
Let's Play Air Piano!

Participatory Technology Design

Using Nintendo® Wii Technology

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Abstract

In the context of the project 'Engineer Your Sound!' (EYS; 2008–2009) funded by 'Sparkling Science', a program of the Austrian Federal Ministry of Science and Research, three high school students and their technical coach, a sound engineer, developed an 'air piano' based on the Nintendo® Wii technology. This article, written by the students together with their technical and pedagogical coaches, gives background information on EYS and thus the context for the development process of the air piano, and provides a description of how the idea was generated and how the instrument is constructed. Based on the principle of gesture mapping, infrared reflecting material attached to the finger is moved in front of an infrared camera (the remote of a Wii console) and, depending on its position, MIDI commands trigger various notes in the sound of a piano.

Introduction

The artifact described in this chapter is the result of a transdisciplinary¹ research process which also determines the character of this text. Thus, the individual authors will repeatedly and explicitly refer to themselves in order to indicate their respective contribution.

In fall 2008 a team of researchers, pedagogues, a group of high school students, and a sound engineer started a project cooperation to test music as a vehicle to foster young people's interest in technology (Thaler & Zorn 2009; 2010). The main objective of this project, 'Engineer Your Sound!' (EYS),² was to develop didactic concepts for innovative teaching using music related technology (Hofstätter et al. 2010a; 2010b). This was to be achieved in the spirit of the researchers' agenda to promote

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participatory technology development and of the funding program 'Sparkling Science' by the Austrian Federal Ministry of Science and Research, which fosters the cooperation of research and school. Thus, a crucial part of the outcome of EYS (such as this chapter) is a co-production of the academic staff and the participating high school students.

The heart of this text is the description of the development process and the construction design of an 'air piano', which is one of the many outputs of EYS. First, Birgit Hofstätter, who was the pedagogical coach working with the students, will give some more details on EYS in order to explain the broader context in which the development of the musical device was embedded. Sonja Deutschmeister and Johanna Nather, two of the students³ who developed the air instrument, will then report about how the idea was generated and how they experienced the development process. Finally, Birgit Gasteiger, sound engineer and the technical coach in EYS, will provide details on the underlying technology of the air instrument and the construction itself.

Engineer Your Sound!

The concept for EYS was developed by Anita Thaler (IFZ) and Isabel Zorn (University of Koblenz-Landau), two researchers focusing on SET (Science, Engineering and Technology), education and gender. EYS was a cooperation of 28 students aged 17 to 18 and two of their teachers of the Musikgymnasium Dreihackengasse Graz – a high school with a focus on music, a team of researchers and pedagogues of IFZ (Inter-University Research Centre for Technology Work and Culture), and a researcher and a sound engineer of IEM (Institute of Electronic Music and Acoustics, University of Music and Performing Arts Graz). Isabel Zorn took on the role of an external moderator and adviser for the project team.

The project was segmented in various stages: At the very beginning the high school students (all of them simultaneously studied at the conservatory) were introduced to music related technology at IEM. Based on these impressions, in a brainstorming process the students generated ideas for music designs (some including filmic elements), which were

created with the support of sound engineer Birgit Gasteiger (Gasteiger & Hofstätter 2009; Hofstätter et al. 2009). Except for some professional recordings produced in a sound studio at Graz University of Technology, all designs were realized using low-tech devices easily accessible for the students. Film material was produced either with mobile phones or digital photo / film cameras the students owned themselves or borrowed from family members. Sound material was not only recorded but also downloaded from sound archives on the Internet. In this phase the following project goals were at the centre of interest: to raise the students' awareness for the omnipresence of technology in their everyday lives and to encourage a playful approach to new technologies by using them in a creative way.

In reflecting their experience with music technology, the students together with Birgit Hofstätter, Anita Thaler and Christine Wächter from IFZ and Isabel Zorn from the University of Landau, developed two didactic concepts for technology-based music instruction in school (Hofstätter et al. 2010a; 2010b). This outcome is about to be evaluated in various educational contexts. In the final phase of EYS, the students participated in the dissemination process by presenting their results to the public (e.g. at an international conference) and by contributing to publications (Hofstätter et al. 2010a; 2010b and this article).

I (Birgit Hofstätter) was responsible for the pedagogical and didactic matters throughout the project. In the first part of EYS I supported Birgit Gasteiger in coaching the project groups – with her focusing on technical issues and me on a gender sensitive didactic approach in the spirit of undoing gender (Hirschauer 2001; West & Zimmerman 1987). We continuously reflected group activities and shared our findings and questions with Anita Thaler, who did a process evaluation of EYS, and Isabel Zorn who was our adviser for pedagogical matters and gender aspects. From this meta-discussion we developed a list of recommendations which were partially also supported by findings in other technology-based projects with children and youths (Schelhowe & Zorn 2005; Zorn 2007). This list was included in the publications of the didactic concepts (Hofstätter et al. 2010a; 2010b).

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The 'air piano'

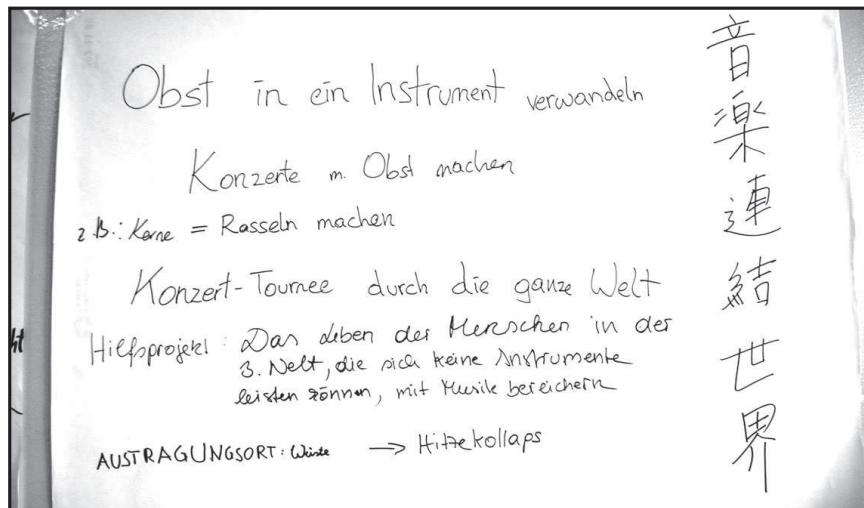
Most of the designs in EYS predominantly used existing technology to produce creative artistic work. We (Sonja Deutschmeister and Johanna Nather), however, aimed in another direction and used existing technology to create a new application. Together with our technical coach Birgit Gasteiger we designed an 'air piano' based on the underlying technology of the Nintendo® Wii Remote. In the following we will describe how the idea was born and the challenges of our initial project goal. After that, Birgit Gasteiger will explain the technical background and the construction itself.

The idea

Our idea at the beginning of the brainstorming process was to create instruments for people who do not have enough money to buy conventional instruments (see Image 1). In the course of the workshop we became motivated to create something more unusual and thought of invisible instruments (see Image 2): the idea of creating air instruments was born. In order to better distinguish the project groups in EYS, a name had to be found – something original and interesting. Each team had to define an output, which in our case was to interpret the famous piece 'The Blue Danube' by Johann Strauss. So, 'Danube' was our first notion which we complemented by the word 'just', because 'Danube' alone seemed too simple and short to us. 'Just Danube' became the perfect motto of our group in achieving our goal.

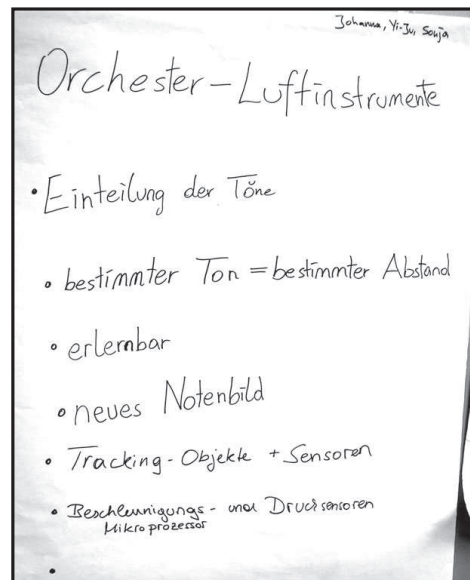
During the process of designing the first air instrument we had to find out that the efforts to play 'The Blue Danube' would go beyond the scope of the EYS project (we also had to attend our regular classes and practice our instruments). It took weeks from defining the goal of our project to the moment we could play the first note on the air piano. One major challenge was to program as many notes as required to play the piece, another one was learning to play the instrument since the positions of the notes were invisible. We thus decided to work on programming a simple scale and to at least be able to create three notes simultaneously. In the following, the designing process and the construction are explained.

Image 1. Our results of the first brainstorming session at the first workshop.



The keywords are: instruments made of fruits, global concert tour, charity project for people in third world countries. Photograph by Isabel Zorn

Image 2. The more detailed concept of our project, titled 'Orchestra – Air Instruments', after the first workshop.



Photograph by Isabel Zorn

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Introduction – example application

In order to introduce the team of ‘Just Danube’ to the field of air instruments, I, Birgit Gasteiger, read up on an example application of a ‘virtual air guitar’ (Huovilainen et al. 2004; Karjalainen et al. 2006) developed at the Technical University of Helsinki. This design is a combination of a guitar synthesizer and a control unit which enables playing the instrument by moving one’s hands in the air. The distance between left and right hand defines the pitch of the synthesized sound, while the motion of the right hand corresponds to the paradigm of plugging a guitar string. The sound synthesis is achieved by using a physics-based synthesis model producing the sound of a Stratocaster electric guitar in real-time. The motion tracking of both hands works through an optical method based on color detection. Thus, in order to control the instrument, the player wears colored gloves which are subsequently extracted from the video stream of a webcam. The position and motion data of the hands further provide the control parameters for the sound synthesis model.

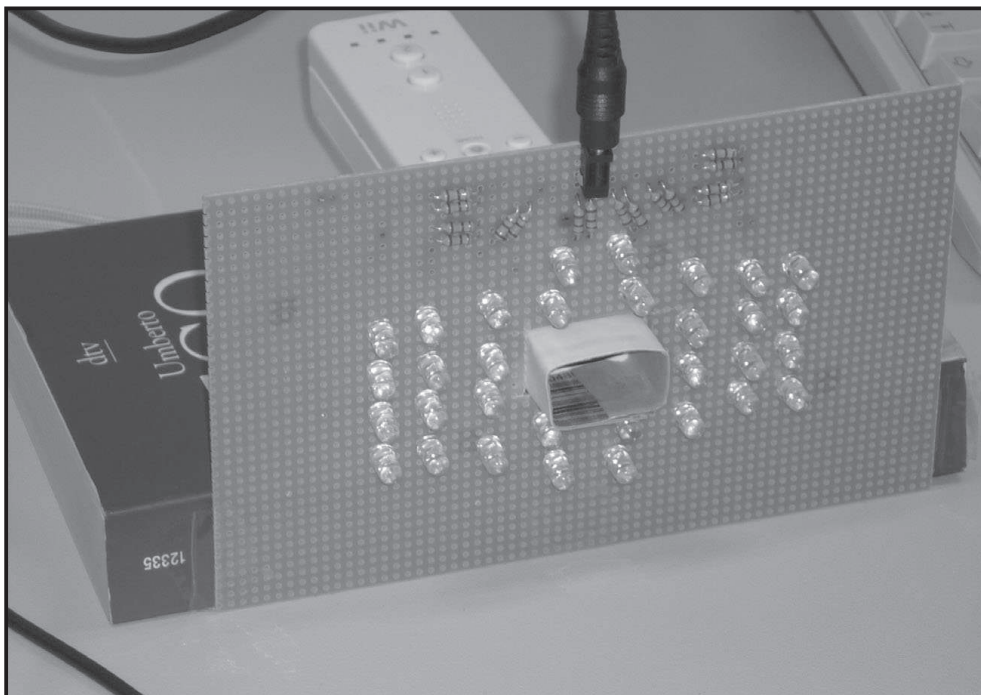
In the implementation of the air piano we aimed at controlling the instrument with single fingers and achieving an authentic piano sound reproduction. In order to meet these requirements, the control unit was designed using the Wii Remote (unofficially nicknamed ‘Wiimote’), which is the controller of the Nintendo® Wii console. An authentic piano sound reproduction was achieved by using wavetable synthesis.

The instrument setup – the Wiimote as control unit

The usage of the Wiimote for position tracking of individual fingers was first introduced by Johnny Chung Lee (Lee 2008a) at the TED (Technology, Entertainment, Design) conference in 2008. He did not publish any technical specifications of the Wiimote but derived a number of technical details through reverse-engineering (Lee 2008b). The Wiimote comprises an acceleration sensor, a speaker, a vibration motor, and an infrared camera for finger tracking. The player’s fingers are marked with infrared reflecting material and positioned at a distance of about 1.5 m from the Wiimote and an infrared emitter consisting of a circuit board with diodes attached (for

illustration of the control unit see Image 3. The emitter continuously sends out infrared light, which is reflected by the marked fingers and sent back to the camera.

Image 3. Control unit of the air piano: A circuit board with infrared light emitting diodes attached and the Wiimote (infrared camera) to which the light is reflected.



Photograph by Anita Thaler

In addition, the Wiimote is fitted with a multi object tracking (MOT) functionality which allows the simultaneous detection of a maximum of four fingers, so called 'blobs'. The position data of the white blobs is transmitted to a computer via a wireless Bluetooth connection and received by the graphical programming environment Pure Data (PD). Data processing in PD is based on the PD external 'wiimote' developed by Mike Wozniowski (n.y.), which outputs an identification number for each detected finger and its position in x- and y-coordinates within the camera

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image. In the horizontal direction (x-axis) the camera image is divided into 8 sections which correspond to the pitches of one octave. When a finger is detected in one of these sections the corresponding pitch is played back, while the removal of the finger corresponds to the virtual gesture of releasing the finger from the piano key (gesture mapping).⁴

Wavetable synthesis

Wavetable synthesis describes the playback of the recorded digital waveforms of the instrument sound by the use of a wavetable synthesizer (Kahrs & Brandenburg 1998). The digital waveforms are stored in a file format specially developed to support sound reproduction using wavetable synthesis. This file format, called 'SoundFont' (Trachtman n.y.), is based on the file structure of the 'Resource Interchange File Format' (RIFF). The content of a soundfont comprises the digital audio data and additional control data supporting articulation and dynamic sound synthesis. Sound reproduction is controlled by a wavetable synthesizer. Notes are played using MIDI (Musical Instrument Digital Interface) commands, as e.g. 'note on' or 'note off'. Additional parameters such as note number and velocity indicate the pitch and the amplitude of the triggered note. The functionality of a soundfont synthesizer for the air instrument is realized by the open source PD external 'fluidsynth' developed by Frank Barknecht. The soundfont applied is also available free of charge and comprises 88 pitch recordings with different attack dynamics.

To sum up: The advantage of using the Wiimote is that it allows precise control of the instrument with single fingers without disturbing the movement of the hands due to sensors or cables. In addition, the students' interest is attracted by the use of a modern and commonly available technology, which is especially appealing for young people. Furthermore, the realization of the hardware setup is simple and affordable.

Image 4. The project team (from left to right: Sonja Deutschmeister, Yi Lu Chung, Johanna Nather, Birgit Gasteiger).



Photograph by Anita Thaler

Conclusion

In view of the objectives of the project 'Engineer Your Sound!' the air piano represents the ideal outcome of an innovative participatory technology design process: The technology of a device young people use in everyday life (control of a game console) is transferred and adapted to a different context by the young users themselves. While they benefited from the support of a sound engineer, the students themselves played a crucial role in this process by contributing

- a) the original idea
- b) their musical expertise and
- c) their effort in learning how to work with the program and how to set up the device.

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According to the implicit objective of EYS to encourage young people reluctant to see themselves as technologically competent by using a gender sensitive didactic approach, it must also be emphasized that the group working on the air piano consisted solely of women. The didactic motto of the process was: Everyone in the team has an equal share of participation in each step of the designing process, i.e. each member knows how to set up the device, how to program the notes and how to play the instrument.

Acknowledgments

We wish to extend our thanks to Anita Thaler and Isabel Zorn for encouraging us to write this record of our work, and to Anita Thaler for her additional inputs which made this article as authentic as possible.

Notes

- ¹ Transdisciplinarity in this context is understood as a participatory approach (Maasen 2010, 258) with representatives of a group of stakeholders being actively involved in the research process. In this case the students took the place of stakeholders who not only framed the problem but actively contributed to its solution.
- ² 'Engineer Your Sound! Participatory technology design using the example of music. Secondary-school students developing didactical concepts for interdisciplinary engineering education' (2008–2009), funded by the program Sparkling Science, an initiative of the Austrian Federal Ministry of Science and Research (<http://www.sparklingscience.at/en/>); for further information on the project see <http://eys.twoday.net/> and <http://www.ifz.tugraz.at/eys>.
- ³ Initially, the group had a third member, Yi-Ju Chung, who dropped out towards the end of the process, with the result that Sonja Deutschmeister and Johanna Nather completed the design together.
- ⁴ For an audio-visual demonstration of the air piano see the videos at the YouTube channel of EYS: <http://www.youtube.com/EngineerYourSound>.

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