PREFALLL135. AN INTERACTIVE TANGIBLE INSTALLATION FOR AUDIOVISUAL COMPOSITION

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This paper introduces Prefalll135, an interactive installation that uses the kinetic energy of falling water to generate real time visuals and sound. It consists of a tangible user interface of watermills and taps, which enables users to control the water's flow. The angular velocity of each watermill is mapped to parameters of the audiovisual system, permitting the users to create dynamically their own collaborative or solo audiovisual composition.

Prefalll135 integrates both Do-It-Yourself practices, regarding the construction of the physical interface through means of personal fabrication, as well as Do-It-With-Others practices, respecting the collaborative development processes employed and the extension of the use-value produced by open-source communities. Being a project inspired by nature, Prefalll135 fosters the concept of reuse and free access to resources, both in digital and physical spheres.

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1 INTRODUCTION

Technological advances in the Human Computer Interaction and the social web domains enable the involvement of an increasing number of creators and audiences both at end-user level as well as during the development process, leading towards a more democratized approach of the creative act.

Embedded interaction, tangible interfaces and ubiquitous computing narrow the gap between users unfamiliar with new technologies and interactive installations. Everyday objects are augmented with a layer of digital information, without changing their original function, look and feel (Kranz, Holleis, and Schmidt 2010). The users are invited to interact with them by using the skills they already have for sensing and manipulating their physical environments (Ishii 2008). Thus Windows-Icons-Menus-Pointer (WIMP)—based interfaces disappear from the foreground, while computation technologies weave themselves into the fabric of everyday life until they become indistinguishable from it, as it has been anticipated by Mark Weiser (2010). Moreover, tangible interfaces permit simultaneous manipulation of interactive artifacts by multiple users, supporting multi-user collaborative interaction. TUIs can be used as sharable interfaces, where collocated groups are able to work together on shared representations (Marshall, Rogers, and Hornecker 2007). Contrary to single user technologies of sequential interaction, tangible interfaces can support control sharing over collaborative activities. (Jordà 2008)

Advances in the social web domain facilitate the involvement of an increasing number of creators to collaborative DIWO and Peer-to-Peer (P2P) projects. In DIWO practices the process is as important as the outcome, involving participants in continuous peer enactments, through digital and physical networks (Garrett 2012). A wide range of users employ social web tools to collaborate in peer-production projects and participate in FLOSS and OSHW communities. They meet the communities' members both in digital and physical spaces, while they share, reuse and freely redistribute the produced use-value under commons-oriented licenses (Bauwens 2015). DIY makers use their own digital communities (Kuznetsov and Paulos 2010), where they similarly share designs, ideas, instructions and interact with each other. The rise of desktop manufacturing technologies, together with commons based peer production, privilege a more sustainable productive model of "designing globally-manufacturing locally." (Kostakis et al. 2015)

Fig. 1. Detail of Prefalll135 interactive installation.

2 INTRODUCING PREFALLL135

Prefalll135 consists of a DIY construction that counts with a semi-transparent acrylic box of approximately 2m x 1.5 m x 0,20m (height x width x depth). Inside the box, a waterfall is formed by an amount of water flowing from the highest level of the structure to the lowest. A water pump elevates the water back to the top of the construction, making the water circulation autonomous and potentially endless.

The water flows through three different levels, each one counting with a water container. Three taps are fixed on each container, and below each tap a watermill is mounted. The watermill rotates by the falling water when the corresponding tap is open. By manipulating the taps, the users of the installation are able to determine the flow of the water and to control the rotation of the watermills.

Sensors connected to an open source hardware electronic microcontroller detect the angular velocity of each watermill. The input data are used by a custom open source software to generate audio and graphics dynamically. The visuals are rear-projected and mapped on the vertical surfaces of the construction, while the sound is directed to the speakers surrounding the installation. Thus the physical construction is augmented by a digital audiovisual layer that evolves in real time according the users' interaction.

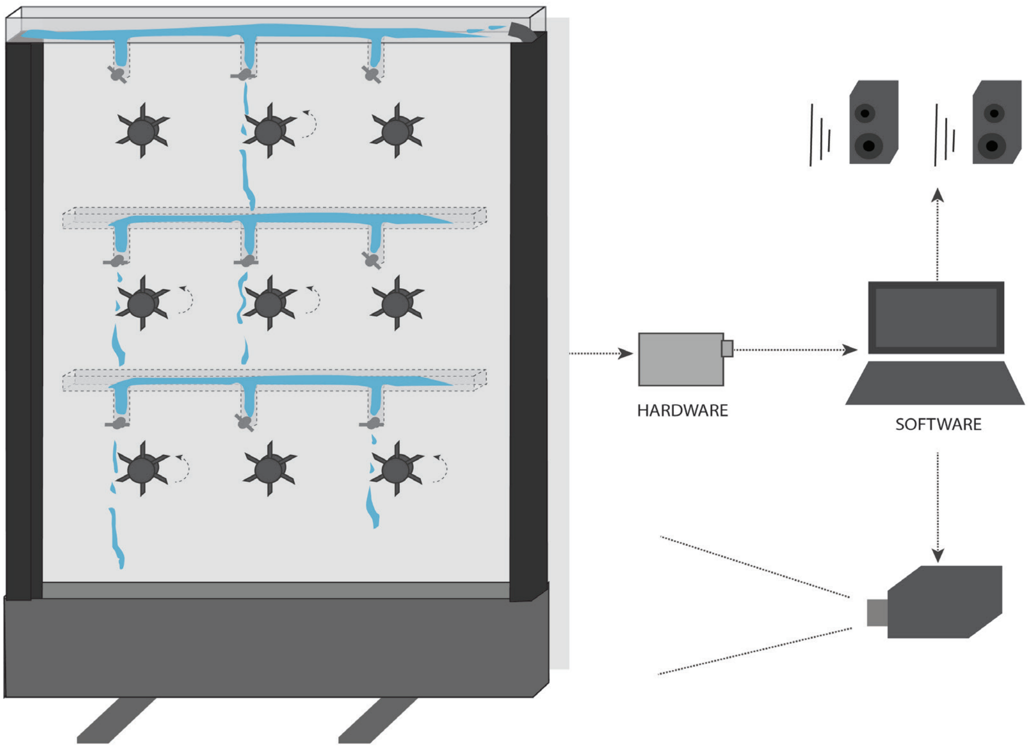


Fig. 2. Detail of Prefalll135 interactive installation.

3 DIY TANGIBLE USER INTERFACE

3.1 THE PROTOTYPE

Re-appropriation of obsolete objects or materials, broad access to digital fabrication technologies and shared knowledge databases are some of the practices gradually leading to a democratization of manufacturing, which influences all sectors of design, production and distribution of material objects (Mota 2011). A new class of creators and producers emerge as "the dominant paradigm of user-as-consumer gives way to alternative framings of the user as creative appropriator, hacker, tinkerer, artist, and even co-designer or co-engineer" (Tanenbaum et al. 2013). DIY is currently a wide spread phenomenon covering a variety of domains including art, electronics, crafts, music and more, while its practices have been of increasing interest to HCI researchers who argue on the benefits of the application of these practices to the HCI domain (Kuznetsov and Paulos 2010; Tanenbaum et al. 2013).

Following the DIY concepts, the first version of Prefalll135 used exclusively recycled found objects. The wooden base of a bed, plastic pipes, camping water buckets, or components of children's toys such as plastic windmills, were some of the re-appropriated materials re-purposed under a new context. These objects were customized and mounted on a single construction to serve the prototype's needs. The idea of a DIY construction of recycled objects underlined the notion of sustainability that was present throughout the development of the project. In general, the DIY stance during its various and different manifestations in the middle of the 20th century turned into a creative act of rebellion against mass production, consumerism, planned obsolescence and waste (Mota 2011). Current DIY initiatives keep reflecting these notions and support "the ideology that people can create rather than buy the things they want." (Kuznetsov and Paulos 2010)

3.2 THE STABLE VERSION

The need for a more robust and precise construction led to the redesigning of the physical part of the installation. Found materials also bared certain limitations. For example, it was difficult to find a semi-transparent surface of a sufficient size for supporting rear projection. Furthermore, the lack of a water pump required manual elevation of water, from the lowest to the higher container of the installation.

During the re-designing process of the physical interface a series of experiments on 3D printing practices took place. Digital fabrication technologies, such as the 3D printing technology, can be considered as another indispensable practice towards the democratization of manufacturing. Personal 3D printers are in a process of becoming economically affordable and accessible to a wider range of users. Their ability to provide physical substance to digitally designed objects provides the possibility to produce and circulate goods outside the centralized manufacturing model (Mota 2011). As a result of the realized experiments, certain parts of the watermills were 3D printed in the new version of the construction. The new version counted with an acrylic box, nine watermills, nine taps, four water containers and a one water pump.

Fig. 3. The prototype (left) and the stable version (right) of Prefalll135.

3.3 DESIGN GOALS

The tangible interface was designed with a primary goal to target user groups unfamiliar with new technologies and WIMP—based interfaces. Interactive functionality was embedded into water taps and watermills, which are objects with familiar functioning. Users were expected to interact through opening and closing the taps, directing the water to the watermills and making them rotate. Namely, interaction design was based on well-understood actions related to common physical objects. This design approach made the interface intuitive and self-explanatory, without any need for instructions or a user manual.

A second design goal of Prefalll135 was to support multi-user collaborative interaction. Prefalll135's tangible interface permitted simultaneous manipulation of interactive artifacts by multiple users. The users can open and close different taps at the same time and share control on the flow of water and the audiovisual output. Thus they experience their audiovisual creation while they apply collaborative scenarios.

4 HARDWARE

Electronic prototyping platforms wrap the details of microcontrollers functionality in user-friendly environments allowing users to build sophisticated applications with a relatively low learning curve. Among the variety of available platforms the Arduino[1] microcontroller was selected. One reason for this choice was the fact that Arduino hardware is open source and distributed under a Creative Commons license. It has also a wide community of users contributing to the creation of a common knowledge base, which includes detailed documentation and software/hardware extensions and applications. Moreover, its widespread use has led to the development of libraries that wrap the communication of Arduino boards directly within other programming languages or environments, which facilitates the development of applications that integrate Arduino-based input/output modules. Arduino consists of a series of open source hardware boards and an IDE (Integrated Development Environment). For this project an Arduino Mega Board was used.

Several options were available for capturing the velocity of the watermills' rotation. The first version of the project did not use an electronic circuit and followed quite a different approach. It captured the rotation of the watermills through a computer vision module. For this reason a unique *fiducial* marker was attached to the rear part of each mill. A camera placed behind the watermills recognized the ID of each watermill and the angle of rotation.

1. "Arduino", accessed December 28, 2015, https://www.arduino.cc/

Later this option was abandoned and an electronic circuit replaced the computer vision module. The electronic circuit proved to be stable and accurate, while it avoided lighting or other setup issues related to the use of a camera. By opting for this approach, a rotary encoder was necessary. Instead of using a commercial one, a lower cost DIY rotary encoder was built using the CNY70 sensor, a reflective optical sensor with a transistor output. The sensor consists of an infrared emitter and a phototransistor in a leaded package, which blocks visible light. The sensor is able to sense whether the emitted infra-red light is reflected back or not. Thus if it is mounted near a spinning wheel with a striped black and white pattern, an appropriate circuit will produce a logic-level pulse stream whose frequency is directly proportional to the angular velocity of the wheel[2].

2. Fastolfe, Dr., "Rotary encoder based on CNY70 photoreflector," *Recreactional Robotics: Building and programming autonomous mobile robots for fun* (blog), August 19, 2011, http://recreationalrobotics.blogspot.gr/2011/08/rotary-encoder-based-on-cny70.html

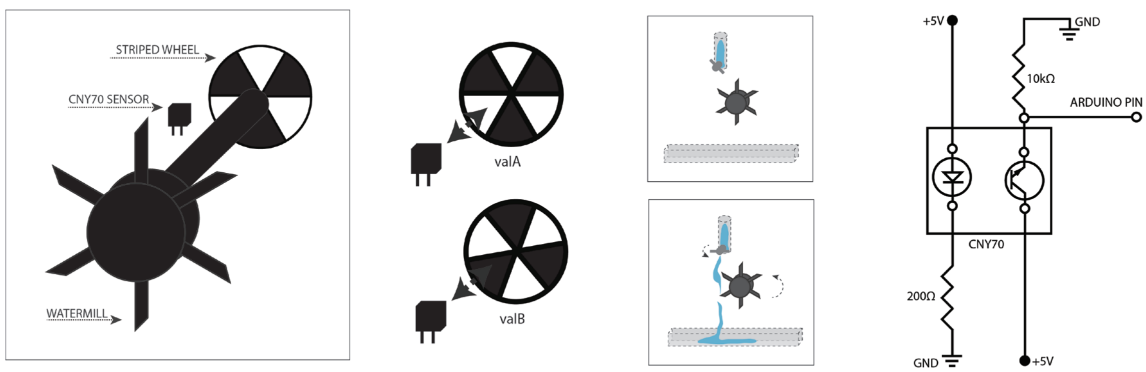


Fig. 4. Angular velocity detection.

Nine striped wheels were printed and attached to the rear face of each watermill. Each CNY70 was mounted as close to the spinning wheel as possible, and connected to the Arduino Mega Board. Thus, the software of the installation could easily calculate the angular velocity of each mill by reading the input of the corresponding Arduino's analog pins.

5 SOFTWARE

The software of Prefalll135 consists of a custom program developed for the needs of the installation. The software contains three modules. The first module handles the interaction and communication between hardware and software, and between the different software modules. The second one handles the visual generation, while the third one is responsible for the audio generation. The first two modules were developed in C++ using the openFramewoks[3] toolkit, while the third module was developed with Pure Data[4].

3. "openFrameworks", accessed December 28, 2015, http://openframeworks.cc/

4. "Pure Data", accessed December 28, 2015, https://puredata.info/

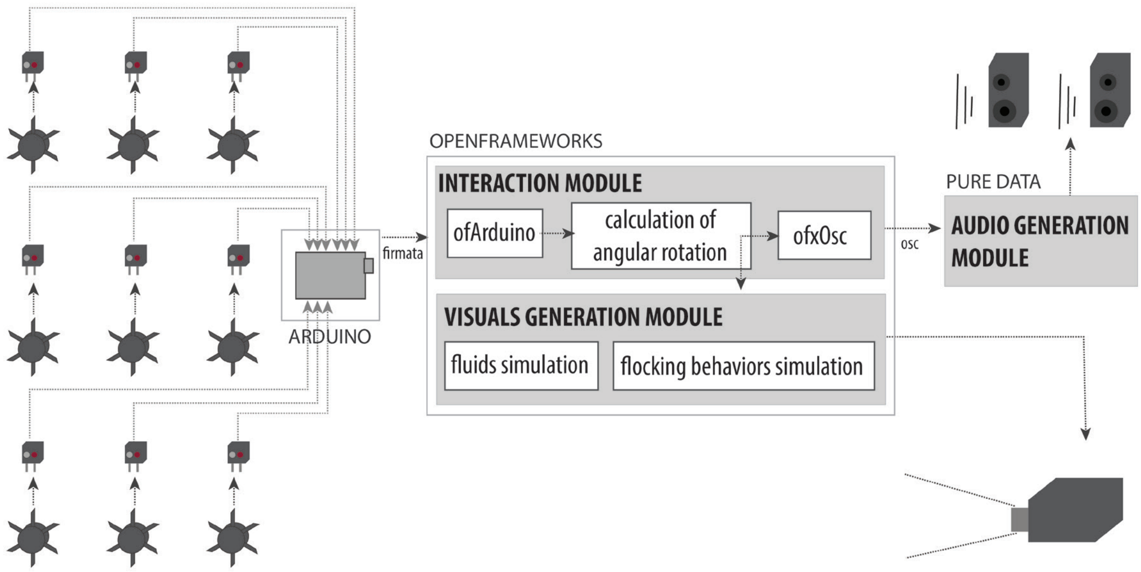


Fig. 5. Functioning of Prefalll135.

5.1 INTERACTION MODULE

The openFrameworks platform was selected primarily due to the fact that it is an open source toolkit for C++, a high performance, efficient and flexible programming language. Additionally openFrameworks provides a user-friendly framework, easily extended, while it wraps together several commonly used libraries, which enable communication between the different modules of Prefalll135. Furthermore, it has a broad community of users contributing to the extension and documentation of the project.

In order to achieve communication with the hardware, the interaction module of the installation establishes a connection between Arduino and openFrameworks through an instance of the *ofArduino* class using the *firmata* protocol. Through this instance, the software is able to read values directly from any Arduino's pin and calculate the angular velocity of the watermills. In this way all the input data is made available for the visuals and audio generation modules. In order to send the required info to the audio generation module an instance of the *ofxOsc* class is initiated which uses the Open Sound Control (OSC) protocol to send data through a network connection.

5.2 VISUALS GENERATION MODULE

The visuals generation module uses the angular velocity of each watermill to dynamically generate graphics. The generated graphics draw inspiration from the natural element of water and consist of a fluid simulation function and a simulation of a flocking behaviour function.

The fluid simulation uses the *MSAFluid* open source library by Mehmet Akten[5]. The library solves and displays real-time 2D fluid simulations based on Navier-Stokes equations and wraps in an API the fluid solving algorithms by Jos Stam (2003). The API provides methods for adding and getting forces and controlling fluids' color at any position.

The flocking behavior simulation is based on the code *Pond* (Reas and Fry 2014) written by William Ngan[6]. The code was re-written in the C++ programming language and adapted to the installation. This code is an implementation of Craig Reynolds' model of separation, cohesion, and alignment (Reynolds 2001). The model coordinates animal motion such as bird flocks and fish schools and consists of three simple steering behaviors, which describe how an individual member of the flock moves, given the positions and velocities of its neighbors. The behaviors include a) *Separation*, steering to avoid crowding local neighbors, b) *Alignment*, steering towards the average direction of local neighbors and c) *Cohesion*, steering to move toward the average position of local neighbors (Reynolds 2001).

The rotating watermills act as points of attraction for the flock, while the attraction force is proportional to the angular velocity of the watermill. The rotation of the watermill also increases the velocity and energy of the flock members and changes their color. Each watermill affects only the flock members that are inside a circular area of certain radius around the watermill. Simultaneously a simulation of an agitated fluid is generated and projected around the rotating watermills. In order to achieve perceptual coupling of the physical watermill and the digital image, the nine points calculated by the software have to coincide with the watermills when projected on them. For this reason a calibration mode has been designed that enables refinement of the projection mapping.

5.3 AUDIO GENERATION MODULE

The audio generation module was programmed in PureData, an open source visual programing language suitable for real-time sound processing and generation. The data concerning the rotation of the watermills is send to the audio module from the interaction module through the Open Sound Control (OSC) protocol. Similar to the visuals, the inspiration for the generated sound was found in the sounds of natural elements such as water and wind. Three different methods of audio composition were employed in order to achieve this result: additive, subtractive, and wavetable synthesis.

5. "ofxMSAFluid", Memo Akten, accessed January 05, 2016, http://www.memo.tv/msafluid/

6. "Metaphorical | A Notebook of William Ngan," accessed December 28, 2015, http://www.metaphorical.net/

The additive synthesis module has been used to simulate the sound of wind, the subtractive synthesis module simulates the sound of rain, while the wavetable synthesis module simulates the sound of falling water drops. Each watermill has a specific function in the audio module. Some of them generate original sounds while others affect parameters of the previously generated sounds such as the volume, frequency or wave forms, thus creating dynamic evolutions in the overall audio output. The use of algorithmically generated sounds has been privileged over the employment of pre-composed material, avoiding ROM-based solutions.

6 COMMUNITY AND USER FEEDBACK

6.1 COLLECTIVE PRODUCTION AND COMMUNITY FEEDBACK

The paradigm of collaborative production in the artistic context is gradually gaining ground and the reasons range from non for-profit personal and social-driven incentives to economic motivation. Participation in DIWO, P2P projects, FLOSS and OSWH communities promote the feelings of shared creativity and knowledge, communication and the development of social relationships (Benkler 2006). Moreover, working in DIWO projects and producing collectively result affordable for a wider public, especially in times of economic crisis (Koutsomichalis and Rodousakis 2015).

The Prefalll135 project emerged through the collaboration of interdisciplinary artists of the *Once Upon A Byte* art and technology collective based in Barcelona. Later more people got involved in the project through the workshops, presentations and residencies that took place during the development process. The Prefalll135 development team participated actively in FLOSS and OSWH communities by sharing, reusing, and extending the freely accessible use-value. Prefalll135 distributes its source code under a Creative Commons Attribution-ShareAlike 4.0 International License, that prevents private appropriation and places it in the public domain[7]. The Prefalll135 team often collaborated remotely and asynchronously, following the paradigm of internet aided CSCW (Computer Supported Cooperative Work). They extensively used social web tools (wikis, blogs, media sharing platforms, mail lists and VoiP) to share resources, communicate, co-edit and document the development process.

Apart from sharing the project results online and virtually meeting the developer communities in digital spaces (forums, wikis), the creators considered it appropriate to meet the communities' members in physical spaces as well. In this context,

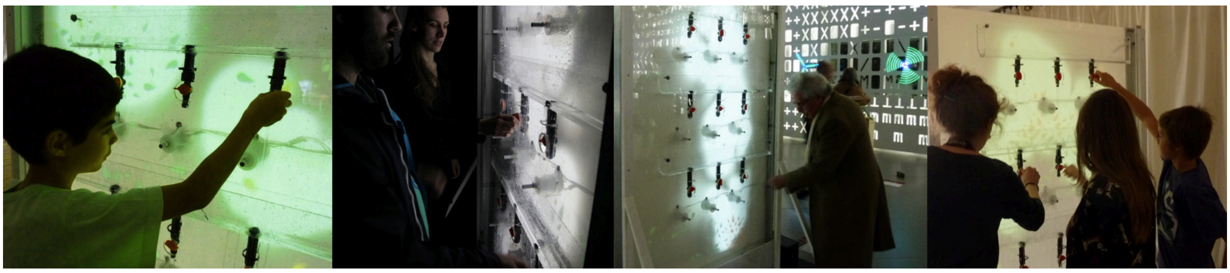
7. "Creative Commons", accessed December 28, 2015, http://creativecommons.org/

they participated in presentations addressed to the openFrameworks and Arduino developer communities at *ZZZINC—Cultural Research & Innovation* in Barcelona and at *FrownTails* in Athens, respectively. During these presentations the authors further propagated the knowledge acquired during the development of the project and also received the communities' feedback. Further interaction with the communities of developers and artists was achieved through a number of workshops and residencies, that the creators of Prefalll135 attended.

6.2 EXHIBITIONS. USER FEEDBACK

In parallel with the presentations to the developer's communities, a series of exhibitions addressed to the broad public took place. The project was exhibited at various venues, festivals and institutions, such as *Sonar*, the 19th Festival of Advanced Music & New Media Art in Barcelona; *Fabra i Coats Creative Factory* in Barcelona; and the *Creative Algorithms* exhibitions at *Espaço o Tempo* in Montemor-o-Novo, and *Pavilhão do Conhecimento* in Lisbon. During these exhibitions, the development team had the chance to discuss issues related to the project with the audience, study users' interaction and receive feedback from a broad public. The exhibitions attracted numerous and diverse audiences, with regard to age, motivation for visiting the exhibition, and level of familiarity with interactive technologies. Especially valuable in terms of observations on user interaction and feedback was the participation of Prefalll135 at the *Creative Algorithms* exhibition, where more than five hundred students of schools of the area visited the exhibition and interacted with the installation.

Fig. 6. Functioning of Prefalll135.



6.3 REMARKS AND OBSERVATIONS

Below is presented a selection of interesting remarks and observations in relation to users' interaction.

The interface seemed to be easily comprehensible by the majority of the users, independently from age and technological skills. The absence of WIMP-based interfaces encouraged novice users to interact, explore and get engaged with the installation. Regarding the motivations for interaction, greater diversity was observed. For example, children focused on the ludic aspects of the installation considering it a game. Users familiar with digitally synthesized sound regarded Prefalll135 as an instrument for sound composition. Other users explored the possibilities of creating a visually engaging augmented sculpture. Similarly, part of the users focused either on the visual channel of the installation or on the audio channel, while most of them perceived the audiovisual output as a whole. In relation to the collaborative possibilities offered by the installation, children seemed to explore them more extensively, often applying scenarios of simultaneous interactions. Finally in terms of learnability and predictability (Levin 2000) of the audiovisual system, the visual response to users actions seemed more easily apprehensible but also more predictable than the audio response. Concerning the audio response, while most of the users easily associated the generation of a sound with the rotation of a watermill, novice users encountered difficulties in understanding the function of watermills that affected the overall audio output of the installation as opposed to watermills that function as sound generators.

7 CONCLUSIONS

This paper introduced Prefalll135, an interactive tangible installation for audiovisual composition. The custom software and hardware built for the installation were presented, as well as the challenges of incorporating the natural element of water with new technologies and everyday objects. Certain technologies and practices from the HCI and social web domains were discussed, which facilitate the participation, interaction and collaboration of an increasing number of users either at end user level or production level, contributing to a more democratized access to the creative process.

Prefalll135 is a project that draws inspiration from nature and underlines the concepts of sustainable design, preservation of resources (either natural or digital), and free access to such resources. DIY and DIWO communities support sustainable approaches through practices including the re-appropriation and re-purposing of obsolete materials, the development and free distribution of open tools and open data, free access to resources through commons-based licensing and knowledge sharing. Prefalll135 integrates both DIY and DIWO practices, it is produced collectively and develops close interconnections with the open source communities. Considering the development process equally as important as the result, multiple iterations of design/

development-discussion/feedback have taken place both in digital spaces (forums, blogs) as well as in physical spaces (community member meetings, workshops, residencies). The result of this process has been the development of multiple constructive collaborations and a rapid evolution of the project.

Regarding the interaction design, the main goals of Prefalll135 were to engage a wide range of users through an intuitive interface and to promote collaborative synergies. The first goal has been pursued by embedding interactive functionalities in everyday objects and avoiding WIMP-based interfaces. The second goal has been pursued by enabling simultaneous manipulation of interactive tangible artifacts by multiple users. According to users' interaction, observations and feedback during the multiple exhibitions of Prefalll135, it is estimated that these goals have been achieved at a certain point, as both novice and experienced users got engaged with the installation and easily managed to control the interface, while many of them applied scenarios of collaborative interaction. However a more systematic user study and effective evaluation of the users interaction would be valuable for the future improvement of the interface and the user experience.

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