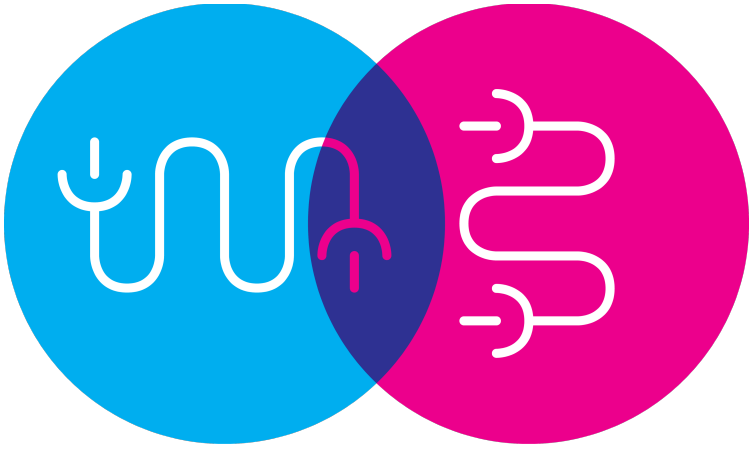

| | |
|---|---|
| Project Acronym: | **MusicBricks** |
| Project Full Title: | **Musical Building Blocks for Digital Makers and Content Creators** |
| Grant Agreement: | **N°644871** |
| Project Duration: | **18 months (Jan. 2015 - June 2016)** |

# D6.1 Feedback on #MusicBricks from the Industry Testbed

| | |
|---|---|
| Deliverable Status: | **Final** |
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| Due Date: | **Jan 2016 (M13)** |
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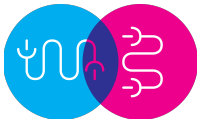
| Dissemination Level: | **Public** |
| Task Leader: | **TU WIEN** |

Authors: *Thomas Lidy (TU WIEN), Jordi Janer (UPF), Sascha Grollmisch (Fraunhofer), Frederic Bevilacqua (Ircam), Emmanuel Flety (Ircam), Marta Arniani (Sigma Orionis), Michela Magas (Stromatolite)*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°644871



The #MusicBricks project consortium is composed of:

| | | |
|---|---|---|
| **SO** | Sigma Orionis | France |
| **STROMATOLITE** | Stromatolite Ltd | UK |
| **IRCAM** | Institut de Recherche et de Coordination Acoustique Musique | France |
| **UPF** | Universitat Pompeu Fabra | Spain |
| **Fraunhofer** | Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V | Germany |
| **TU WIEN** | Technische Universitaet Wien | Austria |





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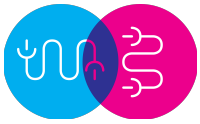

## Revision Control

| Version | Author | Date | Status |
|---|---|---|---|
| 0.05 | Thomas Lidy (TU WIEN) | July 15, 2015 | Initial Draft / Framework |
| 0.1 | Thomas Lidy (TU WIEN) | September 2, 2015 | Information about Content to add |
| 0.2 | Thomas Lidy (TU WIEN) | January 4, 2016 | Executive Summary, Introduction, Framework |
| 0.3 | Thomas Lidy (TU WIEN) | January 19, 2016 | Feedback on TUW tools |
| 0.4 | Jordi Janer (UPF) | January 19, 2016 | Feedback on UPF tools |
| 0.5 | Thomas Lidy (TU WIEN) | January 20+21, 2016 | Presenting the incubated projects |
| 0.6 | Sascha Grollmisch (Fraunhofer) | January 21, 2016 | Feedback on Fraunhofer tools |
| 0.65 | Marta Arniani | January 25, 2016 | Review |
| 0.7 | Frederic Bevilacqua, Emmanuel Flety (Ircam) | January 26, 2016 | Feedback on R-IoT |
| 0.9 | Thomas Lidy (TU WIEN) | January 28, 2016 | Conclusions |
| 1.0 | Marta Arniani (SO) | January 28, 2016 | Review |
| 1.0 | Michela Magas (STROMATOLITE) | January 28, 2016 | Final Draft |
| 1.0 | Marta Arniani (SO) | January 29, 2016 | Submission to the EC |


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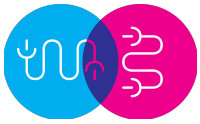

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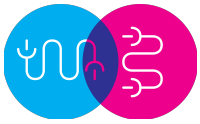

# 1. Executive Summary

The present document is a deliverable of the #MusicBricks project, funded by the European Commission's Directorate-General for Communications Networks, Content & Technology (DG CONNECT), under its Horizon 2020 research and innovation programme.

The #MusicBricks project organized and hosted a number of Creative Testbed events in which people with various backgrounds (artists, hackers, makers, startups, researchers, …) experimented, created, prototyped, remixed and presented a wide range of new applications (hacks, apps, instruments, performances), all using a set of #MusicBricks tools that were provided by the #MusicBricks consortium (see Deliverable D3.3).

**From these Creative Testbed events, the best projects were selected to be taken into the Industry Testbed programme of #MusicBricks: an incubation program to foster the projects' development towards market-ready prototypes.** This incubation programme gives the incubatees and projects the unique opportunity to develop their initial idea towards a sustainable prototype to be presented in industry environments (startup events, investors, trade shows etc.).

At the same time, the #MusicBricks Industry Testbed provides invaluable feedback to the authors of the #MusicBricks tools, firstly, in terms of stability, reliability and usability, secondly, in terms of integrability and applicability together with other tools from #MusicBricks as well as third party software and hardware, and thirdly, also in terms of performance requirements on the market as well as licensing and IP considerations.

**This deliverable presents the projects incubated by the #MusicBricks Industry Testbed and presents a collection of important feedback that was gained during the incubation process for the #MusicBricks APIs, GUIs and TUIs.**

The most recurring feedback request was on the real-time capabilities of the tools, which many did not possess. Further feedback was on extending existing interfaces and APIs for advanced features. Some of these requests have been addressed directly during the incubation period in the Industry Testbed. Others are evaluated for future improvement. Some of the music analysis processes are not feasible to be done in real-time. Yet, the extended capabilities, improved performance, more integrated design and improved documentation led to maturity in terms of the tools' Technology Readiness Level for the market.


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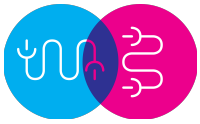

# 2. Introduction: From Creative Testbed to Industry Testbed

The #MusicBricks project organized four Creative Testbed events throughout 2015 (described in greater detail in D5.4). In each of them, the #MusicBricks tools were presented (among other hardware and software components useful for hackers and makers) to motivate people to use them in their hacking ambitions.

These were the four Creative Testbed events:

## 2.1. #MTFScandi

Music Tech Fest Scandinavia took place from the 29th to the 31st of May 2015 in Umeå, Sweden, at Sliperiet, the newly-opened interdisciplinary centre at Umeå University's Arts Campus. The festival incorporated 74 presentations, showcases and demonstrations of new musical inventions, interfaces, performances and projects across the weekend. Music producers gathered in the 'Trackathon' - a 24 hour challenge to create a new recorded work using a pre-selected library of sounds.

#MTFScandi also featured a 24-hour hack camp that provided the first Creative Testbed and seed ground of ideas for the #MusicBricks projects. **50 hackers from 14 countries** gathered to respond to a series of technical and conceptual challenges, and the #MusicBricks tools and technologies were made available to the hackers for the first time. The #MusicBricks partners were on hand to both showcase the technologies' capability and coach the hackers in the use of the tools.

**Four strong #MusicBricks ideas were selected** by the judging panel to be supported to go through the Industry Testbed to develop towards a commercial prototype. Judges were impressed by the level of innovation and the commercial possibilities of the projects. The judging panel featured highly respected invited guests from music and technology fields including Josh Saunders, Matt Black, Jason Singh, Paul Sonkamble and LJ Rich, as well as the #MusicBricks partners.

These are the projects awarded for the Industry Testbed at #MTFScandi:

- Airstrument
- FindingSomething_BondingSounding
- Dolphin
- Interactive Cube

## 2.2. Sonar+D Music Hack Day Barcelona

In 2015 the Music Hack Day at the Sonar Festival in Barcelona (17th - 19th June 2015) offered a new theme of wearable and multi-modal technology applied to music creation and performance. This special track brought together experts on bio and motion sensing, interaction design and wearable interface prototyping.

An innovative set of technologies (both software and hardware) was provided to help participants to conceptualise, build and demonstrate you their wearable interfaces. The list of technologies available included 3d printers, knitting machines, toolkits for rapid prototyping using body signals, hackable shoes, Nao robots, Brain Computer Interfaces, conductive ink, etc. (see the event's Tools page for more details).

A dedicated **full-day #MusicBricks Workshop** was held on June 16h (1 day prior to the event) to guide aspiring hackers through the extensive set of tools.

For the hackday, **100 hackers** were selected beforehand from 200 applicants based on their skills, previous portfolio of projects and plans for hacking. The 24-hour hackathon resulted in **36 projects** presented on stage. **12 projects used #MusicBricks.** On the jury to judge the nominations for the #MusicBricks Industry Testbed were Ching-Wei Chen (Soundcloud), Matt Johnson (Bare Conductive), Gustavo Giudici (Bastly) and one member from each #MusicBricks partner.

These are the four projects awarded for the Industry Testbed at #MTFScandi:

- Ear we go (Bionic ear)
- Sound in Translation


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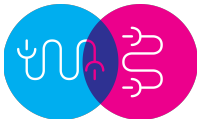

- High Note
- Enboard

The jury was really convinced by the High Note and Ear we go (Bionic ear) presentations. They were clear winners to the jury. For Sound in Translation the jury board saw both the potential of becoming a commercial product (music instrument for generating samples) and being used in performances. For Enboard the jury saw a large range of applications and extensibility.

## 2.3. #MTFCentral

Music Tech Fest Central Europe was taking place in Ljubljana, Slovenia, 18th - 20th September 2015. The festival incorporated 70+ presentations, showcases and demonstrations of new musical inventions, interfaces, performances and projects across the weekend.

#MTFCentral also featured a 24-hour hack camp, providing the third Creative Testbed and seed ground for the #MusicBricks projects. **50 hackers from** as far afield as **Sweden, the United States, Israel and of course central Europe**, gathered to respond to a series of technical and conceptual challenges, and the #MusicBricks tools and technologies were made available to the hackers once again. As with the previous events the #MusicBricks partners were on hand to both showcase the technologies' capability and coach the hackers in the use of those tools. Workshops were given on the Friday evening to guide the hackers through the #MusicBricks tools, their set-up and potential implementations.

**Three more #MusicBricks** were added to the available toolset by the industry partners at #MTFCentral in addition to the eight previous bricks: SyncJams, POF and Sonarflow (see Deliverables 3.3 and 5.2 for more information). Furthermore, event partner and sponsor Philips brought their own Hue lighting solutions toolkit for the first transversal experiment joining #MusicBricks with sound and light for therapy, communication and performance.

As a key milestone in the #MusicBricks project and as a fundamental and highly anticipated part of the festival, #MTFCentral also saw the onstage presentation of the results of the eight initial #MusicBricks incubated projects that emerged from the #MTFScandi and the Sonar+D Music Hack Day. All eight teams incubated at the time of the festival were represented.

At the #MTFCentral hack camp awards were judged by some eminent and highly respected music minds, including Graham Massey, Rolf Gehlhaar, Matt Black, and Nitin Sawhney, as well as by the #MusicBricks partners. Three more #MusicBricks ideas were nominated by the judging panel to be supported towards a commercial prototype. Once again the judges were highly impressed by the level of innovation and the commercial possibilities demonstrated:

- Gesture-based Interactive Remix Dance Floor (GIRD)
- Manuphonia
- Hue-wee Jam session

Hue-wee Jam session was created by Alexander Schindler from TU Wien. As TU Wien is partner in #MusicBricks, the consortium decided not to take the project into the Industry Testbed but to present the idea at the fourth Creative Testbed.

## 2.4. Waves Vienna Music Hack Day

The Waves Vienna Music Hack Day has been added as an additional #MusicBricks Creative Testbed Pilot. The event was organised by partner TU Wien IFS + HCI departments, Austrian Computer Society (OCG), Waves Festival, and supported by #MusicBricks through personnel at TU Wien IFS, as part of the 5-day Waves Central Europe Festival, taking place in Vienna and Bratislava.

The hackday was designed as an single day (10 hour) event. Participants were spread across many different age groups and backgrounds (as can be seen from the diagrams below) and came from a range of different countries including Austria, Hungary, Germany, UK, Slovenia, Slovakia, Sweden and Iran. A surprising 70% had never visited a hack event before.


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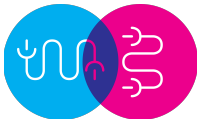

Inspired from previous international editions of Music Tech Fest and Music Hack Day, a large set of toolkits were provided, both in hardware and in software, with **#MusicBricks being prominently presented** by the TU Wien team.
A total **70 people registered** for the Waves Vienna Music Hackday and a final **50 attendees**, including **15 children,** participated in the event. The event went extremely smoothly and the organisers were overwhelmed by the positive reaction and enthusiasm of the participants. It was particularly satisfying to see how the attendees mixed and teamed up and had great fun in experimenting with music and technology and working on exciting new ideas.

**10 hacker teams** worked on their ideas, with **7 projects presented** at the end of the day. Out of these 7 hacker projects, 4 used #MusicBricks tools: 3 used the R-IoT board for gesture recognition and one used the #MusicBricks Transcriber.

The #MusicBricks jury decided to award **LightBeat**, the project that was working with the #MusicBricks Transcriber from Fraunhofer IDMT to detect beat onsets for controlling the Philips Hue lights (loosely inspired by the previously nominated Hue-wee Jam session), as the 11th project to become part of the Industry Testbed.


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# 3. Industry Testbed: incubated projects

Following the selection at the four Creative Testbeds, the projects were taken to the next step: The #MusicBricks Industry Testbed, an incubation programme that supported the projects with:

- Assistance with #MusicBricks tools
- Financial support (for material, travel, additional resources)
- Business planning in thinking towards the market
- Advices for partnerships and technologies

The incubations were carried out between June 2015 and February 2016, with approximately 3 months duration per incubated project.

## 3.1. Dolphin

**Team: Rojan Gharibpour (Sweden)**

**#MusicBricks used: R-IoT gesture sensors**

The Dolphin platform is about generation and playing of sounds and music in relation to head movements and head gestures. It is like a menu structure (e.g. comparable to a mobile phone's voice box), which can be navigated completely hands-free through head movement and nodding gestures. This is achieved by mounting a #MusicBricks R-IoT gesture sensor on a headset.

The Dolphin platform is a framework created by its author, Rojan Gharibpour, and adapted from open source libraries. It comprises a set of tools and libraries, which can load and run special applications written for Dolphin framework.

The framework provides the application with input data from the sensor like current sensor orientation and/or produces 3D sounds to be played on behalf of the the currently running application for spatial location and direction of sound sources. It can be used to navigate menu structures or virtual worlds. Of course it has also applications in Augmented Reality and is therefore applicable to a wide range of industries.

The code is written in C# and running on a Unix based system - in this particular setup it is running on a Raspberry Pi as the hardware to enable a portable setup with only micro-boards involved.

#MTFScandi presentation: https://www.youtube.com/watch?v=Npj7uf-1Q_o


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## 3.2. Interactive Cube

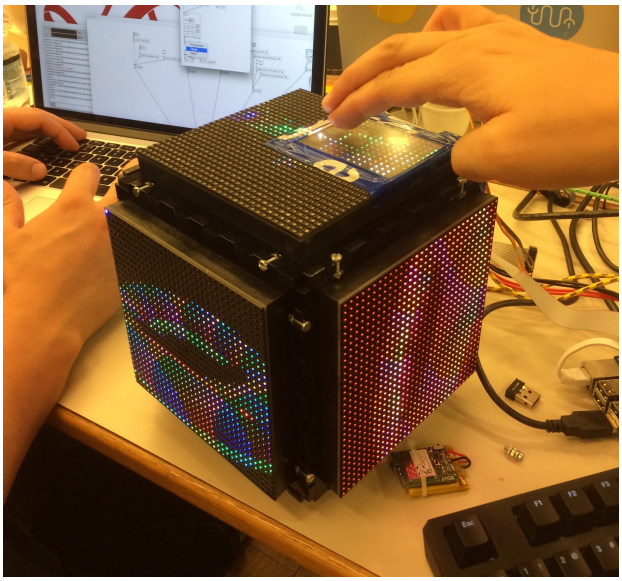
**Team: Balandino Didonato (UK), Per-Olov Jernberg (Sweden)**

**#MusicBricks used: R-IoT gesture sensors**

The Interactive Cube was awarded at the #MTFScandi Creative Test Bed and is an interactive cube display for manipulating audio. The Interactive Cube is composed of 5 LED displays, which show the projection of a sphere on each side of the cube.

The position of the sphere within the cube is determined by the orientation of the cube, which is tracked using the R-IoT device. At the same time the cube orientation defines the mix of five audio loops. Moreover, the movement of the cube drives a stereo panning effect.

The colour and size of the sphere, as well as the VU audio meters, are regulated by the audio signal.



#MTFScandi presentation: https://youtu.be/8a17_66Da7w?t=6h37m59s
#MTFScandi awards: https://youtu.be/HwC11hLbe0E?t=2h28m43s
#MTFCentral presentation: https://www.youtube.com/watch?v=Kx1sFe0oGT0

## 3.3. FindingSomething_BondingSound

**Team: Francisco Teixeira (Portugal), Horacio Tome-Marques (Portugal), Fanni Fazakas (Hungary)**

**#MusicBricks used: R-IoT gesture sensors, Onset Description**

FindingSomething_BondingSound is an audiovisual performance involving movement sensors and neuro-feedback from brainwave sensors (brain-computer-interfaces).

The idea is based on a challenge proposed at the #MTFScandi hackathon: Music Communication. FindingSomething_BondingSound represents the duality between the mind and the body.

There is constant fight between the mental & the physical fulfilment to achieve an enlightened state of being. As Napoleon said: "There are only two forces in the world, the sword and the spirit. In the long run the sword will always be conquered by the spirit."

What mediates this fight in this performance is the sound. The mind controls audio and video samples organized in a mental playlist according to its activation or relaxation and the body controls the effects according to its position, acceleration and angle. The challenge is to see who wins this fight.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Further software, technologies and devices used:
Mind Dj and Vj Playlist controller/trigger, Kinetic Sound and Visual effector/controller, Emotiv Epoc Headset, HoMy_EmoRAW, Max/MSP, Audio Interface, Dj Mixer, Video Projector.

#MTFScandi presentation: https://www.youtube.com/watch?v=VHTdN9iF5Ag

## 3.4. Airstrument

**Team: Ariel Angel (Israel), Matan Berkowitz (Israel), Rani Dar (Israel)**

**#MusicBricks used: R-IoT gesture sensors, #MusicBricks Transcriber (MelodyExtraction), initially also RhythmTimbre**

Airstrument is a gesture-driven instrument that solely works “in the air” through a wristband with motion and gesture sensors.

It will allow non-musicians and musicians alike to jam along to their favourite tracks using hand gestures and movements.

The software flow allows the user to ‘upload’ a song / audio file, process it using the #MusicBricks tools (detect chords, progression, scale, scale shifts) and plays along always in tune with the harmony, rhythm and melody of the original piece.

The prototype is designed as two colourful wristbands, one for each arm, which use the #MusicBricks RIoT sensor to track movements and also comprises a new, intuitive musical UX.

It is planned to turn the prototype into a consumer product.


The #MusicBricks project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement n°644871

#MTFScandi presentation: https://www.youtube.com/watch?v=_zYtSA8Iv04

## 3.5. Bionic Ear

**Team: Cárthach Ó Nuanáin, Ángel Faraldo, Martin Hermant, Daniel Gómez (Spain)**

**#MusicBricks used: Essentia**

The "Bionic Ear" (originally “e-ear” or “ear we go”) was created to help musicians get in tune with an existing musical ambience.

A producer wants to jam along with (a) a performer who is playing a guitar, keyboard or other chordal based instrument and (b) a digital artist who wants to create real-time mapped graphics for the performance. The producer pulls out his phone and places it near the guitarist. The Ear starts analysing the music and estimates the chord as well as other useful features such as the spectral profile. In the producer’s Digital Audio Workstation, an application (i.e. a sampler) is ready to play pre-analyzed snippets of music so the performer is in time and in tune with the performance. On the other hand, the digital artist also receives the analyzed musical information and uses it as real time data to animate the visuals.

The Ear Mobile will be a mobile app running a stripped down version of Essentia or #MusicBricks Transcriber capable of operating on Android and iOS tablets and smartphones. It will capture features such as key, tempo, MFCC and other spectral features to be then transferred to a computer via OSC messages through a Wi-Fi network to fulfil the use case scenarios.


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#MHD Barcelona presentation: https://www.youtube.com/watch?v=sWerNCeb7JE&t=1h2m36s
#MTF Central presentation: https://www.youtube.com/watch?v=9cPuopxrG3o

## 3.6. Sound in Translation

**Team: Timothy Schmele (Germany), Juan José Bosch (Spain), Andrés Bucci (Spain)**

**#MusicBricks used: RhythmTimbre, Transcriber**

The main idea for this project is to support musicians in the creative process when performing or composing using loops. More specifically, the prototype creates musical loops from the user's musical collection which have certain rhythmic similarity compared to an input audio.

Sound in Translation will thus enhance musical creativity by reducing the time it takes someone to browse through his/her data collection and create loops that fit the initial musical idea.

The main context of use is within a live performance, but can also be useful for the generation of ideas for composers at the studio. By analyzing the music collection, the system is able to present usable and similar loops that are arranged in a (e.g. 8x8) button grid, using automatically computed musical information.


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#MHD Barcelona presentation: https://www.youtube.com/watch?v=sWerNCeb7JE&t=6m8s

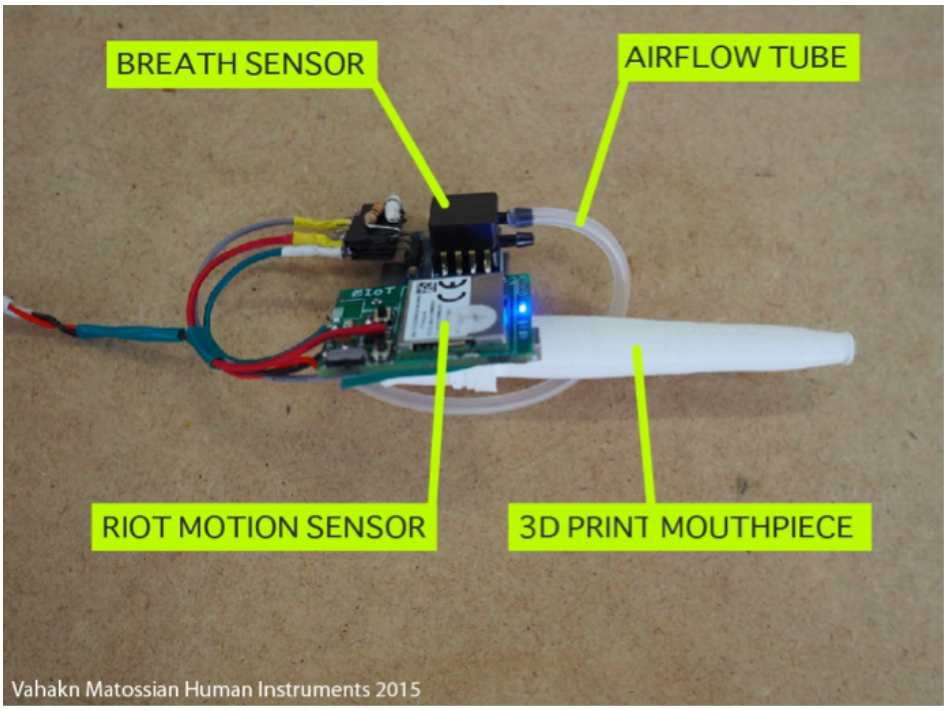
## 3.7. High Note

**Team: Vahakn Matossian (UK), Rolf Gehlhaar (UK), Pere Calopa Piedra (Spain)**

**#MusicBricks used: R-IoT**

High Note is a hands free wireless accessible musical instrument that uses breath control, head movements and other gestures to control music via a MIDI interface.

The project's aim is to design and develop a device that enables artists with severe accessibility impairments the chance of a profession in music.




#MHD Barcelona presentation: https://www.youtube.com/watch?v=sWerNCeb7JE&t=1h21m13s

## 3.8. Enboard

**Team: Juan Felipe Gómez (Spain/Colombia), Steven Bolaños (Spain/Colombia)**

**#MusicBricks used: R-IoT**

Similar to dancing, skateboarding has specific physical expressions, in various aspects, ranging from its sonority to its corporal output, which with the right tools can be mapped and used to generate a unique audio-visual live experience.

Enboard aims at achieving this, using a R-IoT sensor to map different skateboarding states, as well as a microphone to input live skating sounds, which could be potentially used as live sound assets and to create compelling visuals out of the movements of the skateboarder.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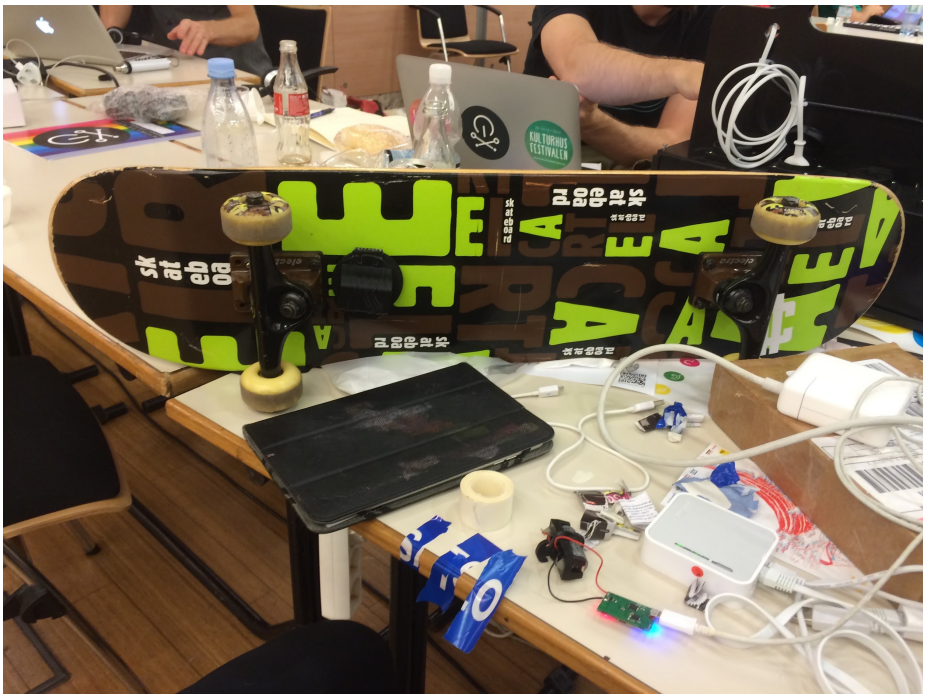

#MHD Barcelona presentation: https://www.youtube.com/watch?v=sWerNCeb7JE&t=30m57s
#MTF Central presentation: https://www.youtube.com/watch?v=2lAj6aKUAIc

## 3.9. Gesture-based Interactive Remix Dance Floor (GIRD)

**Team: Tracy Redhead (Austria / Australia), Jonathan Rutherford (Austria / Australia)**

**#MusicBricks used: R-IoT, Essentia~RT code from Bionic Ear**

A gestural based interactive dance floor experience that allows a performer or audience members to interact with music in an immersive environment.

The lighting in the environment plays a vital role. Using individually programmable LED “neo pixels”, the project creates individual lighting fixtures. Each fixture will be a standalone hardware device driven by PD on a Raspberry Pi and enabled via wireless signal or its internal microphone. The fixture will have several modes for 1) an emotional atmospheric interpretation of the music using #MusicBricks software 2) gestural controlled mode lighting using the #R-IoT board and 3) interaction feedback to guide the user based on the music being interacted with.

An individual or group can interact with this environment using a #MusicBricks gesture sensor within a wearable bracelet or object. Based on individual’s movements they are able to manipulate stems or trigger loops and samples in order to remix, re-contextualise and compose music.


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## 3.10. Manuphonia

**Team: Maya Lekova (Bulgaria), Terhi Marttila (Germany / Finland), Kristjan Sešek, Rok Milošič, Adrijana Bundalo, Ernest Beličič (all from Slovenia)**

**#MusicBricks used: R-IoT**

Use R-IoT sensor module to recognise different gestures and make sound based on them.

The core idea of this project is to make music by using gestures. It is intended to fill the gap between performer's movements and the soundscape. The idea comes from the observation that humans can both react to sound and shape it at the same time, much like they do when playing an instrument. To free people from the need to own a physical instrument to play music, Manuphonia are developing a product which combines hardware sensors, machine learning techniques and software that maps sounds to gestures.

An Android application will implement a library for effective gesture recognition combined with samples for different instruments and a library of predefined sounds. The user will have the ability to record custom gestures and bind them to existing samples for each connected sensor.

The target users are:

- Professionals that will use the product as part of their performance
- Non-professionals that will use the product in their free time.


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#MTFCentral presentation: https://www.youtube.com/watch?v=H-wyfofFOB4

## 3.11. LightBeat

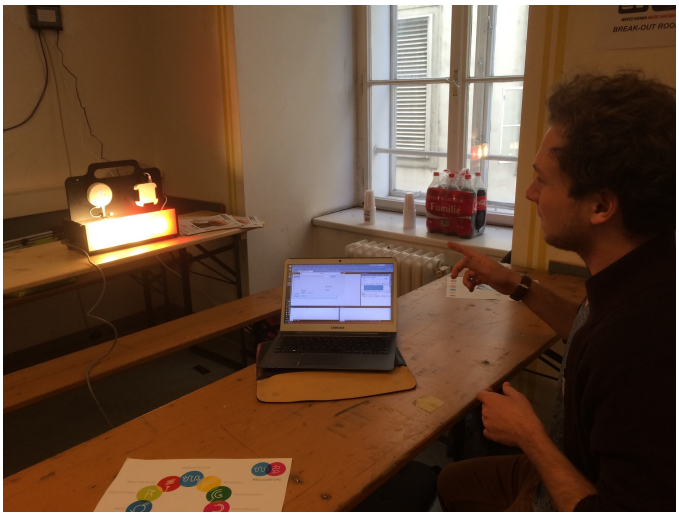
**Team: Stefan Salcher, Adrian Jandl (Austria)**

**#MusicBricks used: originally #MusicBricks Transcriber, adapted for use online APIs, indirectly Essentia through AcousticBrainz**

LightBeat is a platform for a universal music visualization solution in the spirit of #MusicBricks. It originated in the idea of Collaborative Playlisting in a bar or at a party at home. The LightBeat idea adds an immersive light environment by analysing the sound for beats. By incorporating music analysis technology, pre-analysed music is visualised on a range of connected devices.

The first version was built using the #MusicBricks Transcriber by Fraunhofer combined with the Philips Hue wireless LED light system. For a larger catalogue of audio, online APIs with pre-annotated metadata derived from the audio are also incorporated.

The goal is to build a device agnostic light control platform and a consumer friendly interface so that any home user can use it with a large range of light systems. This is accomplished by establishing a virtual interface for sound visualisation to allow the connection of different types of hardware both professional and consumer level.

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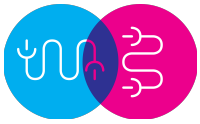

# 4. Feedback on #MusicBricks from the Industry Testbed

In this section we describe the feedback that we received from the Industry Testbed, during the incubation period where we worked hands-on together with the projects, for an average of 3 months for each incubated project.

The feedback on #MusicBricks APIs, TUIs and GUIs has been received in various ways:

- Initial Skype Calls with all the projects
- Exchange of ideas while defining the project plan and scope
- Continuous communication over channels such as Slack and email
- Intermediate Skype Calls or face to face meetings to discuss the progress
- Status-checks and final Skype calls.

## 4.1. R-IoT Motion Sensing and Motion Analysis (IRCAM)

The R-IoT has been used in 8 of the 11 incubation projects. Several groups requested multiple R-IoT devices for their projects. We therefore investigated the possibility to duplicate the R-IoT externally, which resulted in successful batch testing in Month 11 of the project.

Several Incubation projects requested improvements and modifications of the firmware. We thus provided the following new features:

- **New connection mode** using the module as an access point allowing the direct use of the R-IoT with a smartphone and/or a computer. The external WiFi router (which was necessary before) is therefore only an option now. This **enables smartphone app development** and easier bench testing, a new calibration method for the absolute angles and the magnetometers.
- **Embedded analysis:** The R-IoT "brick's" improved firmware now includes the **motion analysis directly embedded** in the R-IoT processor. Specifically, IRCAM proposed a minimalist firmware that can be augmented with specific motion recognition algorithms, and which runs directly on the embedded platform. This allows for computing internally with a high sampling process and streaming the motion parameters at a reduced sampling rate, reducing thus the WiFi bandwidth.
- **Improved compatibility with OSX:** the first generation of R-IoT was based on a USB serial interface whose manufacturer driver was incomplete on OSX. The design was reverted to the former USB chip used in an earlier version of the sensor modules (FTDI brand) and now firmware upgrades are possible on all platforms (OSX, Windows and Linux).
- **Extended documentation:** In order to make the firmware development easier and usable by a larger number of users, the documentation was improved. A specific guide was written **covering basic aspects of the programming and flashing** of the R-IoT module : http://ismm.ircam.fr/wp-content/uploads/2015/10/R-IoT-Programming-Flashing-Guide.pdf?ca825b
- **Integration of external sensor signals:** Some of the incubation projects required the use of external sensors to be connected to the R-IoT module (breathing pressure) and this was used as an opportunity to extend the standard firmware with this feature. The firmware allows sampling the 2 on-board analog inputs and exports the data as OpenSoundControl (OSC) messages along with the standard sensor's data flow (acceleration, angular speed, magnetometer and absolute angles).

Throughout the Industry Testbed's incubation periods, the engineers were available to answer questions to the teams regarding the R-IoT MusicBrick.

Partners communicated extensively with some of the teams, specifically when new features were requested but also when configuring the unit. Requests were handled usually by email, using Slack mostly for being notified only, and occasionally Skype for hands-on sessions or more specific questions. In general, communication has been sparse overall, as the sensor modules were often used "as is", which concludes that the module can be used "as is" in standard cases. Support was needed mostly for more specialised cases.

A more intensive technical exchange was with the teams Hi-Note, Airstrument and Manuphonia regarding firmware flashing, external sensor integration, code customisation and module configuration.


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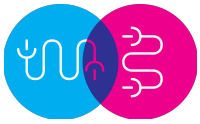

With the new firmware, the R-IoT MusicBrick enables **many more possibilities**:

- motion and gesture detection directly on the board
- reduces the need for an external WiFi router
- communicates directly with smartphones
- processes external sensor signals

This is a great improvement towards facilitated use of the device - thanks to the feedback received from the teams incubated in the Industry Testbed.

## 4.1. #MusicBricks Transcriber (by Fraunhofer IDMT)

An interesting use case of the Fraunhofer Transcriber has been with the **LightBeat** project. It originally used the #MusicBricks Transcriber to derive beat onsets from the audio to control the Philips Hue light system. To account for the delay of the Philips system, they pre-analyzed the audio tracks using the Transcriber, and buffered the audio to sync with the lights.

Their verbatim feedback for using the #MusicBricks Transcriber was:

> *"After trying different ways of using the analysis results provided by the Transcriber in XML Form (which is the format we choose) we decided to base the visualization mainly on the "beat grid". In the short time during the hack, we found that the beat grid worked best as a perceivable link between the music and the attached lights.*
> *We expect to incorporate the other analysis results (melody / bass line) and other analysis tools from #MusicBricks in order to better capture the dynamics of a song and display them.*
> *In terms of the technical usage, we are planning to programmatically use the command line interface to feed the files to the software. Reading the output from the generated XML file is not the most direct way to receive the content, but should still work well.*
>
> *While analysing the first test files we noticed the unexpectedly long time taken by the software to finish the analysis. Are there reasonable ways to speed this process up?"*

The Light Beat team **asked if the performance of the #MusicBricks Transcriber** (processing 3 minutes of audio in 20 seconds) **could be further improved, towards real-time** applications. Although further optimisations were made, the requested processing time of less than 1 second for 3 minutes of audio is not feasible with the current hardware.

They had also planned, in a second phase, to take the focus of the music analytics from pre-analysis to live music. For that, however, they would have a strong real-time requirement for the audio analysis, with very low delay in the tens of microseconds range. This is currently not feasible with the #MusicBricks Transcriber.

However, the team realised, that in the original case, they would need a large audio catalogue for pre-analysis in order to satisfy the user's needs, who typically want to choose from a large catalogue of popular music. The licensing fees for the use of such a large catalogue are however unfeasible for the LightBeat project, which seemed to lead to a major blocker on the technological side.

The solution, which came up in an intensive Skype session together with multiple partners from #MusicBricks, is the use of Online Music APIs, which already store a large catalogue of audio descriptor metadata from pre-analysis of large catalogues of popular audio tracks. Two of those are the Spotify/ echonest API and the AcousticBrainz API (which internally uses UPF Essentia for music analysis, also part of #MusicBricks).

**Airstrument:**

Aside from LighBeat two other projects use the #MusicBricks Transcriber for main melody extraction as well as its BPM extraction. The **Airstrument** team were asking for real-time transcription, similarly to their LightBeat project colleagues. The **Sound in Translation team** used the beat tracking functionality only.


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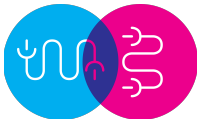

The use of the Fraunhofer Real-time Pitch Detection API was considered by several teams throughout the hackathons of the Creative Testbed, however it was not used in the final projects that were taken forward to the Industry Testbed.

## 4.2. RhythmTimbre: Rhythmic and Timbral Audio Feature Extraction (by TU Wien)

The **Rhythmic and Timbral Audio Feature Extraction** library (#RhythmTimbre) was used by two projects during the Industry Testbed incubation phase:

- Airstrument: a gesture controlled “air” instrument
- Sound In Translation: Assisted live remixing in a musical performance

In addition, startup company MusiMap, present at the 3rd Creative Testbed event, showed great interest in employing the #RhythmTimbre library and provided further feedback on integration requirements.

An early feedback was about the **input formats**:

The audio file reader was completely rewritten to be compatible with 24bit WAV files, in addition to 16 and 32 bit WAV audio.
Later, it was extended to the capabilities of reading also AIFF and M4A audio files, in addition to MP3 (via an external converter).
This greatly enhances the applicability of this #MusicBrick in typical settings of studios and sound/ movie production: these work with a great variety of audio file formats and need high-quality formats such as 24 bit audio.
With the learnings of adapting to a broader range of formats, additional formats can be added more easily in the future, in case of further requests. In fact, the audio reader code was adapted in a generic way so that the experienced programmer can plug in further importers.

**API connectors**:

During the incubation period of the Industry Testbed TU Wien worked hands-on with the “Sound in Translation” project. This led to further adaptations of the API connectors and then function return values. Now it is possible to do sub-song analysis for Rhythm and Timbre meaning that any particular segment of an audio input stream can be analysed. This leads to a “near real-time” setup, as it was demanded by the “Sound in Translation” project - likewise as many other hacker projects that are designed for on-stage or interactive performance. In “Sound in Translation”, a user creates drum / sound patterns using a hardware controller (see photo in the section above) and the system instantly searches for songs with a similar pattern. This is made possible by the adaptation of the #RhythmTimbre brick to analyse short terms segments and store its analysed patterns/features for instant retrieval when requested.
A range of further adaptations of the API function calls have been done, to make the #RhythmTimbre tool more flexible and extensible, through additional parameters.

Extension of **Output formats**:

As each project is working with various formats not only for input, but also reading, storing and processing the results of #RhythmTimbre analysis, following requests and requirements of the projects assisted during the Industry Testbed incubation phase TU Wien also adapted the output formats. In addition to plain text CSV files to store the numbers along with analyzed file ids, the #RhythmTimbre tool now also supports the ARFF format (popular in the Machine Learning community), Pythons NPZ format and the HDF5 format (popular in science and data analysis, for large and structured data sets). In fact two entire new classes have been written and adapted, to accommodate for this: rp_feature_io.py and classes_io.py. The second one takes care of loading and storing category associations together with the analyzed audio files (classes, such as genre labels, moods, instruments etc.), both in single and multi-category annotations.

New library for **Classification**:

By popular demand, especially from the startup domain (e.g. MusiMap) TU Wien added an entire new library - rp_classify.py - for high-level classification and recognition of high-level concepts such as genres, moods, emotions or instruments. This adds Machine Learning to the library. On top of the


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extracted audio descriptors (Rhythm and Timbre) a model for recognising such high-level concepts has been added. The user can typically provide own annotated training data to create a new model, but we also included a pre-trained one for music genres. Then these model(s) can be used to predict the trained categories for any number of new pieces of music. Recognition is fast, so that it potentially can also be used to recognise smaller segments of audio in a “near to real-time” setting.

**Facilitating installation** and improving stability:

Further improvements in error handling, and verbose messages have been made so as to inform the user specifically if something does not work the way desired. To facilitate the installation, documentation has been improved, adding a quick guide for setup and getting started, as well as a full-length tutorial. Most importantly, submission to the popular package repository PyPI is being prepared: once available, it will facilitate the installation process into a single line for complete installation of all packages from the online repository via PIP.

## 4.3. Onset Description (MTG-UPF)

This #MusicBricks component was used by two different projects: “Bionic Ear” and “FindingSomething BondingSounding”. These have represented the opportunity to gather direct feedback to improve the robustness of this tool.

Principally, there were stability and compatibility issues that have been fixed. For example, there were technical fixes for stabilising its execution on Max7 and getting it portable without dependencies on other libraries. The brick has been ported to max7 /Pd 64 and 32 bit on OSX and Linux (almost finished).

In terms of algorithms and actual functionalities, this feedback has helped to strengthen onset detection (adaptive base thresholding and ratio thresholding on underlying superflux novelty). In terms of optimization, a refactoring of the average feature computation is done on a separate thread, which results in lighter load for the audio processing thread.

In terms of functionality, this tool has been extended with more Essentia algorithms. It allows having a more detailed description of the onset, allowing new use-case beyond detecting uniquely the presence of an onset in the input sound signal. This brick is part of EssentiaRT~ , a real-time subset of **Essentia** (MTG's open-source C++ library for audio analysis and audio-based music information retrieval) implemented as an external for Pd and Max/MSP. UPF will further extend EssentiaRT~ with new algorithms to be used as real-time object under these frameworks.

Thanks to the maturity achieved in the latest developments, this #MusicBricks component is now used by another incubated project (GIRD). In this project, the sound description will be used to control lighting.

## 4.4. Search by Sound: Music Similarity Retrieval API (by TU Wien / Spectralmind)

The Search by Sound API was considered to be used by several teams throughout the hackathons of the Creative Testbed, including some of the awarded ones, however was not used in the final projects that were taken forward to the Industry Testbed.

In discussions with several hackers considering the use of the Search by Sound, we gathered important feedback for the API:

It is very well appreciated to be able to use music analysis without the need of installing any libraries or dependencies and completely use it online through a web server doing the audio analysis using a simple REST API.

However, people expect both more flexibility on what can be processed (MP3, WAV, other formats, or even the audio from Youtube videos) and also what is returned from the API. For now, Search by Sound returns matching similar song IDs together with the degree of similarity (distances).


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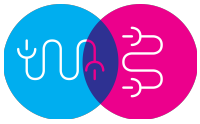

People would like the API to deliver also 1) the full audio and 2) the full metadata, both stored internally and also from external services (this might rise some rights issues, but at least a link to the audio file on a free web resource like freemusicarchive.org) could be provided.

In one of the Creative Testbeds, the SME MusiMap became aware of the Search by Sound API. The company evaluated it, but decided to go for the more low-level RhythmTimbre library (see above), as it better fits their needs on being extensible for audio-description.

## 4.5. Melody Extraction API (MTG-UPF)

None of the incubated projects in the Industry Testbed made use of this #MusicBricks component. The Melody Extraction API was presented in the MHD workshop (Barcelona, June 2015) and participants could install it and experiment its features during the workshop. On site support was necessary in some cases for the correct compilation and installation of this tool. The complexity of the installation of this MusicBrick however, led teams to not make use of this API during the Creative Testbed.

However partners believe that the Melody Extraction API, as part of the Essentia Library, has a sufficient level of maturity (TRL) to be further deployed by creative users.

A first important conclusion about the current status concerns the installation requirements, which are a high barrier to new users. This component needs to be provided as pre-compiled binaries for various platforms (Linux, OSX, Windows), so that it can be easily installed as a Python module directly. A second conclusion is that creative users expect to have access to real-time tools. In this sense, this algorithm can be partially implemented as a real-time processing object for frameworks such as PureData and MaxMSP.

Ongoing development at UPF is progressing in these directions. The Melody Extraction API is part of the Essentia library (www.essentia.upf.edu), and thus is being continuously maintained and extended beyond the end of the #MusicBricks project.

## 4.6. Freesound 2.0 Web API (MTG-UPF)

Freesound was used in the Creative Testbeds as a source of sound content for some projects, while the API functionality was not used. Therefore none of the selected incubated projects in the Industry Testbeds have made use of this API.

It is worth noting that in general the projects developed in the Creative Testbeds leaned towards autonomous real-time systems, and online API and web services requiring some skills in web programming attracted less interest.

Nevertheless, to demonstrate the potential of the Freesound API as a #MusicBrick for new users, UPF developed a demo application for the sake of showcase. The following is a short description of one prototype that was built using the aforementioned tools.

The *HandsFreeSoundMachine* uses voice and gesture inputs to control timing and timbre of a drum machine. Voice input is used to query sounds from an online repository, while gesture analysis is used to define the rhythm of a 4-track step sequencer. Voice input can have two functions: (i) a speech recognition input, and (ii) a vocal imitation input to control the acoustic characteristics of the retrieved sound. This system combines hardware and software tools together with online web services. It integrates: a commercial bluetooth headset, the RIoT wireless motion sensing platform, the Freesound API, and a publicly available Speech Recognition online service (Google Speech API). This hands-free interaction system combines voice and head gesture, hence allowing a musician to play another instrument simultaneously (e.g. a guitar).

A more technical and detailed information about the prototype is given in deliverable D3.3 as part of the WP3 developments. The Freesound API and this prototype will be presented at the workshop “Music and HCI” at the forthcoming CHI Conference in San José, California, May 2016.


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# 5. Summary and Conclusions

Throughout very recent history, we have seen a **tremendous shift from software to hardware**. Even though hackathons were rooted in software and applications (also the ones part of the #MusicBricks co-organized events Music Tech Fest and Music Hackday), there is now an enormous demand for hardware tools at these events, devising new ideas around portable, wearable and bio-sensing technology that heavily involve hardware, but also software.

Consequently, we have seen **enormous requests for the gesture recognition hardware sensor board "R-IoT"** provided by IRCAM as a #MusicBricks component. 8 out of the 11 projects taken to the Industry Testbed incubation phase used one or more R-IoT boards in their prototype development, for a **total number of 17 devices**. At the time of the start of #MusicBricks and for the first Creative Testbed, IRCAM had only 10 devices ready for testing and prototyping purposes. Given the high demand, which was seen already clearly at the first Creative Testbed, new devices had to be produced. While a second batch was again assembled by hand by the IRCAM team, to satisfy the needs of further Creative Testbed events, a third batch was tested through an external board assembly manufacturer, to have more devices available for the Industry Testbed.

The experience and feedback gathered from the Industry Testbed leads to **two main conclusions for the R-IoT sensor** board (as a physical hardware device):

- For some applications / projects, its standard capabilities met the requirements and it can be used more or less "out of the box", through the help of the given documentation, with little support needed. This is typically the kind of support that can be given by the community, once the device is spread on a larger scale.
- For some other applications - more concretely 3 projects out of 8 that used the R-IoT brick in the #MusicBricks' Industry Testbed - a higher level of assistance is needed, because of very specific requirements: Connection of external sensors to have an integrated stream of signals, flashing of the device with customized firmware, or extended on-board processing of gestures. This is typically achieved only by first-hand support of the original creators of the R-IoT device. For that, communication channels such as email, Slack and Skype have been seen as suitable to bring the projects forward. Face-to-face meetings at the Creative Testbed events to work hands-on with the device, and special face-to-face and Skype sessions organised by parters Stromatolite and TU Wien to help teams working with the R-IoT (e.g. Enboard, Dolphin, GIRD) have also been seen as very beneficial.

Given the feedback received from the Industry Testbed (and prior Creative Testbed events) the R-IoT brick has been drastically improved. The biggest change was the on-board recognition of gesture events, now an integrated part of the firmware on the chipset, which previously was achieved only through a Wi-Fi router and a computer which did the gesture recognition. **This on-board integration not only reduces the size and overall complexity of the setup but also enables direct an application with smartphones and wearable devices, not possible before.**

Regarding the **software tools** offered as #MusicBricks

- **MusicBricks #Transcriber** has been used by Airstrument, SoundInTranslation, LightBeat
- **#RhythmTimbre** has been used by SoundInTranslation, initially also by Airstrument, and is under consideration by GIRD
- **#Essentia** (which includes Onset Description and Melody Extraction) has been used by Bionic ear, GIRD (and is considered a future option in Airstrument, Sound In Translation and LightBeat)

The most eminent feedback for the software tools was the **large demand for real-time** performance. Many people who worked on new ideas at the Creative Testbeds came from a performance, artistic or interactive background and are used to apply things that work in real-time. On the contrary, most tools that are the results of scientific research are designed in a way to work "offline", e.g. analyse a full song before outputting the results. With the exception of the Real-time Monophonic & Polyphonic Pitch Detection by Fraunhofer, most software music analysis tools need a certain analysis window of 1 or more seconds, to accomplish tasks such as detecting melodies, beats, onsets or rhythm.

The #MusicBricks partners supporting the awarded projects in the Industry Testbed tried to modify the original tools as much as possible, to respond to this requirement. For example the **#MusicBricks Transcriber was adapted** to reduce the analysis time of audio material to less than 20 seconds for a full


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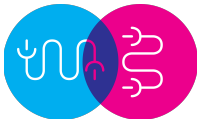

song, and **#RhythmTimbre was extended** in a way so that also short segments of audio can be queried in a “near-to-live” way. Nevertheless, given that these methods of analysis require a larger window of audio material to be analysed, a real-time or near-to-real-time application is nearly impossible. **UPF reacted** to that and made a particular version of their Essentia software (covering onset detection and melody, key, etc. extraction) **for mobile and real-time purposes, called EssentiaRT~**.

**Further feedback was received on APIs:** Typically, people desired extended capabilities, which were enabled through extending the existing APIs, adding (or opening) new features that were doable by the tool, but not accessible or feasible by the standard API yet. To this respect, the tools were improved towards larger usability in both the hacker & maker communities and industry with regards to popular features that are now available. This is accompanied by improved documentation, which is a prerequisite to make this wider feature set available to a large audience.

With the building of the documentation, the “ad-hoc support” available to incubatees during the Industry Testbed, where #MusicBricks partners were available to directly support the 11 project teams and work hands-on with them, will be superseded by community forums and available documentation.

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**Thus, the feedback gathered in the Industry Testbed was very valuable for the maturity of the tools, increasing their Technology Readiness Level, as well as their ease of use by non-experienced users in wider market applications.**


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