VentHackz: Exploring the Musicality of Ventilation Systems

Maham Riaz
RITMO, Department of Musicology,
University of Oslo
Oslo, Norway
maham.riaz@imv.uio.no

Ioannis Theodoridis
Centre for Educational Research in Music,
Norwegian Academy of Music
Oslo, Norway
ioannis.theodoridis@nmh.no

Çağrı Erdem
Department of Informatics,
University of Oslo
Oslo, Norway
cagrie@ifi.uio.no

Alexander Refsum Jensenius
RITMO, Department of Musicology,
University of Oslo
Oslo, Norway
a.r.jensenius@imv.uio.no

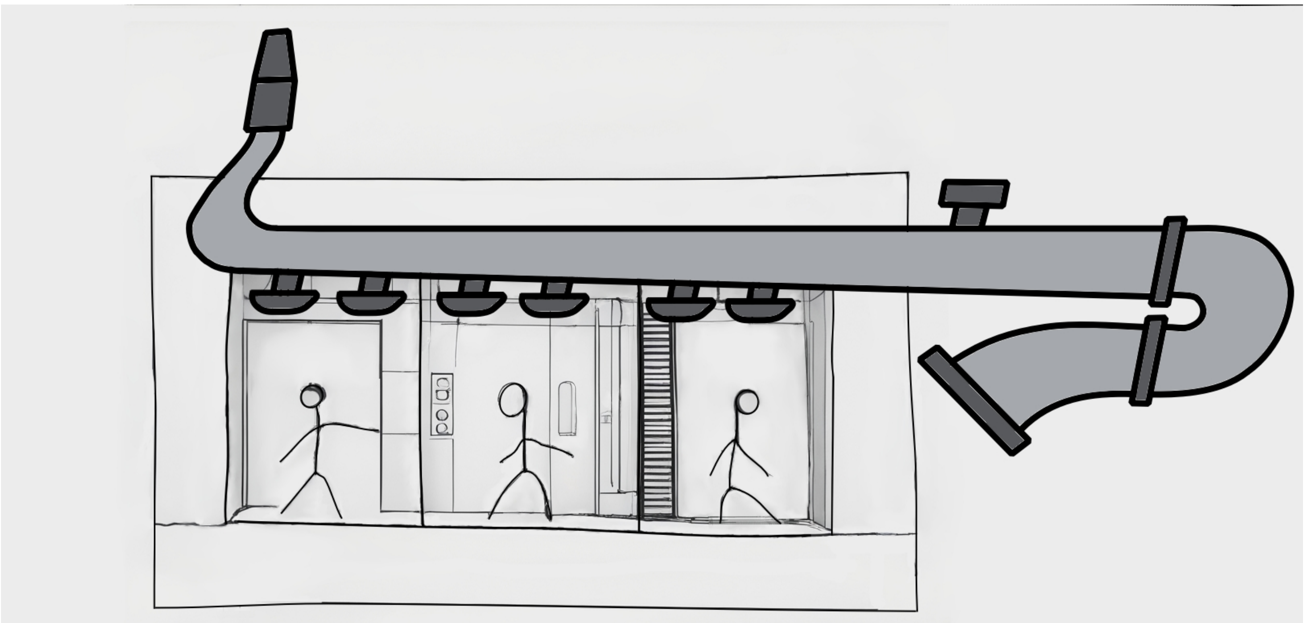

Figure 1: Ventilation systems can be thought of as wind instruments with sound-producing and sound-modifying parts.

Abstract

Ventilation systems can be seen as huge examples of interfaces for musical expression, with the potential of merging sound, space, and human interaction. This paper explores conceptual similarities between ventilation systems and wind instruments and explores approaches to "hacking" ventilation systems with components that produce and modify sound. These systems enable the creation of unique sonic and visual experiences by manipulating airflow and making mechanical adjustments. Users can treat ventilation systems as musical interfaces by altering shape, material, and texture or augmenting vents. We call for heightened attention to the sound-making properties of ventilation systems and call for action (#VentHackz) to playfully improve the soundscapes of our indoor environments.

NIME '25, June 24–27, 2025, Canberra, Australia

Keywords

Ventilation systems, HVAC, Soundscape, Wind instruments, Room acoustics, Urban intervention

1 Introduction

Many people spend much of their lives inside buildings under the ever-present hum of ventilation systems. These systems serve practical functions such as air circulation and temperature regulation. However, they also contain latent acoustic potential that can be explored creatively. The NIME community has, for years, emphasised the use of non-traditional instruments to encourage new forms of musical interaction [6, 8]. While ventilation systems are typically viewed as utilitarian infrastructure, they can be explored artistically. They are, after all, sound generators with air flowing through ducts, the hum of fans, and the vibrations of mechanical components, forming a soundscape that may be manipulated.

This paper explores the potential of ventilation systems as new interfaces for musical expression using the approach of "hacking," modifying existing machinery for new purposes. Involving ventilation systems in NIME projects introduces new ways to interact with ambient sound, allowing users to probe the sonic opportunities these often-overlooked mechanisms offer. Our starting point is the research question: How can a musical instrument be created from/in a room or building?

We start by observing how a ventilation system is constructed as a set of connected pipes, not too dissimilar from the principles of wind instruments. Then, we connect knowledge about ventilation systems to action–sound theory [7], a framework for understanding relationships between sound-producing and sound-modifying actions in a musical context. Sound-producing actions create sound, and sound-modifying actions alter the characteristics of that sound. In the case of ventilation systems, the airflow that passes through ducts, fans, and motors acts as the sound-producing actions of the systems. In contrast, elements such as adjustable vents, dampers, and architectural features can be understood as sound-modifying elements, shaping the tonal qualities of the sound. As a result of this dual interaction between sound production and modification, users have control over the system's sound in real time. This paper calls attention to the ventilation sounds in our environments and suggests playful approaches to improving the soundscapes through various hacks under the label #VentHackz (media and code available online).[1]

2 Background

Ventilation systems—sometimes referred to as "heating, ventilation, and air conditioning" (HVAC) systems—are built to maintain indoor air quality in various settings, from residential to industrial spaces. While these systems have three main functions, this paper focuses on the one property that produces the most sound: ventilation.

2.1 Ventilation system mechanics

Ventilation facilitates the exchange of stale and fresh air, maintaining and regulating indoor air quality, often measured as the CO_2 level in a room. Contemporary ventilation systems can vary in design but operate on a fundamental principle: supply vents expel air into a room while return vents draw it back in. Figure 2 shows a ventilation system with supply and return vents. The kinetic energy generated by the air inflow and outflow can be used for sound production.

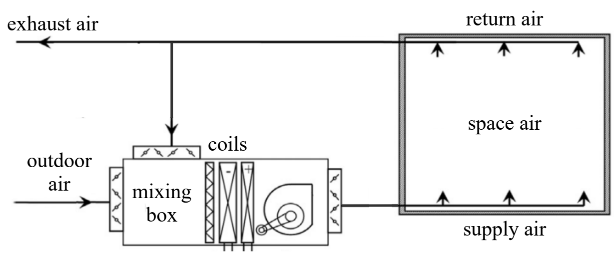

Figure 2: General schematic of a ventilation system [16].

Many new buildings have "active" motorised ventilation systems and rely on air ducts, fans, motors, filters, and air vents, all of which work together to facilitate airflow. However, there is a growing interest in "passive" ventilation, the traditional approach to creating airflow in buildings. This is a question about energy efficiency and sustainability on one side and acoustic requirements and sufficient air quality on the other. There are some examples of new concert halls built with natural or hybrid ventilation systems [9]. They aim to maintain low background noise levels and meet environmental noise criteria through innovative designs, including inline silencers, sound-absorbing materials, and strategic use of natural air paths.

From the perspective of organology—the study of musical instruments—ventilation systems can be likened to *aerophones.* This family of instruments, such as the saxophone, produces sound through vibrating air columns [20]. When a player blows into the mouthpiece, the reed vibrates, generating pressure waves that travel through the instrument's air column. These waves resonate within the saxophone's body, and their frequency is determined by the length of the air column, which is adjusted by opening and closing the tone holes.

The saxophone's tone holes and keys allow the player to vary the instrument's effective length, controlling the pitch [19]. When a tone hole is uncovered, it creates an opening for the vibrating air to escape, shortening the column and producing a higher pitch. Conversely, covering a tone hole lengthens the column, resulting in a lower pitch. This interplay of air, vibration, and resonance lies at the heart of the saxophone's operation.

Ventilation systems manage airflow like saxophones do (Figure 1). In a ventilation system, air circulates in and out of spaces through a network of vents. Similarly, a saxophone's tone holes function as controlled air outlets. Each hole acts as a vent, allowing air to escape at precise points along the instrument. Just as the placement and size of vents in a building determine how air moves between rooms, the arrangement and size of the saxophone tone holes dictate the air column's behaviour and the resulting pitch.

Additionally, the player's manipulation of the keys can be compared to adjusting airflow in a ventilation system. One might close specific vents in a building to redirect airflow to other areas. On the saxophone, closing a key effectively "seals" a vent, extending the vibrating air column and lowering the pitch. On the other hand, opening a key allows air to escape earlier, shortening the column and producing a higher pitch. In both cases, the system relies on controlling openings to achieve a desired outcome, whether air circulation or harmonious music.

2.2 Noise reduction and auditory aesthetics

Ventilation systems often produce a continuous hum or hiss, which results from constant airflow caused by the tandem operation of fan motors and compressors [17]. While persistent noise can interfere with sonic experiences, such as speech intelligibility or musical clarity, the acoustic properties of ventilation systems occupy a contested space between nuisance and aesthetic potential. Environmental noise has long been framed as a technical problem to solve. Fluctuating levels during system operation (e.g., when airflow is ramping up or down) create an inconsistent sound environment, amplified by air ducts transmitting noise between rooms and structural vibrations propagating low-frequency tones.

This framing, however, overlooks decades of artistic and theoretical engagement with noise as an aesthetic medium. Since Luigi Russolo's 1913 manifesto "The Art of Noises," which celebrated mechanical and industrial sounds as music, designers and composers have investigated noise's capacity to shape spatial and emotional experience [18]. With their inherent rhythmic and textural qualities, ventilation systems sit at the centre of this

[1] https://osf.io/enb3m/?view_only=09ef03393ef349d197fd1771b71ad9a4

discourse: their hums and hisses can be attenuated for functional comfort or creatively amplified as site-specific sonic identity.

Practical noise-reduction methods include soundproofing ventilation ducts with linings or installing silencers within the ventilation system to reduce noise levels [15]. Sound-absorbing materials prevent noise from escaping into the room, such as in VentHack #1 illustrated in Figure 3, which will be discussed later. Similarly, installing vibration isolators or reinforcing the mounts of ventilation equipment can reduce structure-borne noise by preventing low-frequency vibrations from transmitting through the building. Selecting low-noise fans and motors for the ventilation system can help mitigate noise. Variable-speed fans can operate more quietly by adjusting speed to meet thermostat or CO_2 demands rather than running at full power all the time. Proper design of airflow paths by avoiding sharp turns in the ventilation ducts can help smooth turbulence and reduce noise.

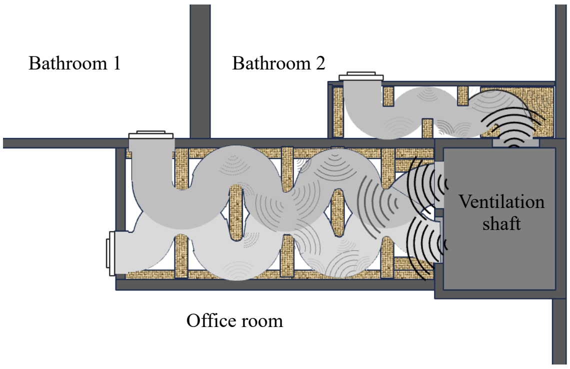

Figure 3: A schematic of the sound maze implemented in VentHack #1.

Sound-masking systems can control overall ambient noise levels [22], producing electronic sound that blends with HVAC noise to create a consistent soundscape and reduce noise perception. Active noise cancellation systems can also reduce ventilation noise by propagating an out-of-phase sound wave into the space [12]. These technical interventions need not preclude aesthetic experimentation. Ventilation systems have a history of modification to produce harmonious tones and musical sounds. The Seattle Central Library's ventilation system creates a subtle, ambient soundscape [11]. Additionally, Fraunhofer IBP has experimented with sound-controlled window ventilation, automating window opening based on noise levels.[2]

2.3 Improving visual aesthetics

While essential for indoor air quality, ventilation systems often disrupt a room's visual harmony. Exposed vents and ductwork can appear industrial, stark, or invasive, clashing with the room's aesthetic. To address the visual disruption caused by the appearance of exposed vents and ductwork, homeowners and designers use creative solutions such as decorative ventilation covers, wallpaper overlays, and smart interior design. These approaches conceal unsightly elements and blend them into the room's decor without compromising their function.

[2]https://www.ibp.fraunhofer.de/en/projects-references/sound-controlled-ventilation.html

2.4 Artistic use of ventilation systems

Church organs may be the musical instruments that most closely resemble the size and functionality of ventilation systems [19]. While inspiring, organs are custom-built for musical purposes, are not commonly available, and are out of topic for the current project.

The idea of transforming the environment into a musical instrument has been explored in art installations. Zimoun creates large-scale sound installations using simple materials and mechanical elements.[3] Similarly, Imao Takuma's "Work With" series repurposes air conditioning systems as sound generators, treating infrastructures like the Kiyosu City Haruhi Art Museum as frameworks for acoustic intervention. By altering airflow, valve operations, or sensor inputs, Imao's work temporarily transforms ventilation systems into collaborators.[4] His installations foreground the entanglement of system logic and artistic agency, inviting visitors to perceive buildings as resonant entities.

Other precedents include the "Singing Ringing Tree" in England, a 10-foot-tall Aeolian harp sculpture producing tones as the wind passes through its pipes.[5] In spas and wellness hotels, designers manage ventilation and ambient noise to create sonically relaxing atmospheres, sometimes using sound healing frequencies [4], a principle that can extend to building ventilation.

Few examples exist in the literature on artistic ventilation hacking. Some installations use blowing air [2], motorised components [10], or architectural features [13] to modify musical expression. One of the most relevant examples is Max Neuhaus's "Times Square" installation from 1977 [5], where he placed electronic sound generators and a loudspeaker within a ventilation shaft. The piece produces a rich, harmonic sound texture resembling the after-ring of large bells, changing in pitch, timbre, and tone as people move around the area.

3 Principles of ventilation hacking

Our approach is based on accepting that a ventilation system is needed to ensure good air quality in a space and thinking about its construction and the airflow as an instrument, producing multisensory, interactive experiences emphasising the connection between sound and space. This section describes a ventilation system's sound-producing and sound-modifying parts, as well as the possibilities and limitations of what an end user in a room can modify (Figure 4).

3.1 Sound production

Ventilation systems generate sound through airflow, mechanical components, and structural elements. Motors driving fans and compressors form the foundation, producing vibrations and tonal hums. Fan rotation adds sonic layers, with blade design, speed, and airflow patterns shaping pitches and harmonics [14].

Airflow is a primary sound mechanism when directed through elements like reeds, plates, or ducts. This resembles aerophones and how wind instruments produce sound through controlled airflow to create vibrations, resonance, and pitch. [21]. The interaction of airflow with physical structures shapes sonic qualities. Adjustable vents, dampers, or variable-speed fans can modify tonal characteristics and intensity, offering users control over sound output.

[3]https://zimoun.net/
[4]https://art360.place/en/exhibitions/takuma-imao-work-with-10-air-conditioning-equipment-kiyosu-city-haruhi-art-museum/
[5]https://tonkinliu.co.uk/singing-ringing-tree

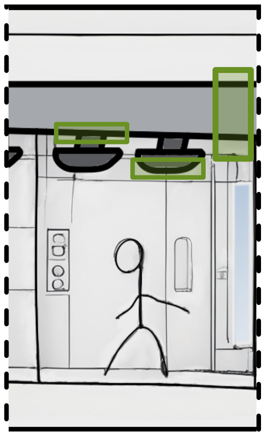

Figure 4: Possible implementation points for VentHackz.

Ducts contribute to a spectrum of sounds, from steady hums to turbulent whooshes, depending on airflow velocity and volume. Mechanical vibrations from components like dampers or slats can resonate with airflow, producing harmonics.

3.2 Sound modification

Ventilation sound can be shaped and refined to achieve desired acoustic effects. Creating sound mazes by installing diffusers, baffles, or louvres within the ducts disrupts turbulent airflow, helps reduce harsh noise, and shapes tonal qualities.[6] This is comparable to how mutes or resonators in a musical instrument alter sound output to refine its timbre and character.

Acoustic foam or other sound-absorbing materials can be applied within ducts to dampen vibrations and limit resonance. Their mass, absorption, or stiffness can filter out extra noise. Structural modifications to duct size, shape, or material allow precise sound control. Resonance chambers or narrowed duct segments can amplify specific harmonics, likening the system to a tuned instrument.

Controllable mechanisms like adjustable dampers and vents enable real-time sound modulation, letting users alter tonal characteristics, harmonics, and intensity, similar to organ stops. Different materials, such as metals or composites, enhance acoustic versatility: metal ducts produce bright, resonant tones, while composites yield warmer, softer sounds.

Architectural design can amplify or attenuate ventilation sounds. Airflow against perforated surfaces, tuned chambers, and movable components lets structures shape soundscapes, creating evolving tones, rhythms, and harmonics that respond to airflow or environmental changes. Even subtle shifts in material, shape, and surface texture significantly impact timbre [1].

3.3 External factors as sound modifiers

External conditions also serve as natural sound modifiers for ventilation systems. Wind interacting with outdoor vents introduces tonal shifts, adding variability and movement to the soundscape. Temperature and humidity affect ventilation inflow and outflow.

Sensors, such as temperature or CO_2 detectors, further enhance the system's adaptability. By adjusting airflow based on occupancy, activity levels, or environmental factors, the system can respond to the space's needs in real time. This responsiveness creates an interactive and immersive auditory experience, transforming ventilation systems into integral components of the environment's soundscape.

3.4 Social and physical constraints

Ventilation systems sit somewhere between public and private spaces, influencing personal environments both aesthetically and health-wise. Most people can, at best, modify the temperature setting in a room; the operation of the ventilation system is otherwise left to professionals. While ensuring safety and efficiency, this professionalisation can lead to undemocratic decisions that overlook end-users' experiences and opinions. Consequently, users remain unaware of simple yet impactful improvements to enhance ventilation aesthetics and functionality. This dynamic limits individual creativity and agency within the built environment due to institutional and cultural constraints. As part of a building's infrastructure, ventilation systems often remain hidden, making them "invisible" and contributing to a lack of awareness and user engagement.

To unpack this set of constraints, we can use Michel de Certeau's concepts of "strategies" and "tactics" [3]. Strategies are the design choices made by authorities, while tactics are the everyday actions individuals use to navigate and resist these constraints. In this context, traditional ventilation systems are part of the "place"—fixed, stable, and controlled by authorised building maintenance and conventional design. When users engage with these systems, modifying them with lighting and acoustic treatment, they transform them into "spaces"—dynamic environments shaped by human interaction. This transformation affords fluidity and adaptability in the built environment, enabling everyday actions to reshape and redefine it. Here, tactics and infrastructure become entangled: the improvisational, subversive acts of the user (tactics) do not merely oppose the predetermined frameworks (strategies) but intertwine with them, creating hybrid forms of agency.

4 Examples of user-friendly VentHackz

It is possible to conduct ventilation hacks within user constraints. Figure 5 shows a collection of VentHackz implemented by the authors. These include a series of ventilation augmentations, mechanical hacks, and digital hacks.

4.1 Augmented vents

As the internal mechanics of ventilation systems typically fall outside users' expertise, creative modifications can instead focus on augmenting vents within rooms. This can be achieved by adding structures like sound mazes from the ventilation ducts, allowing the ventilation to protrude organically into the living space. Like an organism growing out of the wall, these extensions can introduce new acoustic and aesthetic properties while maintaining airflow. Users can personalise their environment by treating the ventilation as a dynamic element interacting with the room's interior, merging functionality with aesthetic preference. This approach respects the professional boundaries of the system's core mechanics while empowering users to enhance their space meaningfully.

VentHack #1: The sound maze concept for augmented vents involves constructing a wall-extending structure through which the ventilation ducts travel in a maze-like pattern (Figure 5k). These ducts, made from thin plastic, take several turns within

[6] https://www.griffith.edu.au/__data/assets/pdf_file/0030/196194/18.00-Mechanical-Services-v18.pdf

the box lined with sound-absorbent materials (Figure 3). At first, a sound-insulated flexible duct was used, but this maintained the waveguide properties of the squiggled duct and channelled the sound along the duct instead of dispersing through it into the surrounding sound-absorbent materials. Allowing the air to navigate through this sound-absorbing maze creates a quieter and more aesthetically integrated ventilation system within the living space without modifying the off-limits structural place of the building's ventilation structure.

VentHack #2: The multifunctional augmented vents concept creates augmented ventilation structures that integrate ventilation, lighting, and acoustic treatment (Figure 5b). Instead of traditional dropped ceilings or wall-mounted lights, these protrusions act like multifunctional boxes that attach to existing vents without altering the off-limits structure, offering improved acoustics and a visually cohesive design while maintaining airflow. This approach transforms ventilation into a versatile element enhancing both functionality and aesthetics. These augmentations challenge conventional classifications as they do not neatly fit into categories such as building infrastructure, light installations, furniture, or decoration. Instead, they occupy a liminal space, blending elements of each category to create an accessible, user-friendly, multifunctional extension.

4.2 Mechanical hacks

While the primary goal of noise control in ventilation systems often focuses on dampening sounds to achieve silence, this approach may not suit everyone's preferences. Some individuals find complete silence unsettling and prefer a certain ambient noise level. Rather than merely silencing these systems, we can explore ways to transform the typically annoying and tiresome noises into more aesthetically pleasing background sounds.

The simplest hacks involve directly attaching a sound-modifying object to the return (pulling air) or supply (pushing air) vents. These hacks rely on air pressure differentials in the ventilation system while it runs. Additionally, different materials and shapes interfering with airflow yield notable changes in sound.

VentHack #3: The return vents provided enough pull to hold lightweight material without glue or additional support. An A4-sized paper was thus mounted on one of the return vents (Figure 5a). Acting as a physical filter, the paper provided a muffled effect for the ventilation sound.

VentHack #4: Modifying the idea from the previous hack, we held a circular piece of cardboard at the return vent (Figure 5f). Being stiffer and less malleable than paper, it covered the duct end less tightly and altered the ventilation sound accordingly.

VentHack #5: Next, we experimented with the lid of a frozen pizza box, cutting one edge into multiple strips and bending every alternate strip (Figure 5h). This allowed us to experiment with a different material thickness, leaving the return vent partially open and redirecting some air over the bent cardboard strips. This sounded like wind gusts passing through trees.

VentHack #6: We pierced a square piece of dense cardboard in the middle before mounting it on the return vent. A slight tap to offset it from perfectly centred on the vent created a turbulence effect resulting from air pressure differentials. The cardboard piece was left in a perpetual state of being pushed and pulled by the vent, creating a rattling sound as it repeatedly hit the vent.

VentHack #7: By creatively modifying the airflow dynamics and ventilation openings, we attempted to emulate natural sounds such as the gentle rustling of the wind in the trees, the soothing flow of a river, or the melodic calls of singing birds. In this example, a rhythmic whistle was produced by merely altering the gap of the ventilation duct openings (Figure 5i). The whistle produced specific notes, which could be interpreted as being in the key of C harmonic minor. The whistle settled on multiple octaves of C whilst fluctuating around G, Ab, B, and C in an ornamentation-like rhythm.

VentHack #8: A kazoo-like cardboard structure was constructed with a thin passage for air to pass through and rattle a paper membrane to explore the feasibility of attaching resonating constructions as attachable "mouthpieces" to the ventilation openings. A latch could widen the opening gradually to tweak the airflow pressure (Figure 5j). Unlike typical wind instruments, in which air is blown, these ducts sucked air, which made a narrow passage crucial. The resulting sound was too quiet compared to the remaining sounds of the ventilation.

VentHack #9: Drawing inspiration from culturally significant wind chimes, such as fūrin in Japan and Korean wind chimes, which produce auditory and aesthetic effects in response to airflow, we explored the impact of sound, movement, and light in ventilation systems. An initial experiment involved attaching wind chimes to a supply vent. As air flowed through the vent, the turbulence and periodicity inherent in the system moved the chimes, creating a soothing soundscape.

VentHack #10: We 3D-printed custom mesh ping pong balls and filled them with small beads (Figure 5l). The lightweight, textured object moved with the airflow, producing a rhythmic rattling sound when attached to the supply vent.

VentHack #11: A subsequent modification comprised a handcrafted honey bee sculpture made from wire and beads (Figure 5c). Suspended from the supply vent, airflow governed the sculpture's motion.

VentHack #12: Following the previous hack, we introduced a thin layer of foam to adjust the air inflow at the return vent, thus manipulating pressure differentials, causing the sculpture to exhibit user-controlled motion (Figure 5e).

4.3 Digital hacks

Combining VentHackz with circuitry and creative coding unlocks new possibilities. Simple battery-powered circuits with switches or sensors can harness the motion of air at supply or return vents to create visual patterns or detect lighting changes in the room.

VentHack #13: To further expand on VentHack #10, an LED light was embedded within the 3D-printed ball (Figure 5g). The combination of airflow-induced motion and internal illumination created a visually appealing effect, projecting patterns of light and shadow onto the surrounding surfaces. This demonstrated how airflow could produce both auditory and visual stimuli, easily turning a mechanical system into a multisensory installation.

VentHack #14: To explore digital interactions, we created an interactive system involving a light-dependent resistor (LDR), an LED, and a speaker connected to a Bela board running a PureData patch. The system was designed to react to light levels. When the room lights were turned off, the LDR activated the circuit, triggering the LED and speaker to emit Morse code signalling the word "HELP." This exploration introduced a context-aware layer to the system, combining the ventilation structure with light and sound (Figure 5d).

These hacks show how ventilation systems can be used as interactive and immersive interfaces. Sound, motion and light with analogue and digital interventions have the potential to enhance

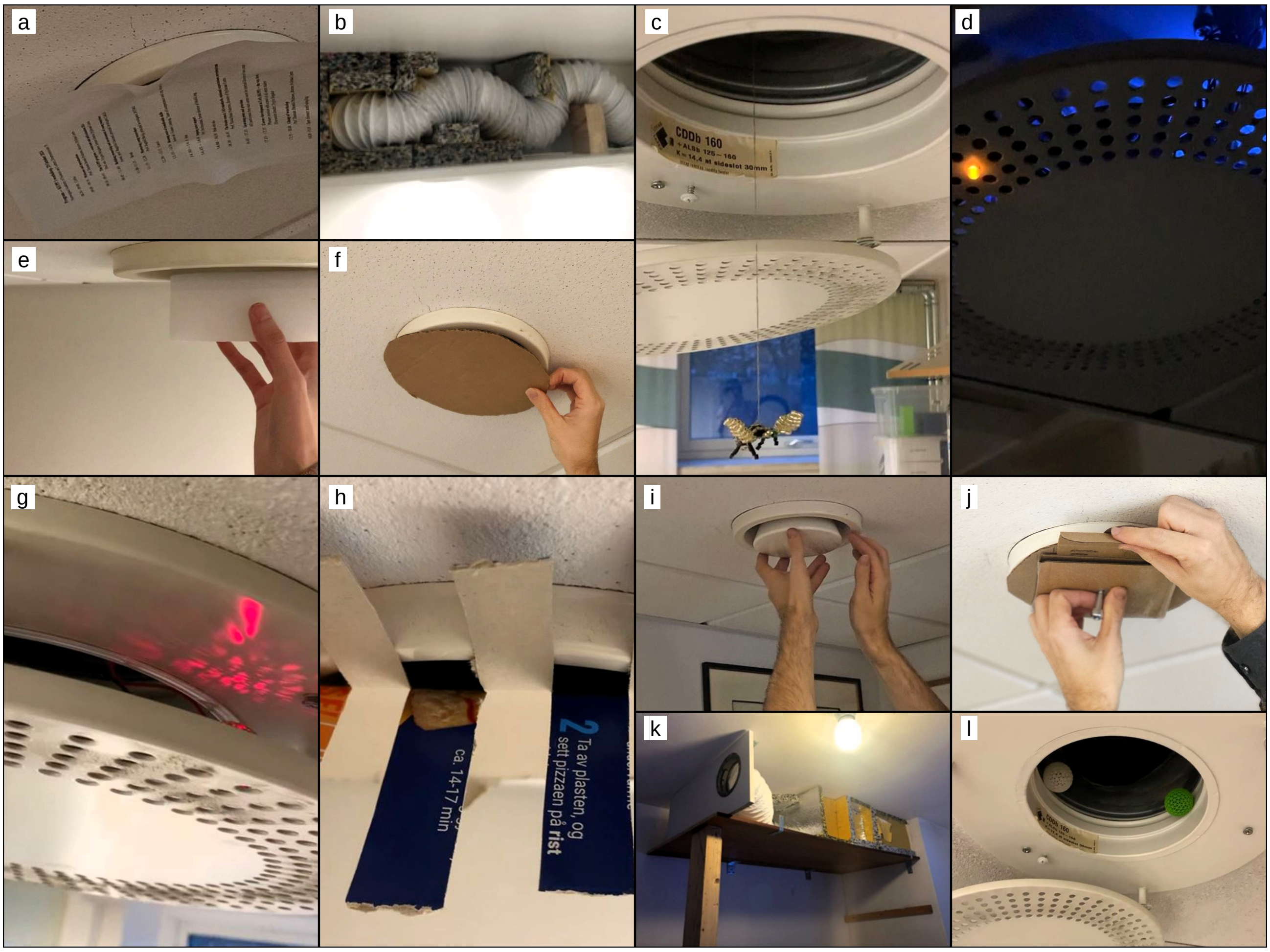

Figure 5: A collection of VentHackz conducted by the authors, see text for descriptions.

indoor spaces. These explorations draw upon the legacy of wind chimes while leveraging contemporary fabrication techniques and programmable systems.

4.4 Audio analysis

Figure 6 shows spectrograms of how three simple VentHackz can dramatically alter the sound in the space. These sounds were recorded in an office with one supply vent and two return vents (Figure 6a). Figure 6b shows the frequency content of usual ventilation sound, which is heavy on low frequencies and presents a relatively consistent progression through a 10-second time interval. Figure 6c is for VentHack #6. With a square piece of cardboard covering one of the return vents of the same system, we achieved a constant rattling sound of air pressure differentials that caused the cardboard to move and hit against the ventilation surface repeatedly. In the spectrogram, some other frequencies become more dominant. Finally, Figure 6d and e are two variations of VentHack #7. After closing one return vent and altering the tightness of the other return vent, it was possible to get two completely different soundscapes, as shown in the spectrograms.

5 Discussion

Ventilation systems can be viewed as NIMEs that blend sound, space, and human agency. They are like large-scale, building-sized musical instruments with sound-producing and sound-modifying objects. The sound output of these systems can give way to new forms of embodied interaction, where the physical manipulation of airflow and mechanical components generates new sonic and visual experiences.

Over the last year, we have explored ventilation hacking in various workshops, and it has been the topic of a public seminar. Several hacks have been tested in practice (as described above), while others have only been developed conceptually. Several suggestions have been made for developing interactive ventilation hacks to enhance engagement, offering opportunities to create immersive environments where sound conveys information to the user. Here, sonification can be key in communicating contextual information, such as the time of day, through the ventilation system's airflow. For instance, the airflow could slow down during lunchtime as a reminder to take a break. This subtle auditory cue enhances awareness of daily rhythms and fosters a connection between users and their environment. Similarly, musification principles can help promote social or celebratory atmospheres. For example, the system might produce a special musical output on Friday nights.

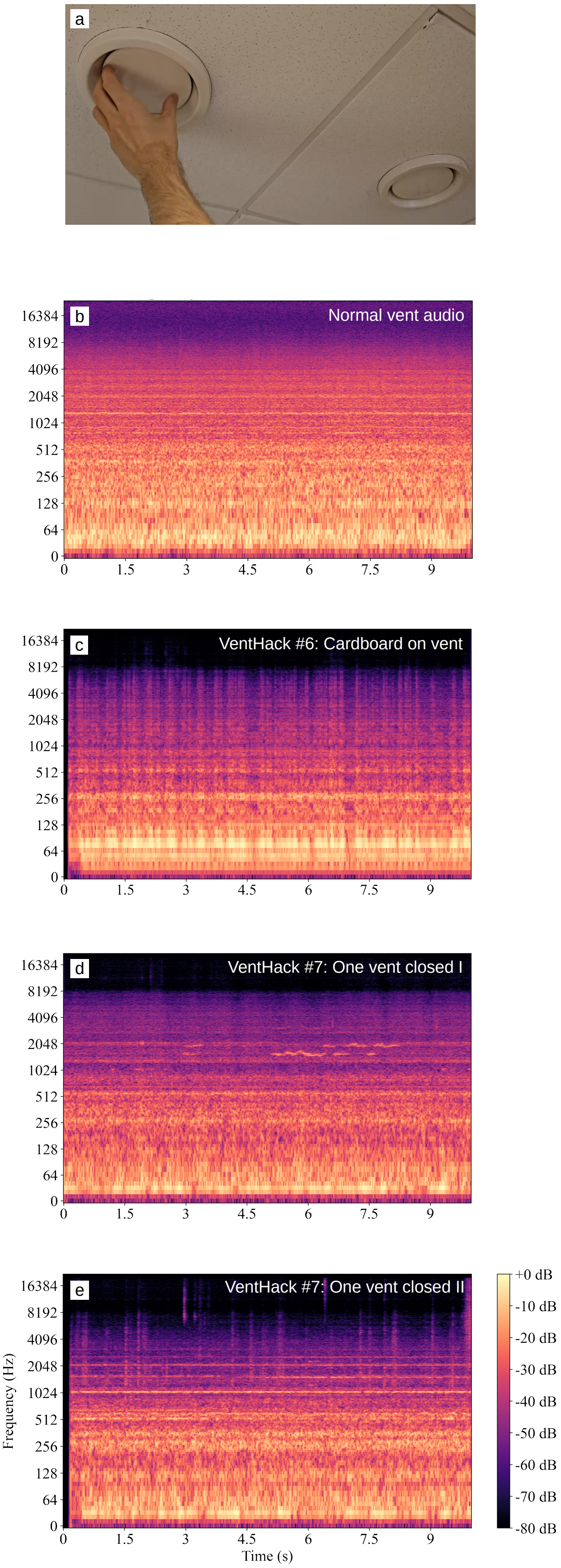

Figure 6: Spectrograms of the recordings of a dual vent system (a) showing the sound effects of some hacks (c–e).

Using gamification strategies could offer another layer of engagement, where the system interacts playfully with its users. Imagine opening a door and being greeted by a personalized sound produced by the ventilation system—a whimsical acknowledgement of movement within the space. Deliberately designed interactions could further encourage physical activity. Opening the door might prompt a change in airflow, inspiring curiosity and a sense of agency. These approaches collectively encourage users to view ventilation systems as interactive and creative elements of the indoor environment.

Our approach to ventilation hacking focuses on an often overlooked part of in-door environments, reinventing the role of ventilation systems and expanding the boundaries of what constitutes a musical instrument in contemporary practice. Introducing subtle changes in shape, material and texture to vents makes it possible to interact with ventilation systems as a musical interface that already constitutes a big part of our daily indoor soundscapes. The videos of our hacks are available for viewing in a public playlist on YouTube.[7] We invite fellow ventilation system enthusiasts to share videos of their hacks with us and the world using the hashtag "#VentHackz" on social media platforms.

6 Ethical Standards

Our ventilation hacks prioritise safety, ensuring air quality standards are upheld and noise levels comply with health guidelines.

Acknowledgments

The Research Council of Norway supports this project through projects 262762 (RITMO), 324003 (AMBIENT), and 322364 (fourMs).

References

[1] Rolf Bader and Patrick Kontopidis. 2024. Designing Musical Instruments and Room Acoustics with Acoustic Metamaterials. In *Sonic Design*, Alexander Refsum Jensenius (Ed.). Vol. 12. Springer Nature Switzerland, Cham, 298–320. https://doi.org/10.1007/978-3-031-57892-2_16 Series Title: Current Research in Systematic Musicology.
[2] Kirsty Beilharz and Aengus Martin. 2012. The 'interface' in site-specific sound installation. In *Proceedings of the 2012 conference on New interfaces for musical expression*. https://www.nime.org/proc/beilharz2012/
[3] Michel De Certeau. 1984. *The Practice of Everyday Life*. SF Rendall (Trans.). Berkeley: University of California Press.
[4] Inphinity Design. 2024. Integrating Sound Healing Frequencies into Wellness Hotels [online]. https://inphinitydesign.com/architectural-symphony-integrating-sound-healing-frequencies-into-wellness-hotels/ (accessed in 16 April, 2024).
[5] Charles Eppley. 2017. Times Square: Strategies and Contingencies of Preserving Sonic Art. *Leonardo Music Journal* 27 (2017), 21–26. Publisher: MIT Press.
[6] Stefano Fasciani. 2024. Bibliometric Analysis of NIME References and Citations. In *Proceedings of the International Conference on New Interfaces for Musical Expression*. NIME. https://www.duo.uio.no/handle/10852/111715
[7] Alexander Refsum Jensenius. 2022. *Sound actions: Conceptualizing musical instruments*. MIT Press.
[8] Alexander Refsum Jensenius and Michael J. Lyons (Eds.). 2017. *A NIME Reader: Fifteen Years of New Interfaces*. Springer, Berlin.
[9] Vangelis Koufoudakis, Byron Harrison, Simon Brown, and Luca Dellatorre. 2018. Naturally Ventilated And Hybrid-Ventilated Performance Spaces. In *Proceedings of the Institute of Acoustics*, Vol. 40.
[10] Michael Krzyzaniak. 2022. How to build pipe organ robots. In *AudioMostly 2022*. ACM, St. Pölten Austria, 121–128. https://doi.org/10.1145/3561212.3561225
[11] Michael Kubo and Ramon Prat. 2005. *Seattle Public Library, OMA/LMN*. Actar.
[12] Martin Larsson. 2008. Active Noise Control in Ventilation Systems : Practical Implementation Aspects. (2008). Publisher: Blekinge Institute of Technology.
[13] Sasha Leitman, Dale Carnegie, and Jim Murphy. 2024. Resonant Object Interface: Implementation and Initial Exploration of a Tactile Acoustic Interface. In *Proceedings of the International Conference on New Interfaces for Musical Expression*. 632–634. https://nime.org/proceedings/2024/nime2024_93.pdf
[14] Alex Michaud. 2019. Silence Is Golden: Optimizing the Acoustic Environment. https://blog.priceindustries.com/optimizing-acoustic-environment

[7] https://www.youtube.com/playlist?list=PL74s_qMlTkiDFFqNbmHkmLXDBFeFVn2ue

[15] Kwok Wai Mui and Ling Tim Wong. 2006. A Method of Assessing the Acceptability of Noise Levels in Air-Conditioned Offices. *Building Services Engineering Research and Technology* 27, 3 (Aug. 2006), 249–254. https://doi.org/10.1191/0143624406bse157tn Publisher: SAGE Publications Ltd STM.

[16] Luis Perez-Lombard, Jose Ortiz, and Ismael R. Maestre. 2011. The map of energy flow in HVAC systems. *Applied energy* 88, 12 (2011), 5020–5031. https://www.sciencedirect.com/science/article/pii/S030626191100448X Publisher: Elsevier.

[17] Elena Rossi, Domenico De Salvio, Dario D'Orazio, and Massimo Garai. 2019. Measuring and Identifying Background Noises in Offices during Work Hours. *IOP Conference Series: Materials Science and Engineering* 609, 4 (Sept. 2019), 042005. https://doi.org/10.1088/1757-899X/609/4/042005 Publisher: IOP Publishing.

[18] Luigi Russolo. 1913. *The art of noises*. http://paulheimbach.de/Sammlung/pdf/russolo_noise.pdf Publisher: Something else press Glover, VT.

[19] Albrecht Schneider. 2024. Aspects of Sound Structure in Historic Organs of Europe. In *Sonic Design*, Alexander Refsum Jensenius (Ed.). Springer Nature Switzerland, Cham, 225–258.

[20] Michael Segell. 2005. *The Devil's Horn: The Story of the Saxophone, from Noisy Novelty to King of Cool*. Publisher: Farrar, Straus and Giroux.

[21] Erich Moritz Von Hornbostel and Curt Sachs. 1961. Classification of musical instruments: Translated from the original German by Anthony Baines and Klaus P. Wachsmann. *The Galpin Society Journal* (1961), 3–29. https://www.jstor.org/stable/842168

[22] Farideh Zarei, Joonhee Lee, Roderick Mackenzie, and Vincent Le Men. 2022. Evaluation of the Uniformity of Sound-Masking Systems in an Open-Plan Office. *Applied Acoustics* 186 (Jan. 2022), 108464. https://doi.org/10.1016/j.apacoust.2021.108464