

THE UNIVERSITY OF CHICAGO

AUVI: AN AUDIO/VISUAL PERFORMANCE APPLICATION  
THE PROBLEMS OF AND THE SOLUTION TO AUDIO/VISUAL  
SYNCHRONIZATION IN LIVE PERFORMANCE

A MINORFIELD PAPER SUBMITTED TO  
THE FACULTY OF THE DIVISION OF THE HUMANITIES  
IN CANDIDACY FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY  
DEPARTMENT OF MUSIC

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CHICAGO, ILLINOIS

MAY 2006

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## I. Audio/Visual Synchronization - a Brief History

In Western concert music, the synchronization of large groups of singers and/or instrumental ensembles during live music performances has always been an issue. The rise of polyphonic music in the Renaissance made it necessary to develop ways to rhythmically organize the independent voices.

*Depictions of choirs from the 16th to the 18th centuries often show one man with his hand raised, evidently beating time. Often he holds a scroll of rolled-up paper in the time-beating hand. Some writers speak of the time-beater holding a small stick ('baculus') but depictions of this are rare. Sometimes it seems to have been the choirmaster or precentor who beat time; in other cases one or more of the singers apparently kept the beat without assuming additional authority.*

*The multiple-choir (cori spezzati) practices of the early 17th century made time-beating even more necessary. Viadana (1612) says that the maestro di cappella should stand with the first choir, controlling the movement of the music and cueing the entrances of the singers. When the additional, ripieno choirs are to enter, the maestro 'raises both hands as a sign that everyone should sing together'.<sup>1</sup>*

The clarification of rhythmic notation around the 16<sup>th</sup> century was certainly a large step forward in achieving temporal synchronization between separate instrumental

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<sup>1</sup> J. Spitzer, N. Zaslav: 'Conducting', *Grove Music Online* ed. L. Macy (Accessed 9 April 2007), <<http://www.grovemusic.com>>

and vocal parts.

*Modal rhythm and its subsequent revisions opened manifold possibilities for temporal coordination, as it became possible to conceive of temporal coordination against an abstract series of durations rather than in terms of one actual part against another. (...) The earliest Western polyphony was notated in score format. This generated an immediate sense of synchronization of its component voices. The shift from score notation to partbook or column notation (with the tenor at the bottom) presupposes the presence of an abstract series of durations which governs the rhythmic structure in each part.<sup>2</sup>*

The complexity of music, however, and the growing size of the instrumental and vocal groups made it more and more difficult to create a well synchronized performance. The production of stage-based works, such as operas, for example, which involved the precise synchronization between the orchestra, singers and stage crew, was even more of a challenge. Up until the beginning of the 19<sup>th</sup> century, in order to make the performance of large ensemble compositions possible, the composers (very often the principal musician of the given ensemble) had to lead the musicians by playing an instrument (violin or harpsichord) and/or beating time audibly by striking an object and thus disturbing the concert. Jean-Baptiste Lully was a famous French composer who used his cane to beat the time during performances. In fact, during the performance of his *Te Deum* in January 1687, he injured his foot with the point of his cane. The self-inflicted

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<sup>2</sup> J. London: 'Rhythm, §II: Historical studies of rhythm', *Grove Music Online* ed. L. Macy (Accessed 9 April 2007), <<http://www.grovemusic.com>>

injury subsequently spread to his leg and lead to his death three months later. During the 18<sup>th</sup> century, opera orchestras and productions grew in size and the relationship between the ensemble and the voices became even more complex. The performances were lead by two leaders, the composer himself playing the harpsichord, and the principal violin player. This so-called dual-leadership system was confusing for the performers involved as the authority lines were rather blurred. When taking into consideration the forces necessary for opera productions, one cannot forget the often underestimated and forgotten contribution of prompters, who, for centuries, aided the performers. Located in a box on the stage, with the help of a mirror (currently often a TV set), they are able to clearly see the conductor and thus cue the performers, often providing them with lines of forgotten text, and making sure their singing is well synchronized with the orchestra.

The first two decades of the 19<sup>th</sup> century brought an important improvement in the synchronization of musical performance. Composers like Ludwig Spohr and Carl Maria von Weber started to use a violin bow, rolled manuscript paper and finally a baton during orchestral performances to facilitate synchronization between the involved forces. The directors of the orchestras became called conductors and took on the role of leading stage personalities in the mid 19<sup>th</sup> century. The slow separation of the role of the conductor and the composer, as well as the increasing number of performances of pre-existing compositions by composers who were either deceased or not present for the performance, raised concerns over issues related to musical interpretation and the boundaries of freedom during live performances. By the end of the 19<sup>th</sup> century, conductors leading performances of new and old compositions were leaving their mark

on the composition with their own personality and interpretation.

The invention of the phonograph by Thomas Edison in 1877 brought about important changes to the music industry. For the first time in history, music lovers were able to listen to music not performed live by musicians, but reproduced by a mechanical device. Thus it happened that the visual component typically associated with live performances became separated from its usual musical counterpart. On the one hand, the phonograph enabled music to be popularized, but on the other hand, it limited the freedom of interpretation. From this moment in history onwards, every time a recorded work has been played using a mechanical device the reproduction of the work has been exactly the same.

The invention of the motion picture camera in the second half of the 19<sup>th</sup> century<sup>3</sup> proved just as important for the visual arts as was the invention of the phonograph for the musical arts. Motion pictures were, however, a purely visual art. Until the 1920s, when new technology allowed for the production of films with attached soundtracks, the moving pictures were silent. Just as the visual component was detached from music with the invention of the phonograph, the associated sound component was detached from moving visual images with the invention of the motion picture camera. Even though listeners quickly got used to hearing mechanical reproductions of music without visual representation of the performers, film producers and theatre owners were aware that it was (and still is) very awkward to see two dimensional, moving images without

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<sup>3</sup>Although the Frenchmen Louis Lumiere is sometimes credited with inventing the first Motion Picture Camera, the Cinematographe, in 1895, others, such as Edison and Dickson had developed similar inventions around the same time.

accompanying sound. In his *The Silence of the Silents*, Rick Altman quotes an interesting fragment of an article from *Nickelodeon* written by an anonymous author about Gregg Frelinger's selection of piano music to accompany films:

*Exhibitors are rapidly becoming educated to the value of appropriate music incidental to the pictures shown. Not only is the effect of the program greatly enhanced by the use of appropriate music, but the pictures themselves take on a more realistic and pleasing atmosphere. It is safe to say that the proper musical accompaniment doubles the attractiveness of any moving picture.*<sup>4</sup>

The reason that music accompaniment is vital for the “attractiveness of any moving picture” is that although a majority of information is received by humans through our eyes (over 70%)<sup>5</sup>, it is speech and the hearing system which allows us to communicate with the world outside of ourselves. This is no doubt the main reason why silent films were never really silent. Silent movies more often than not featured slides with text written on them because vision alone was not in any way sufficient to effectively communicate the plot. This alone illustrates the importance of sound for the communication and exchange of ideas.

There was not an industry standard in which music and sound were presented during the silent film shows. In the late 19<sup>th</sup> century, lecturers describing the films were quite common during the moving picture presentations. Attempts were made to create a

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<sup>4</sup> 106. *Nickelodeon*, 1 May 1910, 239. after Rick Altman's *The Silence of the Silents*, Musical Quarterly, Vol. 80, Oxford University Press, 1996; p. 679

<sup>5</sup> S. Abramson: "Sense-sational", *Health* ed. S. Kelley (Accessed 22 April 2007), <<http://www.health.com>>

technology which would make it possible to present films with synchronized music. In the last decade of 19<sup>th</sup> century, Thomas Edison and William Dickson invented a Kinetophone: a device to play movies with accompanying sound. Other attempts included Leon Gaumont's Chronophone, and the Elgephone invented by Horace Short and Charles Parson. All these inventions involved sound-on-disc technology linking a phonograph with a film projector. There were many reasons, however, why these technologies never became very popular. Phonography-based sound film systems lacked standardization, as they were often developed, patented and produced by different companies than movie production companies. Furthermore, the synchronization of the sound and film was very poor. When films began to be presented in large movie theatres, the sound could not be projected well in such large spaces. In fact, it was not possible to do so until the invention of electric amplification circa 1925.

In the first two decades of the 20<sup>th</sup> century, theatre owners would often hire musicians to accompany movies with live music. An improvising pianist or instrumental ensembles played music during the silent film shows and tried to match the mood of the film. The lack of clear directions as to what kind of music should be played during a given scene led to many misinterpretations. Rick Altman points out in his article *The Silence of the Silents*:

*Starting in 1909, ... recognizing that they were losing control over the interpretation of their own products, film producers waged a series of campaigns to reduce the current*



*cacophony to a set of standardized practices.*<sup>6</sup>

Beginning in 1909, movie studios provided cue sheets for films which organized the music by mood or dramatic situation. Following the success of D.W. Griffith's 1915 film *The Birth of a Nation*, pre-composed movie scores were often performed during the movie shows. Music and image were reunited.

Performing live music with motion pictures draws attention again to the problems of the synchronization of music with a visual medium (assuming synchronization is desired). In order to synchronize a live orchestral performance with a film in the early cinema era, the conductor was provided with a stopwatch. The tempo of the music was thus adjusted to the constant projection speed of the film. The freedom of musical interpretation and the individuality of live musical performance were, therefore, greatly restricted.

Throughout the 1920's, inventors and film producers were constantly experimenting with sound-on-disc systems, which eventually allowed them to release films with synchronized sound. In 1926, Warner Bros. introduced the Vitaphone, a sound-on-disc system, which used electronic amplification, making it possible to play films with synchronized music at a comfortable volume for large audiences. Following the success of *The Jazz Singer* (1927), the first movie with synchronized dialogue, and then of *The Lights of New York* (1928), the first movie with all-synchronized-sound, the movie industry moved into the sound era. By 1929, all movies featured sound. The

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<sup>6</sup> R. Altman: *The Silence of the Silents*, Musical Quarterly, Vol. 80, Oxford University Press, 1996; p. 690

sound-on-disc technology was soon followed by sound-on-film technology in which the sound accompanying the visuals was recorded directly on the photographic film. As a consequence of the growth of the film industry and sound-on-film technology, various techniques were developed to achieve exact synchronization of the music and motion pictures during recording sessions. One of these techniques, still in use today, is the “click track”, an audible beat in variable speeds heard over headphones by the conductor, which, when used in conjunction with a movie projection at the back of the orchestra, greatly improved musical cueing and the synchronization of the two separate mediums. Streamers (in use since the 1930s), vertical lines moving over the screen, are yet another way of giving the conductor cues as to how fast the music should be played in order to unite music and visuals temporally. Currently, all synchronization is done in post-production using computer software which generates click-tracks and streamers. Films are viewed on video monitors and time code, a precise time/frame counter, helps to achieve exact synchronization between the two independent mediums. The introduction of synchronized sound into films resulted in a boom for the movie industry. Music, however, lost some flexibility, independence, freedom and a great deal of artistic expression when presented in conjunction with films. Live music, performed during silent film shows, was entirely replaced by pre-recorded and edited music synchronized with film in post-production.

Film music not only took on a subordinate role in serving the picture to create the right mood, often overpowered by dialogue and special effects sounds, but it also lost any trace of freedom that was present during live performance. With only a very few

exceptions throughout movie history, music was always composed for the feature films after they were already completed<sup>7</sup>. In fact, film composers are often called upon only when the rough cut of the movie is finished. The time allotted to composers to complete the music for full length feature films is usually restricted to a maximum of eight weeks, often less. An extreme example of this practice was implemented during the composing and recording of James Horner's two-hour-long score for *Troy*, directed by Wolfgang Petersen. The scoring mixer Simon Rhodes recalls the rush in which the music was composed and produced:

*James had 13 days to write the music. There was a moment when he was writing 10 minutes of music a day and there's about two hours of music in the film, a fair amount of it orchestral, and we had 12 days to record it." Recording began on April 10, working seven days a week until completion on April 21, with final dubbing done in London the following day.*<sup>8</sup>

The time available to film music composers, when compared to that which would be needed by composers of so called "art music" for a work of similar length, is astonishingly short. For that reason, composers have to employ one or more orchestrators to help them complete a full score. Examples of composer/orchestrator collaborations include those of Erich Korngold with Hugo Friedhofer, John Williams with Herbert Spencer, and Jerry Goldsmith with Arthur Morton, among others. As a result of this

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<sup>7</sup> Extraordinary examples of music composed before the movie was filmed includes Ennio Morricone's score for *Once Upon a Time in the West* and *Once Upon a Time in America*

<sup>8</sup> M. Hurwitz, "Recording the Score for Troy", Mix Online ed. T.Kenny (accessed on 10 April 2007) <http://mixonline.com/>

procedure, the music loses its individuality and the composer his/her artistic uniqueness and artistic vision. In fact, it is quite common that when the score is too original the producers, right when the movie is due for release, reject it. New music is then commissioned and its artistic quality and instrumentation is usually much poorer than the original score, due to the extreme time limitations and the burden of having to compose something not 'too unusual'. An infamous example of this procedure is John Barry's syrupy score to Joffe's *The Scarlet Letter*, which replaced two rejected scores composed previously for the film by Ennio Morricone and Elmer Bernstein. The decision is often made not based on the artistic quality or musical appropriateness of the score, but on commercial bets, based on specially organized pre-release movie previews. Gabriel Yare, the composer of the original score for *Troy* (directed by Wolfgang Petersen) writes about the events which led up to the rejection of his score by Warner Bros. Pictures.

*After the test screening on 10th March, though, everything had changed. The focus group at the preview decided my music was "overpowering and too big, old fashioned and dated the film." Thus in this 24-hour period my score was completely rejected by director and studio, and a collaboration of one year came to an end, despite the fact that it was unfinished work and that the dub was temporary and, although good, not always perfect. What shocked me the most was that I wasn't given the chance to fix or change my score or even to answer to any of the questions or accusations being leveled at my work, despite the fact that I had sessions booked to redo some cues to the new picture and new versions of other cues. Indeed, the decision to replace me had been taken and meetings with other composers had already taken place before I even spoke personally to*

*Wolfgang. I was later informed that it was "...a problem with the writing" and that the score was beyond the hope of being fixed and they were happy to have a new composer write the whole score just a month-and-a-half before the worldwide release on the 14th May.*<sup>9</sup>

The relationship between moving pictures and sound was, on occasion, reversed when the image was used as a visual illustration for the music. The practise existed from the early stages of the sound film and was popularized by Walt Disney's series of short cartoons *Silly Symphonies*, produced in 1929 and throughout the 1930s, and by the full-length animated feature film *Fantasia* (1940). Throughout the 40s and 50s, the Panoram, a film jukebox, popularized soundies, short three minute long films which featured popular jazz artists of the time, such as Duke Ellington, Count Basie and Cab Calloway. The Panoram consisted of 16mm films projected on glass. A similar idea was used for the Scopitone, a French color film jukebox popular in 60s. The fast expansion of pop music culture and the subsequent corporate need to promote new pop artists further cemented new conventions of visualizing music. Films like the Beatles' *Help* from 1965 were distributed to promote the artists. In 1975, a visualization of Queen's *Bohemian Rhapsody*, created by Jon Roseman and Bruce Gowers, had a large influence on record sales. The visual effects used in this promotional clip helped to establish the visual language of popular music and, for that reason, is often quoted as the first modern music

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<sup>9</sup> Gabriel Yare: "The Score of Troy — A Mystery Unveiled", The ScreamOnline ed. S.Vail (accessed on 10 April 2007) <http://www.thescreamonline.com/>

video. The genre was largely popularized with the creation of MTV (Music Television) station in 1981.<sup>10</sup>

The dominance of the big film production companies in the creation of motion pictures declined with the release of the Portapak in 1965, the first portable video camera/recorder produced by the Sony Corporation. Before then, the only way to capture moving pictures was to use film cameras which required expensive celluloid film or by using the technology of TV broadcasting. Television cameras, contrary to film cameras, captured moving pictures using electronic technology and cathode ray tubes. Portapak was the first video camera available commercially that used a similar method of capturing images to that used in TV broadcasting. However, it was small enough to be carried by a single person. The captured images were recorded onto magnetic tape, which could later be viewed on one's television using a video cassette player. The quality of the image, although not very good in early video cameras, allowed for the creation of visual works independent from TV broadcast corporations and the established film industry. Until the release of Portapak, video equipment was extremely expensive and heavy, which made the production of video images possible only in the tightly controlled environment of TV broadcasting facilities. The new portable cameras brought a fresh air of artistic freedom to artists, who now were liberated from the profit-oriented productions of big film and TV corporations.

The decentralization of moving pictures production resulted in the creation of a new art form, video art, which broke away from established film conventions. Video art

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<sup>10</sup> Alf Björnberg: "Video", Grove Music Online, ed. Stanley Sadie (accessed on 10 April 2007) <http://www.grovemusic.com/>

uses moving images but does not necessarily have to employ actors, have a narrative or plot, does not require a big production crew and does not have to follow a traditional music/visuals relationship. Most film directors and cinematographers employed in the movie industry are forced to work using certain conventions and under particular constraints imposed by the big movie production corporations. This means that they usually have to adhere to the corporation's idea of how motion pictures should be made. Video artists may not be so constrained in their practical and aesthetic approach to their art. The beginning of video art is often attributed to Nam June Paik; a classically trained musician influenced by the art and ideas of John Cage. The first video recording was, according to myth, made by Paik using the Portapak during the Pope's visit to New York in the Autumn of 1965 and was played by the author in New York City's Café a Go-Go the same day (this fact is often questioned as Portapak was not available in New York until 1967).

The independence of video artists made possible a new relationship between them and artists working in sculpture, dance and music. An excellent example of changing traditional relationships between arts like music, dance and visuals can be seen in John Cage's *Variations V* from 1965. The piece is a collaborative work between Cage, David Tudor, Gordon Mumma, the Merce Cunningham Dance Company as well as Stan VanDerBeek and Nam June Paik, who manipulated television images projected on a screen behind the dancers. The sound was created using a series of photocells and radio antennas which picked up the movement of the dancers. Cage, Tudor and Mumma

modified the final sound. The traditional relationship between live music and video/technology was often questioned by Paik. In the piece *TV Brassiere for Living Sculpture*, he incorporates sound and video art as an integral part of the piece.

*TV Brassiere for Living Sculpture is one sharp example to humanize electronics ... and technology. By using TV as bra ... the most intimate belonging of human being, we will demonstrate the human use of technology, and also stimulate viewers, NOT for something mean, by stimulate their phantasy [sic] to look for the new, imaginative, and humanistic ways of using our technology*<sup>11</sup>.

The influence of new types of collaborations between music and the visual arts quickly expanded from small performances to large scale operatic and music-theatre works. One of the most influential of these works is *Einstein on the Beach*, an opera/music-theatre piece which resulted from a collaboration between Robert Wilson and Philip Glass and was performed for the first time during the Avignon Festival in 1976. The five-hour-long performance of the piece comprises of four acts and five “knee plays”, and is not based on a traditional libretto but is a result of both the composer’s and director’s mutual influence:

*The ‘story’ of Einstein comprises visual images and aural references relating to Albert Einstein, his life and his work. Glass and Wilson used as a ‘libretto’ a sketchbook of visual themes, before developing a spoken and sung text during the rehearsal period.*<sup>12</sup>

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<sup>11</sup> Douglas Fogle: “Curatorial Essay”; Walker Art Center; (accessed on 10 April 2007); <http://www.walkerart.org/>



In 1993, a collaboration between composer Steve Reich and video artist Beryl Korot resulted in a large, three hour long multimedia opera, *The Cave*. The piece creates yet another alternative of traditional music theatre form: it calls for a five channel video recording presented on five large screens placed on the stage, replacing traditional actors, stage and plot with video recordings of interviews. In the program notes for the 2006 performance of the piece in the Barbican Theatre in London, Beryl Korot comments on the influence of the portable video on the development of art:

*In the early years of video, late 1960s, early 1970s, we talked about the fact that video was then a one-way communication from the networks to the home, but with the advent of portable equipment, and the proliferation of video equipment in general, people could begin to write in the medium, as well as read it. The possibilities for visual literacy increased, but this whole area of creating with such tools and developing new forms for presenting visual information is still so new. And the idea of creating something that was both rich in information and formally adventurous is a challenge the medium seems to offer, and yet is not often explored.*<sup>13</sup>

As one can see in above examples, new technology provided new means of artistic expression and new audio-visual art forms such as, for example, performance art or music-theatre works. The development of technology helped to bring together composers,

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<sup>12</sup> Tim Page: 'Einstein on the Beach', *Grove Music Online* ed. L. Macy (Accessed 27 March 2007), <<http://www.grovemusic.com>>

<sup>13</sup> Fragment of the interview with Beryl Korot and Steve Reich by Jonathan Cott from program note printed from the libretto, Barbican Theatre, London, 2006

visual artists and choreographers as well as helped artists question the role of new technology in contemporary society.

## II. Digital Technology and Audio/Visual Synchronization

In the modern world, computers have become an important instrument in the creation and presentation of art. The digital medium, in and of itself, is very hybrid, in that it allows for the transformation, mapping and reuse of large amounts of data. As William Gibson writes in the Foreword to *Multimedia*:

*Digital computers were initially designed as calculating machines. The first fully electronic computer, the ENIAC, was built by the United States military during World War II to produce ballistics tables for artillery in battle ... Computers then were clumsy, hulking devices ... that did calculations for scientific research. Only a handful of scientists considered the possibility of personal computing for creative purposes by nonspecialists.*<sup>14</sup>

It took hundreds of years and generations of artists to develop traditional tools, such as oil paint or musical notation, used in the creative process. Although digital technology accelerated the development of traditional and new artistic forms, it has been on the artistic landscape for only a small fraction of the time humans have been creating art. Its relative newness generates non-art related obstacles for artists. A few select ones have had the privilege to work with programmers, engineers, scientists and designers who assisted them in overcoming these obstacles. Most, however, have had to master the new

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<sup>14</sup> W. Gibson: "Geeks and Artboys", *Multimedia* ed. R. Packer, K Jordan, New York W. W. Norton & Company, Inc. xvii.

skills and tools to overcome the technological gap between traditional tools and new technology. Currently, artists are asked to create new technologies, and then to use them to critically comment on the surrounding and/or internal world.

The function and importance of digital technology in art varies and depends on the individual artist's perspective. However, one can certainly distinguish two basic ways artists use computers. For one, digital technology is used as a tool assisting in the art creation process. Completed works are later presented in more traditional art forms, such as painting, sculpture or photography. An interesting example of such use of technology can be seen in a series of sculptures called *Skulls* by Robert Lazzarini. The artist used 3D computer-aided design files that were distorted and then produced as sculptures. A second way of using digital technology in art employs the technology as its very medium, making use of its interactive and participatory features. An example of such usage can be seen in multimedia installations or in virtual reality environments. Two examples of classic virtual reality environments are *Osmose* (1995) and *Ephemerer* (1998), created by the Canadian artist Charlotte Davies. Although the above examples are related to the visual arts, one can find similar distinctions between using computer technology as a tool and as an interactive medium in the musical arts as well. The most obvious example of the utilization of computers as a tool is their ability to be used as a publishing device. Thanks to computers and low cost printers, copying and printing scores became easy and cheap, thus liberating composers from big publishing companies.

Composer assistance computer applications, such as *Open Music*, developed by the Institut de Recherche et Coordination Acoustique/Musique (IRCAM), are examples of

more complex tools which help composers to create unexpected musical structures, which are often performed later by acoustic instruments. Computers are currently essential mediums for the creation of electronic music compositions and interactive works that take advantage of live sound creation and performance.

Currently, the boundaries between the disciplines, such as the visual and musical arts, science, technology and programming, are collapsing. More and more artists try to create multidimensional art in which visual and musical elements are of similar importance. When approaching the creation of audio-visual works, the issue of synchronization between the visual and musical elements arises. When a work is written for fixed media, such as film or video, the musical and visual components are most often created separately and then synchronized in postproduction using specially designed software. However, when the composition has a live musical component, synchronization between live instruments, computer generated sounds and video becomes a major challenge. The most common solution to this problem is to restrict the freedom of the live performers and force them to adjust their performance and tempo to the electronic or visual element. Examples of this can be seen in pieces for live instrument(s) and tape. The musicians have to follow exactly the time guidelines provided, often using a stopwatch to synchronize the tempo, rhythm and duration of their performance with the fixed media. Mario Davidovsky's *Synchronisms*, a series of pieces for acoustic instruments and electro-acoustic tape, are examples of this synchronization technique. A slightly different approach is used by Jaroslaw Kapuscinski in his composition *Catch the Tiger* for video and piano. The performer is provided with a click track with the

tempo/beat of the piece via headphones. Both solutions, however, restrict greatly the flexibility of live performance. The tempo and duration of a musical performance often depends on multiple factors, such as acoustics, the atmosphere of the performance hall, audience reaction, characteristics of the individual instrument or the disposition/mood of the performer(s). By specifying exactly the musical pace, the composer limits the players ability to use the tempo to enhance the quality of the performance. Furthermore, watching a stopwatch or listening to a click track distracts the player, who is unable to pay full attention to the music she/he is playing.

A partial solution to the problem of synchronization between live performers and electronic media is to use MIDI sensors on the instruments to physically track the action of the musicians. The sensors send MIDI data in response to some characteristics of the musical performance, like, for example, the pitch or the dynamics. This data is later used by the computer to trigger particular musical or visual events. Various MIDI controllers, such as wind controllers similar to the Yamaha VX7 wind MIDI controller or various keyboard MIDI controllers, among others, were developed and made synchronization using MIDI relatively available and common. However, they operate only in the digital realm and can be used only as controlling devices that cannot, by themselves, produce convincing emulation of acoustic sound. It takes years of practice to develop the technique to master any acoustic instrument. Recognizing this problem, manufacturers such as Yamaha created instruments which took advantage of both the digital and acoustic realms. The MIDI Piano is a full sized piano capable of producing acoustic sound and, at the same time, by virtue of sensors picking up the player's physical activity,

is also capable of sending MIDI information to a MIDI interface and, ultimately, a computer. The price of these instruments, however, makes this technology very inaccessible, as it hovers around \$30,000, depending on the size of the instrument.

Although the MIDI Piano very successfully combines the digital and acoustic realms, it is an exception. Other attempts to combine both worlds using string or wind instruments are rather ineffective due to the complexity of the instrumental sound, on the one hand, and the intricacy of the physical movement of the performers, on the other.

Composers may dream about computers being able to follow the score of their composition, triggering given video sequences, electronic sounds and processes at the appropriate time. In fact, efforts have been made to make such synchronization possible. In a few recent compositions, such as Philippe Manoury's *En Echo* for soprano and computer or Mark Volker's *Deep Winter* for flute and electronics, the computer analyzes the sound of the instrument, picked up by and converted into an audio signal via microphone. The pitch detection algorithms allow for the conversion of the pitches into MIDI information. This information is later compared with the score, which was saved earlier as a MIDI sequence on the computer. As a result of this operation, the computer is able to track and follow the pitches played by the musician and trigger the musical and video cues at the proper moment. Although the pitch tracking of acoustic instruments is sometimes very effective, there are still many problems with the implementation of this technique. The pitch tracking algorithms are fairly accurate when applied to monophonic instruments with quasi-periodic or virtually periodical waveforms, such as the flute or clarinet. They are much less successful, however, with instruments capable of playing

polyphonic voices. Pitch tracking becomes a very complex process when applied to more than one instrument, and currently it is practically impossible to track the pitches of larger instrumental ensembles.

The majority of developers currently creating the available software for audio and video production and performance, as well as the manufacturers of audio and video hardware, focus mainly on customers working within the realm of pop culture, or the burgeoning market for amateur enthusiasts. The technological advancement of the software and hardware, as well as the large number of companies developing related products, creates a very competitive environment in which the improvement of products largely depends on the commercial success and sale numbers of existing products. However, in the early stages of computer technology, the development of software and hardware for artistic purposes was carried out by classically trained artists and was centered around universities and their computer music studios. John Chowning's development of the Frequency Modulation Synthesis technique at Stanford University is a perfect example of an early electronic music discovery which was made by a classically trained composer and that had a huge impact on the music technology industry. Currently, because the computer software and hardware used in art production has reached a very high level of complexity, the main work in developing new products is done by computer programmers and engineers. The products, most of the time aimed at reaching the pop art industry, are often used by classically trained artists, who try to bend the software and hardware capability to their own needs. An instance in which this practice was implemented was during Howard Sandroff's (electronics) and John Bruce



Yeh's (clarinet) performance of *Dialogue de l'ombre double* by Pierre Boulez in 1989. Sandroff used a set of three commercially available digital Yamaha stereo mixers to create a performance of a complex multi-channel piece at a time when multi-channel presentations were possible only in select institutions due to the availability and cost of the equipment.

Currently available software designed for the creation and/or performance of audio and visual works can be separated into a few main groups. The first group, operationally the simplest, comprises of digital media player applications that imitate tape, CD or DVD players. Apple's iTunes and Windows Media Player fall under this category of software. The applications are often capable of playing back previously uploaded audio and video files and often allow for multiple audio and video formats. However, just as with tape and CD players, digital media player applications are almost useless in live performance situations. Although they can be used to perform fixed media compositions, the cueing of separate tracks can be very cumbersome. These player applications usually do not allow multi-track playback nor live sound and/or video manipulation. An interesting feature of the digital media player, which usually comes with the application, is the visualizer. The device responds to some characteristics of the sound, such as amplitude or spectrum, and uses fractal algorithms to generate ever changing visuals. Although images generated by visualizers can be very interesting, the mechanical nature of the process makes them rather tiresome and monotonous after a while.

A more sophisticated group of software deals with recording and the production of original source data as well as with postproduction and the manipulation of captured

material in closed, studio like, environments. Separate tools are usually developed for audio and video media. The audio software, also often referred to as sequencing software, is usually connected to an audio interface which converts the signal from analog to digital or vice versa. The most popular software, which is currently considered an industry standard, is *ProTools*, by Digidesign. It is used in most professional recording studios. The full version of *ProTools*, with its necessary hardware, costs about \$14000 and largely exceeds the resources of most individual artists. Other, cheaper sequencing programs, sold without audio interfaces, include *Cubase* (priced around \$1000) developed by Steinberg Media Technologies GmbH, Apple's *Logic Pro* (\$1000), Motu's *Digital Performer* (\$500) and Ableton's *Live* (\$500), among others.

The visual arts software parallels to audio sequencing software are video editing programs like *Avid Xpress* (priced at about \$2000), Apple's *Final Cut Pro* (\$1300) and *Adobe Premiere* (\$850). Both audio and video editing programs can be used as compositional tools, allowing editing, and manipulating of earlier captured material in great detail. More sophisticated software like Digidesign's *ProTools* or *Final Cut Pro* allow precise synchronization of the audio and video sequences, often in multi-channel audio environments. However, the primary objective of sequencing and editing software producers is for postproduction and to provide tools for capturing original material. These programs are not intended for use in live concert situations. Although they provide multi-channel capabilities, when used in conjunction with live instruments, the lack of a clear and easy to operate cueing system, as well as the lack of live processing capabilities, makes recording software virtually useless during live performances.

A separate category of hardware and software has been developed to accommodate the needs of disk jockeys (DJ) and video jockeys (VJ). Both DJs and VJs perform live manipulating, cueing and mixing of prerecorded media. The hardware traditionally used by DJs for manipulating audio often consists of DJ consoles, turntables and DJ mixers, which allow the performers to seamlessly switch between records or CDs, applying various real-time effects. With the improvement of the speed of computer processors, companies started to develop software versions of the hardware, which, instead of playing vinyl records or CDs, play audio files. An example of this type of software is Torq DJ Software developed by M-Audio.

Video Jockeys use a similar type of software to manipulate video files instead of audio files. One of the more advanced examples of VJ software is *Arkaos VJ DMX*. The system consists of image processing software and separate hardware accelerated video processing cards, which enable multiple video projections and manipulations. The cost of the software is about \$850 and is rather expensive for individual users. Both DJ and VJ software is developed with popular culture customers in mind and is not really used in high art concerts.

*Isadora*, developed by the company Troika Tronix, is an interesting graphic programming environment, providing interactive control over digital media with a special emphasis on live and real-time manipulation of digital video. Unlike other live video processing applications, the program offers building blocks that can be linked together to create a performance specific environment. Although primarily concerned with video processing, *Isadora* shows that open structure environments offer much more flexibility

to artists. The downside of open structure environments is, however, that they are usually characterized by a high level of complexity and have a slow learning curve. The main shortcomings of live video processing programs is the fact that they do not provide a simple and easy to use interface which can be used in conjunction with live, classically trained performers, their audio processing capabilities are very limited and they are typically rather expensive.

One of the most popular and actively used open programming environments for live audio and video performances is *Max/MSP/Jitter*, an object oriented programming environment distributed by Cycling'74. *Max/MSP/Jitter* offers almost unlimited possibility for artists to create and manipulate digital audio and video media by using a system of objects/applications interconnected graphically. Although extremely versatile and open, the downside of this environment is again its complexity and its very slow learning curve. A positive aspect of *Max/MSP/Jitter* is that, similarly to any other programming language, it allows the programmer/artist to create independent, individual project oriented applications. An example of an interesting application created in *Max/MSP* (the version of the program without Jitter – the video processing collection of objects) is *MaWe* developed by Marcin Wierzbicki and Marek Choloniewski. The complete program consists of a set of audio players, which can be linked together and processed live in conjunction with live instruments, or not. The audio players can be turned on/off using a computer keyboard or MIDI controllers and can have live sound manipulation components applied live via a system of plug-ins.

The summary above of the existing types of software for audio and video

production/performance demonstrates that the available applications are usually concerned with either the audio or video aspects of audio-visual production. Software with more available options as well as open programming environments are very complex; they require a lot of technical knowledge and experience in audio/video processing and programming. Most of the existing applications are limited to either the recording/postproduction end of the creative process, or, if they are created for live performance, the main target of software developers is popular culture customers and the software therefore deals with the mixing of prerecorded video and audio samples. One clearly sees that, although the existing computer technology is capable of handling the computational power necessary for the live presentation of audio-visual works with live performers, the software available currently for this type of presentation has either very limited audio and/or video capabilities, or is very complex to use. More sophisticated systems tend to be extremely pricey. *AuVi*, an audio/video performance software, attempts to fill this existing gap and addresses the issue of synchronization of audio and visual material in live performance situations.

### III. A Guide to *AuVi* – an Audio/Video Performance Application

*AuVi* is a free software designed to assist composers and performers during concerts of multi-channel audio or audio/visual works with live instruments. The software was created in the Max/MSP/Jitter object oriented programming environment. The full version of Max/MSP/Jitter can be obtained online from [www.cycling74.com](http://www.cycling74.com) or can be used in the free Runtime version of this environment (available at the same domain address). The necessity for such a program became apparent when trying to perform the author's own *Eppur Si Muove* for chamber ensemble, four channels surround electronics and video in May, 2006. The difficulty in finding affordable software that would allow precise live synchronization of multi-channel audio and video cues with a live ensemble with a limited rehearsal time forced me to create a new application, which later became the fundamental concept of *AuVi*. The basic functions of the application allow the performer of the computer audio/video part to start the pre-recorded and pre-set cues at any given time of the piece and to adjust the speed of the video performance to the variable tempo of the ensemble. This way, the video part does not constrain the flexibility of the performers and can be adjusted 'on the fly' by the performer of the electronics part. Whenever a new software is developed, the question of how complex/flexible the application should be must be addressed. Optimally, the computer program is simple to operate and, at the same time, gives the user unlimited flexibility. Unfortunately, with flexibility comes complexity. The more options the application offers the more time the user has to spend learning them. *AuVi* is a simple to operate multi-channel audio and

video player application and can be operated even by those without extended knowledge of computer programming. In order to overcome the simplicity vs. flexibility issue, *AuVi* offers only very basic operations and lets the more advanced users design more complex functions using the unlimited resources of the Max/MSP/Jitter programming environment. The advantage of this solution is that *AuVi* can be adapted for different types of projects and, although the original concept does not include any live audio and/or video processing, it can be easily expanded to include them. This way, it does not force the author of the work to use application specific real time operations, but allows artists with more programming skills to develop project specific processes. The limit of how the application can be expanded and used depends solely on the knowledge of the user.

Many works for live instruments with electronic media use pre-composed electronic material which should be started at particular points in the piece. The performer of the electronic part follows the score and starts the cue at the appropriate time with or without a sign from the conductor or musician. *AuVi* is designed to make the performance of works using multi-channel pre-composed audio and video easy by clearly indicating cues currently playing and those which are upcoming. The audio and video material used during the concert should be created in advance using software better suited for audio and video editing/processing.

During the performance, *AuVi* is controlled from the main user interface window, which appears automatically when the application is opened. The interface window is divided into several main segments, each containing a different function. In the upper

part of the window, against the brown background, one can see tools for uploading audio and video files. The video playing engine implemented in *AuVi* uses Jitter's QuickTime movie playing object 'jit.qt.movie' and therefore is capable of playing all QuickTime supported formats. The object plays the movie directly from the disk. When the yellow 'Load Movie' button is pressed the user can upload the movie into the program. In the middle of the brown strip in the upper part of the window, the user can specify the number of audio and video cues necessary for the performance. The program uses the scripting available within the Max/MSP/Jitter programming environment to create the cues. Each cue represents a small audio/video engine. The program supports up to 175 cues in one session, which should be more than sufficient for one session. Setting the exact number of cues necessary to perform a given project or concert makes *AuVi* a project specific application. Each object in Max/MSP/Jitter represents a small program. Therefore, by limiting the number of cues to that which is necessary, the user saves the computer's processing power. When the yellow button Load Files is pressed, a new window appears with pairs of audio/video playing engines numbered from 1 to the cue number specified by the user. The objects named 'player' represent audio engines, the ones called 'vidcue' represent video cues. The number next to the name is associated with the cue number. The individual and previously created audio files can be set to each audio player by pressing the little squares, or 'toggles', above the 'player' object. *AuVi* currently supports 4 channels of audio at the same time and each square represents one audio channel. Audio files loaded to channels 2-4 should be mono, the one loaded to channel one can be either mono or stereo. This gives the user the option to use a stereo



interlaced audio file which will be loaded to both the first and second channels. When double-clicking on any of the ‘player’ objects, one can discover the inner mechanics of the playing engines. The application will play audio files from any specified location using Max/MSP/Jitter’s ‘sfplay~’ object, which plays the AIFF, WAVE and other types of audio files directly from the disc (please consult the Max/MSP ‘sfplay~’ manual for full specifications concerning the file types supported by the object). Because the files are played by ‘sfplay~’ directly from the disk, there is no limit to the duration of the audio files uploaded to *AuVi* (as could be the case if the files had to be uploaded to RAM). When looking inside the ‘player’ objects, one can see how many channels have been uploaded into each ‘sfplay~’ object. If a stereo file has been uploaded to channels 2-4, only the left channel will be audible.

The ‘vidcue’ objects, unlike the ‘player’ objects, which each represent a separate system of audio engines, do not contain any video engines, but instead access a main ‘jit.qt.movie’ located on the main interface window (this object is hidden and therefore may not be visible if the patch is locked). *AuVi* was designed to play only one movie at a time. The left number box above the ‘vidcue’ object allows the user to set and access any frame of the loaded movie when the cue is recalled. When the frame is set, a small button and the frame number appear below the ‘vidcue’ object. The right number box above ‘vidcue’ sets the tempo of the piece in metronome values. As the speed of the performance may slightly vary from one performance to another, once the tempo is associated with the cue, the speed of the video playback during the performance can be adjusted, ensuring precise synchronization with the performers.

*AuVi* is designed to automatically remember and save the settings created by the user. All uploaded audio files as well as frame numbers and tempo indications are saved in the 'auvipathfinder.ctx' file. This file is accessed by the Max object 'coll' when the application is opened, so one does not have to upload all the cues again when she/he opens the program. All the uploaded files can be seen when the blue 'Loaded Files' button at the top of the main interface window is pressed. This way the user can quickly check if the files and cues are uploaded correctly, as they are listed in the ascending cue order. Pressing the 'clear all cues' button at the top right corner of the user interface window clears all the cues.

The final audio distribution process is monitored in the right bottom corner of the interface window and is set on the dark red background. The audio signal from the audio playing engines is sent to the 'p chandist' object and then distributed to the individual channels. The assignment of the individual channels is controlled by the small matrix located above the digital to analog converter object 'dac~'. The small square to the left top side of the 'dac~' indicates the on/off status of the 'dac~'. *AuVi* currently supports four discrete audio channels at the same time. When the Audio On/Off button, located in the center of the interface window (green background), is turned on, the user can see the allocation of the individual channels. The default setup of the application sends the input from channel 1 to output 1, channel 2 to output 2 and so on (the automatic channel assignments can be changed inside of the 'p matrix' object, located above the matrix when *AuVi* is unlocked). The vertical lines represent the audio input channels (sent from the audio 'player' objects) and the horizontal lines represent the output channels and are

directly connected to ‘dac~’. The user can easily switch the channel input/output allocation by creating and deleting red points on the surface of the matrix. To the right side of the ‘matrix’ and ‘dac~’, four meter displays are visible. Each meter displays the audio level of the single output channel and allows monitoring of the overall audio signal level during the performance. The strength of the signal can be adjusted using a volume slider on the right side of the meters. The slider functions as a master volume control and adjusts the audio level of all four channels at the same time. The current level is represented as a floating number (0. being no sound at all and 1. being full volume) on the right side of the volume control slider. The final setting of the volume control is automatically saved by the application and will be recalled when the application is opened again.

Above the main volume control, on the green background, the main control system of *AuVi* is located. The digital audio processing and video engine can be turned on using the main Audio On/Off switch. A little toggle to the left side of the main audio switch allows for the linking of audio and video, so both can be started at the same time. The linking switch is on when the program is opened and can be turned off if the user decides to use audio or video features of the application separately, which conserves the computer’s processing power. To the right side of the main Audio On/Off toggle, the user can see number boxes indicating upcoming (grey number box) and current cues (red number box). The upcoming cue can be set using the mouse, computer keyboard arrows or keyboard numbers from 0 to 9. The different ways of setting the upcoming cue number allow flexibility during both concert and rehearsals. When the preset cue is turned on

with the return key, the cue number is sent to the video and audio engines. The small AutoCue toggle, located above the current cue, allows for automatic setting of the next cue number. Therefore, for example, when cue number 1 is turned on, the AutoCue system will automatically set the next cue number box to number 2. This system is designed to speed up the process of setting and turning on the cues so the user can allocate her/his attention to other aspects of the performance. The digital time display positioned to the right side of the red current cue number box shows the time elapsed since the cue was turned on. This information may be useful for the user to turn on/off certain live manipulation processes during the performance. The time display is automatically set to zero whenever a new cue number is started or the Main Audio switch is turned off.

The video controls are located on the left side of the main interface window against the yellow background. The movie can be started using the start movie toggle. The three number boxes below the start movie toggle (blue, red and black) help the user to adjust the speed of the movie to the live performers. The blue number box displays the tempo associated with the score and was previously loaded in the 'vidcue' objects. Because the tempo of the performance can be different from the tempo indicated in the score, the user can tap the tempo of the performance using '/' key on the computer keyboard. The current performance tempo will be displayed in the red number box as a metronome value and in the black number box in milliseconds. *AuVi* calculates the difference between the score tempo and the performance tempo and adjusts the speed of the movie playback. The resulting rate of speed needed to synchronize the video with the

performance is displayed in the number box at the bottom of the yellow background area of the main interface window. The float number 1. indicates that the movie is played without any speed adjustment; numbers smaller than 1 indicate a smaller playback rate and numbers bigger than 1. a faster playback rate. The application takes the average beat time indicated by the user and so the changes in the video speed playback are smooth. Whenever a new cue number with a new tempo change is entered the speed of the video goes back to 1. Although there are no limits on how fast/slow the movie can be displayed, the user should take into consideration the fact that a too extreme playback rate may change the content of the displayed video, or, in the case of a too slow playback, may cause the video to lose the continuity of the display. This, however, should not be an issue if the conductor stays close to the tempos indicated in the score, in which case, the movie playback rate will be adjusted only slightly, ensuring continuity of the visuals and proper synchronization between the visuals and the live performance.

A preview of the currently playing movie can be seen in the 'jit.pwindow' object on the left bottom corner of the interface window. The numbers below the preview window give the user information on the 'jit.pwindow' performance. The floating number fps is an excellent indication of how the computer processor is handling those processes in progress (the smaller the number of fps, the worse the performance). The numbers on the pink background below display the current time of the movie and displays hour/minutes/seconds and frames from the beginning of the movie. *AuVi* is designed to play the movie in full screen using external video projection. The video signal is sent remotely to the 'jit.window' object, which creates an independent window displaying the

same picture as seen on the preview window. The user can very simply place the external window display on the external projector desktop and then press the 'esc' button on the keyboard to project the movie in full screen mode. The full screen mode is indicated on the right side of the preview window against the blue background of the main interface. The original size of the external 'jit.window' object is set to 720x576 pixels; however the size can be changed with the menu below the full screen indicator (additional sizes can be added to the menu when the main interface patch is open: please refer to the Max/MSP 'umenu' manual for more information).

On the left side of the interface application window, there are two small boxes located against the dark purple background. When double-clicked, the box referred to as 'p vidproc' opens a new window with video signal input and output. When the small toggle referred to as 'video processing on/off' is turned on, the video signal from the movie engine is seamlessly routed to the 'p vidproc' processing patch. The user can design his own video processing using the full capabilities of the Max/MSP/Jitter programming environment. The processed video, previewed at the bottom of the 'p vidproc' window, is sent to the preview window in the main interface window as well as to the external video projection remotely via the 's vidproc' object. The user may design his/her own audio processing inside of the 'p audproc' object (double click to open), located below 'p vidproc'. Eight discreet audio inputs are already created, as well as four audio outputs, and are ready to send the audio signal to the main digital to analog converter on the main interface window. An internal volume control, with four audio signal monitors, is included to scale down the signal level before it is sent to the main

‘dac~’. The user should take extra care to make sure that the combined signals coming from the audio players and the audio processing is not over-blowing the ‘dac~’ and not creating audio distortion. One extra feature of *AuVi*, located on the left lower side of the interface window, allows the user to write notes directly on the interface. The notes are automatically saved. This can be very useful during rehearsals as well as during the performance, as the user can, for example, write down the order of the starting processes and have it easily visible during the performance.

*AuVi* has been designed to aid composers during the presentations of multimedia compositions in conjunction with live performance. In the modern world, rehearsal time allocated to new music compositions is usually very limited, especially if the performed works employ the conductor and larger instrumental forces. *AuVi* has been created to decrease the rehearsal time that must be spent trying to synchronize the live performers with fixed media, for the computer part performer adjusts the electronic media to the live performers. It allows the musicians to concentrate on making music instead of worrying about synchronizing with the electronic part. The simplicity and intuitiveness of the application, the cueing system and variable movie speed projection, ensures smooth rehearsals and concert performances, even if the user is not very experienced with live electronic performance. The expandability of the application renders it useful for those who plan more advanced electronic video and audio processing, shortening the time they would have to spend on designing the basic functions of their application. *AuVi* works with any multi-channel audio interface compatible with current Macintosh or Windows operating systems.

Although *AuVi* is primarily designed to be used during presentations of audio/video works, it can be used as an application to present audio tape pieces only as well. Its multi-channel capabilities and its cueing system, which allows for the preloading of audio files, makes it an excellent tool for concert organizers, as it does not require switching between multiple applications during the concert to present pieces for various media. *AuVi* has already been used during several concerts, including the presentation of my own *Eppur Si Muove* for chamber ensemble, electronics and video in Chicago on May 19<sup>th</sup>, 2006, as well as during the Mixed Media Concert on December 12, 2006 in Bytom, Poland, among others. The pieces presented using *AuVi* included audio-visual works with live instruments, audio tape pieces and fixed media multimedia presentations.

Plans have been made to expand *AuVi* to include the possibility of using eight discreet audio channels. This adaptation is called for by the quickly changing multi-channel technology standards, which upgrade the currently used quadraphonic sound systems with 5.1 or 7.1 movie standard systems. However, this change requires a redesigning of the audio playback engines and will be implemented shortly. In order to remain currently viable, the software will have to be adjusted to accommodate ever-changing industry standards. In the meantime, *AuVi* will hopefully find its place and application in the contemporary art scene.



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