THE SOUNDSCAPE HACKATHON: BOOSTING SOUND IN URBAN DESIGN THROUGH IMMERSIVE AND VIRTUAL APPROACHES.

Jorg De Winne[1,2] **Karlo Filipan**[3] **Bart Moens**[2]
Paul Devos[1] **Marc Leman**[2] **Dick Botteldooren**[1] **Bert De Coensel**[1,3]
[1] WAVES Research group, Department of Information Technology, Ghent University, 9000 Ghent, Belgium
[2] IPEM, Department of Art, Music and Theather Studies, Ghent University, 9000 Ghent, Belgium
[3] ASAsense cvba, 8000 Bruges, Belgium
jorg.dewinne@ugent.be

ABSTRACT

A fitting sound environment may have a positive impact on the everyday users of a space. However, outdoor urban spaces are still mainly designed with a focus on visual appearance. Hereby the important role of sound is often neglected. Urban design plans, three-dimensional scale models and computer-generated visualizations all provide a clear and realistic picture of how a planned urban space could possibly be shaped. Providing a way to present the sound environment of this urban space is less straightforward. Combining virtual reality with immersive audio, is a technique that is often applied to reach this objective. In order to explore creative new ways of modifying and presenting sound in virtual reality during the design of urban outdoor spaces, a 3-day soundscape hackathon was organized. Four teams of acousticians, designers and computer scientists were challenged to redesign existing urban environments, by manipulating immersive audio-visual recordings of these spaces. As a result, the teams developed a range of possible approaches to incorporate creativity in the process and to present their sonic designs. The tools developed allow to explore the soundscape of future urban spaces, and therefore might inspire urban designers to take sound into consideration.

1. INTRODUCTION

Since long, environmental noise has been recognized as a main contributing factor to the liveability of an area [1]. The local community can introduce other factors they consider as important [2]. To do so, citizens have to be an active partner in the co-creation process of new urban environments, which has not been the case up until recently [3]. Instead, this was the responsibility of architects, urban designers and local authorities.

Lately, the soundscape of a space is being considered equally important as its visual aesthetics [4, 5]. The term soundscape refers to the acoustic environment as perceived by people, in a certain context [6]. Altering (even partly) that perception or the acoustic environment itself is the aim of soundscape design, where sound is treated as a resource rather than a waste. By preserving or even accentuating sounds that are not at all disturbing, a matching soundscape can be created that may even support the characteristics (e.g., lively, calming) of the space [7, 8].

Efficient and realistic acoustic simulation, and immersive audio-visual reproduction systems are available to those involved in the sonic design of urban spaces [9]. The combination of these techniques with virtual reality (VR) is probably the most powerful tool of the moment. Besides being very affordable and easy to work with for both experts and non-experts. Being able to interact with the environment in real time and having the impression to be physically present in it are two of its major benefits [10, 11]. These techniques make it easier for urban designers to take soundscape design into consideration, and consequently hold the opportunity to have a positive impact on the everyday users of a space.

A Soundscape Hackathon was organized on 3–5 April 2019, in parallel to the Urban Sound Symposium. The participants of both events represented a broad mix of backgrounds (e.g., acousticians, sound engineers, artists, architects, city representatives, urban planners), which is essential in the context of co-creation. The event took place in the laboratories of the Institute for Psychoacoustics and Electronic Music (IPEM), a research group at Ghent University. A detailed description of the event and a complete (technical) overview of the results has been published in extended form in [12].

In this paper, the focus is pointed towards the immersive and virtual approaches to encourage the use of sound in urban design that the teams developed during the Soundscape Hackathon. In Sec. 2, the general hackathon approach is discussed. In Sec. 3, the Soundscape Hackathon is described as it was organized by the authors, including task description, the available equipment and the evaluation criteria. Sec. 4 presents the approaches the different teams developed. Next, in Sec. 5 it is critically discussed why and how these approaches are suitable to boost sound in urban design, together with their benefits and dangers. Finally, in Sec. 6, some conclusions are formulated about the soundscape hackathon and its aim to boost sound in urban design through immersive and virtual approaches.

2. THE HACKATHON APPROACH

2.1 Definition

The word hackathon is an aggregation of the words hack and marathon. Hacking refers to figuring out how certain systems work and subsequently using those insights to adapt them to perform previously unintended functions [13]. Based on this etymology, describing the hackathon as a problem focused computer programming event [14] or as a contest to pitch, program and present digital innovation prototypes [15] might not do justice to the type of event a hackathon really is. It can be better described as a social event where participants work together and/or compete to find creative solutions to a challenging problem.

2.2 Hackathon Format

Hackathons can have different formats, topics and aims and are organized in all kinds of fields: improving specific (genres of) applications, being restricted to participants from specific demographic groups and even addressing social issues beyond the conventional tech world [16]. As an example of the hackathon's success, Facebook's Like button is the result of a company-internal hackathon event to encourage new product innovation [16]. For companies and organizations, the hackathon became a novel approach to quickly develop new software technologies, explore new areas for innovation, spot future employees and recruit good ideas worth funding [16]. Hackathons can also have scientific aims, thereby focusing on bringing researchers together to work on interdisciplinary projects, get collaborations off the ground or form funding proposals [17]. Their goal can be to write a scientific paper [18] or to gain skills, experience and basic understanding in a specific field [19].

Despite the diversity of hackathons, some general conclusions about the format can be drawn. The hackathon starts with some presentations, providing information about the challenges and their aims, the tools available and some practicalities of the event. The aim can either be defined by the organizers ar can be generated in cooperation with the participants at the event itself [13, 16]. In a strictly limited amount of time (between one day and one week) [13, 16], teams of three to six participants prepare a presentation and demonstrate their solutions [16]. This size of teams allows to efficiently work towards a solution while still having enough different perspectives from the team members [17]. In case the hackathon has a competitive element, the winning team is selected by a panel of judges and prizes are awarded to close the event [16].

2.3 Benefits and Pitfalls

Multiple benefits are associated with the hackathon approach. They are highly interdisciplinary and allow intensive collaboration on specific problems [13, 16]. Because of the different perspectives, they are the perfect place to stimulate outside-the-box ideas [19] and to nurture innovation [16]. Hackathons are not solely about the results, but also about the skill set participants develop, such as communication, teamwork and presentation skills [19]. Equally important is the knowledge transfer between members [19], and the opportunity to meet new people and create networks for the long term [16].

Next to benefits, there are some possible pitfalls participants and especially organizers should take into account. Firstly, more restrictions to build a product requires a more structured approach, which may reduce creativity [16]. Secondly, strict time limits force participants to work under time pressure [13, 16], which may be counterproductive. Thirdly, competition can as well limit creativity, as groups may worry more about other groups rather than focusing on their own work [17]. Organizers should be aware that hackathons are not a cheap way to quickly develop business plans, apps or software. Instead they are a place to get creative ideas flowing and build concepts, to be converted into concrete products or designs later on.

3. THE SOUNDSCAPE HACKATHON EVENT

3.1 Goal

Hackathons are an excellent tool to benefit from the expertise of different parties and have already been held in different domains (see Sec. 2.2). However, to our best knowledge a soundscape hackathon has never been organized, even though the fields of soundscapes and of urban acoustic design bring together a lot of different stakeholders.

The general aim of the Soundscape Hackathon was to redesign and improve the soundscape of urban open spaces. Participants were given from April 3rd around noon until April 5th around noon to work towards a creative solution. They were provided with eight high-quality immersive audiovisual recordings, collected within the framework of the Urban Soundscapes of the World project (see Sec. 3.3) and could select up to three of them to work with. At the end, attendees of the Urban Sound Symposium were invited to attend the presentation of the results. It was therefore important for the teams to make use of virtual and immersive approaches to demonstrate their ideas. The participants were challenged to *"Do something with the soundscape"*, more specifically to

1. create a sound environment that enhances the usability of a place and increases its engaging character through a better soundscape [6];
2. assure that their ideas can be implemented and fit in real contexts;
3. create their own tools or to use existing tools to generate the modified audiovisual scenes;

3.2 Teams

The hackathon was announced on the website of the Urban Sound Symposium and invitations were spread through the academic and professional networks of the organizers. Both individual candidates and teams of up to four people could apply to participate by submitting a short CV and a motivation letter. The only information provided to possible candidates was the aim of designing a more suitable soundscape for outdoor public places in a range of cities worldwide and the possibility to win an award in cash. Tab. 1 gives an overview of the four teams of acousticians, programmers and artists that participated in the hackathon, together with their affiliation and background.

Team	Affiliation	Country
	Experience	
Immensive (3)	Immensive [20]	Italy
	VR model design	
Noize Makers (4)	IFFSTAR; freelance	France
	Audio manipulation, auralization	
Trio Akustiko (3)	TU Graz	Austria
	Public interactive audio-installations	
URCHI (4)	Universitat Pompeu Fabra; Universitat de Barcelona	Spain
	Music therapy, artistic projects	

Table 1: The participating teams with the number of members between brackets, their affiliation, country and some relevant experience.

3.3 Urban Soundscape Data Set

The dataset provided to the teams consisted of a selection of documented, high quality immersive audiovisual recordings, recorded at a range of locations in cities worldwide. They are collected within the framework of the Urban Soundscapes of the World project [9], which aims to set the scope for a standard on immersive recording and reproduction of urban acoustic environments with soundscape in mind. The reference database is designed to support the further introduction of urban soundscape design in education and practice and contains good as well as bad examples of urban acoustic environments. Eight 3-minute recordings from different cities were selected based on the availability of a reasonably good visual scene, but with a soundscape that could have been better and leaves room for optimization. Attention was paid to the purpose of the space, the number of people and sounds present in the scene, and possible salient events that occurred during the recording. Tab. 2 gives an overview of the recording locations, including some details and features of the scene.

ID	Location Coordinates Scene features	City YouTube preview
R0008	McGill University Campus (45.504202, −73.576833) Tranquil lawn - relaxing - constant traffic noise - honking	Montreal (CA) `https://bit.ly/2Nrj9gu`
R0018	Rose Fitzgerald Kennedy greenway (42.354721, −71.052073) Art - constant traffic noise - braking & accelerating - talking	Boston (US) `https://bit.ly/2XyRUo0`
R0032	Jinwan Plaza (39.131835, 117.202969) Spacious - river - calming effect - distant traffic noise	Tianjin (CN) `https://bit.ly/2YeMdIZ`
R0043	Signal Hill Garden (22.296008, 114.174859) Green - pavilion - bird sounds - calm garden - noisy industry	Hong Kong (HK) `https://bit.ly/2YgrDYx`
R0063	Potsdamer Platz Campus (52.509192, 13.376332) Lively - talking people - traffic noise - honking - accelerating	Berlin (DE) `https://bit.ly/2X9NzYV`
R0064	City Hall (40.712014, −74.007495) Benches to rest - art - fountain - traffic - construction works	New York (US) `https://bit.ly/2XEqjS8`
R0092	River Walk - Arcade (41.887138, −87.631663) River - relaxing walk - tourist boat - talking - traffic noise	Chicago (US) `https://bit.ly/2xcrVUy`
AT01	De Brouwerstraat (51.197695, 4.421701) 'Garden street' [21] - greenery - car free - silence - bird sounds	Antwerp (BE) `https://bit.ly/2Lt24jD`

Table 2: Overview of the recording locations, including specific scene features.

3.4 Equipment

The hackathon event took place in the audio laboratories of IPEM [22]. The next paragraphs describe some of the specific tools and features these labs provide. All labs and available technology could be reserved for 2-h time slots.

3.4.1 Art-Science-Interaction Lab (ASIL)

The 'Art-Science-Interaction Lab' $(10\,\mathrm{m}\times 9.5\,\mathrm{m}\times 6\,\mathrm{m})$ features a 62 loudspeaker system. The room is acoustically treated to reduce reverberation. In the lower corners, four sub-woofers are placed; along the walls and ceiling 58 loudspeakers are placed, which have a coaxial design and a 110° dispersion angle. Loudspeakers are divided over a first ring ($2\,\mathrm{m}$ height, 34 speakers), a second ring ($4\,\mathrm{m}$ height, 14 speakers) and a ceiling array (10 evenly distributed speakers). Fig. 1 visualizes the structure. To limit external noise, the speakers' amplifiers are located in an adjacent room. Finally, audio connection to the amplifiers is performed using Audinate's DANTE audio over IP (AoIP) protocol [23]. Participants could connect to the system using one CAT6 Ethernet cable in conjunction with the Dante Virtual Soundcard for 64 discrete audio channel output; or a USB3 soundcard. Mapping the computer's output channels to the speakers was done in the Dante Controller matrix interface.

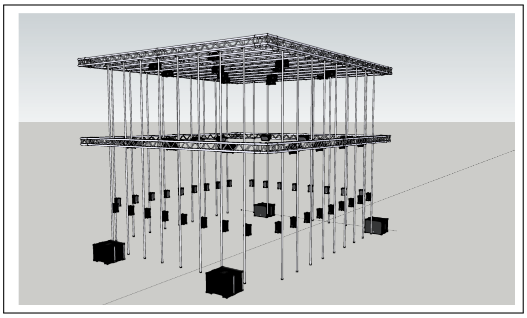

Figure 1: Schematic of the Art-Science-Interaction-Lab.

3.4.2 *Maker Space*

The 'Maker Space' is an adjacent lab ($20\,\mathrm{m}{\times}4\,\mathrm{m}$) with a smaller 8-channel loudspeaker system placed in a circular array with a radius of $1.8\,\mathrm{m}$. Loudspeakers are placed evenly at $2.5\,\mathrm{m}$ height and aimed to the center of the array. The setup is ideal for small-scale individual experiments and tests. Participants could connect to the speakers using the DANTE protocol (over UTP or using USB interface).

3.4.3 *Audio Rendering Techniques*

Two 3D audio rendering techniques were available and recommended to use during the Soundscape Hackathon: wave field synthesis (WFS) and ambisonics. These are physics-based audio reconstruction techniques that aim to create a particular acoustical pressure field at the location of the listener [24] using loudspeaker arrays. Both techniques provide 3D localized sound to reconstruct virtual environments, based on a definition of the room, the audio signal and the desired playback location.

Ambisonics, introduced by Gerzon et al. [25] is based on the decomposition of a sound field into spherical harmonics. Using higher order ambisonics, an enlarged 'sweet spot' can be achieved for multiple listeners; however, the effect is limited to the center of the room [26]. Wave field field synthesis is achieved through superposition of elementary spherical waves. The advantage of this technique is the reproduction of physically correct sound fields in an extended sweet spot area, allowing multiple listeners to move away from the center [27]. A dedicated WFS sound renderer (Barco IOSONO Core [28]) was available in the ASIL Lab to accurately render 3D sound objects [29]. The IOSONO is a user friendly audio processor which translates any incoming audio object (consisting of the audio signal, sound type and playback location) to the discrete speaker outputs. DANTE presets were provided for this configuration.

3.4.4 *VR Systems*

Each team was provided with an Oculus Go, an easy to use, standalone VR device. Participants received instructions to playback the provided soundscapes on the VR system. For more advanced and custom VR experiences, an Oculus Rift combined with a computer of sufficient requirements was available. The Rift is superior in terms of image quality and immersive experience. Reservations could also be made for the HTC Vive Pro together with a dedicated powerful computer. This device is even more performing in terms of display resolution, audio quality and tracking accuracy [30]. It is capable to track a $10\,\mathrm{m} \times 10\,\mathrm{m}$ area very accurately, making it very well suited for room-scale immersive experiences [30]. It was therefore only available in the bigger ASIL Lab.

3.5 Evaluation Criteria

The jury evaluated the results based on three criteria, which were announced at the start of the event. All three contributed equally to the final score.

1. Creativity. Do the teams use innovative ideas and concepts to bring soundscape design to a broad public? What soundscapes do they select and why?
2. Theoretical soundness. Do the adjustments sound correct? Is the modification physically possible and realistic? Do they comply with soundscape theory?
3. Use of technology. How do the participants make use of the available technology in their designs? Are different technologies combined? Is the selected technology suitable to present their idea?

Jury members from the professional and academic soundscape community were selected to cover all three evaluation criteria, based on experience and academic background. To ensure fair competition, attention was paid so that no immediate relations with the participants existed.

4. RESULTS

4.1 Immensive

Team Immensive selected the Montreal soundscape. Its rather quiet ambient sound and little disturbance from other noise sources creates opportunities to enhance the usability of the place. A fitness island with a rowing machine, an elliptical machine and an exercise bike was placed towards the center of the lawn. By adding sounds of the related real activities (rowing, cross-country skiing and biking), the sound environment was enhanced and the gym activities were made more enjoyable. An arc-shaped relaxing zone with sonic benches surrounds the fitness island. Users can interact with the benches to manage the type and intensity level of the sound they emit, adapting the soundscape to their own desire. The team developed custom VR software, using an Oculus Rift, to allow the user to 'row' on the rowing machine or to experience the sonic benches. The provided ambisonics recording was mapped to a virtual 7.0 surround speaker setup, whereas extra sounds were added as point sources with hemispheric sound propagation. The Unreal game engine combined both sounds in the virtual scene. Fig. 2 shows both modifications.

Figure 2: Sonic benches and part of the fitness island.

4.2 Noize Makers

By means of a video presentation, team Noize makers guides the spectators to the middle of New York City Hall Park. Through ambisonic playback of the ambient sound on the surrounding speakers in the ASIL Lab, it is very clear that despite being in a park, the soundscape is very noisy (with traffic, construction works, voices, etc.). A voice-over reads a poem about how a local feels when hearing the heavy rhythm of New York City. With their modifications the team tries to find an opportunity for relaxation and harmony in the middle of a bustling city. To present their solution, focus is shifted towards the virtual scene through VR goggles. The team used part of the speakers to add very localized sound objects (like a fountain, bird sounds, voices, etc.) to the ambient noise of the scene by means of WFS. Careful speaker selection limited the degradation in the WFS effect and allowed them to use the other part of the speakers to playback the ambisonics recording. This clever hack possibly lead to a better combined WFS and ambisonics effect. In the visual scene, the added sounds were emphasized by means of 3D legend objects, pointing towards the location of the sound (Fig. 3).

Figure 3: Noize Makers used 3D legend labels to point towards the location of the added sounds.

4.3 Trio Akustiko

Team Trio Akustiko allowed the users to experience an extra virtual layer on top of the original Potsdamer Platz recording, which is still visible in the background (Fig. 4). By clicking the corresponding buttons, users can adjust the visual scene and add a fountain, trees, playing children, a food truck, some low hills with benches to sit on or a combination of these elements. Adding those elements also adds corresponding sounds to the specific location of the virtual objects. The original ambisonics recording was played through the lab's speaker system, while the added stereo sounds were played back trough open-ear headphones. This VR approach allows people to be immersed in the improved urban design and to experience how it could be, both visually and acoustically. People can explore multiple options and can form their opinion on the different designs.

4.4 URCHI

Team URCHI selected the Boston soundscape, characterized by traffic noise, car horns, tram bells and voices. They opted to apply a negative (removing/hiding sounds) and a positive (adding sounds) acoustic design. By placing a dome overgrown with a creeper plant on the lawn of the Boston park, the surrounding noise can be screened [31]. In order to further mask the road traffic noise and to increase the impression of pleasantness and quietness [32], a small fountain was placed inside of the dome. In addition, they placed a gravel path towards the entrance of the dome,

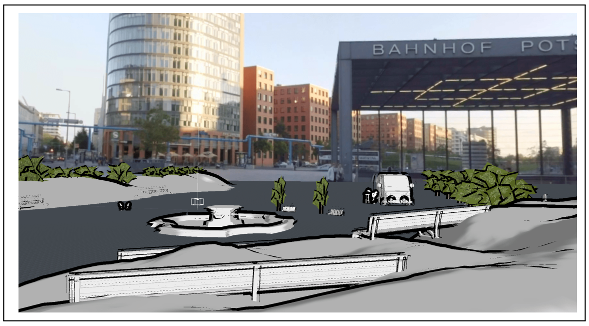

Figure 4: Trio Akustiko added a virtual layer to the scene.

with associated sounds to attract attention. Fig. 5 shows a sketch of the design. As no modifications were made in the visual scene, the effect needs to be created in the audio recording. Playing a sample of calm gravel steps at the correct location in the 3D scene resembles a person walking towards the dome. Applying a fitting low-pass spectral filter to the fountain sound creates the impression that the fountain is inside the dome. When entering the dome, the filter is applied to the surrounding 'outside' soundscape recording, while simultaneously being removed from the fountain sound. Lastly, moving inside the dome can be simulated by changing the spatial position of the fountain. Sound levels were manually adjusted to create a natural sounding and immersive experience.

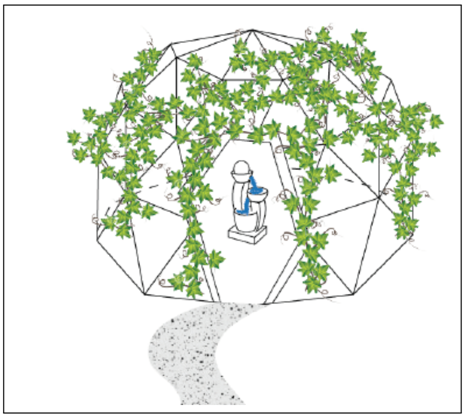

Figure 5: Sketch of the modifications by URCHI.

5. DISCUSSION

5.1 Hackathon Outcomes

As discussed in Section 3.4, the hackathon participants had a wide range of visualization and audio rendering techniques at their disposal. The way the teams used these tools to present their solutions varied considerably.

Despite the differences, a common aspect in all interventions is the use of natural elements. These elements not only have a beneficial effect on the urban soundscape [7], they provide opportunities for mental restoration, stimulate social interaction and encourage physical activity [33]. In some way, all interventions made use of nature-related aspects. URCHI and Trio Akustiko added additional elements, such as a dome overgrown with a creeper plant (URCHI) or an entire virtual layer with hills and trees (Trio Akustiko). Team Noize Makers emphasized existing elements like the different bird sounds that could be present in the scene. Next to this, three teams added non-green elements to support the services the green provides: a food truck for social interaction (Trio Akustiko), benches to rest and restore the mind (Trio Akustiko, Immensive), a fountain or wind chimes for calming sounds (Trio Akustiko, URCHI). The gym equipment by Immensive has a double purpose: it stimulates physical activity, but also adds the potential of social interaction.

Another common thread, especially enabled by the use of VR technology, is the interaction between the user and its environment. Being able to control the space you are in, together with its soundscape, creates a larger sense of presence and immersion, and may therefore make the presentation more convincing. URCHI included the sound of footsteps when walking towards the dome on the Boston greenway, while for instance the sound of moving water is generated when using the rowing machine at the McGill University Campus (Immensive). Such basic forms of interaction allow the user to shape the soundscape of the space. Trio Akustiko allowed people to shape the entire visual and auditory scene by providing buttons to add different elements. Thanks to VR and immersive audio they can experience the different outcomes. An even higher and more advanced level of interactivity could be obtained by providing haptic feedback devices. These were not available in this hackathon, but would allow users to create sound or alter the soundscape by manipulating objects inside the VR environment.

Part of the interventions focused on adding sounds to the existing auditory scene. Team Noize Makers visually accentuated them with special legend objects that guide attention to the added sounds. Accentuation is less critical for interventions like on Potsdamer Platz (Trio Akustiko) or on the McGill University Campus (Immensive). In these cases the added objects are rendered differently on top of the original scene and already focus attention. However, when such objects visually dominate the scene, they might lose appreciation of their added functionality. It is therefore important to have a balance between attracting attention and becoming part of the scenery when creating the VR outcome. On the other hand, two interventions involved suppressing existing sounds: the added hills at the Potsdamer Platz (Trio Akustiko), and the dome on the Boston greenway (URCHI). Thanks to the current audio rendering software of VR engines, it is relatively easy to add new sounds to an existing soundscape. A greater challenge lies in suppressing sounds from very specific locations or directions. Both teams approached this challenge by reducing and spectrally shaping the ambient soundscape as a whole, thereby approximating the physics of sound propagation involved. If easy-to-use software tools for sound propagation are made available, participants of future soundscape hackathons can fully investigate the potential of suppressing existing sounds.

In order to efficiently increase the quality of the soundscape and the urban space as whole, modifications should make sense physically. The creative possibilities that the current VR technology offers, are endless. Although some VR modifications can be physically feasible, others are totally unrealistic and may easily violate the laws of physics. Interventions where the real environment is not physically altered, such as adding labels on top of the existing scenery (Noize Makers), are relatively easy to implement. Others require landscaping efforts to realize them: added hills at Potsdamer Platz (Trio Akustiko) or building a dome overgrown with a creeper plant in the Rose Fitzgerald Kennedy greenway (URCHI). Moreover, they overestimated the acoustical screening effects in their auralization. Next to approximating the physics of sound propagation, as was described in the previous paragraph, participants without the right knowledge may not consider some indirect effects like the flow of persons in emergency situations or the cost of implementing a modification in reality.

5.2 Evaluation of the Event

As this was the first soundscape hackathon, the authors acknowledge that there is still room to improve the organization of the event. A small questionnaire was distributed in order to receive some feedback as an inspiration for improvement. In general, the event was perceived as creative and interesting, and certainly to be repeated. Combined with how the organizers experienced the event, three main points of improvement could be extracted from the questionnaire responses.

1. Selection of participants. Although a wide mix of backgrounds attended the Urban Sound Symposium, the hackathon participants mainly were acousticians and sound professionals with a technical background. Having other parties as well, like artists, architects, city representatives, public space designers, software developers and residents, more creative ideas could have emerged.

2. Evaluation. To decide on a winner, the jury members individually obtained an overall result by scoring the three evaluation criteria based on the final presentations. To reduce the competition and instead stimulate cooperation, it was suggested to have multiple smaller awards for different sub-challenges. Instead of having an outcome-centered evaluation, the degree of collaboration within and between teams could then be used as an extra evaluation criterion or as a sub-challenge.

3. Final presentations. Due to time and space constraints, it was not straightforward to coordinate the final presentations and to provide access to a broader audience. However, their presence can reflect the participation of local residents. It could even be possible to include an award based on the score of the audience.

6. CONCLUSIONS

This paper investigated the hackathon format as a way to generate ideas and creative concepts for applying the soundscape approach in urban public space design. By using immersive approaches and creative virtual reality concepts, the wide mix of backgrounds that typically participate in a hackathon may create innovative and outside-the-box approaches. A Soundscape Hackathon was organized in Ghent, Belgium on 3–5 April 2019 to test this approach. The participants of the hackathon were challenged to design a series of urban soundscape interventions, to apply them using a range of virtual reality visualization and auralization technologies that were available at the hackathon venue, and finally to present their solutions to colleagues in the field and to a professional jury. In the end, Team Noize Makers was declared as the winning team and received an award and a monetary prize. This paper gave some insights in the process and organization of the event, but focused on the results the teams developed. A critical discussion presented the benefits and shortcomings of using immersive and virtual approaches to boost the use of sound in urban design. The use of VR and immersive audio can create a high level of interactivity and can let users experience the future urban space. VR has an endless range of creative possibilities. Unfortunately, they are not always realistic or physically feasible. By realizing that participants can possibly oversimplify important aspects such as the physical feasibility, safety or cost, or that their creativity can be limited by time constraints or the aspect of competition, the hackathon methodology can still be improved. Both participants and organizers perceived the event as successful, and found it interesting to see how young scientists and young professionals came up with creative solutions, immersive approaches and artistic presentations. The organizers were impressed that the teams were able to audio-visually present the redesign of a space in a limited time frame and with relatively good quality. All in all, this first soundscape hackathon showed that the format and main concepts of a hackathon are well suited to be applied in urban sound design, and that the format may present a viable approach to boost the use of sound in urban design.

7. ACKNOWLEDGEMENTS

This research was funded by the HEAD Genuit Foundation grant number P-16/11-W "Urban Soundscapes of the World". Their support is gratefully acknowledged. The research was part of C3PLACES ("Using ICT for co-creation of inclusive public spaces"), and received funding from the European Union's Horizon 2020 research and innovation program (Urban Europe) under grant agreement no. 693443. Furthermore, the authors want to thank all participants and jury members of the Soundscape Hackathon.

8. REFERENCES

[1] T. Lindvall and E. P. Radford, "Measurement of annoyance due to exposure to environmental factors. the 4th karolinska institue symp. on environmental health," *Environ. Res.*, vol. 6, no. 1, pp. 1–36, 1973.

[2] M. Pacione, "Urban liveability: a review," *Urban Geogr.*, vol. 11, no. 1, pp. 1–30, 1990.

[3] M. Foth, "Participation, co-creation, and public space," *J. Public Space*, vol. 2, no. 4, pp. 21–36, 2017.

[4] B. Hellström, *Noise design: architectural modelling and the aesthetics of urban acoustic space*. Ph.D. dissertation, Royal Institute of Technology, Stockholm, Sweden, September 2003.

[5] S. Olafsen, "Using planning guidelines as a tool to achieve good soundscapes for residents," in *Proc. of Inter-Noise 2009*, p. 6, Ottawa, Canada, 23–26 August 2009.

[6] ISO Central Secretary, "Acoustics — Soundscape — Part 1: Definition and conceptual framework," International Stand ISO 12913-1, International Organization for Standardization, Geneva, Switzerland, 2014.

[7] B. De Coensel, A. Bockstael, L. Dekoninck, D. Botteldooren, B. Schulte-Fortkamp, J. Kang, and M. E. Nilsson, "The soundscape approach for early stage urban planning: a case study," in *Proc. of Inter-Noise 2010*, p. 10, Lisbon, Portugal, 13–16 June 2010.

[8] K. Sun, B. De Coensel, K. Filipan, F. Aletta, T. Van Renterghem, T. De Pessemier, W. Joseph, and D. Botteldooren, "Classification of soundscapes of urban public open spaces," *Landsc. Urban Plan.*, vol. 189, p. 17, 2019.

[9] B. De Coensel, K. Sun, and D. Botteldooren, "Urban soundscapes of the world: selection and reproduction of urban acoustic environments with soundscape in mind," in *Proc. of Inter-Noise 2017*, p. 7, Hong Kong, China, 27–30 August 2017.

[10] G. M. Echevarria Sanchez, T. Van Renterghem, K. Sun, B. De Coensel, and D. Botteldooren, "Using virtual reality for assessing the role of noise in the audio-visual design of an urban public space," *Landsc. and Urban Plan.*, vol. 167, pp. 98–107, 11 2017.

[11] F. Ruotolo, L. Maffei, M. Di Gabriele, T. Iachini, M. Masullo, G. Ruggiero, and V. P. Senese, "Immersive virtual reality and environmental noise assessment: An innovative audio–visual approach," *Environ. Impact Assess. Rev.*, vol. 41, pp. 10–20, 7 2013.

[12] J. De Winne, K. Filipan, B. Moens, P. Devos, M. Leman, D. Botteldooren, and B. De Coensel, "The soundscape hackathon as a methodology to accelerate co-creation of the urban public space," *Apl. Sci.*, vol. 10, no. 6, p. 19, 2020.

[13] G. M. Jones, B. Semel, and A. Le, ""there's no rules. it's hackathon.": Negotiating commitment in a context of volatile sociality," *J. of Linguist. Anthropol.*, vol. 25, pp. 322–345, 12 2015.

[14] H. Topi and A. Tucker, *Computing Handbook: Information Systems and Information Technology*. Boca Raton, FL, USA: Chapman and Hall/CRC, 3rd ed., 5 2014. ISBN 978-143-989-854-3.

[15] S. Leckart, "The hackathon is on: pitching and programming the next killer app," *Wired*, 2 2012. Available online: https://www.wired.com/2012/02/ff_hackathons/ (accessed on 19 July 2019).

[16] G. Briscoe and C. Mulligan, "Digital innovation: The hackathon phenomenon," p. 13, 2014. Available online: https://pdfs.semanticscholar.org/cb8e/44ec1bcd6062e5fccafb6837030be334731d.pdf (accessed on 6 June 2019).

[17] D. Groen and B. Calderhead, "Science hackathons for developing interdisciplinary research and collaborations," *eLife*, vol. 4, 7 2015.

[18] D. Groen, "The 1st science paper hackathon: how did it go?." Available online: https://www.software.ac.uk/blog/2016-09-26-first-science-paper-hackathon-how-did-it-go (accessed on 29 July 2019).

[19] A. Ghouila, G. H. Siwo, J.-B. D. Entfellner, S. Panji, K. A. Button-Simons, S. Z. Davis, F. M. Fadlelmola, The DREAM of Malaria Hackathon Participants, M. T. Ferdig, and N. Mulder, "Hackathons as a means of accelerating scientific discoveries and knowledge transfer," *Genome Res.*, vol. 28, pp. 759–765, 5 2018.

[20] "Immensive." Available online: https://www.immensive.it/ (accessed on 17 July 2019).

[21] "Pilootproject tuinstraten." Available online: https://www.antwerpen.be/nl/info/59d738412d2a3cb90c44ccef/pilootproject-tuinstraten (accessed on 15 July 2019).

[22] "IPEM's art-science-interaction lab UGENT." Available online: https://www.ugent.be/lw/kunstwetenschappen/ipem/en/services/asil/overview.html (accessed on 28 June 2019).

[23] F. Rumsey, "Audio networking for the pros," *JAES*, vol. 57, pp. 271–275, 4 2009.

[24] J. Ahrens and S. Spors, "Implementation of directional sources in wave field synthesis," in *Proc. of the 2007 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics*, pp. 66–69, New Paltz, NY, USA, IEEE, 21 October 2007.

[25] M. A. Gerzon, "Periphony: With-height sound reproduction," *JAES*, vol. 21, pp. 2–10, 2 1973.

[26] J. Ahrens, H. Wierstorf, and S. Spors, "Comparison of higher order ambisonics and wave field synthesis with respect to spatial discretization artifacts in time domain," in *Proc. of the AES 40th International Conference*, p. 8, Tokyo, Japan, 8-10 October 2010.

[27] F. Gergely and P. Fiala, "Spatial aliasing and loudspeaker directivity in unified wave field synthesis theory," in *Presented at DAGA*, p. 4, Munchen, Germany, 19–22 March 2018.

[28] "IOSONO core." Available online: https://www.barco.com/en/product/iosono-core (accessed on 28 June 2019).

[29] S. Mauer, F. Melchior, and M. Dausel, "Design and integration of a 3d WFS system in a cinema environment including ceiling speakers - a case study," in *Proc. of DAGA*, p. 2, Darmstadt, Germany, 19–22 March 2012.

[30] C. Hunt, "HTC vive pro vs. oculus rift: How much better is the new VR headset?." Available online: https://www.windowscentral.com/htc-vive-pro-vs-oculus-rift (accessed on 1 August 2019).

[31] Z. Azkorra, G. Pérez, J. Coma, L. Cabeza, S. Bures, J. Álvaro, A. Erkoreka, and M. Urrestarazu, "Evaluation of green walls as a passive acoustic insulation system for buildings," *Appl. Acoust.*, vol. 89, pp. 46–56, 3 2015.

[32] B. De Coensel, S. Vanwetswinkel, and D. Botteldooren, "Effects of natural sounds on the perception of road traffic noise," *JASA*, vol. 129, pp. EL148–EL153, 4 2011.

[33] A. Chiesura, "The role of urban parks for the sustainable city," *Landsc. and Urban Plan.*, vol. 68, no. 1, pp. 129–138, 2004.