

# Connecting SUM with computer-assisted composition in PWGL: Recreating the graphic scores of Anestis Logothetis

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## ABSTRACT

This paper describes further developments of the SUM tool, initially developed for the sonification of images, towards the composition and execution of graphic scores. Closer integration of the SUM user library within the computer-aided composition environment of PWGL has allowed the composition and realization of more complex graphic scores. After first explaining the existing structure and sonification approach of the SUM tool, we introduce its new macro-structure utilising PWGL's VIUHKA texture generator, which supports higher structural levels and thus the generation of more complex sonic events. As a proof-of-concept demonstration of SUM's new macro scheme, we attempt to reproduce the graphic scores of Greek composer Anestis Logothetis, notable for his extensive graphic-sound taxonomy. We thus demonstrate the combined capabilities of PWGL and the SUM tool to support the computer-aided composition of graphic scores.

## 1. INTRODUCTION

The SUM tool[1] is a user library with a graphical user interface within the computer-aided composition environment of PWGL[2]. Initially designed for the sonification of images, through a user-defined mapping process, it also supports the composition of graphic scores.[3]

Tools for the computer-aided composition of graphic scores can be seen to have grown from Xenakis' UPIC<sup>1</sup>, which allowed the drawing of frequency over time as opposed to the following of traditional musical notation. This has since led to more modern and accessible versions of software such as HighC<sup>2</sup>. While graphical in nature, both are still limited to piano-roll lecture reading the image from left to right. However, graphic scores are by nature open to interpretation. Development of image-sonification toolkits such as SonART[4] have since allowed the exploration of images by raster-scanning or real-time probing. How-

<sup>1</sup> Unité Polyagogique Informatique du CEMAMu (UPIC), a computerized graphical musical composition tool developed by Iannis Xenakis, Paris, 1977

<sup>2</sup> <http://highc.org/history.html>

ever, the definition and management of time is limited for compositional purposes.

The SUM tool can be seen to provide more flexibility in both the composition and execution of graphic scores, by allowing both the pixel-by-pixel exploration of a score as an image, as well as its temporal reading from any number of angles by one or more spatio-temporal time paths. While supporting the importation of existing raster images, it also has the ability to generate vector images internally, allowing the representation of non-traditional symbols or images often used in graphic scores.

This paper will explore the latest developments of the SUM tool in the computer-aided composition of graphic scores. We first present an overview of the existing structure of the SUM tool. We then introduce a higher structural level called the macro-layer. The introduction of macro objects and events allows us to better integrate the SUM tool to the powerful computer-assisted tools of PWGL. For the purposes of this paper, we will utilize a compositional tool called VIUHKA[5] to define the expansion of the macro events. We then demonstrate how this macro-structure can be used to reproduce the graphic score notation of Greek composer, Anestis Logothetis. Through the recreation of one example of his graphic scores, we demonstrate the combined power of PWGL and the SUM tool in the composition of graphic scores.

## 2. SUM EXISTING STRUCTURE

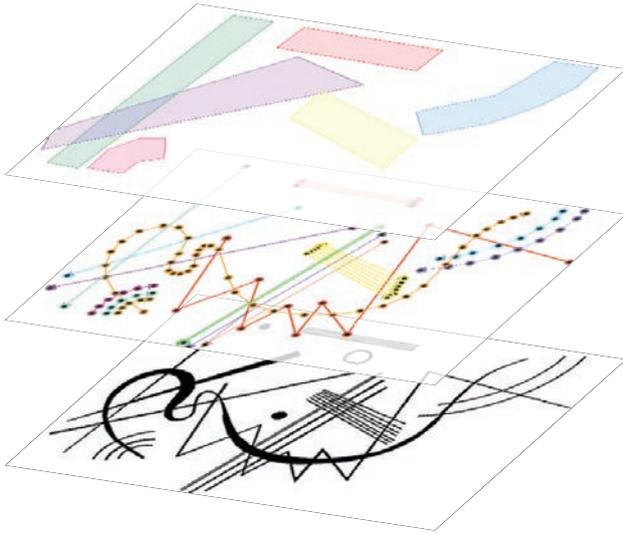
First, we describe the existing spatial and temporal structure of the SUM tool, in order to explain its sonification processes used to map image to sound. In particular, we explain how this structure can be used to generate the variety of image-sound notation utilized in graphic scores.

### 2.1 Existing Image Layers

Currently in the SUM tool, images are used as musical 'data-sources'. Raster images can be imported, with the spatial scale determined by the resolution of the image in DPI. Vector objects can also be created within the tool. SUM supports the superimposition of multiple images, which we call layers (visualised in Figure 1).

Layers have a central role in the design of the SUM tool. A layer defines the context inside which the objects are interpreted. A raster layer allows us to explore bitmap images and vector layers provide the means for both the manipulation and exploration of vector objects. These layers

can either be read independently or in combination with each other.



**Figure 1.** Visualisation of image layers in SUM.

## 2.2 Existing Time Paths

The temporal structure of the SUM tool is path-based, defined by the user drawing a vector path and applying it to one or more image layers. The path samples the image layer(s) according to Bresenham's line algorithm[6]. The user can define the start-time and speed of each path, which then determines the sampling rate and thus the timing of the score. Multiple spatio-temporal paths are also supported, allowing the score to be read at different speeds simultaneously. Thus the timing of an open graphic score can be managed flexibly by the composer or interpreter.

## 2.3 Image-Sound mapping process

In order to sonify the image layer(s) with the path(s), a parameter-mapping process must take place which translates the image attributes (i.e. colour) into audio attributes (i.e. pitch, volume, articulation and timbre). Mapping image to sound parameters in SUM currently relies on the user-definition of one or more mappers, which draws on any combination of image layers to define each sound parameter. This flexible mapping process allows a composer much freedom in defining the relationship between an image and sound as described in [7]. However, the mapped result is still limited to a single sonic event or attribute.

## 2.4 Opportunities and limitations

The existing structure of SUM offers many opportunities for graphic composition. Its flexible combination of multiple image layers and spatio-temporal time paths supports the creation of a multi-dimensional graphic score. At the same time, the vector drawing capability of the SUM tool allows a composer to develop his or her own graphic notation (see [8]).

Currently, the existing layers allow for the pixel-by-pixel exploration of the material. Consequently, the limitation

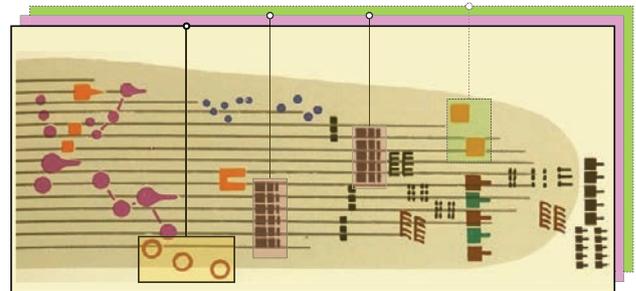
of the current sonification approach is that the rasterisation of bitmap images is both granular and lacks the possibility for defining higher-level temporal structures. In order to overcome the textural and temporal limitations of the existing rasterisation processes, in the next section we utilise the powerful computer-assisted tools of PWGL to generate a new 'macro-structure' for the SUM tool.

## 3. SUM'S NEW MACRO-STRUCTURE

In this section, we propose the generation of a new macro-structure for the SUM tool, introducing the concept of the macro-layer, consisting of any number of macro-objects, and facilitating the generation of macro-events.

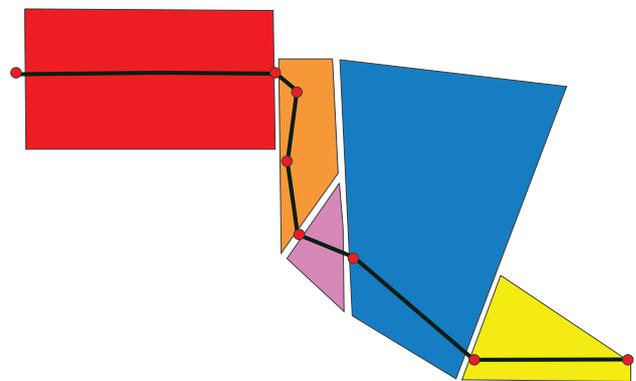
### 3.1 Introducing the macro-structure

A macro-layer is a higher-level layer encompassing SUM's existing image layers, as is visualised in Figure 2. A macro-layer can thus define more complex graphical objects than a single image layer.



**Figure 2.** SUM's new macro-structure: macro-layers consisting of one or more image layers.

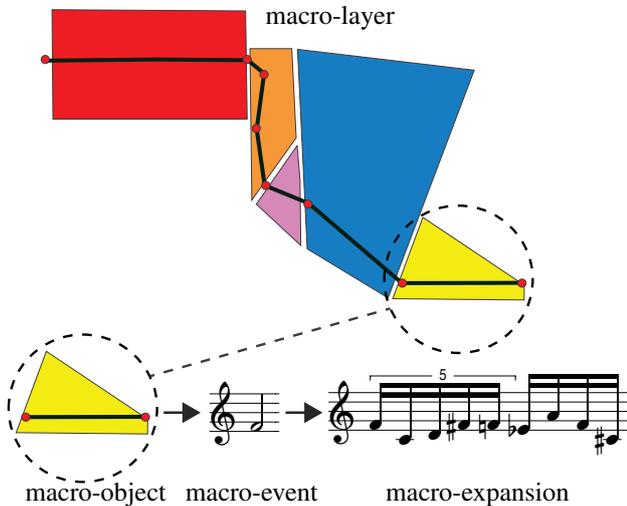
A macro-layer contains graphical objects called macro-objects. Macro-objects are translated into macro-events by applying a path to the macro-layer (as shown in Figure 3). The path effectively "reads" the macro-layer and produces a sequence of macro-events. The macro-events are then expanded through a user-definable macro-expansion process. In effect, a macro-event defines a slice of time with specific, user-definable attributes.



**Figure 3.** Macro time-path for the activation of macro-events.

### 3.2 Macro mapping process

As explained in section 2.3, the existing sonification approach of SUM is limited to the mapping of each image parameter (i.e. colour) to a single sonic event or attribute. With SUM's new macro-structure, the macro-events define a higher level mapping process allowing the generation of more complex sonic sequences (see Figure 4).



**Figure 4.** SUM's macro-expansion process: a macro-layer object is mapped to a macro-event which will be expanded according to a user-definable macro-expansion process.

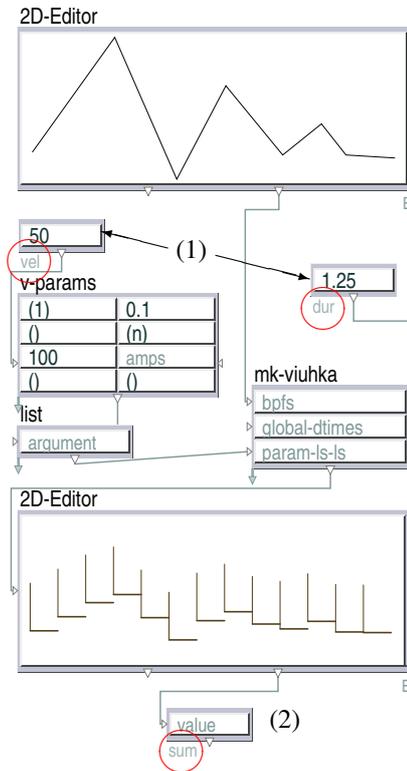
### 3.3 Defining SUM macros in VIUHKA

To define the macro-expansion of SUM's compositional structure, we utilize a PWGL user-library called the VIUHKA. Designed for, and based on, the ideas of the Finnish composer Paavo Heininen, it allows for the creation of complex, multi-layered musical textures for the purposes of purely instrumental music, as well as the production of material for sound synthesis.

From the user's point of view, the macro definition process is relatively transparent. It is based on the user-defined associations between colors and attributes, the composition of the macro-layer and the paths, and finally the definition of the macro-expansion processes through a visual PWGL patch. The association between a given macro-event and a PWGL patch is established by matching a macro-event name to a PWGL patch name.

Currently, we are using an internal transfer protocol to exchange information between SUM and the associated VIUHKA macro patch, which can receive the data through special entry points as shown in Figure 5 (see "dur" and "vel"). The names refer to the attributes of the SUM macro-events which, in turn, are retrieved from their respective image sources, as explained above. During the generation of the SUM score, the macro-events use these entry points to pass arguments to the VIUHKA patch. Each entry point can refer to a single macro note attribute such as duration, pitch, or velocity. Although the arguments represent real musical values, their use in the patch is not constrained in any pre-defined way. However, the VIUHKA

system is designed to produce material that can be subjected to advanced temporal manipulations, as well as be easily scaled to fit inside a specific time span. This means that we can use, for example, the duration of the SUM macro-event directly as a parameter to precisely control the duration of the resulting texture. Finally, the box named "sum" (2) at the bottom of Figure 5 defines the exit point of the VIUHKA macro patch. This returns the value of the macro-expansion and also returns control back to SUM. This described process is repeated for every macro-event.



**Figure 5.** Entry points "dur" and "vel" (1) and exit point "sum" (2) for transferring information between SUM and PWGL.

## 4. RECREATING GRAPHIC SCORES

As a proof-of-concept demonstration of SUM's new macro-structure, we attempt to realize a graphic score. Graphic scores are by nature user-defined in their image-sound taxonomies. The graphic scores of Greek composer Anestis Logothetis (1921-1994) are of particular interest as he developed an extensive semiology in the 1960's, which was implemented in a number of his graphic scores throughout his career.

### 4.1 Introducing Logothetis' graphic score notation

Logothetis' parasemantics have been 'decoded' in [9] by Georgaki and Baveli to produce a taxonomy which is explained briefly below. Three groups of symbol types have been identified, as is seen in Figures 6, 7 and 8 below.

#### 4.1.1 Pitch Symbols

The following symbols were used to indicate the pitch, at any octave (Figure 6).

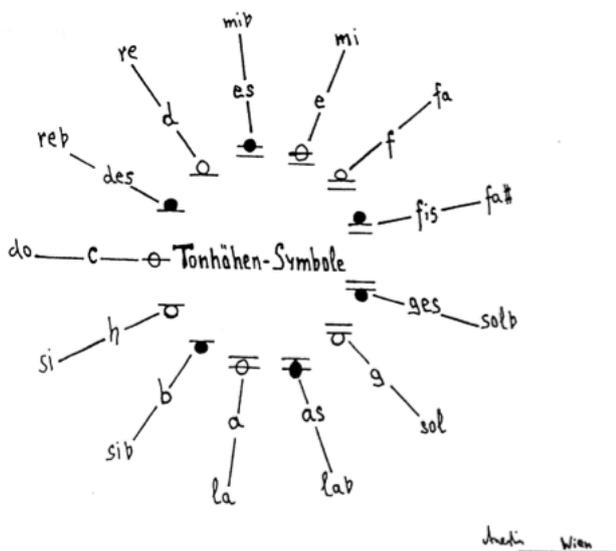


Figure 6. Pitch Symbols, Logothetis [9].

#### 4.1.2 Association factors

Association factors indicate loudness, timbre and sound character through the use of symbols as shown in Figure 7, and summarized in Table 1 below.



Figure 7. Association symbols, Logothetis [9].

Symbol	Meaning
Dots	Duration - Short
Lines	Duration - Long
Size/ intensity	Loudness
Shape	Character - Accent
Color	Timbre

Table 1. Summary of the correlation between form and meaning in Logothetis' association symbols.

#### 4.1.3 Action Symbols, Logothetis

Action symbols utilise lines and dots to represent movement, as shown in Figure 8 below.



Figure 8. Action symbols, Logothetis [9].

#### 4.2 Recreating Logothetis' graphic scores

Now, we demonstrate how the new macro-structure of SUM can be used to play an example graphic score, using a combination of Logothetis' sound symbols arranged non-linearly in graphic space.

As seen in Figure 9, a raster image of the original score is used as a starting point. The score is also analyzed both visually and aurally to reveal the structure of the piece. This structure is then superimposed over the original score with the help of the macro-layer. Then, the different sections of the piece are marked and identified using the vector-based macro-objects. Colors are used to both visually emphasize the different sections and to allow for the generation of the macro-events. In order to define the sequence of macro-objects, a path is drawn over the macro-layer to activate the macro-events in time.

As an example, we will examine more closely one of the macro-expansion patches. Figure 10 shows the definition of the "free pitches" section of Logothetis' graphic score. Here, we are using a combination of standard visual PWGL boxes such as those representing time-varying values and a few special SUM related boxes for defining the resulting musical texture. The box named "dur" (1) defines an entry point for an incoming parameter named *dur*. Here, we use the *dur* parameter to scale the result of the VIUHKA patch inside the duration of the incoming macro event. We are also taking full advantage of the advanced tempo modification features of the VIUHKA tool, by using a tempo function to control the internal temporal evolution of the generated texture. The two breakpoint functions shown at the top left of the patch (2) can be used to select the desired tempo modification, which, in our example, can be one of ritardando or accelerando. The breakpoint function in the middle of the patch (3) defines a complex pitch field that is used to generate the individual pitches of the given texture. In our case, the pitch field is defined in absolute pitch. An incoming pitch parameter could be used to transpose the pitch field to a desired range. However, in the case of this score, we will follow Logothetis' reference pitches.

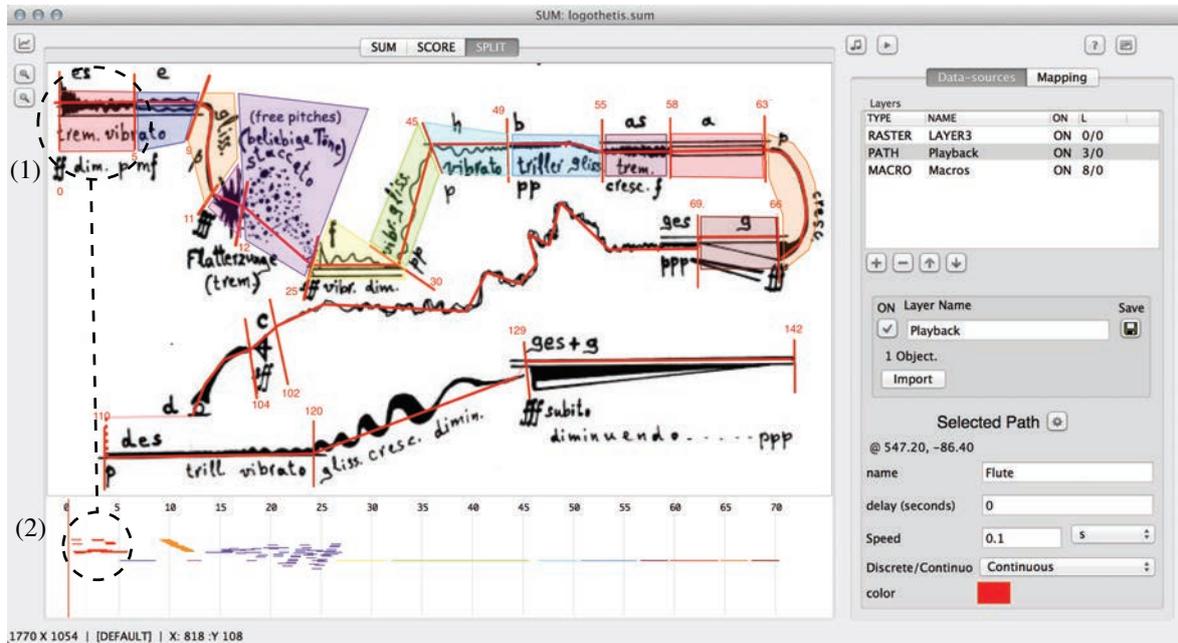


Figure 9. Reproduction of Logothetis' graphic score in the SUM tool

The resulting texture is shown in (4). The pitch contour follows the breakpoint functions given in (3) and the temporal evolution, in turn, follows the selected tempo function (2) by realizing a gradual accelerando. Finally, the box named “sum” at the bottom of the patch (5) completes the macro definition protocol and defines the exit point of the VIUHKA macro patch.

The resulting translation of image to sound is visualised in Figure 9. SUM's GUI shows the original graphic score, overlaid with its macro-layer of color-coded macro-objects above (1), and the resulting piano-roll of pitch versus time below (2). The connection between image and sound object, including the texture of the different sections, is clearly seen through the use of color. The sequence of macro-events, as defined by the vector time path, is maintained in the time axis of the piano-roll.

### 5. CONCLUSIONS

In this paper we have introduced the new macro-structure of the SUM tool, resulting from the powerful texture generation of the VIUHKA. The new macro structure has resulted in a closer integration with its computer-aided composition environment of PWGL. It has allowed us to reproduce the more complex graphic-sound objects of Logothetis, in particular their various textures and temporal evolution. As well as allowing us to execute, interpret and analyse existing graphic scores, it is also hoped that this system will aid other composers in the development of their own graphical notation systems.

### 6. FUTURE DEVELOPMENTS

In the future, further integration of the SUM tool with PWGL's computer-aided tools will allow even more powerful graphic score composition. The macro-events could

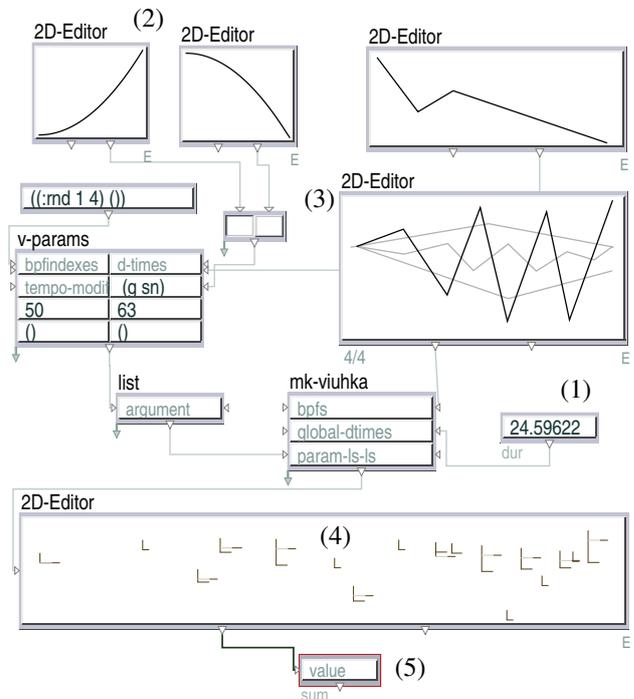


Figure 10. A VIUHKA macro patch defining the “free pitches” section. The patch contains two special SUM boxes named “dur” and “sum” which implement in the visual patch entry and exit points exposed to SUM.

be sent via OSC to other software packages such as MaxMSP. Furthermore, to make the SUM tool more extensible and open-ended, alternative macro-expansion schemes will also be provided, potentially linking SUM to other environments and/or programming languages. Finally, the visuals could be transferred from the PWGL

patch back to SUM to allow not only for the generation of the sonic events, but the graphical composition of the score as well.

### Acknowledgments

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