Spatialization Symbolic Music Notation at ICST

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ABSTRACT

SSMN intends to develop a conceptual framework and a tool set that allows composers to integrate spatialization in musical notation from the onset of the creation process. As the composition takes form and graphic symbols expressing spatialization is introduced into the score, instant audio rendering provides feedback within a surround sound configuration. In parallel, SSMN helps interpreters and audio engineers to learn and master scores that contain complex instructions of motion in space easily recognizable both in printed and animated electronic format. At first the SSMN SpatialTaxonomy was established to identify key motion in space possibilities within musical context; consequently, a collection of SSMN Symbols has been designed and implemented in a software library of graphical objects within MuseScoreSSMN, a dedicated editor that has been developed to allow interactive use of this library along with CWMN. In order to bridge the gap between visual elements and audio perception, the SSMN-Rendering-Engine application is at the heart of OSC inter-application communication strategies allowing the use of DAW and user-defined programming environments along with MuseScoreSSMN. A prototype has been prepared and tested by a user group consisting of composers and performers. Further research shall address other user cases integrating electroacoustic paradigms.

1. INTRODUCTION

1.1 The road to SSMN[1]

The aim of SSMN is to open new ways of substantial integration of spatial relationships and processes in musical thinking as well as in composition, rehearsal and performance practice.

In spite of the availability of a variety of terminologies, strategies and tools for spatialization within the context of electroacoustic music composition[2], decisions about position and movement of sound in space and/or virtual space, quality still often remain a secondary formal issue and, in many cases, are left to a post-production stage instead of being fully integrated throughout the composition process. This practice marginalizes spatialization to an ornamental aspect that could be adapted or reduced without affecting musical substance.

Performers, on the other hand, engaged in the interpretation of music involving electroacoustic spatialization (and other kinds of signal processing) have had mostly a verbal annotation or a poor representation of the ongoing processes in the score. This reduced their possibility of a more intimate and accurate action and reaction within the performance situation. In addition, the usual lack of an acoustic feedback while learning and practicing, prevented performers from preparing a piece with spatial movement and other sound events adding to the difficulties of coping with restrictions of rehearsal time in performance spaces. Finally, the question of a graphical representation of spatialization within the context of sound diffusion of electroacoustic music in concert has been continually addressed, but a generic and practical way to notate spatialization accurately for this purpose has rarely been addressed.

Consequently, SSMN defines a taxonomy of spatial features with a library of graphical symbols designed to represent them, able to be used interactively in creative processes.

In this first introduction, a brief historical overview appropriate to SSMN research will be presented. Taxonomy and symbols will be described in Section 2 and 3 respectively. In order to validate the impact of the new notation in the practice, an open source music notation editor that integrates the above library within CWMN context is under development, allowing editing while auditioning spatialized audio through a rendering engine; the notation editor (MuseScoreSSMN) is presented in Section 4. The software (SSMN Rendering Engine) allowing composers to verify and control the audio results in a desired surround sound configuration will be discussed in Section 5. Section 6 briefly illustrates two user cases. A conclusion then highlights open issues resulting from user group feedback and future development possibilities.

1.2 Previous spatialization notation research

In the earliest attempt to systematically characterize different qualities of sound undertaken by Pierre Schaeffer in his *Traité des Objets Musicaux* (Schaeffer 1966) some basic concepts related to spatial aspects like *spatialisation* and *cinématique spatiale* were first presented without further developing a spatial typology and morphol-

[1] SSMN (Spatialization Symbolic Music Notation). First initiated at the École Polytechnique Fédérale de Lausanne and at the Haute École de Musique de Genève, the SSMN project was further developed at the ICST-Zürich through funding of the Swiss National Foundation for Scientific Research.
[2] See Austin 2004, Assayag, Agon, and Hanappe 1997, Heikinheimo 1972. Harlev 1993. Malausséna 2009. Smallev 2007.

ogy. A thoroughly revision of Schaeffer's theoretical work was done by Lasse Thoresen, who introduced a symbolic representation to Schaeffer's typology starting with a minimal representation of sound attributes and arriving to an expanded set of symbols (Thoresen 2007)[3].

The concept of *spatiomorphology,* as part of a more general *spectromorphology,* was introduced by Denis Smalley as an attempt to define a grammar of localization (Smalley 1997). This takes into account different listening situations, real and virtual acoustic scenarios and individual perception. A first definition of different *spaces* (*internal, external, composed, listening*) is further differentiated introducing sets of *variants, characteristic paths* and *spatial settings*. The same author suggests later a framework for investigation of spatial relationships focusing on the auditors perspective. He highlights the idea of *space-form and* includes a glossary (Smalley 2007).

Bertrand Merlier (Merlier 2008) did a survey on the vocabulary of spatialization considering different kinds of language (artistic, scientific, aesthetic), disciplines (composition, acoustics, psychoacoustics, informatics, musicology) and different perspectives (theory and practice), without any specific technical or aesthetic preference.

The research done at MIM (Laboratoire Musique et Informatique de Marseille) on Temporal Semiotic Units (Unités Sémiotiques Temporelles), identifying 19 different temporal forms that seem to be present in every kind of music is specially relevant for the definition of spatial movement in time (Delalande et al 1996), (Favory 2007).

Various attempts have been done in the last years to define appropriate methods to represent elec-troacoustic music graphically for analysis and performance purposes. Pierre Coupri discusses the problem of graphical representation starting from a distinction between icons and symbols (Coupri 2004). Based on experience accumulated at GRM Évelyne Gayou critically presents transcription and analysis of electroacoustic music (Gayou 2006). Kevin Patton proposes a *Morphological Notation* based on Smalley's *Spectromorphology* focusing on interaction between instruments and electronics (Patton 2007). The composer Ricardo Climent displays his classification of sound spectrum notation (Climent 2008) in his composition *Acute* and explains his *notated methodology.* Ongoing research in sound projection at the University of Illinois includes also strategies of notation of spatialization for performance purpose (Wyatt 2010).

2. SSMN SPATIAL TAXONOMY

The SSMN Spatial Taxonomy is an open-ended systematic representation of all musical relevant features of sound spatiality. It is intended as a basis for symbolic representation possibilities within a musical notation context for composition and performance purposes. This taxonomy is primarily intended as being generic and universal.

The basic units of the SSMN spatial taxonomy are called *descriptors*. There are two kinds of descriptors: room descriptors and descriptors of sound sources. Descriptors can be simple or compound and are assumed to be perceptually relevant although definitive perception is dependent on the interaction between the actual sound and the actual spatial configuration. Although descriptors are primarily defined in structural (geometrical, mathematical, acoustical) terms, they have been conceived in view of musical practice.

Simple descriptors are the basic atoms of the SSMN spatial taxonomy. They are able to denote all single primary features relevant to sound spatiality and can be represented as symbols. Compound descriptors are arrays of simple descriptors. They are used to represent more complex spatial configurations and processes (e.g. patterns, figures, motives, etc.) and can equally be represented as symbols. Descriptors can have several properties that are finally defined through numeric parameters and flags (e.g. the descriptor *Position of loudspeakers* can have the properties *internal* or *external* and *fix* or *variable*).

Structural operations such as *repetition, mirror* and *random* as well as *behavioral interactions* such as *imitation, attraction* and *repulsion* (Dodge 2008) can be used to transform elements previously defined using descriptors or to generate new elements (see table1). Global operations such as *scaling*, *sequencing* and *superposing* can be used to generate relationships between complex unities while *cross–domain interactions* such as *synchronization* and *delay* can be used to rule relationships between different media.

Operations (transformation or generation of new trajectories from preexistent single or compound trajectories)	
Structural operations: Operations on single trajectories	
<u>Repetition</u> <u>Scaling</u> (change of one or more parameters, e.g. augmentation, diminution, speeding up or down, etc.) <u>Dislocation</u> (shift Δx, Δy, Δz) <u>Rotation</u> (x, y, z) <u>Mirror</u> (x, y, z) <u>Crab</u> (reverse direction) <u>Mirror/crab</u>	<u>Segmentation and mute</u> (discontinuity) <u>Modulation</u> (changing periodically one or more parameters) <u>Progression</u> (changing dynamically one or more parameters. E.g. acceleration) <u>Random</u> (changing randomly one or more parameters)

Table 1. SSMN Taxonomy Structural operations.

Although the taxonomy classifies and describes sound in a three-dimensional space, some objects and symbols, for practical reasons (rendering, standard formats, etc.), are represented in two dimensions. This is specified using 2D/3D flags. Since this taxonomy contains a very systematic vocabulary it proves to be useful for other research projects related to 3D Audio currently under development at the ICST.

To assure the validity of concepts within this taxonomy, the SSMN research team has undertaken the task of testing perception of sound spatiality elements both in 2D and 3D mode, with key questions being e.g. what can be perceived or not, and under which conditions.

[3] Thoresen's symbols do not explicitly represent spatial aspects but are concerned with spectral movement including gait, velocity and duration.

3. DESIGN OF SSMN SYMBOLS

3.1 Requirements

In accordance with the SSMN spatial taxonomy requirements, a basic set of symbols was established, designed, periodically tested by the R&D team as well as participating composers, and improved in subsequent design loops. Additional criteria resulted from the need for clarity, legibility and rapid recognition. In this regard, the choice between *symbolic* or *descriptive* paradigms became particularly relevant. Ultimately, the SSMN symbol set has become a synthesis of both approaches (see fig.1).

3.2 The symbol set

In order to facilitate the use of the SSMN symbols and their introduction into the musical score five categories of symbols related to the following aspects were defined:

– Physical performance space characteristics (*geometrical form, size, reverberance, inside/outside*)
– Initial physical placements of performers, microphones, loud speakers and objects
– Localization of sound sources (*acoustic* and *projected audio*[4])
– Trajectories and/or displacement of sound sources, microphones, loud speakers, and objects whether individually, in groups or more complex configurations (*sound clouds, planes, surfaces*)
– Inter-application communication possibilities and protocols (OSC, MIDI) as well as integration with external programming environments.

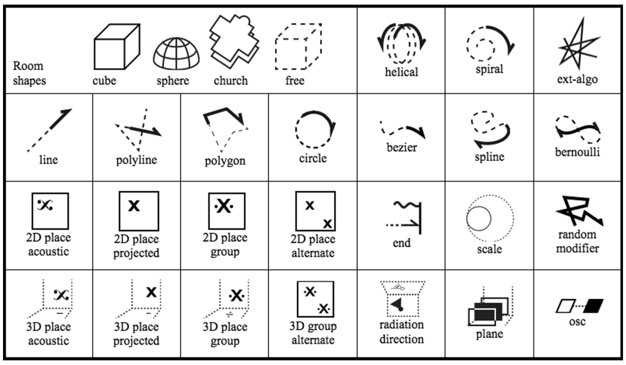

Figure 1. Extract of SSMN symbols set

4. MUSESCORESSMN

4.1 Requirements

The choice of MuseScore as notation editor for the SSMN project was based on the criteria of Open Source software with a large active community involved in its development. As MuseScore 1.0 provides a usable set of functions to draw symbols onto the screen, to print them and to provide MIDI-feedback but does not have OSC functionality a SSMN dedicated version was branched ('MuseScoreSSMN') from MuseScore 2.0, which allows OSC communication of all parameters and values of the symbols to be transmitted to target software within the tool set and equally receive data for control (on/off/play/pause).

4.2 MuseScoreSSMN features

In MuseScoreSSMN symbols are organized into various palettes according to SSMN categories and classes as well as 2D/3D versions, i.e. *room*, *trajectories*, *position*, *modifiers*, *OSC & Adjuncts*, *Performer*, *Microphone*, and *Loudspeaker*. The user selects the desired symbol and drags it to the appropriate note or rest in the score.

Once a symbol is placed in the score, an inspector window displays user-defined parameters and flags specific to each type of symbol, i.e. *start/end points, start/end radius, direction, number of reiterations, acceleration, amplitude, frequency, yaw, tilt*, etc., with choices of x/y/z or a/e/d coordinates. The actual trajectory designed by the user can be viewed as well (see fig.2).

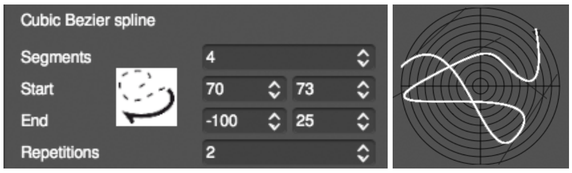

Figure 2. MuseScoreSSMN Inspector window

A 2D/3D radar view displays the activity of the spatial movements from a selected note to another, or over a section of the score. MuseScore 2.0 makes it convenient to obtain visual and audio feedback within the SSMN tool set as it offers I/O possibilities that include Jack-Server connections, MIDI data flow, and OSC port transmission. This is discussed in the next section.

The user commonly places SSMN symbols on any instrumental staff; nonetheless, a dedicated *SSMN Staff* can be utilized to transmit spatialization data as well as OSC messages to any software with OSC functionality independent of notation (see fig.3).

Several templates have been designed to facilitate formatting various score-types. As the MuseScore application offers the possibility of exporting scores in numerous formats that allow inclusion of SSMN graphics, i.e. SVG and PDF, the SSMN team is addressing the issue of declarations to be included in the MusicXML file format (Bellini 2001, Peters 2013).

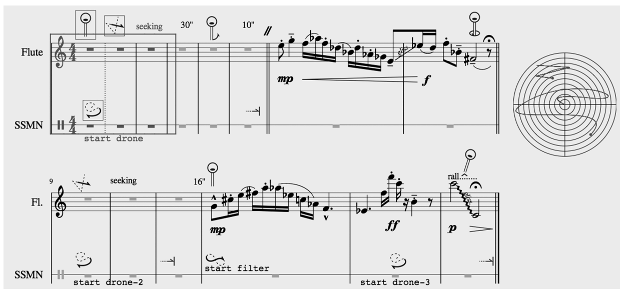

Figure 3. MuseScoreSSMN example with CWMN SSMN symbols, OSC data (text) and trajectory shown on 'Radar'.

[4] Acoustic audio refers to the natural sound of instruments whereas projected audio refers to sounds coming from loudspeakers.

5. SSMN RENDERING ENGINE

5.1 Requirements

Compatible with the Open Source Initiative for standardized Max/MSP Module, the SSMN Rendering Engine has been engineered to allow real-time spatialized audio rendering and visual feedback for all SSMN activity. The prime requirement is the capability of inter-connecting all software that implements OSC support, for instance the notation editor and the rendering environment.

Along with the JACK Audio Connection Kit encompassing MIDI functionalities, the user has the ability of hearing his results in various audio output formats and speaker set-ups, within multiple software configurations and enhancement possibilities, i.e. MuseScoreSSMN, DAWs, AUAmbi plug-in[5], programming environments, effects, multi-canal streaming, etc. (see fig.4).

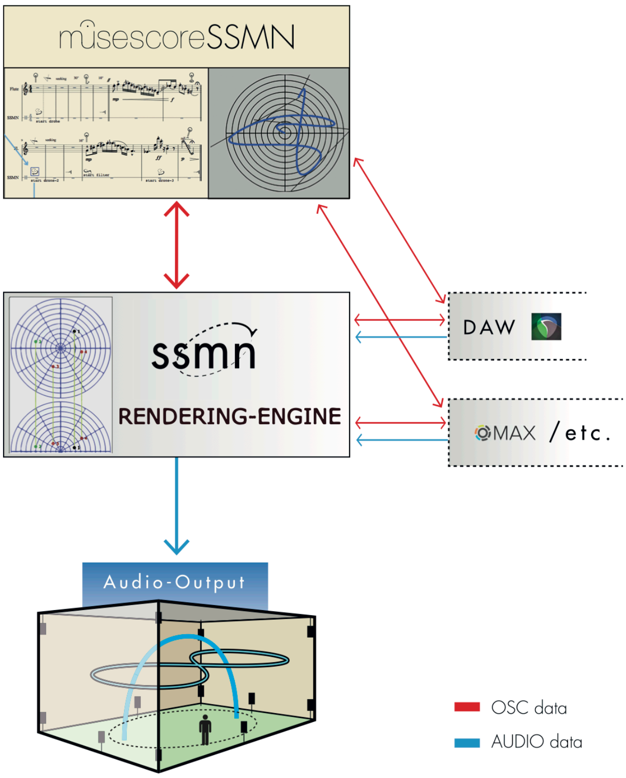

Figure 4. General SSMN Flowchart

5.2 SSMN Rendering Engine primary functionality components

The SSMN Rendering Engine was structured so as to facilitate the organization of the flow and monitoring of data as well as its storage as required by the user.

– *OSC routing*: choice of connections allowing OSC data flow over UDP ports, i.e. synchronized trigger and play/pause/continue/stop messages between MuseScoreSSMN, DAW, sample players and AUAmbi plug-in.

– *Spatialization formats*: as the engine encodes and decodes in the Ambisonic B-Format, the user can select various format transformation options, i.e. 5.1, binaural, stereo.

– *Speaker set-ups*: The user determines speaker configuration, e.g. number of speakers, placement of speakers, 2D/3D.

– *Distance*: The user designs distance characteristics on a GUI to determine the slope of sweet point presence to external perimeter.

– *Effects*: reverb, air absorption, and Doppler effect.– *Record/playback*: All audio activity can be saved and reopened in common audio file formats, including B-Format.

– *Virtual MIDI*: Instrument sonification capability using an optional midi player.

– *2D/3D radar*: The visual feedback as provided by the ICST Ambisonic monitor (aed/xyz and multi-speaker level display) is of primary importance as it allows the user to monitor single or multiple trajectories and sound placements in real time.

– *AUAmbi plug-in*: this AU plug-in allows communication with standard Digital Audio Workstations that have AU implementation, e.g. Digital Performer, Logic audio, etc., thus expanding inter-application spatialization.

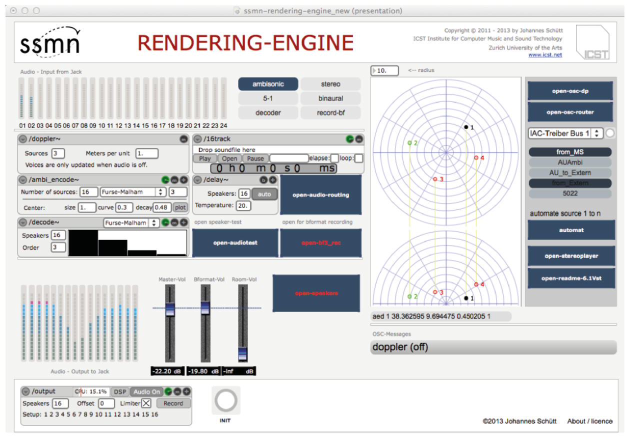

Figure 5. SSMN Rendering Engine Main Screen.

In order to facilitate overall OSC control, a set of descriptions were created that would allow multiple cross-application communication, also adaptable to other protocol context such as SpatDIF and MusicXML (see table 2).

ssmn osc description	
MuseScoreSSMN Transport Control:: (receives:5282)	
/play	/goto
/stop	/tempo
/next	/volume
/next-measure	/pan
/select-measure	etc…
MuseScoreSSMN::spatializationSymbols::(send:5013)	
/aed i f f f i	
MuseScoreSSMN::oscMessage:: (send:5012)	
/any(“s”)	

Table 2. Extract of SSMN OSC description set

[5] The AUAmbi plug-in (2012) was created by SSMN programmer Kaspar Mösinger.

6. CASE STUDY

6.1 Urwerk

A case study of a film score *Urwerk* prepared by composer Vincent Gillioz revealed the interest of combining instrumental notation with 3D spatialization effects to be integrated into 3D cinema. Here the score for 9 instruments and electronics was originally notated in a popular score editor. Initially the composer created his personal graphical symbols and spatialization annotations, but without the possibility of hearing more than a stereo version. Consequently, after exporting his score in MusicXML format (notation only), he then imported it into MuseScoreSSMN where he then placed the SSMN spatialization symbols (see fig.6). Ultimately, the composition along with the animated movie and accompanying audio files were rendered onto an Ambisonic speaker system. Having been able to audition the impact of the sound motion, Gillioz could now edit and modify various parameters of SSMN symbols to his taste and allow for more coherent musical effects.

Figure 6. *Urwerk* in MuseScore SSMN, p.25-26.

6.2 SSMN applied to choreography.

Choreo was a case study demonstrating advantages using SSMN within rehearsal situations. A choreographer, Melissa Ellberger-Meyer, trained performers holding loudspeakers to move along trajectories in a hall. Sound files projected from the portable loudspeakers accompanied the body movements. The printed MuseScoreSSMN greatly facilitated the learning process prior to an actual public presentation (see fig. 7).

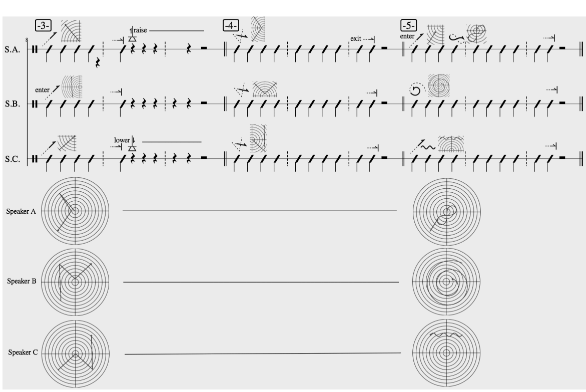

Figure 7. *Choreo* trajectory score

7. CONCLUSION

At this stage of the "work-in-progress" of SSMN[6], its basic workflow is optimized for the user case in which notation for instrumental music (often incorporating live electronics) is introduced into a music editor and spatialized audio rendering is a requirement. Other user cases include the additional use of audio files managed within DAW software.

SSMN equally targets state of the art venues, namely 3D cinema (with a great need for encapsulating height information into surround systems), 5.1 radio and web-based broadcasting (video, music and radio theater productions), choreography notation (Mirzabekiantz 2000), artistic multi-media and interactive installations, surround CD, DVD and Blu-Ray market, as well as game design.

To date, the SSMN user group provided inestimable feedback. Questions that were continuously taken into account concerned the type of strategies adopted, their usefulness, the choice of symbols, the clarity and speed of recognition, the flexibility offered by the tool set and overall user friendliness. Performers and audio engineers noted that they found useful features that allowed them to consult both a printed version of the score containing the SSMN symbols as well as its electronic version allowing rendering the symbols in an active timeline.

At this time, results of the SSMN project have been incorporated into the composition curriculum at the Zurich University of the Arts and have been presented at the Haute École de Musique of Geneva. The potential of the prototype was also tested with choreographers and their composers at Tanzhaus Zurich.

Further aspects are also being addressed such as the integration within the MusicXML protocol and SpatDIF compatibility (Peters, Lossius and Schacher 2013). The actual experience with the composers, interpreters and composition students has shown that they have experienced increased awareness of spatialization possibilities within their own creation process and developed an augmented spatial listening acuity. Thus it is expected that the SSMN project will contribute to generating a sustainable impact on creative processes involving three-dimensional spatialization.

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[6] The SSMN R&D blog maintains updated information and documentation. http://blog.zhdk.ch/ssmn/

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