, Northeast, has jump to the first position over the last two years.

The two most contributing regions account for more than 77% of all papers. The bottom two regions falls behind the oversee contributions from Germany.

As has happened back between 2004 and 2008, developmental papers prevailed. However, in the last years the focus has changed as the SVR scientific community shows now more interest in developing tools, techniques, algorithms or base methodologies to support the development of applications than they did before - less focus on applications and more on the foundations.

It could be seen that the papers published in SVR over the last decade tend to present only two or three (out of five) of the components of an abstract, focusing in their aim and method, and sometimes, their background. However, the number of abstracts that present three components has being growing over the time but none of the others. Although the lack of one or more components does not determine the quality of the paper, it may contribute to reach the target audience, since the abstract is the first (and frequently the only) part of a paper that is read while conducting a literature review.

VII. Conclusions

This paper presented an analysis of all SVR full papers from 2009 to 2013. The results were merged to similar study performed by [2] which evaluated SVR from 2004 to 2008. Evaluated papers were categorized by Content-related and Research-related criteria. Content analyses included application domain, amount of RV and RA focused papers, details on sub areas and, hardware and software technologies used. Research related analyses included internationalization issues, geographical distribution and amount of contributing institutions, collaboration issues, research approach and papers′ abstract structure.

The survey is presented using tables indicating every paper categorization which allows authors and other researchers to scrutinize and discuss results. Graphs are also presented which show the percentage of papers of that category regardless the size of the event.

The VR community seems to work well in groups but within the same institution. The majority of publications in SVR comes from five states of the country: two from Southeast, two from Northeast and one from the South.

Top 10 contributing institutions are less than 10% of all institutions that ever contributed to SVR. This lot is responsible for more than 58% of papers every single year. In terms of Brazilian regions, Northeast participation has been growing slowly and recently overtook the former leader, the Southeast, as the most contributor region to SVR. The two most prominent regions account for more than three quarters of the papers. Germany alone is a country of outstanding contributions among oversees and surpass most of national regions′ contributions. These data suggest that the research area represented in SVR is concentrated in a few institutions and regions and is yet to spread all over the country.

Research approach has not changed significantly since the previous study. SVR is composed primarily of developmental papers. However, we have identified a position exchange regarding specialized and generalizable development research in favor of the latter. Although this is not exclusive to the technological areas (similar shift has happened in other areas such as Health) it is important to point out that regarding research approach the area needs to go more into formulative, descriptive and evaluative research. Such research approaches should be encouraged.

The majority of papers in SVR present abstracts that function much like an introduction than a snapshot of the whole work. This fact highlights that efforts must be endured to produce abstracts that are more complete. This might require abstracts to be a bit bigger than what has been allowed today.

Surveying SVR publications required an extra effort in order to collect all data since they are spread among different databases such as BDBComp, IEEEXplore and ACM Digital Library. Certainly, it would be easier if all documents were available or duplicated into a single database which could facilitate searching and identifying national production, researchers and institutions which would, at the end, contribute to the development of the whole VR/AR area.

It seems evident that the VR/AR community should come together to demand more investment since current financial resources might be restraining researchers options about available technologies which are costly but are much more productive.

Finally, it is possible to assert that national VR/AR research community applied a considerable amount of effort over the last decade to consolidate the area in Brazil and have reached a sustainable level of participation, diversity and volume of research. However, some goals could be suggested to improve area importance, visibility and international relevance: (i) increase the number of participants to the event; (ii) ask for more rigorously scientific research; (iii) enforce more structured abstract, and; (iv) give more value to texts written in English.

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