# Audio-assisted Visualization – Sonification of Complex Urban Systems with the SUM tool

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## ABSTRACT
This paper proposes the use of audio-assisted information visualization in the representation of complex systems, in particular that of the urban environment. It introduces the technique of sonification – the representation of data through sound – and demonstrates its ability to simultaneously represent multiple attributes. As a temporal medium, it can help to reveal complex urban relationships over time. Thus it can be viewed as well adapted to the urban design and planning profession, which must deal with the synthesis of numerous layers of visual data into one urban masterplan. Here we present the Sonified Urban Masterplan (SUM) tool, which utilizes audio to assist the visual representation of urban data.

## Categories and Subject Descriptors
J5 [**Arts and Humanities**] Architecture; J6 [**Computer Aided Engineering**] Computer-aided design (CAD)

## Keywords
Complex systems, Urban dynamics, Urban design and planning, Data sonification, audio-graphic information visualization

## 1. INTRODUCTION: AIMS AND BACKGROUND

Effective representation is critical in the design and analysis of a complex system, defined as 'a system composed of a typically large number of (possibly heterogeneous) elements that as a whole exhibit some properties which specifically result from the interactions between the constitutive elements.'[1] Here a system is seen as more than the sum of its individual parts, and thus the relationship between parts is crucial.

One of the most complex spatial systems is that of the contemporary city, consisting of numerous temporal urban flows interacting within a given spatial urban structure. However the complexity of spatio-temporal relationships produced by these various infrastructure systems, makes the resulting urban dynamic of difficult to predict.

This means that urban designers and planners, allocated the task of spatially organizing the urban system, are faced with the challenge of designing for increasingly complex spatio-temporal data. Traditionally based on visual representation techniques, a more time-based representation technique is called for.

The technique of sonification, defined as the process of representing data through auditory means [2], offers a more temporal form of data representation, utilising the efficiency of the ear in detecting temporal patterns, periodicity, and simultaneously following multiple parallel streams of auditory events [3]. Since its introduction by Kramer in 1994, the use of sonification in scientific analysis has grown dramatically. It can only aid the analysis of complex urban systems.

Furthermore, communication of urban design decisions to the general public is becoming even more challenging, along with the risk of miscommunication due to information overload. Within the climate of a democratic decision-making process, the effectiveness of acoustic communication can help bridge the gap between urban specialists and the general public, assisting in public education and promoting participation.

Thus this paper proposes the use of audio-assisted visualization in the representation of urban data, for the design, analysis and communication of our complex urban systems.

## 2. DESCRIPTION

The Sonified Urban Masterplan (SUM) tool, currently realized within PWGL [4], a widely-used Lisp-based visual CAC environment, allows the synthesis of multiple layers of graphic information into one sonified mapset.

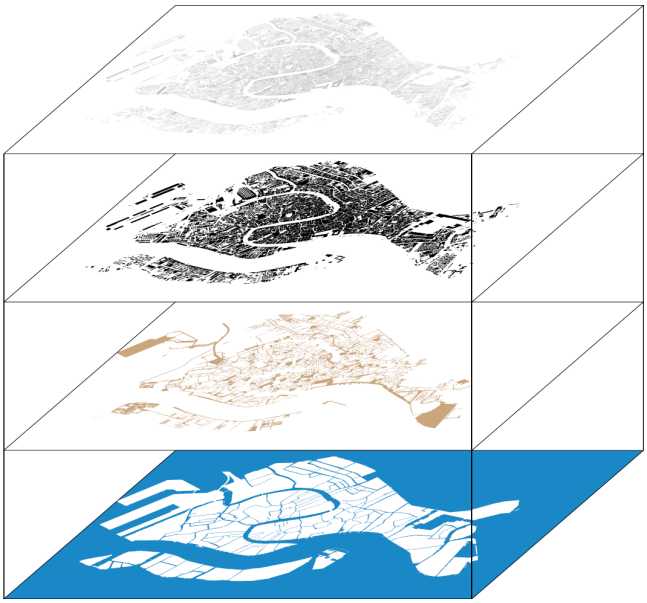

**Figure 1. Superimposition of various layers of urban elements of Venezia to form a '3D matrix' of data**

The tool supports the importation of any number of raster images. Saved at 72 PPI in RGB colour format, these images can be read as a 1:1 matrix of colour-coded pixels, according to a user-defined legend. Each filled pixel represents data, while transparency indicates its absence. When superimposed, these 2D data layers form a virtual '3D matrix' of pixels, called a 'mapset'.

It is up to the user to generate this mapset by organising their data into their layers of interest. In urban planning, for example, each layer can be used to represent a different urban element which, when superimposed, recreates the whole masterplan.

However, whereas the overlaying of graphic layers would normally mask the data of another, here the use of sonification allows the data to be heard, allowing relationships between layers to be effectively represented.

The sonification process consists of simple parameter-mapping implemented through our SUMDL lisp-based description language, where each colour is assigned certain acoustic attributes, such as pitch, volume or instrumentation, as desired.

In order to access this data, the user draws a time-line in the form of a vector polyline. Assigned a certain speed, the time duration of one pixel can be calculated and the image is sampled pixel by pixel accordingly. Multiple paths can be drawn, at differing speeds and with possible delays, allowing multiple flows of interest to be heard simultaneously or separately.

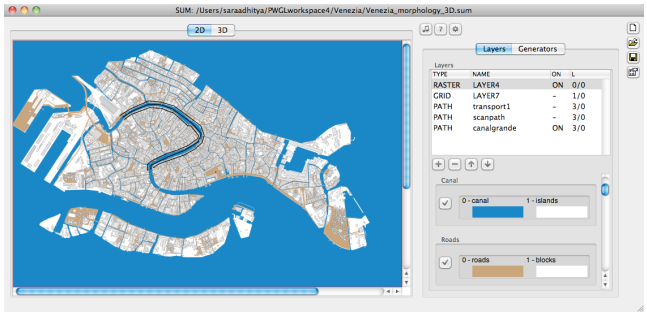


**Figure 2. The SUM tool user interface - allowing multiple 2D graphic layers to be 'heard', even if unable to be seen**

The SUM tool also supports the internal creation of 2D vector objects, allowing designers and planners to modify or create new graphic layers and immediately 'listen' to their effect on the existing urban system. Our current development towards the input and generation of 3D vector objects will aid the visualization of spatial environments.

## 3. APPLICATION AND RESULTS

There is great potential for the application of the SUM tool in the field of urban and regional planning, and its concern with spatially distributed systems and their temporal implications.

Able to represent multiple data layers simultaneously, sonification can make explicit the co-occurrence of different spatially relevant phenomena. As a temporal medium, it is just as effective in exposing complex patterns or correlations over time.

Thus through its integration of sonification and visualization, the SUM tool has the ability to reveal spatio-temporal relationships. This allows the communication of the temporal effects of a spatial structure, indicating possible outcomes such as urban sprawl.

Being a computer-aided design tool in itself, it provides designers and planners with a more time-based approach to spatial design.

Furthermore, the power of acoustic communication can help bring together expert and lay knowledge, promoting public education and participation. The SUM tool can thus be useful to social organizations as a mediating tool within the participatory decision-making process.

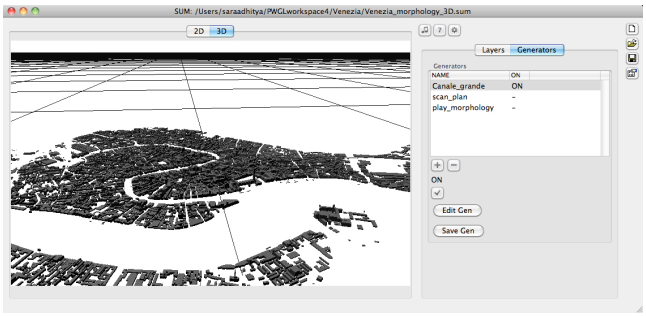


**Figure 3. 3D visualization in the SUM tool**

Beyond application within the field of urbanism, the SUM tool can also be used to represent other complex spatial systems. The flexibility of raster-input permits any visualization, including that produced by other software, to be imported. The relationship between any combination of visual data sets can be sonified.

## 4. CONCLUDING REMARKS

The importance of representation of urban data is clear in the effective design and management or urban systems. However, the increasing quantity and complexity of this data is placing immense pressure on existing visualisation techniques. By supporting information visualisation with audio, the SUM tool hopes to relieve the visual burden of information overload. By appealing to the ears, it also hopes to reveal relationships which would otherwise not have been seen. Integrating space and time, it provides a more time-based tool for spatial design. Last but not least, it hopes to improve communication and participation within the decision-making process. Beyond the domain of urbanism, the SUM tool can be applied to other complex spatial systems, representing more than just the sum of their individual parts but the spatio-temporal relationships between them.

## Acknowledgments:

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## 5. REFERENCES

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