Virtual Reality Evolution in Brazil

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

Juliana Patrícia Detroz, Marcio Geovani Jasinski, Rafaela Bosse, Thiago Luiz Berlim, Marcelo da Silva Hounsell
PPGCA - Graduate Program in Applied Computing
DCC - Department of Computer Science
UDESC - Santa Catarina State University
Joinville, Brazil
{julidetroz, marciogj, rafabosse, thiagoberlim}@gmail.com, marcelo.hounsell@udesc.br

***Abstract*—Virtual Reality 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 language, international participants, areas and sub-areas of application and related technologies. Although oversees participants has proven not constant, papers published in English has proven stable to SVR editions. The study also 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. The number of Augmented Reality papers has grown steadily and a great variety of underlying knowledge fields (such as 3D interaction and real-time simulation) are persistent topics of interest. An expected shift from VRML to other 3D Web technologies have already happened but there are just a few research papers devoted to formulative, evaluative or descriptive approaches. Data show that by improving the research budget to the area could impact productivity; a centralized database of publications would facilitate recovering and analyzing past contributions and; that enforcing more scientifically rigorous and English-written papers could raise the quality and visibility of Brazilians´ research in VR.**

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 practioners 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 also 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. 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], WIE[2] events and RBIE[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 also enables to identify preferences and tendencies for the near future.

The objective of this paper is to present a survey of the latest 10 years of SVR. Such panorama is important to analyze the development of VR/AR area to foresee its next moves.

[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

978-1-4799-4261-9/14 $31.00 © 2014 IEEE
DOI 10.1109/SVR.2014.39

This paper is organized as follows: section II presents related work that proves that the scientific community is concerned to understand and evaluate the directions of certain areas of knowledge is taking over the time; section III explains the methodology used in order to analyze the papers from latest SVR events; section IV presents our findings 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 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 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 3 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 which 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 first four co-author of this paper;

5 – In case of doubts or any further conflict, the VR/AR more experienced co-author (the fifth 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 1 shows a graph of the percentage of publications published in Portuguese or English which corresponds to Table 1 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.

IV. INTERNACIONALIZATION

Since 2001, SVR committees have been encouraging international participation and papers written in English [2]. Table 1 and Figure 1 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.

TABLE I. LANGUAGE OF PUBLISHED PAPERS

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

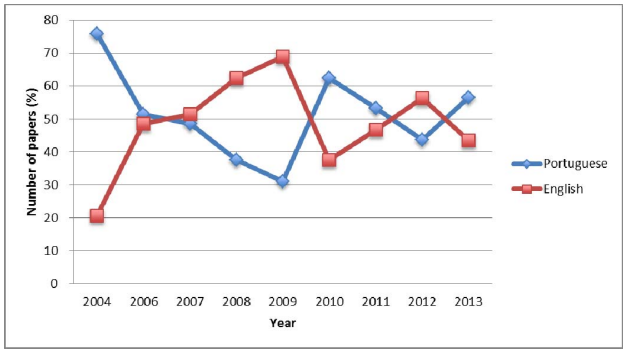

Fig. 1: Percentage of papers published in English or Portuguese.

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 2 and Figure 2 show the contribution of Brazilians´ and Foreigners´ research from 2004 to 2013.

TABLE II. AUTHORSHIP NATIONALITY PARTICIPATION

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

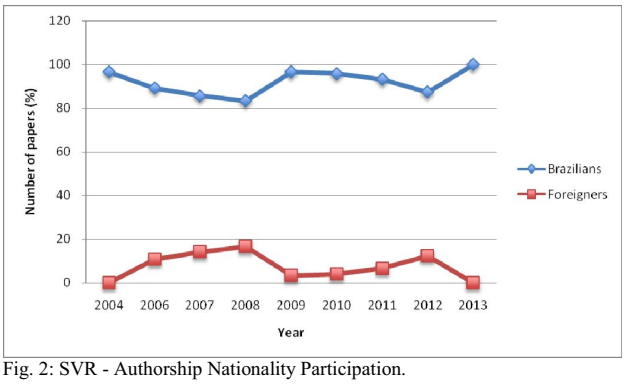

Fig. 2: SVR - Authorship Nationality Participation.

V. MAIN SVR PUBLISHED THEMES

Since SVR receives papers from different domains it is possible to categorize such work according to specific areas. Table III and Figure 3 show such distribution where all training related virtual environments were categorized as education except when it is explicitly related to medicine or industry.

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.

TABLE III. 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

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.

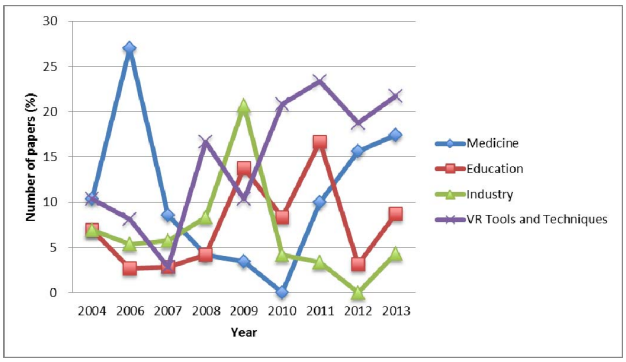

Fig.3: Percentage of papers of specific application areas.

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.

Table IV and Figure 4 present information regarding how AR and Mixed Reality (MR) have been appearing since 2004. Two points are remarkable regarding Table IV and Figure 4: 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.

VI. MAIN SVR ADDRESSED SUBJECTS

Table V and Figure 5 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 VI and Figure 6 categorize papers according to the main focus such as avatars, artificial life and, collaborative/distributed systems. Table VI indicates an absence of artificial life in the last 4 years of SVR.

TABLE IV. 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

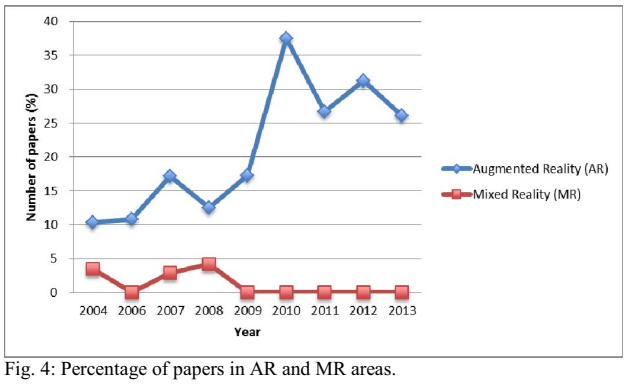

Fig. 4: Percentage of papers in AR and MR areas.

TABLE V. 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;

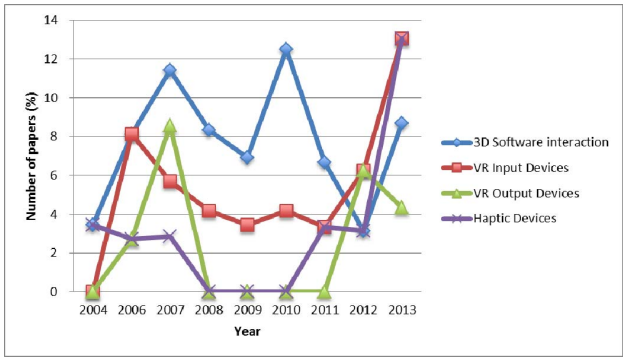

Fig. 5: Percentage of papers discussing interaction issues.

TABLE VI. 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;

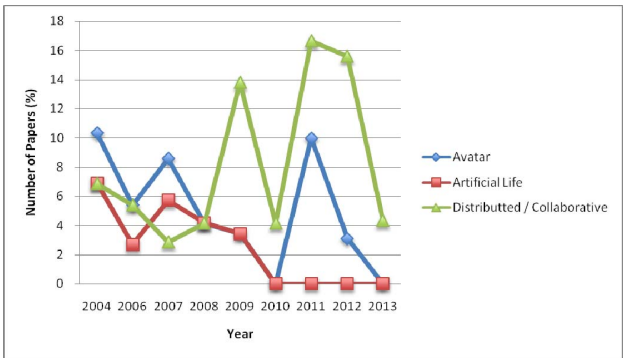

Fig. 6: Percentage of papers about Avatars, Artificial Life and Distributed/Collaborative areas.

Nevertheless 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 VII and Figure 7 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 VII. 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;

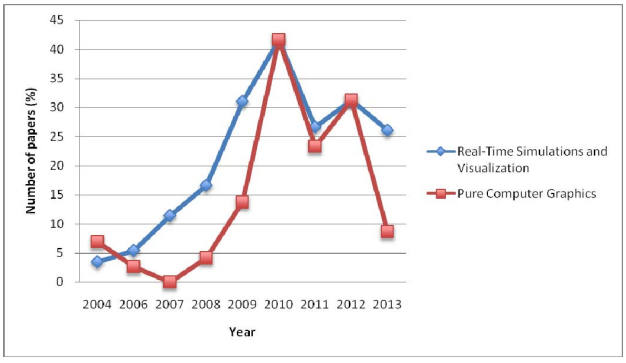

Fig. 7: Percentage of papers in Real-time Simulations, Visualization and pure Computer Graphics

Table VIII and Figure 8 list all papers which did not fit in the main focus of Table VII. Among such works are specific application research and other domains which are not related to Table III such as digital TV technology.

TABLE VIII. 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

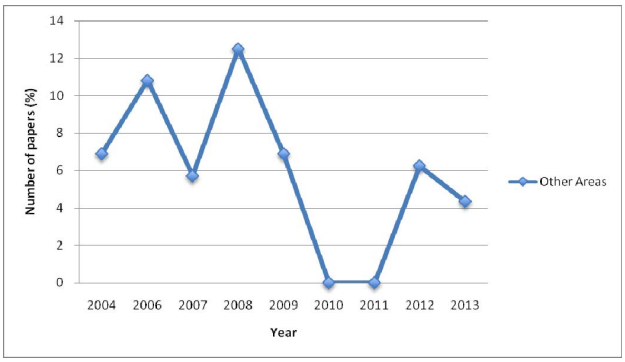

Fig. 8: Percentage of papers related to other subjects.

VII. MOST IMPORTANT TECHNOLOGIES USED

This section discusses the technologies used for the development of the applications presented in SVR papers. Table IX and Figure 9 present papers that used *Web 3D* technologies.

TABLE IX. 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;

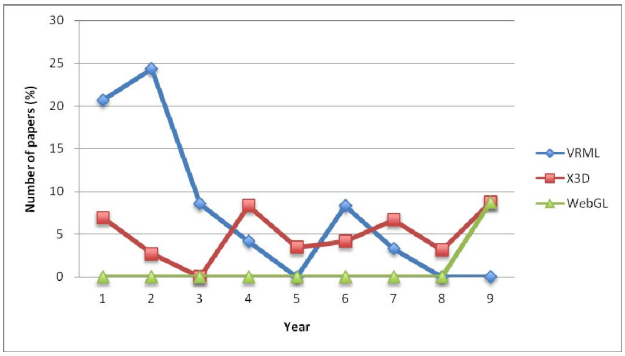

Fig. 9: Percentage of papers related to 3D web-based technologies.

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 X and Figure 10 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 X. 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

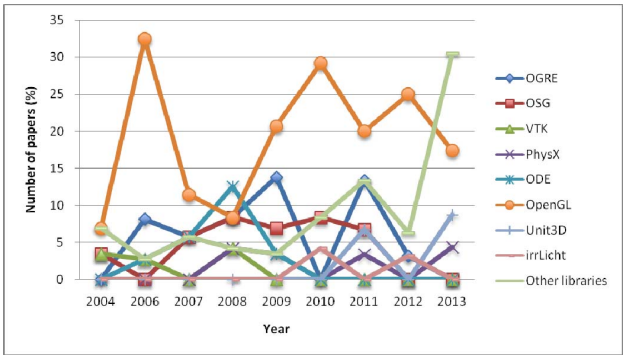

Fig.10: Percentage of papers about graphics engines and libraries.

Regarding technologies for developing AR applications, the most used tools in SVR papers were ARToolKit and, secondly OpenCV. Table XI and Figure 11 show how AR-based technologies appeared in SVR.

TABLE XI. 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

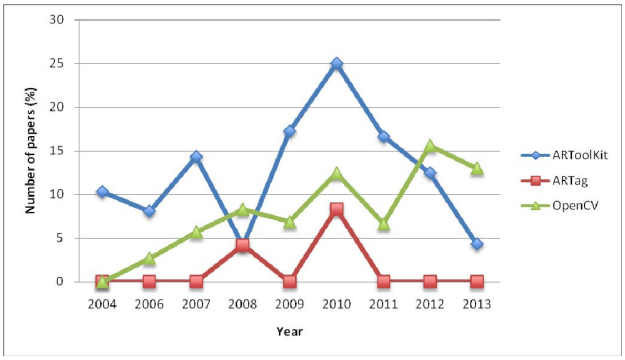

Fig. 11: Percentage of papers related to AR technologies.

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 XI to keep similarity to the previous survey.

A lot of 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 XI, it was possible to identify the use of other frameworks for AR-like applications although just a few of them appeared. Table XII and Figure 12 present the papers found in these tools.

TABLE XII. 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;

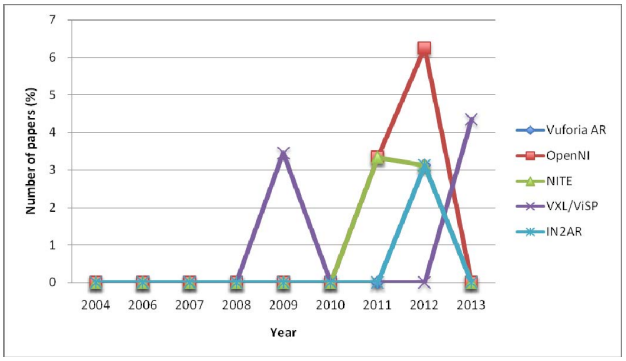

Fig. 12: Percentage of papers related to other technologies for AR.

As shown in Table XIII and Figure 13, 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.

TABLE XIII. 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

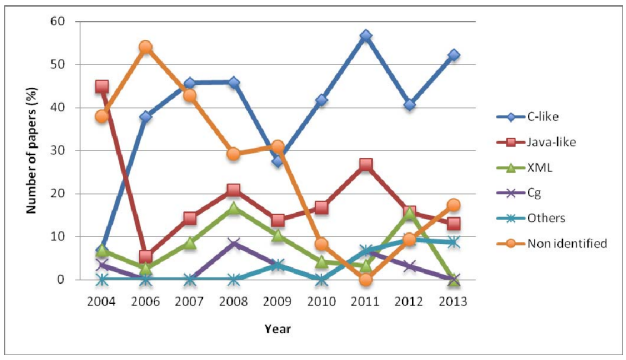

Fig. 13: Percentage of papers using specific programming languages.

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 a lot of remaining papers do not make it clear the language and/or framework it has used.

A handful of papers has been devoted to the development and application of specialized hardware systems as shown in Table XIV and Figure 14. 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 XIV. 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

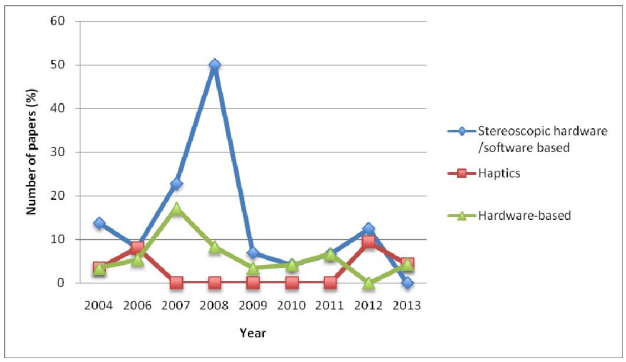

Fig. 14: Percentage of papers related to hardware systems development.

Table XV and Figure 15 show new technologies produced and presented by the authors. The quantity of new technologies is very small but for engine proposals recently.

TABLE XV. 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;

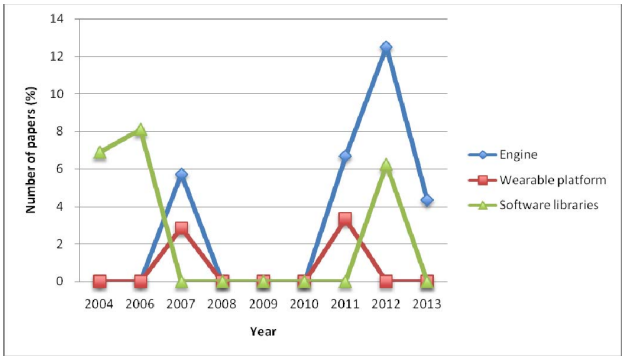

Fig. 15: Percentage of papers presenting technologies developed by the authors.

VIII. RESEARCH APPROACHES APPLIED

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 categorized as: formulative research, descriptive research, evaluative research and developmental research. Table XVI and Figure 16 show the papers classified according to their research approach.

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 2 papers were published.

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.

TABLE XVI. 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

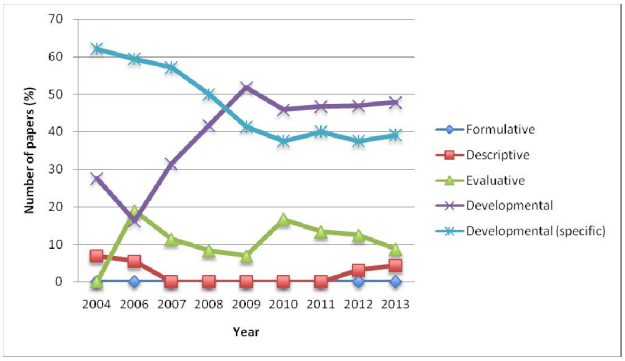

Fig. 16: Percentage of papers according to their research approach.

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.

IX. Discussion

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.

Comparing Figure 1 to Figure 2 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.

Thus, 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.

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.

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.

X. 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 written language, application areas, technologies and research approach.

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.

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 better 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 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.

Research approach has not changed significantly since the previous study. SVR is composed primarily of developmental papers. However, we 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.

Finally, it is possible to assert that national VR/AR research community applied a considerable amount of effort to consolidate the area in Brazil over the last decade and have reached a sustainable level of quality, diversity and volume of research. However, some strategies could be suggested to improve area importance and visibility: increase event's size while keeping current quality of published papers, enforce rigorous scientific researches and pursue international relevance.

XI. ACKNOWLEDGMENTS

The authors would like to thank to André Bonetto Trindade, Ivael Pires, Wanderson Luiz Lupke de Oliveira, Ezequiel Figueiredo de Souza, Fabiano Oss e Gabrielle dos Santos for their contributions in the first two stages of this survey.

REFERENCES

[1] L. de O. Berretta, F. A. A. de M. N. Soares; D.S.A. Fernandes; E. Lamounier; A. Cardoso; M. W. de S. Ribeiro. "Panorama Atual da Realidade Virtual e Aumentada no Brasil". Natal-RN:SBC. Workshop de Realidade Virtual e Aumentada 2010, pp 62-63. Available in http://www.lbd.dcc.ufmg.br/colecoes/wrva/2010/0062.pdf. Accessed 12th, February 2014. (in Portuguese)

[2] A. Raposo, L. Soares, J. Kelner, and V. Teichrieb, "A Journey Through Virtual and Augmented Reality – Reviewing the SVR Symposia from 2004 to 2008," Revista de Informática Teórica e Aplicada, vol. 15(3), pp. 09-24, 2008.

[3] V. V. Odakura; C. A. Barvinski. "SBIE, WIE e RBIE: Publicações da Comunidade Brasileira de Informática na Educação". In: Workshop de Desafios da Computação Aplicada à Educação, Curitiba:SBC. 2012. (in Portuguese)

[4] D. Buchinger, G. D. Juraszek and M. da S. Hounsell. "Estudo Bibliométrico do Crescimento da Área de Realidade Virtual. In: Workshop de Realidade Virtual e Aumentada, 2012, Paranavaí (PR). WRVA 2012. Porto Alegre (RS): SBC - Sociedade Brasileira de Computação, 2012. pp. 1-4. (in Portuguese)

[5] Q. Zhao. "A survey on virtual reality". Science in China Series F: Information Sciences, v.52 no. 3: pp. 348-400, 2009.

[6] C. Kirner. "Evolução da Realidade Virtual no Brasil". Invited Paper. X SVR. João Pessoa- PB: SBC. pp 07-17, 2008. Available in http://www.lbd.dcc.ufmg.br/colecoes/svr/2008/001.pdf. Accessed 12th February 2014. (in Portuguese)

[7] J. Morrison and J. F. George, "Exploring the Software Engineering Component in MIS research," Communications of the ACM, vol. 38(7), pp. 80-91, 1995.

[8] V. Lepetit and m.-O. Berger. "A Semi-Interactive and Intuitive Tool For Outlining Objects in Video Sequences With Application To Augmented and Diminished Reality". In *Proceedings of the International Symposium on Mixed Reality*, Yokohama, Japan. 2001.

[9] J. A. Paradiso and J. A. Landay. Guest editors' introduction: Cross-reality environments. IEEE Pervasive Computing vol. 8(3): pp. 14–15. 2009. Available in http://dx.doi.org/10.1109/MPRV.2009.47. Accessed 14th, April 2014.