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# RESOUND: OPEN-SOURCE LIVE SOUND SPATIALISATION

*James Mooney*  
Newcastle University  
Culture Lab

*David Moore*  
University of Sheffield  
Department of Music

## ABSTRACT

Resound is an open source cross-platform software tool for real time multi-channel sound spatialisation. This paper gives a non-technical account of the key capabilities of the system, predominantly from the standpoint of live performance in electroacoustic music, with specific examples of how the various functionalities might be used.

## 1. BACKGROUND

The Resound system has its roots in electroacoustic music, where the expression ‘sound diffusion’ describes the practice by which music from fixed media (CD etc.) is presented to an audience via loudspeakers in a performance context.<sup>1</sup> Typically the source is stereophonic but, because performance venues are comparatively large, more than two loudspeakers are needed, requiring duplication of the audio signals. Thus arises the necessity of sound diffusion, and with it an entire aesthetic and performance practice [1] [3] [11] [12].

Traditionally sound diffusion has been carried out using standard audio mixing desks as both the means of duplicating signals and as the performance interface, the faders being used to distribute the source channels among multiple loudspeaker pairs. Although widely adopted this approach has its limitations, particularly in terms of interface ergonomics and flexibility of input-to-output mapping. The M2 sound diffusion system [4] [7] [8] sought to address these issues by making more ergonomic use of the familiar fader interface via a dynamic matrix-based mix engine implemented in software. Four years of experience with M2 have revealed new aspects of performance practice, as well as highlighting areas in which further improvements and optimisations could be made.

## 2. SYSTEM DESCRIPTION

Resound comprises two software programs: a server application and a graphical user interface (GUI). The server deals with all signal processing, with live audio inputs and loudspeakers being connected to a multi-channel audio interface. Audio playback directly from the server is

<sup>1</sup> The term ‘sound diffusion’ is used to connote the practice specifically in the context of electroacoustic music. The more general term ‘sound spatialisation’ is used to imply that the practice might apply more widely; in theatre, installation, virtual reality or scientific experiment for example. See <http://culturelab.ncl.ac.uk/auditoryenvironments>.

also possible. The GUI allows the performer to interact with the system and control spatialisation using an OSC or MIDI controller device.<sup>2</sup> The server and GUI applications can both run on the same computer, or on separate machines with communication via Ethernet. The following sections summarise the functionality of the system.

## 3. ONE FADER TO ONE LOUDSPEAKER

Resound can be configured to emulate the operation of a mixing desk based system. Here, the routing of input channels to loudspeakers is fixed and each fader merely controls the output level of a single loudspeaker (hence ‘one fader to one loudspeaker’). This is useful as many practitioners are already familiar with this setup.

## 4. GROUPED LOUDSPEAKERS

A single fader can be used to simultaneously control the levels of a group of loudspeakers. In this way a stereo source could be diffused to a specific pair of loudspeakers, or to a group of four, or indeed to any combination of loudspeakers, without having to manipulate multiple faders.

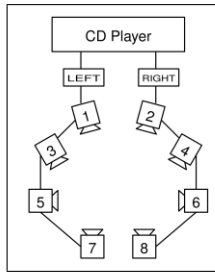
## 5. PROPORTIONAL GROUPS

Faders controlling multiple output levels can be configured to do so in variable relative amplitudes. A single fader could control the diffusion of a stereo source to all the loudspeakers, as described previously, but with a bias in loudness towards, say, the front pair of loudspeakers.

## 6. DYNAMIC INPUT TO OUTPUT MAPPING

In Figure 1 the ‘left’ channel of a stereo source is mapped to loudspeakers 1, 3, 5 and 7, and the ‘right’ to 2, 4, 6 and 8. It is common practice for the mapping of input channels to loudspeakers to be fixed in this way, and this is often ultimately due to hardware constraints. Although Resound can emulate this if required it is in fact possible to route any input channel to any loudspeaker. For example, one could define a routing in which the left channel of a stereo source is routed to loudspeaker 8 and the right

<sup>2</sup> For convenience we will refer to ‘faders’ as the control method throughout this article. Of course, any OSC or MIDI device could be used.



**Figure 1.** Fixed source channel mapping common in traditional stereo diffusion systems.

channel to speaker 1, inverting the normal left-right axis. As with all of the previous examples, this mapping can be controlled with a single fader and implemented alongside other mappings.

## 7. ADDITIVE SPATIALISATION

As a simple scenario let's say that fader *a* controls the level of a stereo source mapped to the main pair of loudspeakers, while fader *b* controls the level of the same source mapped to all of the loudspeakers within the array. If we use both faders together, their effects will be mixed together: fader *b* diffuses the stereo source 'everywhere,' and we can boost the level of the main pair of loudspeakers further by additionally raising fader *a*. This can be referred to as additive spatialisation.

## 8. SUBTRACTIVE SPATIALISATION

It is also possible for a fader to have a subtractive influence, such that raising the fader will progressively *reduce* the level of a given set of loudspeakers. If, for instance, fader *c* is configured to act subtractively on loudspeakers 3 through 8, then raising fader *c* will reduce the levels of these six loudspeakers without affecting the levels of loudspeakers 1 and 2. We might describe this particular subtractive routine as an 'all to mains' transition. It is the ability to perform manipulations additively and subtractively that differentiates Resound from other matrix based systems such as the DM-8 [10].

## 9. SEMI-AUTOMATED SPATIALISATION BEHAVIOURS

In all of the examples so far there has been a simple proportionality - either direct (additive) or inverse (subtractive) - between fader position and resulting output levels. Resound also provides a framework for defining semi-automated spatialisation 'behaviours' whereby the faders are used to control parameters other than loudness. Some examples are as follows.

### 9.1. Mexican Wave

The Mexican Wave behaviour cycles through a sequence of loudspeakers, or a sequence of groups of two or more loudspeakers. The user can control the rate at which the sequence is iterated (including the direction of iteration) and the overall amplitude level by assigning these parameters to faders. The Mexican Wave behaviour can be used, for instance, to automate front-to-back or back-to-front movement within a venue; rotational movement is also a possibility.

### 9.2. Random

The Random behaviour also acts upon a group of loudspeakers, but iterates through the group in a random order as opposed to sequentially. Again, the user can control the rate at which loudspeakers are selected, and overall amplitude level of the behaviour. This behaviour can be particularly effective for the spatialisation of textural or granular material where an erratic spatial effect is sought.

### 9.3. Multi-point Crossfade

The Multi-point Crossfade behaviour is similar to the Mexican Wave, however in this case the behaviour does not iterate automatically through the sequence. Instead, the active loudspeaker(s) at any given time is governed by the position of a fader. This behaviour might be useful, for example, as a way of adjusting the width of stereo images. Traditionally, this would be done by cross-fading the source between 'main' and 'wide' pairs of loudspeakers, necessitating the use of four faders. With the Multi-point Crossfade the same operation can be carried out with one fader.

## 10. PUT IT ALL TOGETHER...

All of the above techniques can be combined within a single performance. A thirty-two fader OSC controller might comprise, for instance, eight faders that operate on specific loudspeakers individually, eight that operate on groups of two, eight that operate on groups of four, and a further eight configured with semi-automated behaviours. Because all interactions within the Resound system can be applied additively or subtractively, there is no conflict between faders that act upon the same loudspeakers: the results are simply summed (positively or negatively). This is particularly useful in the context of semi-automated behaviours, which can be used to dramatic effect on their own or subtly mixed in, as appropriate to the musical context.

## 11. COLLECTIVES

Systems based around mixing desk hardware tend to pose problems with multi-channel sources, owing to the limitations of the 'one fader to one loudspeaker' paradigm. As Harrison notes:

If you've got an eight-channel source, and every channel of the eight has a fader, how do you do crossfades? You haven't got enough hands! [5]

The M2 system improved interface ergonomics by allowing multiple mappings to be grouped, but this introduced secondary problems in that such configurations take a long time to set up. Resound addresses this by introducing the 'collective' [6] as new method of dealing with multiple assignments, allowing these to be made more quickly and efficiently.

With collectives it is thus perfectly feasible to set up spatialisation routines that deal with 5.1, 8, or  $n$  channel images, presenting markedly different performance opportunities from those afforded by stereo. Experiments whereby eight-channel images are spatialised among multiple groups of eight loudspeakers have been carried out at BEAST.<sup>3</sup> Resound is of course able to cater for this kind of configuration; however, because Resound deals with input-to-output mappings dynamically in real time, multi-channel images can also be inverted, translated, rotated, and so on. Furthermore, greater-than-stereo images usually have a front-to-back axis (as well as left-to-right) that can be manipulated in interesting ways. For example, the 'front three' and 'rear two' of a 5.1 image could be 'Mexican Waved' or 'Multi-point Crossfaded' independently between multiple groups of loudspeakers.

## 12. PRESETS

A preset is a snapshot of the complete state of the Resound system. Presets can be recalled instantaneously with a key press, and can be used to swap between input sources without the need for physical repatching, or in various creative ways in performance. Saved banks of presets can be used as a means of sharing spatialisation techniques among practitioners.

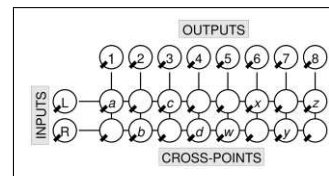
## 13. SPATIALISATION OF MULTIPLE SOURCES

Consider the following scenario.

In my last piece [...] I used a six-channel hexagonal array as a 'surround,' and I had two solo speakers [...] for close-up stuff. What I would like to do [...] is be able to diffuse the 'twos' and the 'sixes' completely independently. [5]

Resound allows the performer to spatialise multiple input sources independently. To realise the scenario described by Harrison, we might assign one bank of faders to control only the six-channel image, and another bank to control only the stereo image. Of course both banks of faders could incorporate their own groups and behaviours. A similar scenario has proved effective in improvisation with multiple live electronic sources [2].

<sup>3</sup> These experiments are described in Chapter 4 of [4]



**Figure 2.** Graphical representation of a mix matrix architecture. (The lettering of cross-point nodes refers to an example in the text.)

## 14. HOW DOES IT WORK?

In essence Resound allows each fader to control the levels of one or more input to output (source-channel to loudspeaker) mappings as defined by the user. This is achieved via the use of a matrix-based mix engine at the heart of the server application. Figure 2 describes a mix matrix architecture diagrammatically. In this case the matrix has two inputs and eight outputs, but in principle it can be any size. Audio inputs are shown on the left, audio outputs along the top. Every possible input to output mapping is referred to as a cross-point. Each node of the matrix has an attenuator that determines the amplitude of the signal allowed to pass through that node. In this way, any input can be mixed to any output in any proportion.

The GUI application acts as a remote control for the mix matrix, allowing the user to map multiple nodes on to faders. Mappings can be made directly; for example we might map matrix nodes  $a$ ,  $b$ ,  $c$  and  $d$  to fader 1, meaning that fader 1 would simultaneously control the level of 'L' to outputs 1 and 3, and 'R' to 2 and 4. Alternatively we can map, say, nodes  $w$ ,  $x$ ,  $y$  and  $z$  to a Mexican Wave behaviour, and then map the behaviour's amplitude and rate parameters to faders 2 and 3, respectively. So, when we talk about faders and behaviours acting upon loudspeakers, this is not strictly accurate: *in effect* they do, but in reality they act upon matrix nodes. The GUI application also allows matrix nodes to be locked to a given value. Locked parameters, once set, are not controlled by faders.

A detailed technical and conceptual description of the system is given elsewhere [6] and source code is available online [9].

## 15. MATRIX MIXING TECHNIQUES

A common stereo diffusion architecture can be emulated by configuring the matrix as illustrated in Figure 3(a). (The numbering of the output nodes corresponds with that of the loudspeakers in Figure 1.) Here, the input nodes are locked at maximum amplitude, as are alternating 'left' and 'right' cross-point nodes. We then assign each of the output nodes to an individual fader. The same configuration can also be realised as shown in Figure 3(b). In this case all of the input and output nodes are locked, and alternating cross-point nodes are assigned to faders. In these simple scenarios there will be no difference to the performer: a 'one fader to one loudspeaker' model with fixed left and right stereo mappings is emulated in both cases. Scenario

(b) is, however, more flexible. Because we are remotely controlling the cross-point nodes as opposed to outputs we have complete dynamic control over the mapping of source channels to loudspeakers.

Although relatively conservative examples have been given for ease of explanation, the same principles can be applied to achieve more unorthodox mappings across larger numbers of input and output channels. Through combining cross-point spatialisation with the ability to map multiple nodes simultaneously to faders, performers can circumnavigate the potentially cumbersome nature of the mix matrix architecture and exploit its latent flexibility.

## 16. FUTURE DIRECTIONS

An embedded scripting language for defining behaviours will increase accessibility and increase the creative potential of the system. High level languages such as Python and Lua are being considered.

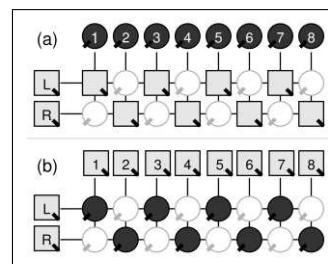
Augmenting the DSP functionality of each matrix node, perhaps by providing filtering and time-delay algorithms, is a relatively straightforward extension of the current capabilities of the system.

Massively multi-channel systems (with two-hundred or more loudspeaker outputs) require exponentially increasing processor power and I/O capability. Systems such as Resound adopt a monolithic approach. A clustered computing solution would be more scalable and is currently being designed.

In the absence of permanent installations, rehearsal, software development and performance documentation is logistically difficult. Virtualisation of large arrays via Ambisonic and binaural implementations is planned.

## 17. CONCLUSION

Resound provides a simple but powerful user-configurable framework for multi-loudspeaker sound spatialisation and is particularly well suited to real-time interaction and improvisation in a performance context. The ability to specify and control mappings in groups, proportionally, additively, subtractively and semi-automatically via behaviours allows performers to realise dynamic, flexible, and easy to control spatialisation routines that would be difficult or impossible to achieve in real time with analogue mixing hardware, particularly with multi-channel input sources. Because the system can operate additively and subtractively, unorthodox or experimental methods can be used alongside more traditional fixed routings, allowing performers to adapt gradually, supplementing and extending their existing repertoire of spatialisation techniques. Effectively, performers are at liberty to design their spatialisation instrument as appropriate to the music and according to their personal preference. Above all, however, Resound is a work in progress, and an open source project that actively encourages collective participation and ongoing development.



**Figure 3.** Two ways of emulating fixed stereo routing. Locked nodes are square; nodes assigned to fader control are black circles.

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