Mem. S.A.It. Vol. 94, 87

Memorie della

New Technologies and Inclusion

S. Varano[1], M. Mele[4], A. Laudazi, R. Bonito[2], S. Ustamujic[2], and L. Venuti[3]

[1] INAF – Istituto di Radioastronomia, Bologna, Italy
[2] INAF – Osservatorio Astronomico di Palermo, Piazza Parlamento, 1, 90134, Palermo, Italy
[3] SETI Institute (USA)
[4] Università degli Studi del Sannio
e-mail: stefania.varano@inaf.it

Received: 17/01/2023; Accepted: 30/01/2023

Abstract. This article collects the contributions of the speakers of the "New technology and inclusion" session of the congress "VARIOUS INNOVATIVE TECHNOLOGICAL EXPERIENCES (VITE I): Virtual and Augmented Reality for Disseminating Science: New Frontiers and Challenges". Many different aspects are taken into account, spanning from the role individuals with disabilities have in building tools for access to scientific culture, the status of the art of Virtual and augmented reality experiences in terms of equity and inclusion, the fuction and responsibilities related to these new technology in modern scientific communication and some examples of use of inclusive AR/VR technologies for scientific research and public engagement.

Key words. Inclusion, diversity, new technologies

1. Introduction

Technologies that allow Virtual and/or Augmented Reality experiences are widely used in many areas of our lives, including applications in the field of scientific knowledge and dissemination. Investigating the design, the representation, accessibility and enjoyability of these resources from the point of view of individuals with special needs or physical impairments allows making important considerations. An inclusive and attentive design, from the perspective of its end users, can restore the equal access that scientific contexts should offer to anyone, regardless their individual conditions and needs. Anyone could be a main character in science when they themselves or others help building a scientific culture equally accessible for all. New technologies can change people's lives, when they are designed to be centered on the users, involving them in the process not only of making reality more accessible but also of creating new realities, welcoming, enjoyable and enriching. In the framework of Universal Design, new ways of designing virtual and augmented reality experiences can be considered, through co-design with experts and users and through attentive design-evaluation iterative processes that leads to contexts usable by all, without needs for adaptations. Astronomical scientific research projects and contents are also presented, that convey important innovation in terms of justice, equity and inclusion in science in general, and in VR, AR and educational environments in particular, through the use of sonification and digital and printed 3D models for dissemination.

2. People with vision impairments and science. A story of success

Many wrong beliefs about people with low or no sight still discourage many of them from following a scientific career; and yet there have been, and there are today, many notable figures of blind or partially sighted scientists in history. Starting from inclusive contexts in which they have lived or that they have created themselves, they have given their contribution to the development of scientific knowledge and their inventions, including their tools to convey science in an accessible way for people with low or no sight, are still now part of our assistive technologies and a powerful source of inspiration for modern researchers, practitioners and developers. The first instrument that allowed people with sight problems to do mathematics with the sense of touch was designed by English Mathematician Nicholas Saunderson (1682-1739), blind since the age of one, during his youth in the 1690s (Tattersall (1992)). His tactile table of arithmetic was a square wooden board of approximatively 30 cm length, its surface divided into 100 squares by thin wooden stripes. Each one of the 100 squares had nine holes in it, arranged in a 3 for 3 grid. Using pins with distinct heads, recognizable by the sense of touch, to be inserted into the holes, Saunderson could represent the decimal representation of a number in every row of the table, being allowed to touch the result without moving the pins, and to perform intricate computations (Tattersall (1992)). The tactile table of arithmetic became the main source of inspiration for later developments in the history of accessible technologies for mathematics, especially for the tools invented by Moyes in the second half of the 18th century and for the Taylor Slate in the 19th century (Tattersall (1992)). More than a century after Saunderson became Lucasian professor at the University of Cambridge, Louis Braille invented his eponymous tactile alphabet, but it was not capable of coding higher mathematical symbols and formulas. It was American mathematician and inventor Abraham Nemeth (1918-2013), blind since his birth, who designed a surprisingly simple and non-ambiguous way of reproducing higher mathematical formulas into Brail with the so-called Nemeth Code (Nemeth (1956)). He also took on the problem of ambiguity in spoken mathematics, developing MathSpeak, a complete guide on how to present mathematics to people with low or no sight in a non-ambiguous way (Isaacson (2012)). Nemeth's inventions are still today used by many blind or partially sighted people around the world and accompany them from childhood to their workplace; moreover, they have been incorporated in a number of modern technologies like screen readers and Braille displays. The contribution of people with low or no sight to science does not limit to assistive technologies: the extraordinary works of Leonhard Euler (1707-1783) in countless field, the road engineering work of pioneer John Metcalf (1717-1810), the discoveries about bees by Francois Huber (1750-1831) and the works of many more are the proof that, given an inclusive contexts, there is no barrier for blind and partially sighted people in science (Mele (2021)).

3. Ultra-technology and different skills: a reflection on the future of the integration between man and machine

As you read this text, in this very moment, millions of people around the world are looking for information about the use of advanced digital technologies. There are those who ask an artificial intelligence engine to write texts or make art masterpieces, and those who instead think about how to create their own avatar for the Metaverse. And while a kid is wearing a virtual reality headset, he doesn't realize that he is not just playing, but he is laying the behavioral basis for the fastest evolutionary phase that man has ever gone through: that of the fusion with technology. Technology was born to meet the limits of the human race, whose imagination and passions far exceed what nature offered. Although we are accustomed to appoint our body as a perfect machine, it seems that in both physical and intellectual and social works, humanity has never really limited itself to the basic functions at its disposal. There is this constant movement to the overcoming, from which derives the energetic trust in science - that all adjusts (and that philosophically, but also concretely target to immortality), but at the same time feeds the anguished substrate of the darkest dystopia, which instead turns a grim look to self-destruction. Poised between these two opposing poles, both fruit of our boundless ambition and our inexhaustible abilities, we are in a century that will show the kaleidoscopic face of disruptive innovation, showing many of the scenarios that, until yesterday, were reserved for the imaginative role of science fiction. It is already happening, and the feeling is that of a fascinating and explosive "whole" to become. In this context, people who conceive, design, develop and manage the use of technology have a great responsibility. In fact, we have to make people aware of technology, educate them not to risk it being wasted or used for the wrong purposes. If we can't control the winds, let's at least manage the rudder. We must ask ourselves about the purpose of this immense advance: where do we want to go? Where is it taking us? Why? Is there good technology and bad technology? Yes, there is. Technology can escape the very hands that have developed it to take a form of its own. And it certainly depends - just to mention a few examples - on how users employ it, where they apply it, by social conventions, and economic goals. We need to reset priorities. Starting over from people and ecosystems. Starting over from the needs linked to life and joy. Joy, for example, is bound by cultural, economic, social and structural barriers. Some are inclined to pity people with disabilities, considering them unhappy. But have we really questioned the reasons for the unhappiness of each individual? The technological super-skills that we already have, can be shaped on the specific needs of those who have limiting differences compared to the context in which they live. Limiting as compared to action, thought, sociality, and the free self-expression. Because of these barriers, one on the other, joy is forced into frustration, lack of meaning and despair. There are conventions that determine what is normal and what is not. Two arms, two legs, five well-developed senses, standardized language, neural connections, cause-and-effect relation. But what happens when ultra-technology completely changes the scenario on which these conventions have always been based? How are skills reconfigured in a virtual reality where shapes are molded at will, when not in real time? What happens to a "real" physical difference when social networks move you to bizarre environments, built on unusual social dynamics and new languages, where one can chose alternative three-dimensional bodies, which are often very different from the anthropomorphic form? We must understand how to manage the compatibility with this new "layer" of existence, with this ultra-internet that certainly is not concrete in a material sense, but that has all the characteristics of reality. We need to start from a user center design, able to put the needs of the person at the center of the technological systems. The starting point shouldn't be the accumulation of wealth, nor the unbridled and demiurgical rush to continually reshape the world. It should be the person, instead, and her/his essence, life, desires, and the right to joy. There are already many examples of how immersive technologies can be used to counterbalance for some types of disability. Modern virtual reality systems can offer scenarios otherwise difficult or impossible to recreate, in which to produce stimuli and carry out therapeutic activities; algorithms can correct movements to allow to inhabit a corrective digital dimension, in which to experience actions that the physical world would not allow. Eye or hand tracking systems compensate even very serious deficiencies of movement, and through embodiment (wearing the shoes of the other) you can change your perspective, in the body of other people, animals or things. But the next step will probably be the most disruptive. We are talking about making perfectly habitable this brand new "parallel dimension", and therefore making it capable of holding part of a person's existence in a satisfying way. A dimension capable of offering total accessibility, and indeed, of reversing the matter of different abilities, resetting the canons of normality that have shaped the world as we know and live it today. Of course, we are not talking about creating virtual realities that are indistinguishable from reality; nor are we talking about replacing reality with artificial paradises. We're talking about developing immersive experiences that are so compelling, that they can be assimilated to real life. And that because life and joy and the "meaning" of life are built on the experiences that follow one another, in the time at our disposal. And if "a virtual reality experience can change the way we think and behave" - as stated by Jeremy Bailenson, the director of Stanford University's Virtual Human Interaction Lab - then we are really entering an era that has no precedent in human history, an era in which to understand and transform ourselves. The purpose of virtual reality, since its inception, has never been to replace physical reality (except in the absence of it). The purpose of VR today is to become the internet of experiences. Experiences that we can imagine, design and make available primarily to those who have difficulty in living in the real world with joy, satisfaction and fullness of meaning. Therapeutic experiences, but also compensatory experiences, according to an updated concept of existence, that considers all the environments and levels at our disposal, provided in a participatory dimension. "Because when you participate outside or inside a digital world, you live" - still says Baileson. This is the technology on which I propose to reflect and invest. An ultra-technology which, instead of opposing the relation between man and machine, harmonizes it. And perhaps, this union - which is showing so many distortions at the moment - could develop evolved, conscious and transformative models, capable of a more equitable distribution of opportunities and experiences. This probably will lead to some ethical or philosophical compromise, but let's be ready to undertake a careful and deep reflection, to make radical choices and to guide with an (unbridled) mind the technological development, directing it with all our strength toward higher purposes.

Fig. 1. Virtual Reality game The Climb2. Credits: Crytek/Oculus.

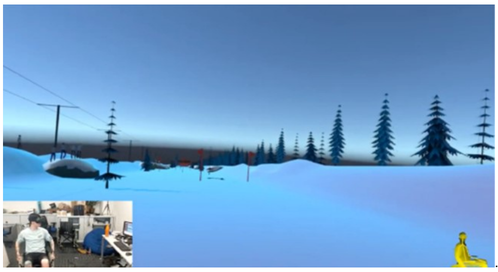

Fig. 2. Virtual Reality game Karamaisu Slope. Credits: Gerling et al.

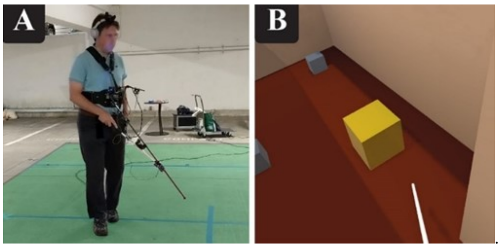

Fig. 3. Haptic and acoustic white cane for VR. Credits: Siu et al, 2020.

4. VR and AR: more equal or just different access?

Virtual and/or Augmented Reality (VR/AR) experiences are widely used in many areas of our lives, including public engagement. We wonder if and how these new opportunities to immerse in different or richer realities can improve inclusion and create more equitable experiences for all. A specific analysis of how VR and AR can be used to improve equity needs appropriate testing and evaluation of existing experiences and an attentive design specifically aiming at improving equity. For a roundup of

Fig. 4. Virtual prosthetic limb. Credits: Aalborg University, 2017.

Fig. 5. Virtual Reality glove for haptic exploration. Credits: Pennstatenews.

Fig. 6. Virtual Reality glove for haptic exploration. Credits: Pennstatenews.

contexts in which VR and AR applications can offer aids for individuals with special needs or opportunities for all to improve their awareness of others' diverse views of the world (Dick (2021)). In an equity perspective, VR experiences can allow: to explore inaccessible spaces and contexts, in particular for people who, due to physical limitations and conditions, cannot, for example, climb a mountain or ski (Gerling et al. (2020)) (see fig.1, 2); to virtually reproduce physical aids (a white cane, see fig.3 or even a prosthetic limb 4) or input-output devices for replacing the missing sensory stimulus with another "vicariant" one (e.g a haptic glove replacing the visual stimuli, 5); to include supplying information (e.g. written texts or Sign Language for spoken contents); to train the exploration of space for users in wheelchair (Li et al. (2020)), (see Fig. 6). VR environments aimed at people with difficulties or disabilities must be carefully designed, with a series of input/output expedients that make their difficulties disappear within the VR experience (e.g. a standard height of a sitting person). Some VR experiences are designed for the controlled exploration of reality and used in many therapeutic fields for pathologies as anxiety of phobia, to provide a controlled and adjustable context. Finally, there are VR experiences designed to increase awareness of the other, to better understand the great diversity of viewpoints and needs each may have (e.g. visual impairment), also fostering carers' empathy. AR experiences can offer integrated digital contents that enhance access and interaction with the real world, making the life context richer, more welcoming, and perhaps even less disabling.

Some examples of inclusive AR applications are: AR viewers that allow to actively increase the size of the characters, change the contrast and brightness on an image (7); AR viewers that highlight the steps during the ascent and descent of the stairs (Zhao et al. (2019)), (see Fig.9); AR apps that allow to get information on objects beyond the physical reach of the person (Rashid et al. (2017)), (see Fig.8). Many of the existing VR and AR experiences are designed to make up for limitations or individual needs of some people. None of these examples specifically represent the scientific framework. VR and AR experiences can favor and perhaps improve equity in access to reality, be it real or virtual, and to

Fig. 7. SightPlus, a medical divide that improves sight for visually impaired. Credits: Give Vision.

Fig. 8. Shopping with Augmented Reality. Credits: Rashid et al, 2017.

Fig. 9. Augmented Reality to facilitate the ascent/descent of stairs. Credits: Zhao et al 2019.

culture, in the framework of Universal Design, namely “the design of contexts and environments usable by all people, to the greatest extent possible, without the need for adaptation” (Mace et al. (1991)). Aiming at universal design means studying and working to create VR and AR experiences neutral with regards to the users’ diverse difficulties or needs. Designing experiences and environments that are equally accessible to all is utopian (barrier free utopia, Shakespeare (2010)). Nevertheless, aiming at this universality implies a process centered on the user, aware of what is being left behind and attentive in not losing too much in terms of equal access. At present, there are no general guidelines for the design of such equal environments and resources. User centered design needs the co-design with end users and experts, to analyze the actual needs of people accessing virtual and augmented reality experiences, in an iterative process of design and evaluation with selected samples of users, to collect feedback and suggestions about what’s needed and effective and assess the best ways to implement them. For public engagement with science, this approach can be very effective also for representing the complexity of scientific data and fostering science process skills in the users, besides their scientific knowledge. In the educational framework, augmented reality can improve the process of knowledge building in the class group, including students with special educational needs (Quintero et al. (2019)). In particular, AR experiences allow integrating existing or self-produced 3D contents and could be very effective in engaging with the contents and processes of science (e.g. creating models out of scientific data).

5. New technologies and inclusion: an international INAF/Vera C. Rubin legacy survey of space and time (LSST) collaboration

A proper way to investigate complex systems as young stellar objects (YSOs) is to apply an interdisciplinary approach which combines multi-band observations, numerical models (**?**Bonito et al. (2010b, 2014)), and laboratory experiments (Albertazzi et al. (2014)). In fact, YSOs consist of several components emitting in different bands: a forming central star, surrounding material or disk, accretion columns, bipolar supersonic jets, and shocks. Vera C. Rubin Observatory Legacy Survey of

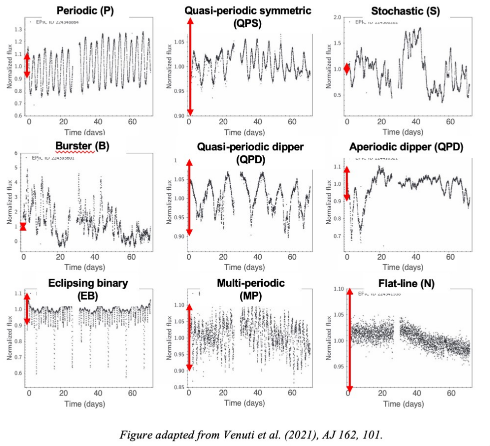

Fig. 10. Different LCs of YSOs due to physical processes related to rotation, accretion, geometric effects.

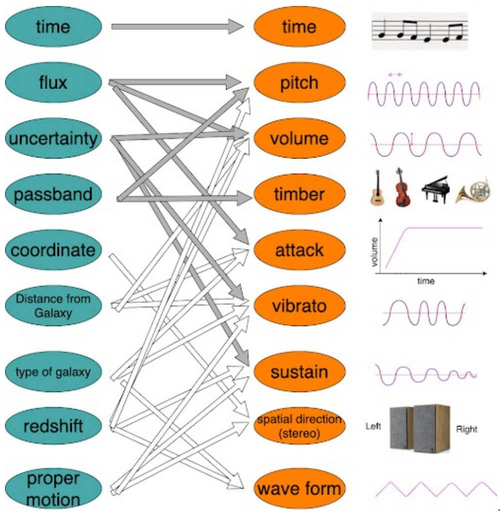

Fig. 11. LSST time-domain data features (on the left) and corresponding sound parameters and a graphical representation of their meaning (on the right), with potential mapping indicated by the arrows (mappings tested by our group using the PLAsTiCC dataset are indicated in gray).

Space and Time (LSST), a decade-long wide-fast-deep survey (Bianco et al. (2022)) with its unprecedented combination of area, temporal sampling rate, and flux sensitivity will allow us to investigate time-domain events in a wide range of processes. In the era of Big Data Astronomy, Rubin LSST data will be accessible through the Rubin Science Platform (see a tutorial on the use of the Portal Aspect discussed during its internship by Alessandro Tramuto, an undergrad student of the University of Palermo[1]. Transients and Variable Stars (TVS) Science Collaboration (SC) of Rubin LSST covers a diverse range of scientific topics, from YSOs to supernovae, from pulsating variables to microlensing, also including a group on Data Visualization and Characterization and one on Justice, Equity, Diversity, and Inclusion[2]. These two groups focus in particular on: Kickstarter programs to mentor students and inclusivity training; Novel data visualizations, including sonification and 3D printing; Collating information for refugee scientists; Broadening awareness of Rubin LSST; Fostering inclusive recruitment practices.

Our team activity has focused on the investigation of YSOs, starting from the analysis of the light curves (LCs) to study their variability in different time scales ((Bonito & Venuti (2023)), accepted for publication on ApJS), from hours to years, taking advantage of the whole decadal Rubin LSST survey, to discriminate between different processes causing the observed variability: rotation, variable emission from accretion shocks, star-disk geometry (see Fig.10 and Venuti (2021)).

In the context of the project Bonito & Venuti et al. 2021[3], we are now developing (see also Ustamujic et al. contribution) 3D models of astrophysical systems that can reproduce the scenarios leading to the observed LCs indicated in Fig. 10 to be used in Virtual Reality and to produce printed kits for a more inclusive Science with Rubin LSST, that will make more accessible our results to visually impaired students/researchers. An alternative way to enhance accessibility to Rubin LSST results, Rubin Rhapsodies: a project to offer access to the Legacy Survey of Space and Time

---

[1] https://youtu.be/rowIiyNXT5I
[2] https://lsst-tvssc.github.io/subgroups.html
[3] https://lsst-sci-prep.github.io/kickstarter_grants.html

data through sound, has been developed by the TVS SC[4]. Sound properties, such as pitch, volume, timbre (see Fig.11), have been used to sonify different LCs of variable astrophysical systems. The Rubin Rhapsodies project is a collaboration between scientists and musicians finalized to the implementation of sonification of Rubin data to expand access to the LSST data, also including the access through the Rubin Science Platform. Therefore, the integration of sonification at the level of the Rubin Science Platform is crucial to allow also visually impaired researchers to analyze future Rubin LSST data, also benefiting the entire scientific community through the extension of the representation space. Multi-band LCs have been sonified and are publicly available on the website of the funded project (Bianco et al. (2022)), and include eclipsing binaries, supernovae, and mystery objects as well, as Rubin LSST will allow us to discover anomalies and true novelties in the near future.

6. Models and observations for a more inclusive science with the Vera C. Rubin Observatory

Young Stellar Objects (YSOs) are complex systems which during most evolutionary stages are formed by a central star surrounded by a circumstellar disk of dust and gas. The material from the disk is transported inwards and is accreted onto the star following the magnetic field lines (Hartmann (2016)). YSOs exhibit significant variability (Fischer (2022)) associated with phenomena related to the magnetic activity and to the circumstellar environment such as: stellar flares as a result of magnetic reconnection in the upper atmosphere; periodic rotational modulation of the surface-averaged brightness due to cool star spots; accretion disk variations either due to intrinsic changes in mass transfer or to geometric effects; jets/outflows due to the highly dynamic processes of mass loss. In this project, we aim to investigate the variability in YSOs at different time scales in the context of the preparatory activities for the Vera C. Rubin Observatory. The observatory will consist of an imaging system with an 8.4-meter primary mirror and will conduct the 10-year Legacy Survey of Space and Time (LSST): a deep survey that will provide images of every part of the Southern Hemisphere sky for ten years, to achieve the largest astronomical catalogue that has ever existed (Ivezi (2019)). In preparation for Rubin LSST data, we are analyzing YSO light curves from public datasets (e.g., PanSTARRS and Gaia) of young star-forming regions from available large-scale surveys. In order to support a more inclusive participation to Rubin LSST activities, we are creating a catalogue of publicly available interactive 3D graphics, and 3D printed kits, based on the modeling and interpretation of a number of physical processes causing photometric variability in YSOs that we plan to investigate with future Rubin LSST data. In Figure12) we present one of the models of our catalogue, created by modifying and adapting for 3D printing the MHD simulation described in (Orlando (2011)), using the open source software Blender. The 3D printed models will help to disseminate some of our results, and to adequately present Rubin science to visually impaired researchers and members of the scientific community at large.

[4] `https://lsst-tvssc.github.io/RubinRhapsodies`

Acknowledgements. RB: The project described in section 5 has been funded by Kickstarter Grant, Bonito & Venuti et al. 2021 supported by the Preparing for Astrophysics with LSST Program, funded by the Heising Simons Foundation through grant 2021-2975, and administered by Las Cumbres Observatory and supported by INAF – Osservatorio Astronomico di Palermo.

References

Albertazzi, B. et al., Laboratory formation of a scaled protostellar jet by coaligned poloidal magnetic field, Science, volume 346, num.6207, doi 10.1126/science.1259694, 2014

Bianco, F. et al., Optimization of the Observing Cadence for the Rubin Observatory Legacy Survey of Space and Time: A Pioneering Process of Community-focused

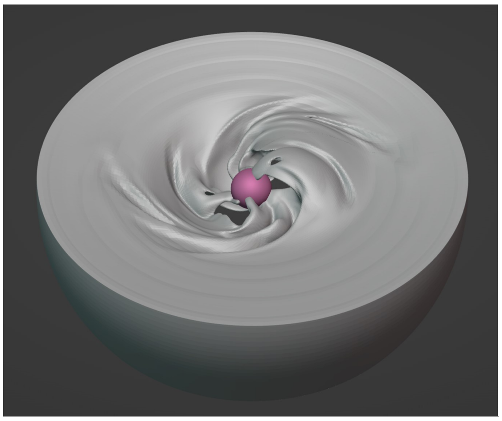

Fig. 12. A young accreting star (represented in pink) surrounded by a warped accretion disk (in grey). The model has been modified and adapted for 3D printing from the MHD simulation described in Orlando (2011)

Experimental Design, arXiv, volume 258, num.1, doi 10.3847/1538-4365/ac3e72, 2022

Bonito, R. & Venuti, L., accepted for publication on ApJS, 2023

Bonito, R. et al., Magnetohydrodynamic Modeling of the Accretion Shocks in Classical T Tauri Stars: The Role of Local Absorption in the X-Ray Emission, apjl, volume 795, num.2, doi 10.1088/2041-8205/795/2/L34, 2014

Bonito, R., et al., Generation of radiative knots in a randomly pulsed protostellar jet. I. Dynamics and energetics, arXiv, volume 511, doi 10.1051/0004-6361/200913595, 2010

Bonito, R., et al., Generation of radiative knots in a randomly pulsed protostellar jet. II. X-ray emission, arXiv, volume 517, doi 10.1051/0004-6361/201014723, 2010

Dick, E., Current and Potential Uses of AR/VR for Equity and Inclusion, ITIF, 2021

Fischer, W. J. et al., Accretion Variability as a Guide to Stellar Mass Assembly, arXiv:2203.11257, 2022

Gerling, K. et al., Virtual Reality Games for People Using Wheelchairs, CHI Conference on Human Factors in Computing Systems, Pages 1 - 11, https://doi.org/10.1145/3313831.3376265

Hartmann, L. et al., Accretion onto Pre-Main-Sequence Stars, journal araa, volume 54, pages 135-180, doi 10.1146/annurev-astro-081915-023347, 2016

Isaacson, M. D. et al., Ambiguity and inconsistencies in Mathematics spoken in the classroom: the need for teacher training and rules for communication of Mathematics, Journal of Science Education for Students with Disabilities, Vol. 15 no. 1, 2012

Ivezi, Z.et al., LSST: From Science Drivers to Reference Design and Anticipated Data Products, apj, volume 873, pages 111, doi 10.3847/1538-4357/ab042c, 2019

Li, W. et al., Automatic Synthesis of Virtual Wheelchair Training Scenarios, 2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), Atlanta, GA, USA, 2020, pp. 539-547, doi: 10.1109/VR46266.2020.00075.

Mace, R. et al., Accessible environments : toward universal design, Center for Universal Design, North Carolina State University, 1991

Mele, M., L'Universo tra le Dita, Edizioni Efesto, 2021

Nemeth, A., Nemeth Code of Braille Mathematics, II edition, American Printing House for the Blind, Louisville, KY, 1956

Orlando, S., et al., Mass accretion to young stars triggered by flaring activity in circumstellar discs, mnras, volume 415, num. 4, pages 3380-3392, doi 10.1111/j.1365-2966.2011.18954.x, 2011

Quintero, J. et al., Augmented Reality in Educational Inclusion. A Systematic Review on the Last Decade,SYSTEMATIC REVIEW article Front. Psychol., Sec. Human-Media Interaction Volume 10, https://doi.org/10.3389/fpsyg.2019.01835, 2019

Rashid, Z. et al., Using Augmented Reality and Internet of Things to improve accessibility of people with motor disabilities in the context of Smart Cities, Future Generation Computer Systems Volume 76, Pages 248-261, 2017

Shakespeare, T., The social model of disability, http://thedigitalcommons.org/docs/

shakespeare_social-model-of-disability.pdf, 2010

Tattersall, J. J., Nicholas Saunderson: the blind Lucasian professor, Historia Mathematica vol. 19, 1992

Venuti, L. et al., Multicolor Variability of Young Stars in the Lagoon Nebula: Driving Causes and Intrinsic Timescales, aj, volume 162, num. 3, pages 101, doi 10.3847/1538-3881/ac0536, 2021

Zhao, Y. et al., Designing AR Visualizations to Facilitate Stair Navigation for People with Low Vision, UIST '19: Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology, Pages 387–402, https://doi.org/10.1145/3332165.3347906, 2019