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The influence of technology on the composition of Stockhausen's *Octophonie*, with particular reference to the issues of spatialisation in a three-dimensional listening environment

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The legacy of Stockhausen's role in developing the art and practice of electroacoustic music is significant, in terms of both the repertory of works he produced for the medium from the early 1950s right up to his death in 2007, and also the supporting documentation he has provided in terms of scores and technical records and his many writings on the medium over the years. What emerges from this documentation is a fascinating and at times significant insight into his compositional methods and underlying aesthetic, itself shaped and influenced by the changing nature of the technology itself. Whereas his earlier works have been subject to close scrutiny in this context far less attention has been paid to those composed in more recent years, involving the use of digital technologies. A key consideration in this context is the distinctive and highly individual nature of his approach to the resources at his disposal, in turn driven by aesthetic considerations which of necessity become embedded in the practicalities of realisation. Thus the study of the changing nature of his *techné* as new tools became available becomes a crucial consideration. This article examines these issues in the context of *Octophonie* (1991) and with particular reference to the concepts and practicalities addressed in his use of three-dimensional spatialisation.

1. INTRODUCTION

In the spring of 1997, the *Computer Music Journal* published a review of Karlheinz Stockhausen's *Octophonie*,[1] released on CD in a stereo-reduced format by Stockhausen-Verlag in 1994 (Stockhausen 1994b). The definitive concert version had been completed in an eight-channel format in 1991, and some allowances must be made for the inevitable consequences of reducing eight playback channels to just two. However, this consideration does not materially undermine the implications of the reviewer's opening comments: 'This must be said at the outset: *Octophonie* (1991) is a total departure from Mr. Stockhausen's previous electronic compositions. Gone are the analog generators and filters of the classic WDR studio. This is a music of samplers, of Yamaha digital synthesizers,

and the Atari sequencer; it takes getting used to' (Schoonhoven 1997: 75).

A similar perspective to that put forward by Van Schoonhoven is to be found in Michael Manion's opening comments on *Octophonie* in his article on Stockhausen's electroacoustic music 'From Tape Loops to MIDI' published in 1994, where he observes that 'The electronic music was produced, [sic] entirely with MIDI equipment' (Manion 1994). In essence the implications of the point that is being made by both writers have legitimate currency, for in the same way that the choice of instruments for an acoustic composition will establish specific opportunities and constraints in a composing context, so important parallels may be drawn with the functional characteristics of the resources used for a particular electroacoustic work. However, in the same way that acoustic instruments are used in different ways and contexts so an equivalent diversity of possible applications must be carefully taken into consideration whenever evaluating the musical impact of a particular technology, not least as in this case here, that of MIDI.[2]

To put this caveat another way, whereas many of the intrinsic characteristics of MIDI synthesisers and samplers will be instantly recognisable in works belonging to the ubiquitous 'note/event'-oriented genres of popular music for which they were originally designed, it is unlikely that a listener to *Octophonie* will readily make such connections. The work undoubtedly embodies the fruits of new methods of working with such devices and it is therefore clear that MIDI has played a significant role in shaping these processes. The question is how, and precisely to what effect.

A subsequent observation of Manion starts to unlock an important line of enquiry: 'since Stockhausen's concept of electronic sounds is quite a bit different than envisioned by MIDI, a somewhat unusual approach, for MIDI, was necessary' (Manion 1994). In considering Stockhausen's approach to technology this article will engage with one key aspect of this work in particular,

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[1] The German title is 'Oktophonie' but Stockhausen uses the form 'Octophonie', as used here, when writing about the work in English.

[2] 'MIDI' – Musical Instrument Digital Interface – literally refers to a communication protocol. However, the term is often used more widely, as here, to refer to the wide range of commercial equipment incorporating this protocol.

the use of spatialisation for a three-dimensional arrangement of eight pairs of speakers. Before embarking on this, however, it is important to identify key features of the technical resources used by Stockhausen in the preparation of the work as a whole and also come to some initial conclusions as to their likely impact on the underlying compositional processes. In turn this requires consideration of some important issues which relate to the wider context of Stockhausen's long-standing engagement with the genre. Notwithstanding the enhanced possibilities of the commercial MIDI-based technologies at his disposal for the first time in the case of *Octophonie*, many aspects of the associated *techné*, that is his art of bringing forth of creative ideas through technology, retain certain features of the procedures and processes that were axiomatic to the composition of earlier works, composed entirely without the assistance of MIDI.[3]

2. BACKGROUND TO THE UNDERLYING MUSICAL AND TECHNICAL PROCESSES USED IN *OCTOPHONIE*

Octophonie was first performed on 12 June 1994 as part of the *Kölner Triennale* organised by Westdeutscher Rundfunk (WDR). In this freestanding concert format it consists of a work lasting slightly over 68 minutes, divided into two sections of almost equal durations (36′18″ and 31′55″ respectively). With the addition of a short bridging section, *Pietà*, between the two primary sections it also forms a key component of Act II of his opera *Dienstag aus Licht*, part of *Licht*, a cycle of seven operas he composed over a period of some 25 years, one for each day of the week, starting in 1977. This fourth opera to be completed in the series received a partial performance including the relevant electroacoustic scenes in Frankfurt, 1991, a fully staged premiere in Leipzig following in 1993.

There seems to be some discrepancy between the resources Stockhausen discusses as used in the realisation of *Octophonie* (Stockhausen 1994a) and remarks he made shortly after completing the work. The score makes it clear that a Sony 3324 digital tape-recorder was available (it is even pictured) was central to the creation of the work at the spatialisation stage. Reference is also made to the use of a large semi-automated mixing console, which would have allowed at least some potential for programming the digital storage, and the retrieval of fader settings.[4] The work was realised at the *Studio für Elektronische* Music, WDR between 23

August and 30 November 1990 and between 5 and 30 August 1991, and these facilities must have been available to him from the outset.[5] However, in a lecture on electroacoustic performance practice delivered on 28 November 1991 at the Freiburg Musikhochschule, just three months after the work was completed, Stockhausen stated:

> Next January I will go again for three months into the Studio for Electronic Music of the WDR in Cologne. Up to now the studio has had no money available for a twenty-four-track digital tape recorder. All the other WDR studios have such twenty-four-track machines and, nevertheless, they record only two-channel stereo with them, because neither the time nor the technicians are available for prolonged mix-downs from twenty-four-track recordings to stereo versions. … Whereas the Studio for Electronic Music, which ought to produce lasting products, has no digital recorder and also no digital mixing console with saveable mixing-setups. So, I must work with an old twenty-four-track analog machine. … [The machines] are fragile; you cannot reliably adjust them to each other, and you cannot know whether the playback or the recording is wrongly set. But there is no other option. I work with this equipment all the same, because I want to realize electronic music. (Stockhausen and Kohl 1996: 91)

The two conflicting statements from Stockhausen seem irreconcilable. Certainly it seems that there was a problem copying a digital master of the work onto a single tape, something that was not resolved until October 1994. It is nonetheless relevant to note that the mix of analogue and digital technologies reflected a time of significant change and diversity in terms of equipment for electroacoustic music, and the inevitable problems of compatibility and integration will not have been helpful. When attention is turned more specifically to the technical facilities that were used to create the work it also becomes clear that Manion's statement that 'the electronic music [for *Octophonie*] was produced, entirely with MIDI equipment' (Manion 1994) is not correct.

Although MIDI quickly became a universal digital control protocol for commercial synthesisers and associated devices following its introduction in 1983, the adoption of all-digital architectures was by no means immediate. The list of equipment used for composing the component sound layers provided by Stockhausen in the score of *Octophonie* (Stockhausen 1994a: O XIX – English version) provides an interesting perspective on this transitional period, the inventory consisting of two Yamaha DX 7 II synthesisers and a Roland D-50 synthesiser in an all-digital category, and

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[3] See Manning (2006: 86–90) for a more detailed account of the concept of *techné*.

[4] Although Stockhausen describes this facility as a computer in the score this is a somewhat misleading description. The device, manufactured by Lawo, was a hybrid mixing console (known as the PTR) limited in a digital context to the direct registration and recall of analogue VCA fader movements.

[5] In addition to recording the dates of composition, the score clearly states that he had completed the spatialisation of the first half of the work by 30 November 1990 (Stockhausen 1994a: O XIX – English version). Further confirmation of this can be found in Stockhausen and Kohl 1993: 151, and Stockhausen 1998: 270.

in a hybrid category an Oberheim Matrix-1000 module, consisting of a bank of six digitally controlled analogue oscillators and associated voltage-controlled filters and envelope shapers.

These resources differed significantly both in terms of their methods of sound synthesis and also the facilities available for modifying their functional characteristics. The Yamaha synthesisers, for example, offered resources for creating sounds based on FM synthesis, exploring a proprietary version of the algorithms first developed by John Chowning at Stanford University in the late 1960s. Although the editing facilities were limited to a slider and a pair of pushbuttons, and a small display panel which could only display a single item of control data at a time, it was possible to craft a repertory of up to 32 different voices as an alternative to the factory-provided bank of presets, which were for the most part limited to 'pop' imitations of instrumental sounds.

The Oberheim, in contrast, offered a much larger library of 1,000 preset sounds using additive synthesis to recreate voices associated with older analog Oberheim synthesisers, including non-MIDI models dating back to the 1970s. Although the functional characteristics of the first 200 voices could be modified by the user, the Matrix-1000 module was not fitted with an interface to allow direct access to the associated control parameters. Such alterations would have required the use of an Oberheim keyboard controller or a computer-based Oberheim-specific voice editing programme, and neither editing facility was available to Stockhausen at this time.

The suggested overarching significance of the MIDI dimension starts to unravel as soon as consideration is given to the devices that are used for the purposes of signal processing. Whereas the two Casio FZ-1 samplers,[6] the Art Proverb effects unit and the Roland SDE 2000 reverberation unit were very much all-digital products of the MIDI era, the Roland SVC 350 vocoder most certainly was not. This classic, manually controlled analogue device dating from the late1970s played an important role in the processing of pre-recorded soprano fragments.[7]

The Roland vocoder was by no means the only pre-MIDI device to play an important role in the composition of O*ctophonie*. The studio had purchased a Synthi 100 manufactured by EMS, back in the mid-1970s, and Stockhausen had already used this synthesiser extensively in *Sirius*, a work for tape and four soloists representing the four seasons, finally completed

in 1977.[8] The features which were to prove of particular significance are the low-pass voltage-controlled filters of the Synthi 100, which were used from time to time to filter sounds and amplitude modulation used at one point to create 'slices' of sound as part of the spatialisation (Stockhausen 1994a: O XXV–XXVI – English translation of the *Introduction*).[9]

It has been a regular practice for Stockhausen to work with an assistant when composing electroacoustic works. *Octophonie* was no exception, this role being fulfilled primarily by his son Simon. A useful insight into the working environment can be obtained from Simon's own comments on his contributions to the compositional process:

> I was the interpreter of the score; this is electronic music, not 'normal' music, and so I had a lot of freedom to create the sounds, and he had final approval. Rather than making 'sounds' which are played in a normal sense, I used micro-composition. For example; I would use samples that were made up of three or four textures, then re-sampled and played polyphonically … . If I had a long sustained sound, I would always add some stereo phasing, or filtering, controlling the filter curves by hand – I don't like sounds that have automatic filter curves, too boring. And my father doesn't like that sort of thing either, so I'm always looking for interesting ways to make sounds. … On the DX-7s for instance, I would make oscillator glissandi, using two sliders. Slider one would control operator 4 and slider two would control operator 2. And using the wheels and aftertouch, you could have four controllers affecting the sound. … Each sound in itself is very lively, and very interesting, so that the music doesn't seem slow, it seems very dense and very complex. (Manion 1994)

This raises some interesting issues in terms of the extent to which Simon's skills and ingenuity in overcoming the natural 'note/event' orientation of such equipment in the manner described impacted upon Stockhausen's creative engagement with technologies that used the environment of MIDI. However the potential complications of trying to dissect such synergies do not undermine the proposition that legacy features of Stockhausen's earliest *techné*, which depended almost entirely on the direct manipulation of hand-operated controls such as knobs and sliders, are still very much in evidence in *Octophonie*. In seeking to establish a suitable context for pursuing this line of enquiry it is profitable first to step back in time and look

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[8]*Sirius* was commissioned by the German Government to mark the opening of the Spacearium in the newly dedicated Smithsonian Air and Space Museum, Washington, DC, on 15 July 1976. The work unfortunately was behind schedule and thus incomplete at its world premiere.
[9]The Synthi 100 delivered to WDR was also supplied, as a special custom order, with an EMS 5000 vocoder. This device, offering 22 filters, might have seen preferable to the Roland vocoder, which only offers 11 filters. However, it is likely that the characteristics of a special extra consonant filter specially designed to handle rapid transients may have influenced the choice.

[6]Although MIDI samplers, arguably, may be classed as synthesisers when they are used to provide imitative instrumental voices, the way in which these devices were used to process externally sampled sounds in *Octophonie* warrants this alternative categorisation.
[7]The score of *Octophonie* is clearly marked 'Soprano→Vocoder' in Layer 4 at 24′56″, and the associated hand-crafted filter sweeps through the formant bands can clearly be heard. See Stockhausen 1994a: score O2.

more closely at some key features of the processes used in two earlier works, *Sirius* (1976), and the flute and tape version of *Kathinka's Gesang als Lucifer's Requiem* (1984).

3. NEW TECHNICAL HORIZONS: TWO IMPORTANT LANDMARKS

3.1. *Sirius*

This work represents a significant milestone in Stockhausen's journey from the classical analogue studios of the 1950s and 60s towards an era increasingly engaged with digital technology. Hitherto he had shown no particular enthusiasm for commercial synthesisers, finding them generally limited in terms of their capabilities. Nonetheless, partly encouraged by his former student Peter Eötvös, they purchased the first two production modules of the portable EMS Synthi A when it first appeared in 1971 and subsequent performances of both *Spiral* (1968) and *Pole* (1970), works for performance with live electronics, were to feature the use of this synthesiser. These experiences prompted Stockhausen to change his views on commercial equipment, leading to his recommendation that WDR should acquire a Synthi 100.

It would appear, however, that this large synthesiser was somewhat of a disappointment, certainly in terms of its sound-producing and processing capabilities: 'Unfortunately there were only 12 oscillators and the filters were very weak, they didn't give me good timbres' (Stockhausen 1985: 28). It is thus somewhat ironic that he should subsequently prefer these voltage control filters to more modern digital equivalents when shaping timbres for *Octophonie* in the manner described above. One key feature, however, was to prove an overriding compensation for these limitations in the context of *Sirius*. The Synthi 100 was equipped with a bank of three digital sequencers which could be programmed to register and reproduce voltage control functions.

Although the method of programming these hardware devices was rather cumbersome[10] Stockhausen took advantage of the facility to develop sequences of control data for three different device functions at a time, working in combination with a variety of manual controllers, ranging from joystick, knobs and sliders to an array of keyboards. Each sequencer offered two functions, one controlling pitch, and the other amplitude, with a maximum of 256 individual steps, and it was possible to use these sequencers to achieve highly rhythmic articulation not only at a macro level in terms

of more conventional note-events, but also a micro level in terms of spectral changes within events.

This empowerment was of fundamental importance to him, for it allowed him to revisit and develop further the concepts of form and timbre which are so central to this work. He observed:

> It is now possible to speed up and slow down musical material and use other methods of transformation that were not possible before. So, we can pass from one realm of perception, melody-figure-formula, into another realm, which is timbre-color. … A composer composes the timbre by building a musical structure and speeding it up. The timbre will always be related to the form because every now and then the composer could stretch the sound and you would hear the form. So I could record any sound in the world and slow it down to last one hour and it would be a form. Any sound can be a form, depending on how slow it is played. Once we understand that figure and timbre are dependent upon speed, we can switch from one realm of perception to another. (Manion 1994)

Sirius, unlike *Octophonie*, has many of the stereotypical trademarks of music produced via synthesisers. The electronic materials are intrinsically those often associated with the Synthi 100 and its siblings, and lack the clarity and refinement of the sounds painstakingly crafted from classical oscillators, impulse generators and filters in *Kontakte* (1959–60). Nonetheless they are arguably distinctive and engaging, a tribute to the painstaking micromanagement of the control functions. The work is significant in another respect in that it is also octophonic, using a configuration of eight pairs of loudspeakers arranged in a circle. This environment for surround sound projection was subsequently to prove popular with a number of electroacoustic composers and it is interesting that in his last electroacoustic work, *Cosmic Pulses* (2007), some 30 years later he should revisit this format (in contrast to *Octophonie*'s intervening cuboid configuration).

One key feature of *Kontakte* is the use of sounds that circle and thus encapsulate the listening area using a quadrophonic playback configuration consisting of four pairs of speakers, one in each corner of the listening area. In this work the rotational effects are created by means of a specially constructed, hand-operated rotating table fitted with a single loudspeaker, used to project monophonic sound material between four receiving microphones, spaced equidistantly around the edge of the table. For *Sirius* Stockhausen used an improved design of this rotational panning facility, using eight microphones rather than four to take full advantage of the expanded octophonic speaker arrangement.

At the same time heightened expectations in terms of the positioning and movement of sounds within the sound listening area led him to experiment with the two manual joysticks provided by the Synthi 100, connected up as quadrophonic panning controllers. These devices

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[10]An attempt by EMS to design a fully programmable computer-based control system for the Synthi 100 was ultimately to fail. Ironically the design engineer, Peter Eastty, left the company before the system had been completed, to work for Giuseppi di Giugno at IRCAM on the design of the 4X.

allowed him to move sounds across the listening area rather than just around the periphery. It was, however, the subsequent delivery of an EMS QUEG quadrophonic effects generator, which was subsequently to feature in the spatialisation of *Octophonie* over a decade later, that fully unlocked the full potential of this particular panning technique.[11]

In an interview the day after the world premiere of *Sirius* in Washington on 15 July 1976 he observed:

> *Sirius* is based entirely on a new concept of spatial movement. The sound moves so fast in rotations and slopes and all sorts of spatial movements that it seems to stand still, but it vibrates. It is [an] entirely different kind of sound experience, because you are no longer aware of speakers, of sources of sound – the sound is everywhere, it is within you. When you move your head even the slightest bit, it changes color, because different distances occur between the sound sources. (Felder 1977: 87)

This premiere of *Sirius* was followed within a year by the opening of IRCAM in Paris. With the initial stages of his opera cycle *Licht* very much in his mind he quickly made contact to see if it would be possible to construct a small portable digital processor that could produce real time transformations of trumpet formants to be played on stage. Unfortunately a device to his specifications could not be produced and Stockhausen reverted to acoustic techniques based on manipulations of a mute (Kurtz 1992: 211). Nonetheless this initial engagement heightened his awareness of the possibilities now being opened up by digital technologies, and IRCAM was clearly keen to court his interest.

3.2. Kathinka's Gesang als Lucifer's Requiem

In 1983 Stockhausen finally took up a residency at IRCAM to compose the electroacoustic version of *Kathinka's Gesang als Lucifer's Requiem* for tape and flute. Here he was to engage with the state-of-the-art 4X digital synthesis system developed by Giuseppi di Giugno in the first instance for the composition of *Répons* by Pierre Boulez. Stockhausen was specifically interested in its capacity to synthesise complex timbres from multiple oscillators. Each of the six memory boards could host 64 oscillators, allowing a maximum of 384 oscillators at any one time. However, even this extensive facility was to prove insufficient for Stockhausen's requirements for spatialised phase rotations of complex harmonic spectra, organised in six layers. He was to remark that 'in order to perfectly realize such a synchronization process, it would be necessary to have six 4X's *simultaneously* at one's disposal' (Stockhausen and Kohl 1985b: 58).

[11] The delivery of the QUEG was fortuitous for another reason. Stockhausen had encountered major reliability problems with the Synthi 100 joysticks when composing *Sirius* (Mische and Blumröder 1998: 11).

The nature of this composing environment was very different from that he had previously encountered, notably in the context of the intensive pre-programming that had to be undertaken by his assistant, Marc Battier, to set up the 4X to realise his complex requirements step by step. The entire work was also created at IRCAM over just two seven-day periods of residency in December 1983 and August 1984. Despite the frustration it seems Stockhausen experienced with the non-real-time pre-programming required for the available technology at the time (and the need he felt to compensate for this by introducing supplementary analogue techniques), the complex web of timbre generated using the 4X for *Kathinka's Gesang* is nonetheless impressive. The experience also greatly enhanced his understanding of and engagement with key practical issues that had for many years been fundamental to his compositional aesthetic.

His thinking was clearly illustrated in a lecture given in association with its first IRCAM performances in the Espace de Projection, which took place on 9–14 May 1985.

> After 30 years in the studio you develop that same kind of sense of where you can find something musically interesting. The tape machine rolls and records: then I stop, roll back, and listen. Always, when I've found something interesting it's through this kind of accident. … One must use new means to find effects and sounds one hasn't known, to enlarge our sensibilities – or it's not worth the effort. (Mische and Blumröder 1998: 156)

This work was originally composed as an entirely acoustic work for flute and six percussion players as the second scene for his opera *Samstag am Licht* (*Saturday from Light*). As Stockhausen noted in an interview concerning the electroacoustic version:

> I used exactly the same score which I had composed for the percussion players in making electronic sounds in the studio, with the general idea of controlling phases between the partials, and choosing the pitch material for the plate-bells which are playing simple formulas in 'Kathinka's Song,' and making them very complex spectra – up to seven hundred partial sounds within each spectrum, and all phase-controlled. And from each to each all the partial sounds are perfectly in phase. Then very slowly, with individual time-processes, they go very slowly in different *glissandi* – each one has a different glissando from the others – which causes de-phasing, or phase-shifting, of an extraordinarily complex kind. So you hear the most fantastic colors, in a continuous process from one attack to the next, and when they all come in phase-that gives an enormous explosion every time, simultaneously in the six loudspeakers. (Stockhausen and Kohl 1985a: 35)

At the same time he readily confirms the significance of having to sacrifice so much to pre-programmed synthesis instructions: 'I still had to add all my experience of analog composition to make that whole process a bit more flexible. Sometimes I even had to add

analog procedures to the digital procedure in order to get music which is "alive" enough' (Stockhausen and Kohl 1985a: 36).

The tensions that thus arose for Stockhausen between the advantages of accessing newer digital technologies with their enhanced capabilities and the desire to retain key elements of his existing and long established 'hands on' *techné* for creating electroacoustic music were to prove profoundly significant for subsequent works, not least *Octophonie*. An interesting insight into his increasing concerns in terms of accessing of older technologies and ways of working is to be found in the transcript of a discussion of his *elektronische Musik* which he led at the University of Cologne in 1997. *Octophonie* was not the first work to use MIDI synthesiser sounds which were specially crafted by his son Simon, the most notable example being *Wochenkreis* a work for bassett-horn and synthesiser player completed in 1988. What he clearly had not anticipated in investing so much time and effort in exploring the possibilities of these commercial products was the inescapable fact that they too would quickly become obsolete, with no guarantee that their replacements would offer equivalent features:

> A fortnight ago I performed some experiments with the assistance of a young Spaniard. We wanted to change the sound colours from Wochenkreis, which he had imitated with his synthesisers from a demonstration cassette. … I said, 'Antonio, have a go at changing the second harmonic, it's far too loud. I don't want to hear these octaves for any length of time – make the second or the ninth a little bit louder.' He answered, 'I just can't do that'. … I literally fell off my chair when I heard that. Unbelievable! So something perfect and essentially corresponding to the original concept of sound synthesis no longer exists, after such a short time, because it is no longer interesting commercially. I also no longer have any idea how nowadays one could produce many of the things that appeared in *Kontakte* that had come about through complicated, time-consuming processes. The equipment of 1958 can be found in the basement of the sound museum in the studios in the Annostrasse. But that would be a work of love. There must be such a mad fellow around somewhere, who, like a copy painter, could build a duplicate. … The original might be more colourful, but this would be with a lot of love. One could then realise *Kontakte* from the realisation score. (Mische and Blumröder 1998: 11–12)

It is with these issues in mind, not least the insight they provide into Stockhausen's changing relationship with the technologies at his disposal that attention is now specifically turned to the spatialisation techniques employed in *Octophonie*.

4. SPATIALISING *OCTOPHIONIE*

4.1. The context

At this point, having examined evidence concerning Stockhausen's aesthetic and compositional intentions and preferences, it will be instructive to study how these ideas materialised in the context of a particular compositional task: the spatialisation of *Octophonie*. Even though the commercially available CD of this work (Stockhausen 1994b), cannot begin to represent the unique three-dimensional spatial perspective of the eight channel version,[12] the effect of the subtleties of shaping achieved within the sounds themselves is still very much in evidence, indicative both of the detailed and intricate manipulation of MIDI device parameters and of the skilled hand-crafting of settings on non-MIDI signal processing devices. This study of the spatialisation process aims to provide some insight into his working method and lead to a deeper understanding of his approach and of the tensions and difficulties he may have faced in putting these ideas into practice.[13]

The score of *Octophonie*, as with other Stockhausen scores such as *Kontakte*, also contains detailed information about the process of realisation. In this case the most detailed information is provided about the spatialisation process. The score contains staves with musical notation showing the eight sound layers together with annotations giving in outline limited information about the timbral content and spatialisation of these eight layers. The main detail is found in the *Introduction* to the score (in both German and English versions), which is mostly very thorough and detailed, although not without the occasional ambiguity.

These introductory notes deal exclusively with the spatialisation of the material (in contrast to *Kontakte*, where the methods of synthesis and issues of timbre are prominent). This indicates the importance of the spatial aspect of this work to Stockhausen and how innovative he thought it to be. It may also reflect the relatively limited control Stockhausen had over the detail of the synthesis process material (as already noted largely created using commercial synthesisers, with the help of his son Simon). It is also clear from the notes that Stockhausen first prepared the material for each of the eight layers and laid these down as mono tracks before starting to implement the spatialisation. An investigation of the technology employed for the spatialisation reveals a complex interaction between the ideals of the composer and the practicalities of the technology of the time. The way in which these issues were negotiated gives further insight into Stockhausen's *techné* and his priorities.

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[12]Whereas Stockhausen states unequivocally in the score that work 'cannot be reproduced in a stereophonic mix' he then maintains that the 'eight simultaneously movement-layers have, however, been preserved in the stereo version' (Stockhausen 1994a: 20). Having studied both octophonic and stereophonic versions closely in suitable listening environments, the authors are inclined to disagree.

[13]Further details on the equipment and techniques used can be found in the score (Stockhausen 1994a); the purpose here is to examine specific examples in sufficient detail to facilitate a discussion of Stockhausen's practice.

Working from the eight mono layers of sound material, Stockhausen distributes these across eight channels to be performed on eight loudspeakers (or groups of loudspeakers) arranged in a cuboid configuration around the audience. Speakers I–IV surround the audience at normal height, in each corner, numbered clockwise from the left rear. Speakers V–VIII are located above the lower speakers, significantly higher (Stockhausen stresses the importance of the height, which should be at around 14 metres).

The timings in the score and the numberings in the introductory notes are not continuous but recommence at the start of each of the three major sections: *Part 1*, *Pietà* and *Explosion*.

4.2. The mixing process

This aspect of the process, described by Stockhausen in the *Introduction* on page O XX (English version) may seem a mere technicality and not something of great musical interest. In fact it provides an informative demonstration of the negotiation between the ideal and the practical realisation with significant creative implications.

The basis of the whole spatialisation process was a 24-track digital tape recorder. Two 24-track tapes were used: one for *Part 1* of the work, the other for *Pietà* and *Explosion*. Initially the eight layers were all recorded onto tracks 1–8 of the tape for each section. The layers were spatialised successively; there would not have been enough equipment, nor would Stockhausen have been able to control the performance, if all the layers had been spatialised at once. As layers were spatialised (using the techniques described below) they each needed to be recorded onto eight tracks of the tape. With only 16 of the 24 tracks remaining, clearly there were not enough tracks to hold recordings of the spatialisations of all eight layers at one time (up to 64 would have been needed plus the 8 for the original layers, making a total of 72 tracks). Instead each layer was mixed with the recordings of the previously spatialised layers.

So, for example, at the start of the work, layers 4 and 5 were spatialised as a single unit and recorded onto tracks 9–16. Then layer 7 was spatialised and simultaneously mixed with the spatialisation already layed down on 9–16 and recorded onto tracks 17–24. When the next layer was spatialised it was mixed with 17–24 and recorded onto 9–16 (overwriting the earlier stage of the process). The spatialisation continued in similar fashion, earlier stages necessarily being overwritten in the process.

This approach, required by the limitations of the equipment Stockhausen had at his disposal (and had selected to use in order to permit his preferred working method), had certain implications, both practical and in terms of creative process.

Although Stockhausen could perform the music live in the studio, something that we have established was a priority for him, manually controlling the performance and working by ear, this only went so far. He could only perform one layer at a time and only work by ear in relation to the previously recorded layers as a fixed entity. He could not hear the whole mix in relation to his performance of a single layer (except for the final layer), nor could he subsequently adjust the balance between earlier layers in the light of performing a new layer – these were already pre-mixed and fixed in place. He could, however, re-work a particular stage before moving onto the next, and there are indications in the notes that he did this, rehearsing a particular spatialisation until he was happy with it. (Today, after nearly another 20 years of rapid technical development, one could easily imagine retaining all 72 tracks on hard-disk and being able to fine tune any of the layers of spatialisation in relation to the whole.) So the issue of 'performed live in the studio' as opposed to 'pre-programmed' (something Stockhausen tried to avoid in the light of his experience with 4X in *Kathinka's Gesang*) is not as clear-cut as it might at first appear. Although each separate layer of spatialisation is performed live, aspects of the whole become pre-set as the process progresses, the technology imposed limitations on how far the studio performance could be 'live'.

On a rather more specific and practical level, it seems that the process of accumulation of layers presented some problems of balance. Towards the end of the whole process it would appear that Stockhausen found it necessary to add into the mix 'supplementary' recordings of layer 5 in *Explosion*, which had already been spatialised and previously recorded in the mix. Page O XXVII (English version) of the *Introduction*, stage 11.4 (24′22.029″– end), for example, refers to a 'correction of track 5 … because it had slightly lost some of its presence'. The material is recorded again 'softly' onto the same four speakers (III, IV, VII, VIII – the right side face of the cube) though with no mention of whether the detailed envelopes employed in the original spatialisation were again used. Soon after, stage 13.1 also refers to a supplementary recording of layer 5 'which had become slightly covered' (although later in the processing schedule this stage in fact deals with material earlier in the piece: 10′00″–11′30″). It is mixed onto the lower speakers (I–IV) at 'circa –5dB'.

It seems that this was again a remedial, unplanned step at a late stage in the mix. It is particularly surprising that this material is added to all four of the lower speakers at apparently the same level. This would seem to dilute or even negate the earlier stage in which this material was sent at different levels to different speakers on the lower plane and was part of a detailed spatial movement from a specific take-off point in the lower plane to a precise landing point in the higher plane. Possibly the descriptions here are simply not as detailed

or accurate as elsewhere, but this seems unlikely. A few other similar descriptions of supplementary recordings of material from layer (track) 5 can be found at around this point in the *Introduction*.

4.3. Spatial distribution

There are three main methods by which Stockhausen is able to position sounds from the eight mono layers within the eight-channel cubic space.

4.3.1. The mixing console

The first of these methods uses an audio mixing console to send the mono source to each of eight output channels with the levels of each output set as required. This can either be a static position or movement can be created during the studio realisation of each layer by manually performing on the faders. An example of static position can be found, for example, in the spatial distribution of layer 7, the 'Stationary Bass Sounds', in *Part 1* of the work. This layer is in fact simply copied equally to all eight output channels without movement.

Another example is of layer 6, 'Sound Bombs', between 1′00″ and 16′58″ (again in *Part 1*). Here the source is copied to only the lower square of speakers (I–IV) and with different levels for each channel to position the sound within this two-dimensional space. The levels were changed between each sound event in the layer (but they remain static during each event) and the settings stored in advance in the 'central computer for programmable sound' (see footnote 2 on page O XX of the *Introduction* to the score, Stockhausen 1994a) which controls the console, and then recalled as necessary during the realisation.

Stockhausen also uses the mixing console to create dynamic spatial gestures. His most common approach to this is to use group faders. For example, in spatialising layers 4 and 5 in *Part 1*, the material is assigned to six different output channels representing speakers II–III and V–VIII. The levels of II and III are preset to determine the take-off point between the lower front two speakers (II and III) and the levels of V–VIII to determine the landing point, somewhere in the upper square of speakers (these levels are again stored on the control computer and recalled at the appropriate point in the realisation). The overall levels of II and III and of V–VIII are then controlled respectively by two group faders. By manually cross-fading these group faders during realisation the sound can be moved from the lower take-off point to the upper landing position. (It is a variation of this process in *Explosion* that seems to have been later diluted by the addition of a supplementary recording of layer 5 across all the lower speakers at equal amplitude – as described above.)

Putting Stockhausen's preference for the live performance of material in the studio into practice is not therefore a straightforward matter. In his use of the mixing console for performance-based aspects of spatialisation it can be seen that nonetheless some data is planned in advance, pre-programmed and recalled. In most cases, however, this automation facility is used to facilitate the performance element, not to supplant it. The impracticality of performing complex spatial movements directly onto eight output channels are overcome (but at the expense of some restriction of options) by working with groups of outputs and conceiving of the overall three-dimensional space generally in terms of movement between different two-dimensional sound planes.

4.3.2. The QUEG (Quadrophonic Effect Generator)

The second and third methods both involve what Stockhausen terms 'panoramic units'. Both units generate four channels of spatialised sound from a mono source, and in each case this is often extended to eight-channel movement by routing the audio outputs via the mixing console.

The first of these methods employs the earlier-mentioned device manufactured by EMS called the Quadrophonic Effect Generator (QUEG). The key characteristic of this device is its facility to take mono inputs and distribute them across four output channels by means of a manual joystick. This gave Stockhausen the significantly enhanced means of hands-on performance control he desired for spatialising individual layers of material. An example of the QUEG being used to create spiral movements can be found in the spatialisation of the first 16 minutes of track 3, 'Crashes', *Part 1* of *Octophonie* (Stockhausen 1994a: page O XXII – English translation of the *Introduction*, and page O 1 of the score). Essentially the QUEG is used here to rotate the mono sound from track 3 of the source material, and the four-channel output is then cross-faded between the upper four speakers and the lower four speakers to create a motion that spirals downwards. However, there is further subtlety in the detail of the realisation.

Stockhausen wished to move from a precise starting point (corresponding to the arrival points of the previously spatialised 'shots' from track 4 – see above) to a precise final 'landing point'. He therefore sends the mono sound from track 3 to 16 different channels, four groups of four channels on the console, each group controlled by a single group fader. The first group represents the starting position (each of the four channels assigned to one of the upper speakers (V–VIII), the four channel faders positioned to place the sound precisely within this upper plane of the cube). The fourth group of channels in similar fashion represent the landing point in the lower plane of the cube (speakers I–IV). The second and third groups both take their input from the four outputs of the QUEG. Each therefore

contains the rotations of the sound performed by Stockhausen with the QUEG joystick. The second group is routed to the four upper speakers, the third to the lower speakers.

The studio performance of these spatialisation gestures comprises the movement of the QUEG joystick together with the movement of the four group faders. By manipulating these controls he could move gradually between (i) a fixed initial starting position in the upper plane, (ii) a rotating sound in the upper plane, (iii) a rotating sound in the lower plane, and finally (iv) a fixed landing position in the lower plane. Starting with group fader 1 open, the remaining 3 group faders were gradually opened in succession, and then group faders 1–3 gradually closed in succession, so as to produce a smooth transition (diagram 1).

4.3.3. *The DMP7s controlled by MIDI sequencer*

The other panoramic setup uses two Yamaha DMP7 mixing desks. The DMP7s are used for spatialisation rather than mixing in the normal sense, and therefore in functional terms have a very different role from that of the main mixing console. Each has two outputs. So by sending the same signal (the mono layer to be spatialised) to both DMP7s and controlling the levels

of all four outputs (two on each desk) spatial movement can be created. The DMP7s could be controlled using MIDI so that spatial movements could be pre-programmed using a MIDI sequencer (probably using a looped pattern) on an Atari computer and played back when needed. Stockhausen prepared a number of such rotational patterns. A control fader attached to the Atari computer (the Cooper Fadermaster) also afforded Stockhausen the possibility of adjusting the tempo of the MIDI sequence, thereby changing the speed of rotation during the studio performance.

The second section of *Octophonie*, *Pietà* (the first 10′ of the second 24-track tape), provides examples of the use of the DMP7 setup (page O XIII (German) or O XXIII (English translation) of the *Introduction*, and page O 3 of the score). Apart from layer 7 and the final 1.6″ of layer 5, all the sounds in this 10′ section are rotated in various ways using the DMP7s. These are considered here in ascending order of complexity rather than in the order they were implemented. Layers 5 (apart from the very end) and 6 undergo a very slow (one rotation every 20″) clockwise rotation. The four-channel output of this process is then assigned to two different groups of four channels corresponding to speakers I–IV (the lower speakers) and V–VIII (the upper speakers) respectively. By cross-fading between
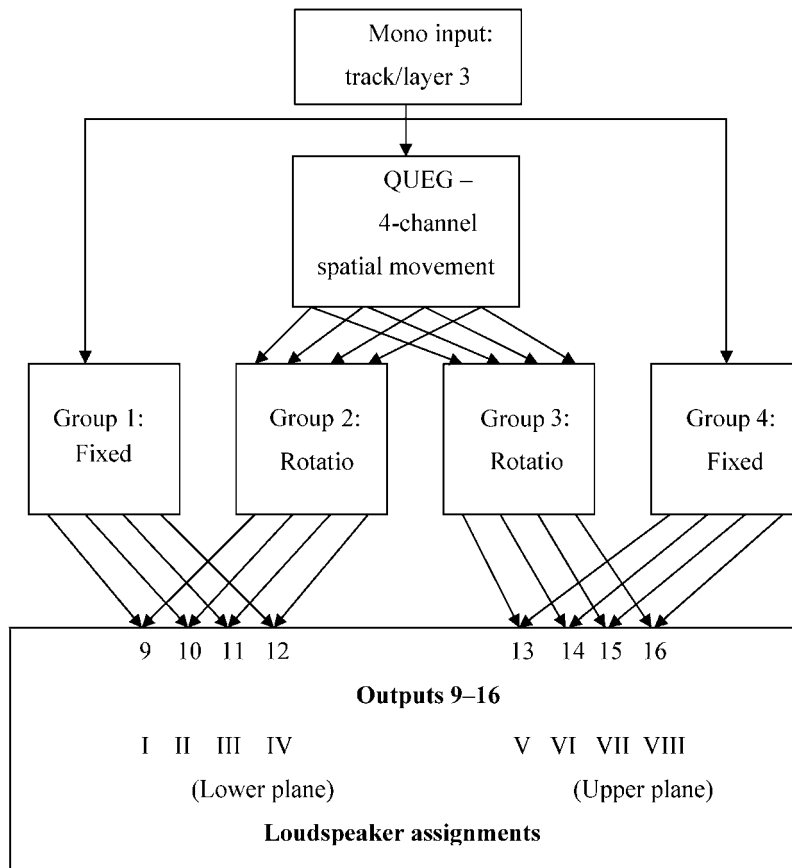

Diagram 1. Schematic representation of spatial processing of Track 3 in *Part 1* of *Octophonie*.

these groups, therefore, the rotating sounds can be made to spiral upwards and downwards. Further variation was added by adjusting the fader levels by hand during the process to introduce 'lateral distortion' to the rotational movement.

With track 1 the assignment of the output of the rotational process is to two sets of channels in diagonal relationships. The first set comprising the upper rear speakers and the lower front speakers, the second set conversely the lower rear speakers and the upper front speakers. This results in looping movements on planes tilting either upwards or downwards in the cubic space, cross-fading between the two sets of channels resulting in a gentle rocking between the two.

There is no cross-fading for track 8. The four outputs from the two DMP7s go respectively to pairs of corresponding speakers in the front and rear planes of the cube: I and II, III and IV, V and VI, and VII and VIII. The rotational movement is therefore in an X shape midway between the front and back of the audience. There is, however, manual variation of speed of the rotations (using the Fadermaster to change the tempo of the Notator sequence on the Atari computer controlling the DMP7s).

Track 4 meanwhile undergoes a slow anti-clockwise rotation. Here the resulting spatial pattern is asymmetric. Most of the outputs are assigned to pairs of speakers. Rather than placing the sounds at particular speaker positions, the intention is therefore, as Stockhausen's diagrams show, to place the sounds midway between speakers in the middle of the certain of the cube's faces. The outputs are assigned as follows: output 1 equally to speakers 2 and 4 (sounding therefore in the middle of the bottom face), output 2 only to speaker 3 (front/lower/right speaker), output 3 to speakers 2 and 7 (sounding in the middle of the front face), output 4 to speakers 1 and 6 (sounding in the middle of the left face). As the sound rotates it therefore moves between these positions.

The DMP7 approach to rotation lacked the live performance element of the QUEG with its joystick but it did allow Stockhausen to focus his attention on controlling other aspects of spatial movement; he could pre-record more precise movements and recall them repeatedly. During realisation, in addition to at times varying the tempo with the Fadermaster he could attend to the group fader levels of the console so important for many of the spatial gestures. The approach is nonetheless significantly pre-programmed and, given his stated preference for live performance of gestures in the studio, it is perhaps surprising he opted for this so frequently in preference to the QUEG. Once again we see the necessity for compromise given the available technology, and the result is thus a hybrid 'live-performedòƒ'pre-programmed' strategy.

5. CONCLUSIONS

With the two panoramic methods, as with the use of the digital mixing console to position sound, it would seem clear that Stockhausen's approach is shaped by practical concerns. The equipment available to him, given his desire to engage in live studio performance as part of the compositional process wherever possible, would seem to have determined, at least in part, his fundamental approach to three-dimensional spatialisation. Rather than controlling eight channels directly he conceives of the space as 2 × 4 speakers, performing rotational movements often in two-dimensional space and then expanding this to a third dimension by cross fading between different output assignments for the two-dimensional rotations. As we have seen, these assignments change during the work, they are varied and imaginative rather than fixed. Indeed, at some points in the work more than one speaker is assigned to particular outputs of the rotation device resulting in rotations that are not in fact two-dimensional and flat. By superposing several layers each with their own complex spatial movement, Stockhausen creates a rich polyphony of spatial movement.

The limitations of the panoramic setups would not be the same if the work were to be composed today. It is now possible to have 'live' control of three-dimensional movement (for example, using Max/MSP – the main challenge is now perhaps the design of practical and intuitive control interfaces for such movement). Working at the start of the 1990s Stockhausen used his imagination to work with great success within the constraints of the equipment available, which was itself, to some extent, determined by the composer's creative requirements. The interaction between technology and creativity in the spatialisation of *Octophonie* is therefore complex and itself multi-layered. It is a complex interactive negotiation between technology and creativity. Despite the restrictions of the technology, the end result is a work in which a rich spatial polyphony is created in three-dimensional space surrounding the audience.

This examination of Stockhausen's approach has not only provided insights into *Octophonie* itself and the ways in which Stockhausen's *techné* was developed and modified to accommodate both the strengths and weaknesses of the resources available at the time. It has also raised a range of more general aesthetic and practical issues, many of them as relevant today as they were at the time of its composition.

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