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Art and Science: A Mutual Exchange

The experience of the Signals and Images Laboratory of the ISTI-CNR

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Abstract. In the Signals and Images Laboratory (SILab) at ISTI-CNR, science, technology and art have developed a symbiotic relationship where, often, each enhances the other. Initially, technologies like gesture recognition were created to support live artistic performances, allowing artists to control music and graphics interactively. Later, these same technologies were adapted for medical purposes, particularly in motor rehabilitation for children and older people. For example, applications initially designed for art and cultural heritage were found to be helpful in rehabilitation, driving new scientific research. This paper shows some examples where this collaboration has produced innovation and research.

Key words. Multimedia Interactive Systems, New Media Art, Rehabilitation

1. Introduction

In our laboratory, science and art have often intertwined in a relationship of mutual service and enrichment. Initially, science was placed at the service of art, as in the case of gesture recognition for live artistic performances, where innovative technologies allowed artists to control music and graphics in real-time. Here, technology was used to enhance creative expression, enabling new forms of interaction with digital media. This same technology later found significant applications, for example, in the medical field, demonstrating that art can, in turn, serve science. Some systems initially designed for artistic performances were adapted for treating autism spectrum disorders or age-related problems. Other applications for art and cultural heritage, such as various augmented and virtual reality applications or those for contemporary dance, have subsequently found new uses in the rehabilitation field, providing the basis for new scientific studies. The following examples illustrate how science and art have never been separate but co-creators of innovation. Sometimes, science and technology have empowered art, but art has stimulated new scientific discoveries at other times.

2. The background: Department of Music Informatics

The use of technology in the artistic field in our institute has distant origins with the Department of Musical Informatics. The music informatics research at CNUCE (Centro Nazionale Universitario di Calcolo

Fig. 1. Pietro Grossi at the TAU2. NUCE - CNR

Elettronico) started in 1965 with the establishment of the Department of Music Informatics thanks to the musician Pietro Grossi (Figure 1).

Around the end of the 70s, the department's research activities focused on automating creative processes, encoding music, creating archives, and using analogical or hybrid instruments for performances. An important project realized by the Department of Music Informatics of Pisa was the terminal TAU2 (Bertini (2007)) and the software TAUMUS, for the IBM 370/168 system of the CNUCE. Around the middle of the 80's, Graziano Bertini and Leonello Tarabella changed the direction of the investigations, changing the department's name to cArtLab (Computer Art Lab). The group started a new period of research concentrated on the interaction between the man and the machine during live performances (Tarabella et al. (2001)). The cArt lab developed a series of systems for the gestural control of multimedia data (sound and graphics) generated in real-time (Tarabella et al. (1997)). Among the various systems developed at the cArt lab, we could mention: Twin Towers: a gesture sensor based on infrared technology; Aerial Painting Hands: a video-processing-based system for painting on a large screen using free hands; and UV-Stick: a video-processing-based music controller. Later, CNUCE and the IEI (Istituto elaborazione dell'informazione – Institute for Information Elaboration) converged into the ISTI (Istituto di scienza e tecnologia dell'informazione A: Faedo). All art related activities have been incorporated into those of the Signals and Images Laboratory (SI), a section of ISTI-CNR which has a much broader field of research activity.

3. Applications for autism spectrum disorder

Thanks to the numerous public demos, the interactive systems developed by cAart lab have also become known to therapists who treat autistic disorders. A collaboration was born that led to the development of the first application project, which has evolved a lot over the years. Without investigating here the complexity of the intervention, we can state that an increased interaction (through the construction of reactive systems where the subject can move freely, generating sounds and images) with the environment intervenes in a very critical aspect of the disorder, that of the interaction with the surrounding world. SIREMI is an interactive audio system designed as a game for autistic children and adult operators to enhance social and problem-solving skills. The system uses movement-based interaction, where children's posture and gestures (e.g., position, arm and leg angles) are detected and used to control synthesized sounds through a GUI. Tested on boys aged 5–7 with low-functioning ASD, the system showed improvements in engagement and interaction with the world around them. (Curzio (2017)). To maintain benefits at home, the follow-up SIDOREMI projects was developed. This home version, which uses Microsoft Kinect V2, allows children to interact through movement in front of a screen, guided by a parent. Families were connected to a central station for real-time or delayed feedback, continuing the rehabilitation process remotely. The project's potential was demonstrated with a 6-week trial in 2015 (Magrini et al. (2019)). Still based on similar technologies, the following SEMI project was developed for assisting children with motor dyspraxia and ASD, primarily aged 6–10, with weekly rehabilitation. SEMI includes interactive games with varying difficulty levels customized to each child's sensory profile. The four core applications—Repeat the Movements, Guess the Movements, Connect the Dots, and Guess the Card—were conceived to create audiovisual feedback to enhance motor coordination (Figure 2). Experimentation showed positive results, with children displaying significant improvements in attention, response time, and motor skills compared to a control group, especially in balance and hand movements (Magrini et al. (2019)).

4. Applications for aging-related disorders

The technology used in autism applications, derived from that used for artistic purposes, has later also found an application in the treatment of aging-related disorders. The main projects in this area were:
1 - WB@Lucca, a project with the goal of creating a mobile platform of personal and personalized services based on the use of innovative and non-invasive ICT technologies in order to improve the quality of life and the well-being of the inhabitants of Lucca and stimulate their social solidarity. WB@Lucca is aimed at a specific category of users: elderly people who tend to adopt sedentary behaviors and offers a series of services which includes some exergames based on gesture recognition devices, for the maintenance of motor skills.
2 - INTESA, a project which aims to improve the quality of life and well-being of older adults, by offering a suite of personalized and innovative mobile and e-health services. INTESA's system enables comprehensive long-term monitoring of various health aspects such as body composition, motor and cognitive abilities, sleep quality, stress, and social interactions. (Delmastro et al. (2019)) In addition to monitoring various parameters relating to the health of the elderly, the system includes Motor, Cognitive, and Balance Monitoring. This service utilizes gesture and motion recognition (similar to the technologies we used for art purposes) and an EEG headset to collect brain activity data. INTESA integrates all these services to provide a comprehensive, personalized system for supporting older adults in maintaining their health and independence.

5. Augmented and virtual reality applications

In recent years, we have applied augmented and virtual reality technologies to arts and cul-

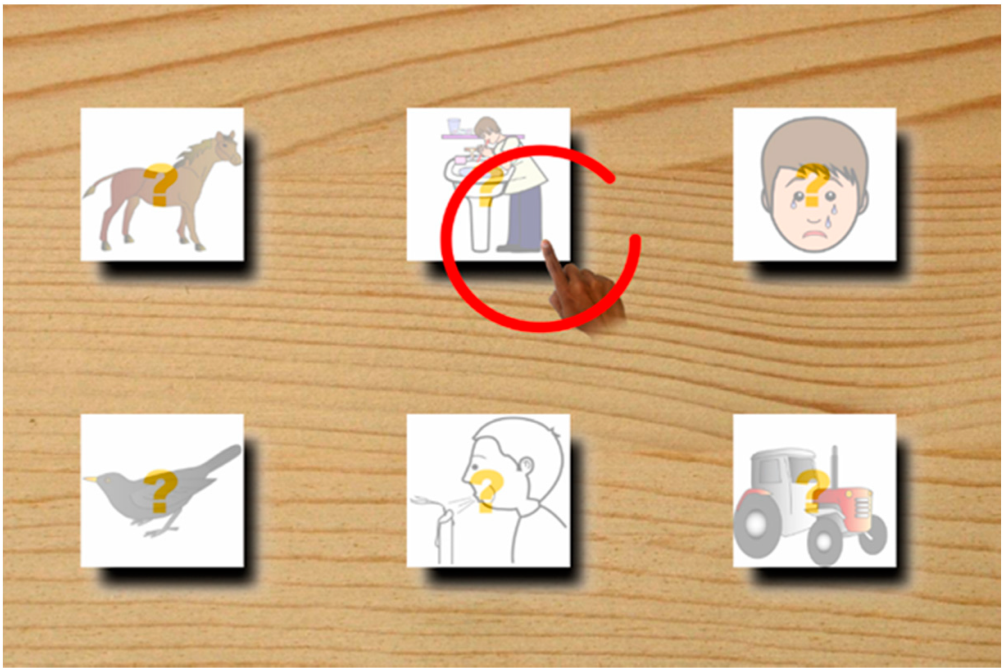

Fig. 2. A screenshot of the "Guess the tile" exergame. This is a gesture driven (using Microsoft Kinect V2) for treating some aspects of the autism spectrum disorders.

tural heritage. Although the applications were intended to enhance a site of particular artistic interest, the development of the system has had implications that have gone beyond the original objective. In the VERO project we developed an augmented reality (AR) application to enhance Venturino Venturi's Piazzetta dei Mosaici in Pinocchio's Park, which includes 21 mosaics depicting key scenes from Pinocchio (Matarese & Magrini (2021)). The app animates these scenes in AR in a playful way, bringing them to life with multimedia content. During development, challenges with outdoor tracking due to lighting and environmental complexity arose. A new multi-block tracking approach was created to address these issues, improving AR localization and ensuring a stable user experience in outdoor settings ((Magrini et al. (2022b)). While analyzing interactive systems for the virtual enjoyment of art, we found that many people need a more engaging interaction with the artwork. For this reason, we developed a project using a low-cost VR headset that allows users to explore and interact with Kandinsky's paintings, reconstructed in 3D. Users can move and recolour the elements of the artwork and then view the changes from the original two-dimensional perspective. Moreover, we found the application helpful as a cognitive exercise for individuals with autism spectrum disorders and was therefore extended and integrated into an experimental project, together with other systems (Magrini et al. (2019)).

6. Dance, Music and Interactive technologies

In recent years, we investigated the possibility of interaction between dance and real-time generated or controlled media. We collaborated with a professional choreographer to create CHNOPS ((Miozzo/Magrini (2024))., a multimedia performance where the dancer directly controls audio and video through movement (Figure 3). The collaboration on these

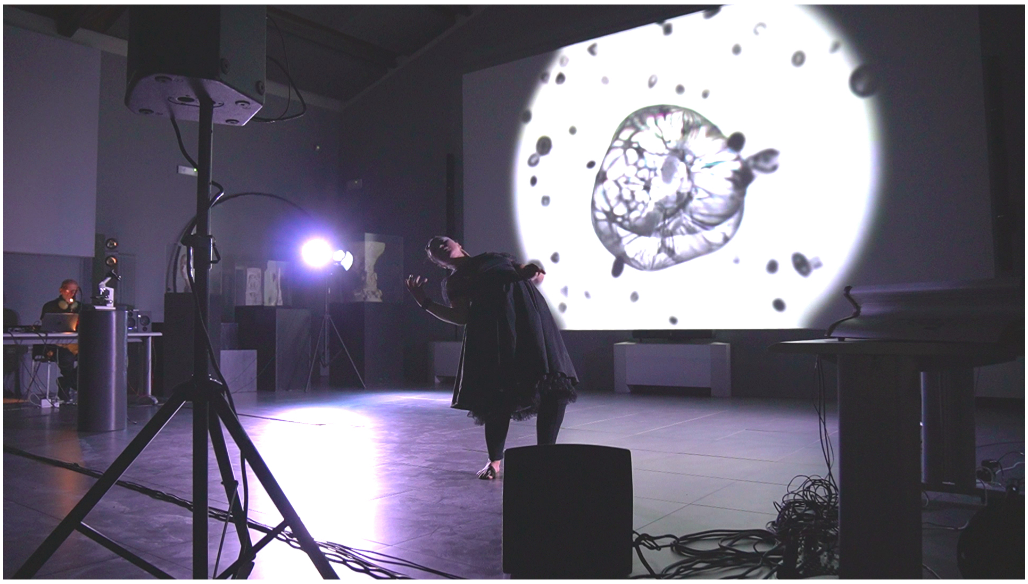

Fig. 3. A shot of the CHNOPS performance. It is a dance performance in which, thanks to the use of wearable sensors and infrared cameras, the dancer directly controls the sounds and graphics in real-time..

topics gave us the idea of organizing *somato-phonic practices*, a practice for professional dancers that combines somatic dance techniques with interactive sound. In this practice, wearable sensors translate body movements into sound, creating a biofeedback loop where movement generates sound, and sound, in turn, influences movement, with the aim of increasing body awareness ((Miozzo/Magrini (2023)). In our somato-phonic workshops, the dancers reported greater control over their bodies and improved coordination with others. Building on these findings, we extended the use of technology in dance to other projects that were no longer intended for dancers. For example, in project THE ((PNRR (2024)), we use wearable sensors, depth maps, and ECGs to explore the effects of synchronized movement on participants' psychological well-being. This approach again demonstrates how we apply technology to the arts and, in turn, use the arts to advance scientific exploration. We also explored the relationship between music and physiological signals (EEG, ECG). In this case, the link between art and science is direct and robust. For example, in 2015, we conducted experimentation trials on a set of subjects, with three-chord harmonic sequences and unexpected out-of-key endings. The experimentation showed a N400-like brain response, similar to that of language (Bonfiglio et al. (2015)): that is a negative-going deflection that peaks around 400 milliseconds post-stimulus onset. As another example, during a concert by a pianist at our auditorium, we tried to visualize (and record) his heartbeat during the performance, initially only for spectacular purposes. Later, analyzing the tracing, we noticed a correlation between the music played and the ECG tracing. This unexpected finding prompted us to delve deeper into the topic, arriving at publishing a related study (Sebastiani et al. (2022)).

7. Conclusions

Nowadays, the use of technology in the artistic field is a common practice. However, in our ISTI-CNR Signals and Images Laboratory activities, we have seen that this relationship is not one-way, but the exchange is often reciprocal. Studying and using innovative technologies in the artistic field leads us to develop applications that frequently find new uses in scientific experiments. Moreover, arts often suggest reasoning paths that are undiscovered by pure scientific processes. We are currently focusing on immersive technologies, particularly for applications in cultural heritage. The study of these applications has inspired us to hypothesize their use for particular rehabilitative purposes, such as treating anorexia nervosa (Magrini et al. (2022a)). The symbiosis between art and science has recently found application in a collaboration with the EGO/VIRGO gravitational observatory, Cascina (Pisa). The collaboration focuses mainly on the sonification of gravitational data in a creative and engaging way to be used in the dissemination events regularly organized by EGO/VIRGO. We are also currently producing a 3D 360 VR video inside the observatory, which will use the audio tracks obtained from the sonification of the data as a sound commentary.

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