The reacTable*: A Collaborative Musical Instrument

Martin Kaltenbrunner mkalten@iua.upf.es
Sergi Jordà sjorda@iua.upf.es
Günter Geiger ggeiger@iua.upf.es
Marcos Alonso malonso@iua.upf.es

Music Technology Group
Universitat Pompeu Fabra
Despatx 330, Ocata 1
08003, Barcelona, Spain

Abstract

The reacTable is a novel multi-user electro-acoustic musical instrument with a tabletop tangible user interface. In this paper we will focus on the various collaborative aspects of this new instrument as well as on some of the related technical details such as the networking infrastructure. The instrument can be played both in local and remote collaborative scenarios and was designed from the very beginning to serve as a musical instrument for several simultaneous players.*

1 The reacTable*

The reacTable*, is a novel multi-user electro-acoustic musical instrument with a tabletop tangible user interface. Several simultaneous performers share complete control over the instrument by moving physical artefacts on the table surface while constructing different audio topologies in a kind of tangible modular synthesizer or graspable flow-controlled programming language.

The instrument hardware is based on a translucent round table. A video camera situated beneath, continuously analyzes the table surface, tracking the nature, position and orientation of the objects that are distributed on its surface. The tangible objects, which are physical representations of the components of a classic modular synthesizer, are passive, without any sensors or actuators; users interact by moving them, changing their position, their orientation or their faces. These actions directly control the topological structure and parameters of the sound synthesizer. A projector, also from underneath the table, draws dynamic animations on its surface, providing a visual feedback of the state, the activity and the main characteristics of the sounds produced by the audio synthesizer. The idea of creating and manipulating data flows is well acquainted in several fields, such as electronics, modular sound synthesis or visual programming, but the reacTable* is probably the first system that deals with this connectivity paradigm automatically, by introducing *Dynamic Patching* [12] where connections depend on the type of objects involved and on the proximity between them. By moving these objects on the table surface and bringing them into proximity with each other, performers construct and play the instrument at the same time, while spinning them as rotary knobs allows controlling their internal parameters.

1.1 Current State

The reacTable* structure and components have been discussed in detail in some earlier publications [12] [10]. Since then, apart from general refinements of the synthesizer and the general system stability, the most significant improvements have been made to the table hardware itself and to the computer vision sensor component, which we have published recently as an open source software framework. The reacTIVison application along with example projects for various programming environments is available online.[1]

The reacTable* currently exists in two variations: the concert table, which sports a highly sophisticated and precisely controllable synthesizer for the professional musician. This table setup was used for the first reacTable* concert. The second version has been configured for public installations, with a more playful and popular sounding synthesizer, which was mostly designed for entertainment and educational purposes. This configutation has been shown

[1] http://www.iua.upf.es/mtg/reacTable?software

at the AES and ICMC conferences in Barcelona, ICHIM in Paris and the Ars Electronica Festival in Linz and was received very positively by the audience. The graphics synthesizer also is flexibly configurable through XML configuration files, which allow the simple adaptation of the visual appearance for various installation contexts. As a showcase demo we developed a commercial advertisement installation for a popular brown soft-drink manufacturer.

1.2 Learning from Musical Control and Performance

Various reasons turn real-time computer music performance into an ideal field for the experimental exploration of novel forms of human-computer-interaction:

- It is an environment that combines outstandingly, expression and creativity with entertainment; freedom with precision, rigor and efficiency[8]
- Users are required to have an open but precise and rather complex control over multi-parametric processes in real-time.
- Playing and creating music with the help of digital tools can be a social and collective experience that integrates both collaboration and competition. Moreover, this experience can also be addressed to children.
- Music performance provides an ideal test bed for studying and comparing use and interaction by both dilettantes and experts, both children and adults.

Early and definite examples of this music-HCI synergy can be found for example, in the research and development taken by William Buxton during the 70s and 80s (e.g [6] [5]). We believe that music performance and control (both traditional and computer supported) can constitute an ideal source of inspiration and test bed for exploring novel ways of interaction, specially in highly complex, multidimensional and continuous interaction spaces such as the ones present when browsing huge multimedia databases. In these types of fuzzy interaction environments, exploration can follow infinite paths, results can hardly be totally right or wrong, and the interaction processes involved could be better compared with playing a violin that being reduced to the six generic virtual input devices that constitute the GKS standard (locator, stroke, valuator, pick, string and choice).

2 Collaborative Music Models

2.1 Quick Overview

There are almost no traditional and just a few contemporary digital collaborative instruments available at the moment. Some traditional Instruments like the piano can be played by four hands although they were not primarily designed for that task. In recent years many musical instrument designers came up with the idea of creating instruments specifically for collaborative music [9]. An early example closely related to the reacTable* is Blaine's Jam-O-Drum[4], a musical installation which encourages visitors to collaboration. In extreme cases, such as the Tooka [7], the instrument only works at all when played by trained and synchronized players.

An illustrative example of a collaborative sound installation is the Public Sound Object [3], which tries to explore several models of remote collaboration in the context of musical practice. The PSO allows network musicians to join a virtual jam session in an abstract musical space, where proxy bouncing ball objects can be remote controlled via a web application. The actual sound synthesis is performed on the installation site and streamed back to the players. Although the PSO architecture has to deal with a significant amount of network latency (time between control action and acoustic result) it overcomes this latency by integrating it as an essential part of the installation. For a more detailed review of collaborative music concept see Barbosa's survey on "Displaced Soundscapes" [2]

2.2 Collaborative reacTable* Models

The reacTable* already had been planned as a collaborative instrument from the very beginning. A table can be considered to be an already culturally defined collaborative space. Tables are places where various people can meet and discuss and where people together can develop their ideas and work on joint projects. Architects work over their plans and models, managers develop their project plans and generals used to move their troops on strategic table models.

These concepts have been widely used and translated to the digital domain by the introduction of Tangible User Interfaces (TUI) [14], where a large group of projects and interfaces as well have been implemented using table interfaces just because of their collaborative nature. Physical objects on a table surface, especially on a round table set-up, are equally accessible for direct manipulation for any participant at the same time.

Figure 1. shows a summary of some possible collaboration models. This includes local collaboration on the same table, and remote collaboration using distant physical or virtual table setups. Additional musical instruments or the audience can collaborate with the reacTable* players on stage.

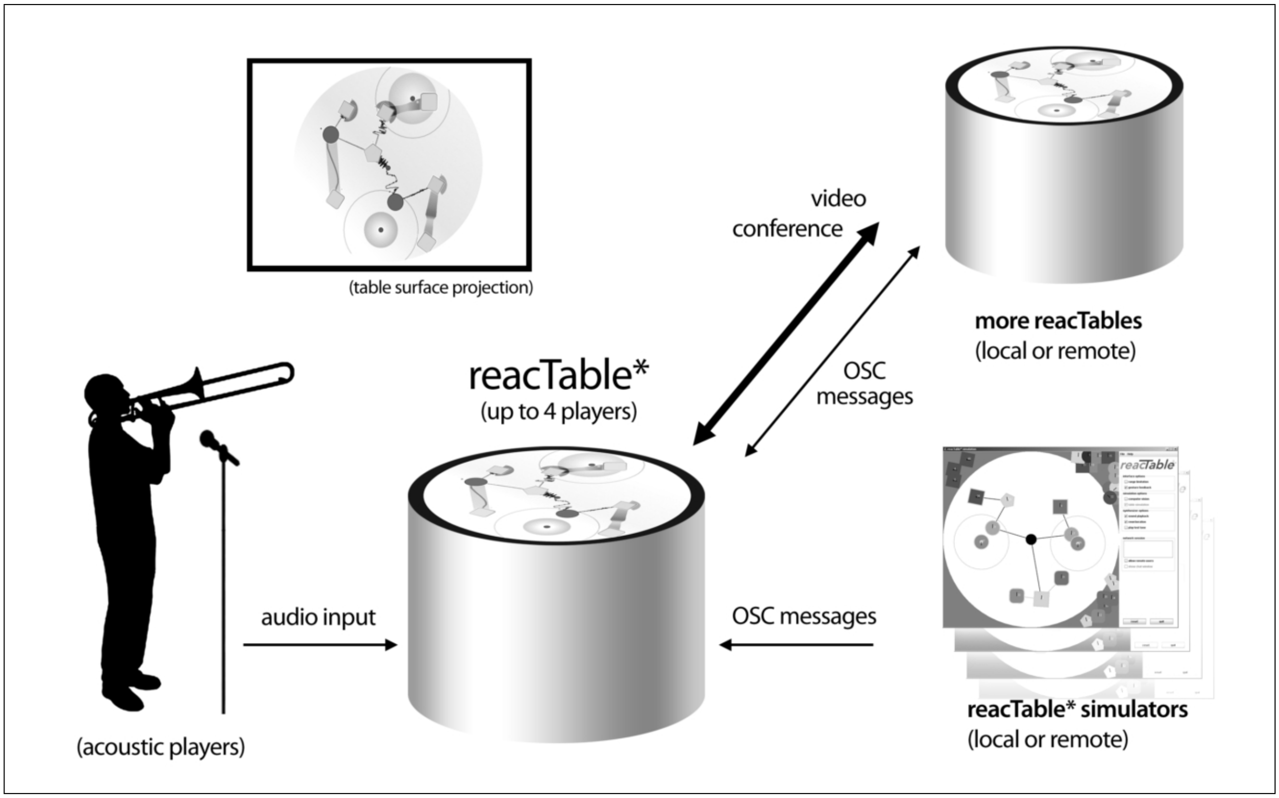

Figure 1. reacTable* collaboration scenarios

2.2.1 Local Collaboration

The current reacTable* is a round table with a diameter of exactly one meter providing an active surface with a diameter of 80cm. With this size the ideal amount of simultaneous players ranges from two to four players at the same time. Of course one could imagine even more players being involved but due to the spatial limitations of a table of the current size, the surface of a quarter of a table represents the bare minimum for reasonable playing. For local players two collaboration styles have emerged so far:

- Spatial separation:
  An additive collaboration [9] style, where each player plays in a dedicated zone of his choice, rather defending the territory than collaborating directly with the other players. Each player builds and plays personal instrument patches aside with the other players. The interaction between players basically is similar to that of the members of a band or an orchestra.
- Shared space:
  An multiplicative collaboration [9] scenario, where the players are building and playing their instrument patches together in a real collaborative process. One player can construct a basic instrument, while the second interferes by adding, removing or manipulating additional objects of the patch. Due to the very volatile nature of the dynamic patching paradigm this collaboration has to be planned and performed very carefully in order to maintain a constructive nature.

Additional musical instruments on stage, such as a trombone or violoncello for example, can participate in a reacTable* session by representing their musical output as a sound source on the table. In the most simple scenario the reacTable* players alone have the full control over the further processing and mixing of such a sound source as physically available object on the table. One could also imagine though, that the instrument players themselves can control the position of a virtually present (projection only) sound source on the table, as well as controlling some other control parameters by moving on stage and other additional gestural control performed by the player.

2.2.2 Remote Collaboration

The second reacTable* collaboration scenario involves the connection of two or more table instruments placed at distant locations. In the concert configuration two reacTables - one in Austria and one Spain - were connected via a conventional internet connection, though technically the maximum number of interconnected tables can be extended easily. Conceptually the two physical table surfaces virtually melt into a single table surface, where players at both locations are playing within the same logical table space. This extends the properties of the local collaboration scenarios we mentioned above to a global context.

Physical objects that are moved on the local table in Barcelona appear as a virtual (projected) object on the remote table in Linz. Both local and remote objects behave the same way, the only difference is that local players of course can not touch or move the virtual objects from the distant table. In a typical collaborative instrument building scenario, a player in Barcelona can place a sound generator object on his table. The object is recognized and located on the surface by the sensor component and a graphical representation of the object is projected underneath the physically present object. At the same time this object's properties data is transmitted to the remote table in Linz, where the same graphical representation is projected at exactly the same position as on the table in Barcelona. Then the player in Linz can place a sound effect on the table surface and after the same process of recognition, transmission and display, the sound effect appears projected on the table in Barcelona. As we will explain in the technical section below, the tables just interchange low-bandwidth control data and no audio data at all. The actual resolving of the dynamic patches and the final sound synthesis are performed independently on both installation sites. Preliminary tests during the development phase showed that under normal conditions with deterministic synthesis objects the resulting musical output was virtually the same on both locations, with minimal differences in the time of appearance and removal of synthesizer modules. Some modules causing a non-linear behavior such as a feedback object could temporarily lead to significantly different sonic results.

In a concert situation the players themselves are quite aware of the fact that those spooky projected objects are moved by some real human players at a distant location. For the audience though this might not be that clear at all. Hence in order to improve the sense of presence an additional projection of a live video transmission showing the table and the players performing at the remote location proved to be a rewarding addition to the overall experience of this remote collaborative performance.
Regarding the maximum amount of players in a networked session we found that the same rule of thumb as for the local collaborations scenario can be applied: Due to the spatial limitations of the table surface four players are a reasonable maximum. Eventually even four tables with one to two players each would be possible, although not all players are should be active at the same time. The players during the *TeleSon* concert entered and left at predefined points of the piece, while only during the finale all four players were present at the same time.

2.2.3 Remote Participation

During the early development phase of the reacTable* prototype, the whole dynamic patching and synthesizer infrastructure was designed without an actual physical reacTable*. The use of a software simulator of the complete physical table and its sensor component allowed the rapid development of the basic instrument features without the need of caring too much about possible real world limitations. This software simulator proved also to be quite useful for the composer of the inauguration piece, because it provided a much more convenient infrastructure for experimentation and rehearsal. This software simulator, which actually also includes all the necessary networking infrastructure, has been written in the platform-independent Java programming language as well as the synthesizers also are implemented in cross-platform environments such as Pure Data (PD) [13]. This portable design allows an easy distribution and installation of the client software to remote machines. Since the development of the Pure Data browser plug-in [1] by the reacTable* team, even a distribution of an embedded web-application has become possible.

In a typical remote participation scenario, the software simulator clients can join an existing remote collaboration session of one or more physical reacTables. The software simulator fully simulates a complete reacTable* setup and therefore shows exactly the same behavior as a real table, although this simulations cannot provide the interaction flexibility of a tangible interface. Simulator objects equally appear as projected virtual objects on the remote tables; remote objects equally appear in the simulator, but cannot be moved by the users. Again the dynamic patch generation and the actual sound synthesis are fully performed within the local simulator software.

In an alternative participation scenario, some members of the local audience at a reacTable* concert who are equipped with a PDA or modern smart-phone could download a stripped down version of the Java table simulator and then control a few virtual synthesis objects on stage via a wireless network or Bluetooth connection. We have developed a preliminary prototype for an off-the-shelf PocketPC handheld computer by porting the existing software to this platform and adapting the interface to the limitations of a small touch-screen interface.

We are also currently working on another setup where a second tangible interface is sending pitch or temporal control to a connected reacTable*. The scoreTable* basically is a sequencer, where objects placed on the table trigger musical events when they are detected by a radar-style sweep. Additional players can compose musical or rhythmical patterns that directly interact with the synthesizer objects on the reacTable*.

3 TeleSon - Invention #8

During the preparations for the International Computer Music Conference 2005, which took place in Barcelona and was organized amongst others by the Music Technology Group it was decided to commission the composition of a piece for the reacTable* from a professional composer. As the result of an official competition Chris Brown was chosen to write and perform this piece for the inauguration concert of the ICMC 2005. Brown has been closely involved in the final development of the reacTable* and his constant feedback during the development of the piece and the synthesizer provided valuable input for the final instrument mappings itself.

The resulting piece *TeleSon*, a composition for two reacTables and four players was finally performed twice in a networked performance between Austria and Spain. Chris Brown and Günter Geiger were performing in Barcelona, while Martin Kaltenbrunner and Marcos Alonso were playing in Linz. The first concert was the actual ICMC inauguration concert, which took place on Sunday, September 4th in the premises of the SGAE in Barcelona and at the Interface Culture exhibition in Linz. The second concert was performed the following Monday, September 5th between the Galeria Metronom in Barcelona and the Ars Electronica Centre Sky Media Loft, and was attended in sum by around 600 persons at both locations.

4 Networking Infrastructure

Networked reacTables interchange their objects' ID, location and orientation by transmitting UDP packages via a conventional IP network using the TUIO [11] protocol which is based on Open Sound Control (OSC) [15] messages. UDP assures the fastest transport and the lowest latency method, while TUIO provides the necessary redundancy to guarantee a stable and robust communication. Connected tables just pass on their raw control data, which they receive from the sensor component, without transmitting any audio data at all. The resolving of the synthesizer patches and the actual sound synthesis is done locally at each installation site, which reduces the impact of possible latency problems to a minimum. Each client just treats the control data from objects of a remote table the same way as from the ones on the local table. We assign for example the IDs `1 to n` to a set of n tangible objects on our local table. Any table in the network is expected to use the same set of objects with the same functional properties. As a consequence we can define the total set of objects in this network session by multiplying number of local objects by the number of tables in a network session. A second remote table then for example appears with IDs from `n+1 to 2*n` for its set of tangibles. Adding another remote table to the session just increments the number of total objects by `n` in our example.

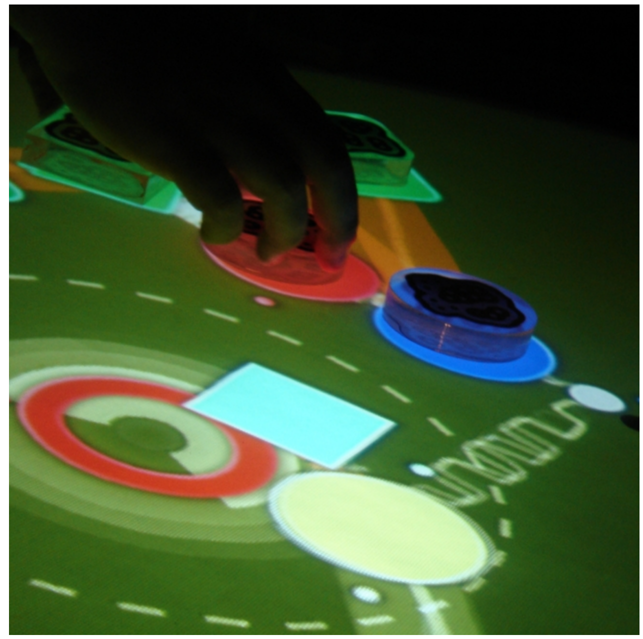

Figure 2. Local and remote synth objects

Basically tables are connected in a peer-to-peer network topology: Each table sends its control data to any table that has been configured to participate in a network session. Yet to facilitate the connection procedure between tables and to overcome potential connection problems caused by routers or firewall configurations, the reacTable* networking infrastructure is using Ross Bencina's oscgroups[2]. This software package consists of a server and client component. The server component informs any connected client that is forming part of a predefined group about the connection details of all other clients that belong to the same group. The oscgroups client component then broadcasts any outgoing OSC message to the remote clients of all currently known group members, and passes all incoming OSC messages to the local OSC application. Oscgroups is very portable and was tested under Win32, MacOS X and Linux

[2]http://audiomulch.com/ rossb/code/oscgroups/

operating systems and was recently ported to the Windows Mobile platform as well.

The reacTable* management component in general just reflects the incoming OSC messages from the reacTIVision vision engine component, but adds a supplementary tag that identifies the source with a sufficiently unique string. This message is an actual extension to the TUIO protocol which does not appear in the original paper. It became necessary because OSC itself does not provide any information about the source of the OSC messages and additionally the osc-group client appears as a local source anyway. Therefore we add a new message to each bundle which follows the format `/tuio/2dobj source username@host`. This message allows the reacTable* client software to assign each OSC bundle to the correct origin.

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