# Quintet.net: An Environment for Composing and Performing Music on the Internet

*Georg Hajdu*

ABSTRACT

Quintet.net is a real-time interactive environment for intermedial composition and performance on local networks as well as the Internet. Since its premiere in 2000, the environment has been used in several large projects connecting players in Europe and the U.S.A., a Munich biennale opera project among them. Quintet.net implements, in a virtual environment, the metaphor of five performers under the control of a conductor, thus dealing with important aspects of symbolic, aural and visual communication among the participants and the network audience. A composition development kit has been added to the environment (which consists of Client, Server, Listener, Conductor and Viewer) to facilitate the development of pieces that take full advantage of the wide continuum between composition and improvisation.

Devising a network performance environment, such as my Quintet.net, is probably among the most demanding tasks a composer or visual artist can face today. Due to the ramifications of such a project, numerous problems from various fields, including computer science, music and media theory, performance practice and hardware design, need to be addressed and solved. This novel medium also calls for a new scholarship that encompasses aspects of philosophy, sociology, (cognitive) psychology, biology, neurology and artificial intelligence research.

Furthermore, the historical developments leading to the creation of this type of environment require thorough analysis alongside an in-depth comparison to other existing network music systems—most of which is beyond the scope of this article. With that in mind, the following is intended to strike an appropriate balance between a sufficient description of the environment and the meta-theory associated with it.

Two theories of the dynamics of human culture are of significance when attempting to describe the philosophical and historical contexts of Quintet.net: The first is that of memetics, a term coined by British biologist Richard Dawkins in 1976 to refer to the theoretical and empirical science that studies the replication, spread and evolution of memes, memes being cultural units, concepts or ideas [1].

The other theory deals with *play*. The Dutch historian Johan Huizinga postulates in his book *Homo Ludens* that play is the key to the understanding of human culture, being

> a free activity standing quite outside "ordinary" life as being "not serious," but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of the time and space according to fixed rules and in an orderly manner. It promotes the formation of social groupings, which tend to surround themselves with secrecy and to stress their difference from the common world by disguise or other means [2].

According to Huizinga, "Play has its validity outside the norms of reason, duty and truth. The same holds for music. The validity of its forms and function is determined by norms that lie beyond a logical notion and beyond a visible and tangible shape" [3].

Both replication of memes and play have shaped the development of digital media since 1945. We have witnessed a co-evolution of machine and art: In computer music, this co-evolution has already reached a third, interactive stage (after the speculative and exploratory stages) [4]. From the mid- to late 1990s on, a shift of paradigm becomes apparent, characterized by the dissolution of the notions of space, identity and function: The separation between composition and improvisation in a live performance disappears, just as do, in the case of interactive installations, the differences between composer, performer and audience.

New notions surface: participatory music, network composition, real-time compositions, autopoietic processes. A new type of composer evolves who, due to the availability of inexpensive hardware and highly developed software, is able to express him- or herself intuitively and interactively without profound knowledge of music theory and computer science.

Marshall McLuhan's statements on our world as a global village, formulated in 1964, are now commonplace in our intellectual discourse. He wrote: "Today, after more than a century of electric technology, we have extended our central nervous system in a global embrace, abolishing both space and time as far as our planet is concerned" [5].

In fact, the implications of such statements were only felt to their full extent 30 years later, with the spread of the hypertext-based World Wide Web and the ensuing expansion of the

**Fig. 1. Quintet.net consists of several components that are connected in a local network or over the Internet. (© Georg Hajdu)**

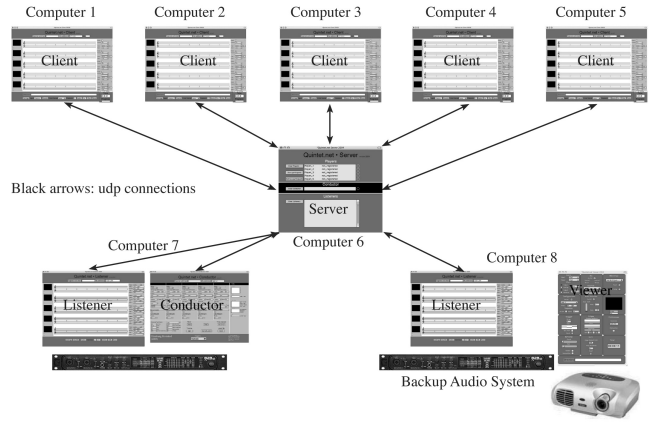


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**Fig. 2. Guitarist Erhard Hirt uses a MIDI guitar in a performance of *MindTrip*. (© Erhard Hirt. Photo © Stephan US)**

Internet. The great advantage of the Web compared to traditional media such as the telephone and television is its interactivity, provided by an up-stream backchannel, which allows the receiver to re-shape the nature of communication, as well as its wide spread and low cost, permitting less financially potent providers to grant global access to information and entertainment [6]. In principle, anyone can now be a provider.

In the interim between McLuhan's statements and the development of the Web, composers infected by the evolving memes of globalization, such as Australia-born artist Bill Fontana, who started his first experiments with long-distance performances in 1978, reacted intuitively with concepts that used telephone and satellite technology to dissolve space and time [7]. In Larry Austin's *Canadian Coastline: Canonic Fractals for Musicians and Computer Band* (1981) and Alvin Curran's *Crystal Psalms,* satellite technology was used to connect musicians synchronously [8,9].

In 1976, a group of computer-savvy young composers centered loosely around Mills College in Oakland, CA, met to explore the musical potential of microcomputers. They started to organize concerts with computer networks in 1978. In 1980, this group was named the League of Automatic Music Composers. Later, this formation mutated into the Hub, which consisted of John Bischoff, Tim Perkis, Mark Trayle, Chris Brown, Scot Gresham-Lancaster and Phil Stone [10].

The Hub mainly relied on the MIDI standard for inter-computer communication. Due to signal degradation, the use of MIDI made long-distance performance of networked computers less than practical [11]. These limitations were overcome as broadband Internet connections and the TCP/IP communication protocol became increasingly available. The first Internet-based music projects, which slowly started surfacing in 1996, are associated with the names of Randall Packer, Karlheinz Essl, Chris Brown and Tod Machover, among others [12–15].

The Hub members have reflected on the non-musical implications of networked music systems from early on, treating computer networks as metaphors for biological and sociological phenomena such as nervous systems, brains, organisms and society. Indeed, Internet music performance bears a resemblance to robotic surgery and artificial limb research, which also include the design of novel extremities.

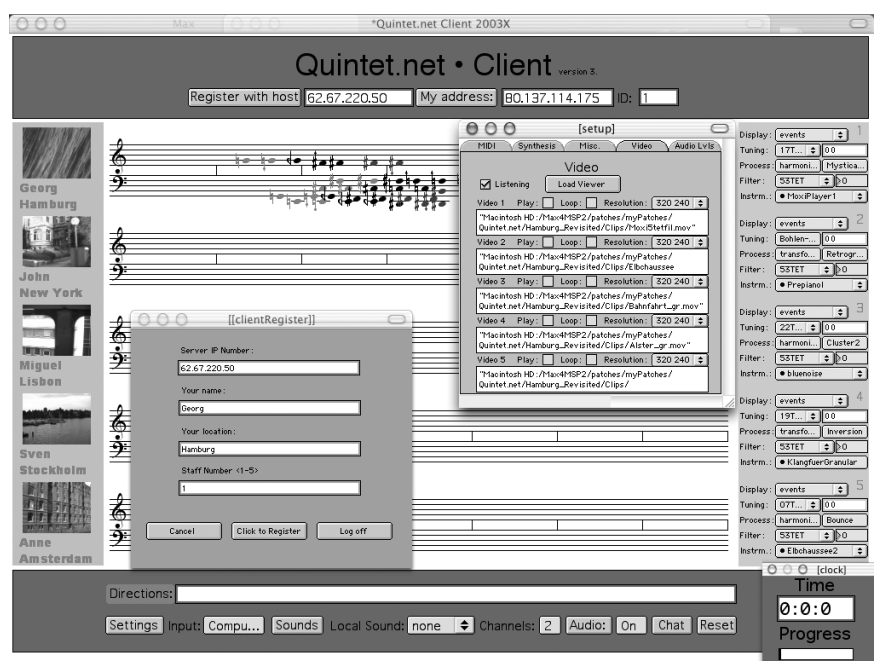
Music performance on the Internet also leads to socio-psychological questions as to the identity of the performer playing on the Net and how his or her presence is felt by the other musicians and their audiences, as well as where "adequate" performances are supposed to take place and how they should be presented—questions that touch on the fundamental roles that musicians and their audiences have taken for granted for centuries.

## QUINTET.NET: THE COMPONENTS

Inspired by the Hub as well as my own experiences with the *Intermezzo* of my opera *Der Sprung* (1994–1998), in which I used a "wired choir"—an ensemble of singers under the control of a computer—I started work on Quintet.net in 1999 [16,17].

Wanting to create something that was

**Fig. 3. Screen shot of the Client program. (© Georg Hajdu)**



closer to a typical musical setting, I used an ensemble of musicians, or more precisely, a quintet under the control of a conductor, as a metaphor for musicians interacting over a network. A quintet seemed the ideal number of musicians for achieving the desired musical density and complexity. Special care had to be taken, however, to implement features that allowed for rehearsal situations as well as intimate contact between the conductor and the musicians during a performance—while taking the role of the cyber-audience into account. Its four components, Client (for the players), Conductor (for the director of the performance), Listener (for the audience) and Server (the central hub), as well as the Viewer add-on (for an additional visual layer), grew out of these considerations. Quintet.net runs on both the Mac OS X and the Windows XP platforms and was programmed with the graphical software Max, with the addition of its audio and video extensions MSP and Jitter. In the following, I will explain the function of each component in more detail.

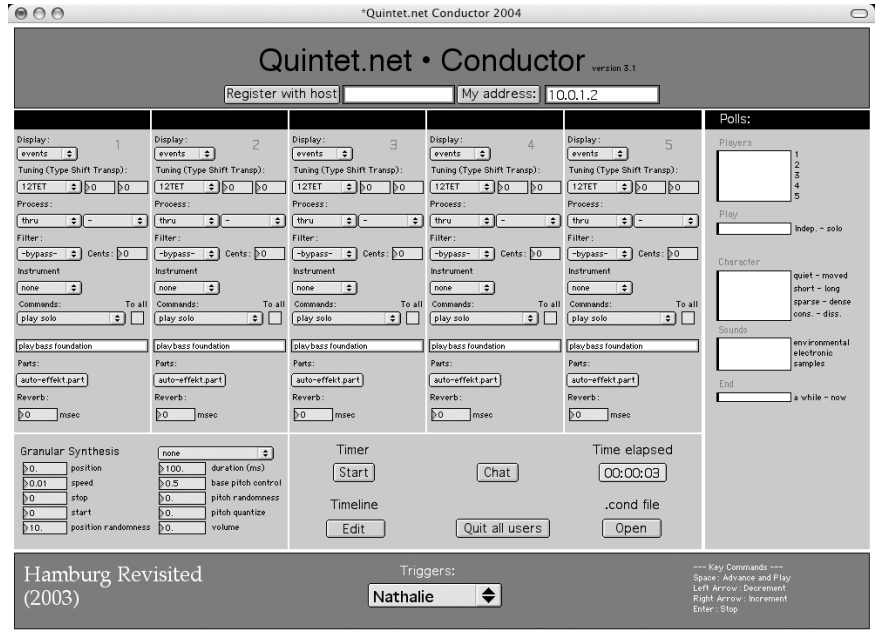



**Fig. 4. The conductor monitors the output of the performance and is in contact with the performers and the cyber-audience. (© Georg Hajdu)**

## Server

The central hub of Quintet.net is the Server, to which all participants first log in. It keeps track of the IP number as well as the name and location of each user (Client, Conductor or Listener) (Fig. 1). The musicians can then play their lines into the Clients and send them on their journeys through cyberspace. Having arrived at the Server, the data packets are copied and sent to all Clients (including the original computer) and Listeners.

In addition to managing the data streams, the Server also assumes further musical tasks, such as manipulating the incoming stream of music with effects algorithms. These include filters, harmonizers and transformation effects that can alter the character of the music dramatically and allow the players to also perform duets with themselves [18].

## Client

The Client has several functional units: an input unit, a sound synthesis unit and a real-time notation unit. Music can be played into the computer through either a microphone, a MIDI controller or simply the computer keyboard (Fig. 2). If the music is input via microphone, a pitch tracker integrated into the program provides for the recognition of the pitches and their transformation into corresponding MIDI messages. The input unit employs a modified MIDI protocol for the transmission of musical events using MIDI *cents* for steady pitch and amplitude as well as for continuous pitch and amplitude changes [19]. The *note* and *bend* events are played back by a built-in multitimbral, polyphonic sampler. With this, every piece can sound distinctively different. The sounds can be further processed with VST plug-ins. Alternatively, VSTi or MIDI instruments can be used for playback. Thus, a pianist located in Hamburg could play on a Yamaha Disklavier placed anywhere else in the world.

As soon as a note event arrives to the Client, the music will be drawn onto the computer screen in "space" notation, in eighth-tone precision on five grand staves (Fig. 3). The Client can import an unlimited number of arbitrary tuning maps [20]. The use of (pitch) filters, constituting a secondary tuning map or pitch grid, permits further control of melodic and harmonic events. Hence, the notation unit possesses three pitch grids: the primary (flexible) tuning grid, the secondary (flexible) filter grid, and a fixed tertiary grid for eighth-tone notation.

Real-time notation facilitates the interaction of players who are sometimes thousands of miles apart from one another, even with non-pitched or complex samples. American composer and computer musician Chris Brown wrote about the use of real-time notation: "Sharing a notation space really broke new ground for this kind of music" [21].

## Conductor

Quintet.net uses the metaphor of an ensemble under the control of a conductor to allow a sixth player, using the Conductor component, to monitor and influence the performance by selecting sounds, tunings, processes and filters (which, without a conductor, can also be changed by one of the Clients) (Fig. 4). The conductor stays in contact with the musicians through textual directions that appear in the Clients' command lines, while a chat window facilitates the exchange of more complicated issues between the participants (including the cyber-audience; see below). If a piece employs a score, the conductor can also send parts and control the background sounds. Different *display* modes allow superimposition of parts and note events. Entering messages into a timeline and executing them during the performance can automate all this.

In certain performances, the conductor is also in contact with the listeners, who can influence the course of the music through voting.

## Listener

The Listener component was designed to give the cyber-audience the opportunity to follow a Quintet.net performance. It is almost identical to the Client component but lacks the input unit. Instead, it features another window with a questionnaire pertaining to important aspects of the performance (such as desired sounds, playing modes and formal development), which can be filled out and sent off by the listeners at any time. This allows the audience to offer feedback, in analogy to what performers often perceive as "vibrations" in a concert hall

setting—an evasive social phenomenon that can have considerable influence on the course of an interpretation [22]. The votes are transmitted in real time to the conductor, who sees the current statistics on his or her screen. It is up to him or her to decide whether and how to communicate the "vox populi" to the performers. This form of feedback, which has a great similarity to political-democratic processes, takes advantage of the up- and down-stream capabilities that the Internet makes available to the online audience.

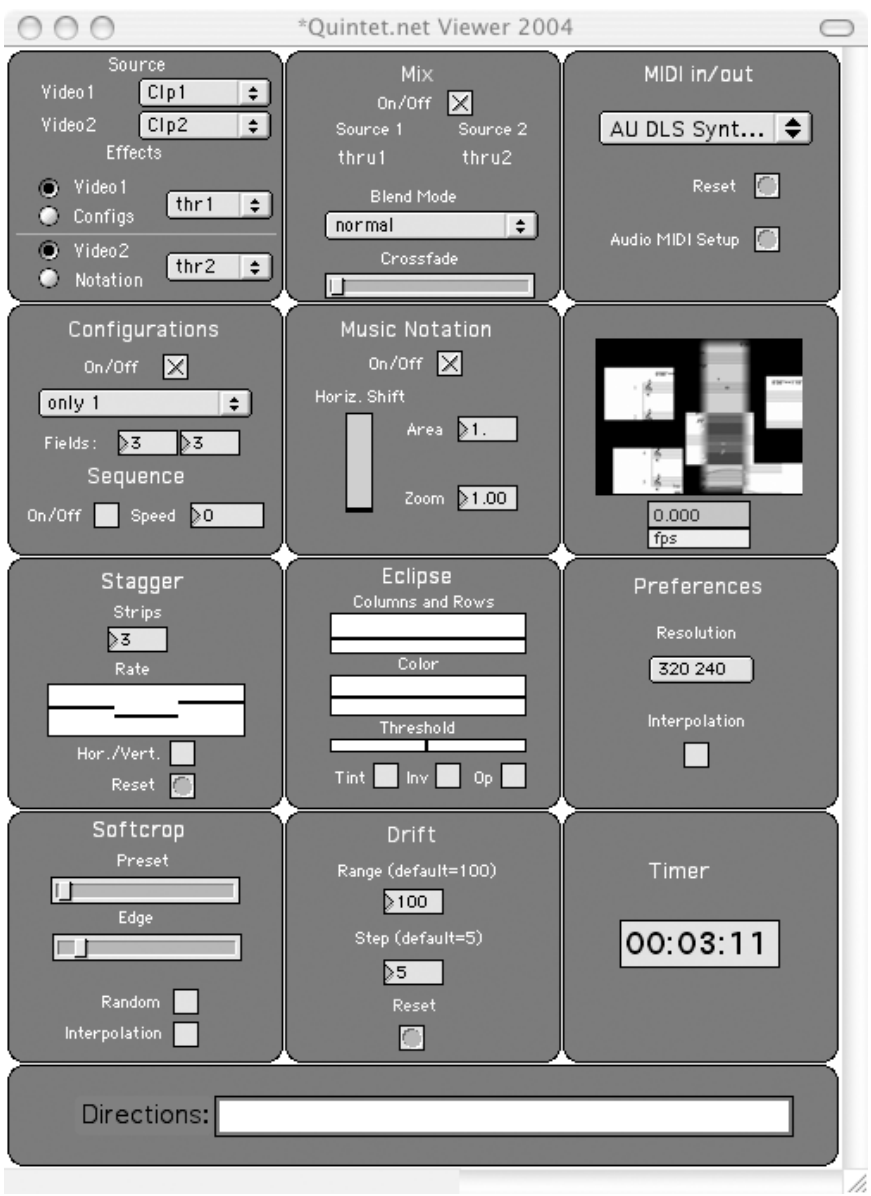
### Viewer

The Viewer add-on was conceived to extend the Quintet.net performance into the visual domain (Fig. 5). Using the Jitter matrix processing objects, this component implements a number of live video-processing algorithms that can be controlled either manually or automatically by sequencing commands from a timeline [23]. The media on which the algorithms operate can be either video clips, live video streams and/or real-time music notation, and can be mixed and superimposed in 2D and 3D at will. The algorithms in turn can be controlled by the actions of the musicians. Thus, the Viewer enables composers/artists to create complex artworks in which the visual components represent an autonomous formal element.

## Composing for Quintet.net

Pieces written for Quintet.net can employ a variety of different approaches, from free improvisation to precise notation, which can be mixed freely. Since composing for the environment can be cumbersome, a composition development kit has been added to facilitate the creation of pieces. Ideally, the composer will first collect and organize his or her audio and video materials, for instance by simulating the piece in an editing tool such as Final Cut Pro. Appropriate samples are either atmospheric or gestural in nature and often include spoken text, processed instrumental or "extended technique" sounds, as well as rich synthetic sounds.

**Fig. 5. With the Quintet.net Viewer component, video streams can be mixed with real-time music notation. (© Georg Hajdu)**




### The Composition Development Kit

The Composition Development Kit consists of several editors: One such, a Bank Editor, is a visual editor that lets the user arrange a chosen set of samples into *instruments,* with defined pitch and envelopes for each sound (Fig. 6). Instruments, in turn, are organized into *banks.* Another visual editor, the Score Editor, allows the creation of scores, which consist of unlimited numbers of parts. These parts can be selected by the conductor during the performance or sent automatically from a timeline [24].

The materials that make up a Quintet.net composition (title, references to bank, score and timeline files, as well as a list of timeline triggers to be executed during the performance) are referred to by a ".cond" file, which can be dynamically loaded into the Quintet.net Conductor. It is shown on the bottom of the Conductor window.

## Performing with Quintet.net

### Space and Identity

In my opinion, Internet performances give rise to the question of how the aesthetical experience depends on the physical presence of musicians. In a performance of the composition *Mind Trip,* in which Quintet.net was featured for the first time and which took place both in cyberspace as well as on a real stage, it became clear how difficult it was both for the musicians and the audience to orient themselves. The musicians had to become accustomed to being present in both spaces simultaneously, while the audience desired a clearer orientation in the sonic space with specific identification of the acoustic sources and their creators. The lack of physical presence on the Internet and the anonymity that arises from this can, however, have the desirable effects of masquerade and the adoption of artificial

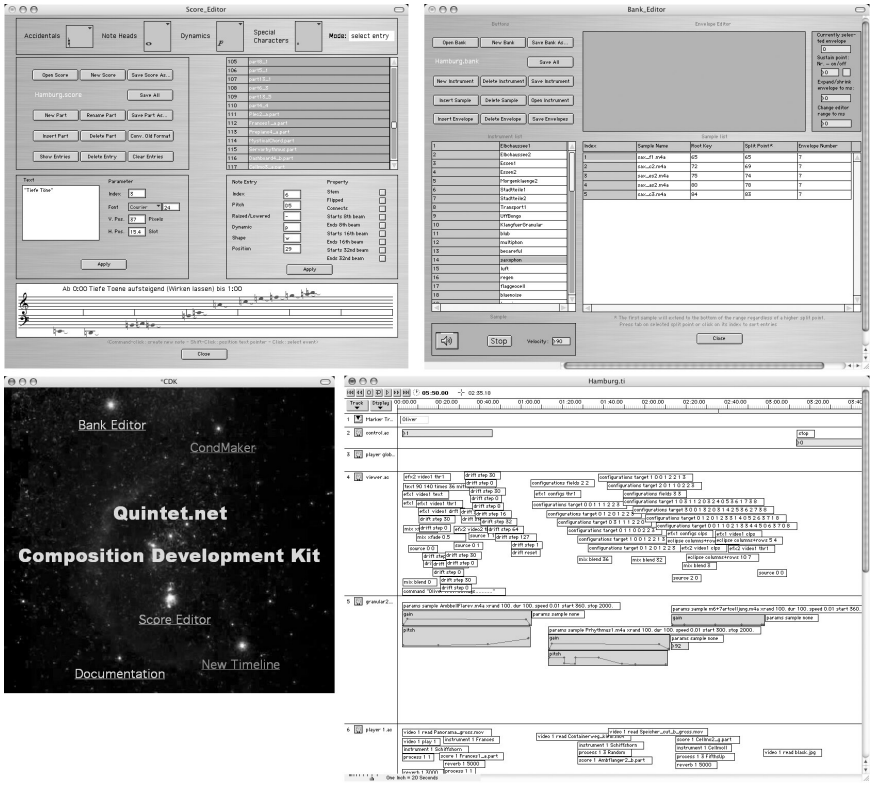



**Fig. 6. The Composition Development Kit facilitates the development of compositions for Quintet.net. (© Georg Hajdu)**

identities. Precisely because the music is transmitted as abstract information over the network—retransformed into sound on the user's computer—the actions of a flutist can be heard as a violin or waterfall. This is probably the great advantage of streaming abstract, high-level data versus low-level audio data (besides the ability to notate music in real time). Hence, Quintet.net would have used the same paradigm even if high-fidelity audio streaming with low latency had been a reality when the environment was conceived.

## Synchronicity

An essential issue in Internet performances is that of the synchronicity of musical events. The effort to resolve it highly resembles an attempt to square the circle—at least in the Internet's current structure. When a musician plays a note into the computer, it cannot be exactly determined when this note will arrive to the computers of the other performers due to jitter in network transmission. Typical latencies on the Internet span from 200 ms to 500 ms, depending on the distance between the performers. Since the ear perceives deviances of as little as 50 ms as being "out of beat," the synchronous performance of exactly notated scores is out of the question from the start. The Internet thus gives birth to its own aesthetic.

Quintet.net compensates for network jitter by buffering events: All events are given a timestamp before they are sent from the Client and subsequently to all of the other participants. When they have arrived at their destinations, the timestamps are evaluated and, presupposing a certain average latency, played back with a delay in comparison to the timestamp [25].

## New Performance Practices

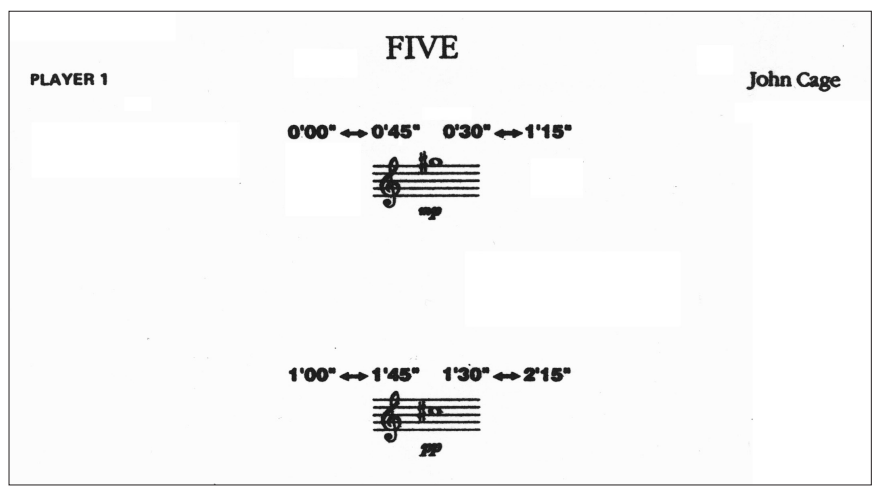
Given the fact that synchronous performance in real time is not possible and can only be simulated, if achieved at all, only certain contemporary music forms are suitable for performing via Internet; but who really wants to perform Mozart or Beethoven in this manner? Long before the invention of the Internet, the 20th century brought about forms that can serve as ideal models for making music à la Quintet.net: John Cage, who was involved in the discovery of new means of expression all his life, completed 48 *Number Pieces* (such as *101* for orchestra, *Four* for string quartet or *Five* for any five voices or instruments) between 1987 and 1992 (Fig. 7). In these pieces musical events are organized through time brackets. In ensemble performance, a tone is thus allowed to be played before, simultaneous to or after another tone, as long as they are both within the same bracket. Interestingly, this form of asynchronicity hardly influences the audible musical result.

Witold Lutoslawski also developed a compositional technique, influenced by Cage's early *Piano Concerto,* in which chronological approximation leads to precisely calculated musical results: the so-called aleatoric counterpoint (the word *aleatoric* refers to the random components in the ensemble performance). He used this technique in most of his compositions following *Jeux vénitiens* (1961).

## Pieces and Concerts

Several pieces have either been transcribed or originally composed for Quintet.net. A total of seven concerts in addition to preparatory rehearsals and semi-public performances have been staged with Quintet.net so far. Five compositions have been performed—three of them specifically written for Quin-

**Fig. 7. Excerpt from the original score of *Five* by John Cage. (© C.V. Peters Muzikverlag)**



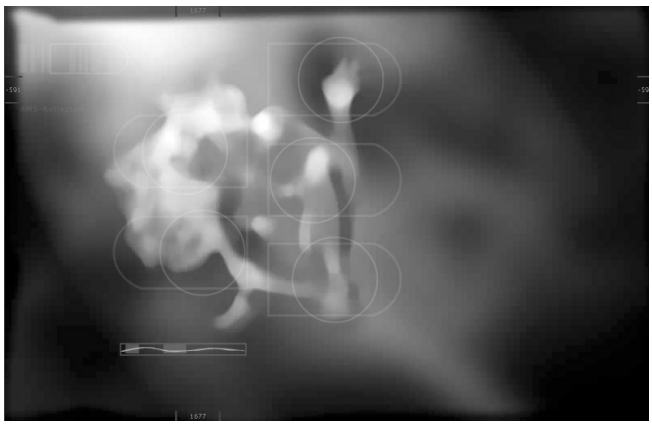


**Fig. 8. Screenshot of Bettina Westerheide's web project, which transformed the Orpheus myth by means of a Flash-animated web site [33]. (© Bettina Westerheide)**

tet.net (*MindTrip, Vamp.net* and *Hamburg Revisited),* one using it as a remote orchestra in an opera setting (*Orpheus Kristall*) and one transcription (*Five).*

Each performance with Quintet.net creates one global as well as up to five local versions. The global version can be followed by the listeners in cyberspace, whereas local variants are created by the performers, particularly when using acoustic instruments.

Quintet.net requires thorough preconcert preparation by all participants, on-line listeners included. After downloading the appropriate component(s) and the sound files, which are specific for every piece, the participants need to log into the Quintet.net server. Once they are successfully logged in, they can then contact the conductor as well as the other participants communicating via the built-in chat feature to receive further instructions, if necessary.

## Georg Hajdu: *MindTrip*

*MindTrip* premiered in Münster, Germany, on 28 October 2000 during the Münster Mystik und Maschine festival and was the first piece ever realized with Quintet.net.

It is a piece about the notion of *contact*, contact between beings: in real life, on the Internet . . . in different solar systems. The story's resemblance to Carl Sagan's *Contact* [26] was unintentional, yet it likewise deals with the paradox of the search for contact, which often enough remains unfulfilled. In this piece, a synthetic narrator tells the story of Xenon, who has been chosen by a future terrestrial civilization to make contact with extra-solar neighbors. This astronomical search is metaphorical for the basic principles of Internet performance, whose motivation is analogous: the use of technology to extend one's presence beyond one's physical boundaries.

*MindTrip* was composed in the summer of 2000 and, in its second version, made use of sonic material that was provided by the performers themselves. It has five sections, each featuring a performer as a soloist with accompaniment.

## John Cage: *Five*

*MindTrip* was repeated in a concert on 15 November 2001. Its performance was preceded by John Cage's five-minute composition *Five,* which—typical of his late *Number Pieces*—features individual parts with time brackets, within which certain notated actions are supposed to be realized [27].

## Manfred Stahnke: *Orpheus Kristall*

In 1999, German composer Manfred Stahnke was commissioned by the Munich Biennale for Contemporary Opera and the Siemens Arts Program to write an opera that makes use of the Internet. Coincidentally, Quintet.net was in its early planning stage, and it immediately became clear that this piece would be an integral part of it. The program notes to the opera's premiere on 3 May 2002 describe the role of Quintet.net as follows:

> Manfred Stahnke's score includes "windows" to the Internet for the performance. Music comes from the Net and combines with the music in the theater. The music is set in motion by the character who remains on stage during the entire performance: Orpheus. What he sings and what his "alter ego" the percussion plays is conveyed to musicians across the globe. They will then improvise to the music they hear and read in notation [28].

**Fig. 9. Performance schedule of Anne La Berge's *Vamp.net.* (© Georg Hajdu)**

| Time (min.) | Bart | Carl | Georg | Marko | Robert |
|---|---|---|---|---|---|
| 00.00 | text samples improv | play a few notes and stop | play a few notes and stop | duo with Robert | duo with Marko |
| 01.00 | text improv until 2' | play a few high notes and stop | play a few high notes and stop | play low notes | play low notes |
| 02.00 | stop playing | play one long note once | play one long note once | sparser duo with Robert | sparser duo with Marko |
| 03.00 | don't play -Georg solo until 4' | don't play -Georg solo until 4' | Georg - your solo | don't play -Georg solo until 4' | don't play -Georg solo until 4' |
| 04.00 | duo with Georg | text samples improv | duo with Bart | improv off line | play 7 chords and stop |
| 05.00 | | | | | |
| 06.00 | more frantic/soft sounds | sparser text improv | play denser and softly | play two sounds and stop | play one long sound once |
| 07.00 | | | | | |
| 08.00 | stop playing | play a duo with Robert | text samples improv | stop playing | play a duo with Carl |
| 09.00 | | | | | |
| 10.00 | play 1 text sample 20 times | play only chords | play occasional sound & text | play 1 text sample 15 times | play high sounds very sparsely |
| 11.00 | | | | | |
| 12.00 | play a duo with Carl | play a duo with Bart | stop playing | text samples improv | stop playing |
| 13.00 | | | | | |
| 14.00 | | | | | |
| 15.00 | don't play-Robert solo until 16 | don't play-Robert solo until 16 | don't play-Robert solo until 16 | don't play-Robert solo until 16 | Robert solo until 16' |
| 16.00 | play 5 notes slowly and stop | play 3 notes slowly and stop | play a duo with Marko | play a duo with Georg | text samples improv |
| 17.00 | | | | | |
| 18.00 | | | play 5 text samples and stop | play 1 text sample once | stop playing |
| 18.20 | play 3 text samples and stop | play 2 text samples and stop | | | |
| 19.00 | play 3 quick fragments | play 7 slow fragments | play 5 melodic fragments | play 1 text sample 4 times | play 2 slow melodies |
| near end | play one beautiful note | play one beautiful note | play one beautiful note | play one beautiful note | play one beautiful note |
| 20.00 | end of piece | end of piece | end of piece | end of piece | end of piece |

**Fig. 10. Screen shot from *Hamburg Revisited*. (© Georg Hajdu)**

The performance took place in four concert halls besides the Munich opera stage—*De Waag* and *STEIM* in Amsterdam, Harvestworks in New York and the Center for New Music and Audio Technologies in Berkeley—with two musicians playing at each site. For the first time, a RealVideo stream was used in the concert and projected onto a separate screen, which enabled the players and the audience to witness the action on stage and provided an added aesthetical and musical dimension to the performance. *Orpheus Kristall* also exists in a second version: as an interactive web site (Fig. 8).

### Anne La Berge: *Vamp.net*

Based on her experience as a performer in all previous Quintet.net performances, the flutist and composer Anne La Berge took the opportunity to write her own piece for the environment. She states:

> "Vamp.net" is a commission from the Gaudeamus Foundation for the presentation of the Actuelemuziek website on the evening of the 10th of October 2002 in the Witte Dame in Eindhoven. In this version, each of the five musicians will be representing one or two of the seven new music programming organizations in Holland, which make up the VAMP (Vereniging Aktuelemuziek Podia) [29].

La Berge also made a video with fragments of the representative cities and halls, which was played during the Eindhoven performance. The combination of instrumental samples with environmental sounds and text fragments of varying lengths turned the piece into a performance with the characteristics of both a radio play and an installation—simultaneously performed by five performers over large distances (Fig. 9).

### *Hamburg Revisited*

In 2003, I conducted a semester-long project with undergraduate and graduate composers from the Hamburg School of Music and Theater. The five composers, Nathalie Herres, Oliver Frei, Moxi Beidenegl, Martin von Frantzius and Donghee Nam, each contributed 3 minutes to a 15-minute collective composition on the sounds and images of the city of Hamburg (Fig. 10). It premiered at the 2003 Campus Innovation symposium in Hamburg and was performed locally by the five composers playing on laptops mounted on music stands, conducted by myself. Making extensive use of the Viewer, this composition was the first Quintet.net piece to feature an artistically independent visual layer to which the performers were able to react.

## Quintet.net in the Context of Other Internet Music Projects

Quintet.net is not the only Internet music environment. Other projects have received considerable public attention, such as (in alphabetic order):

- *Cathedral* by William Duckworth <http://www.monroestreet.com/Cathedral/>
- *Eternal Network Music* by Chris Brown (CCM, Mills College) <http://www.mills.edu/LIFE/CCM/Eternal_Network_Music.html>
- *FMOL* by Sergi Jordá (Institut Universitari de l'Audiovisual Universitat Pompeu Fabra, Barcelona) <http://www.iua.upf.es/~sergi/>
- *GlobalVisualMusic* by Miller Puckette (CRCA, San Diego) <http://www.visualmusic.org/gvm.htm>
- *SoundColors* by Mara Helmuth (University of Cincinnati) <http://meowing.ccm.uc.edu/home.htm>
- *SoundWire* by Chris Chafe (CCRMA, Stanford University) <http://ccrma.stanford.edu/groups/soundwire/>
- *Telemusic* by Randall Packer <http://www.telemusic.org/>
- *TransJam* by Phil Burk <http://www.transjam.com/>

While some projects focus on broadband, low-latency audio (and video) streaming and others are more concerned with building on-line music communities, Quintet.net seems the only one that uses the paradigm of a conducted music ensemble. An in-depth analysis of the specific differences of the abovementioned platforms and projects is beyond the scope of this paper, however. Good sources of information are Golo Föllmer's dissertation "Musikmachen im Netz" and his article "Netzmusik. Musikpraktiken in Computer-Netzwerken" [30].

## Outlook

Quintet.net presents itself as a pedagogical tool that deals with virtually every aspect of multimedia content production. Several projects with students in Groningen, the Netherlands, Hamburg, and Szombathely, Hungary, clearly showed that the environment is flexible enough to allow for individual artistic expression [31]. Although Quintet.net was originally conceived for merely sending abstract control messages over the Internet, it quickly became clear that this was only the beginning. Due to faster computers and broadband Internet connections, audio and video streaming became an integral part of the environment, which greatly expanded its artistic and aesthetical possibilities as a stage for a virtual *Gesamtkunstwerk* [32].

#### References and Notes

**1.** Richard Dawkins, *The Selfish Gene* (Oxford, U.K.: Oxford Univ. Press, 1976).

**2.** Johan Huizinga, *Homo Ludens: Study of the Play-Element in Culture* (Boston: Beacon Press, 1971) p. 13.

**3.** Huizinga [2]. Quoted in Golo Föllmer, "Music in

Toyland. Zum Spielcharakter von Netzmusik," *Positionen* **56** (2003) pp. 16–19. Translated by the author.

**4.** Georg Hajdu, "Der Computer als Inspirationsquelle für Komponisten—ein historischer Überblick," in Bernd Enders, ed., *Musik, Mathematik und Technik* (Saarbrucken, Germany: Pfau Verlag, to be published in 2005).

**5.** Marshall McLuhan, *Understanding Media* (Cambridge, MA: MIT Press, 1964) p. 3.

**6.** Telephone, radio and/or TV are sometimes used together in polls and games to mimic basic functions of the Web.

**7.** Bill Fontana: <http://www.resoundings.org/Pages/musical%20networks.html>.

**8.** Larry Austin: <http://www.music.unt.edu/cemi/larry_austin/LApnotes.htm#canadian>.

**9.** Alvin Curran: <http://www.newalbion.com/NA067/>.

**10.** Chris Brown and John Bischoff, "Indigenous to the Net: Early Network Music Bands in the San Francisco Bay Area," <http://crossfade.walkerart.org/brownbischoff/>.

**11.** When the avant-garde group Musica Viva Elettronica celebrated their 25th anniversary at Mills College, Richard Teitelbaum, who had been grounded by a blizzard in upstate New York, played a MIDI keyboard over a telephone line. A second telephone line allowed him to follow the other players (Alvin Curran, George Lewis and Fredric Rzewski).

**12.** <http://www.zakros.com/bios/packer.html>.

**13.** <http://www.essl.at/>.

**14.** <http://www.cbmuse.com/compositions/index.html>.

**15.** <http://brainop.media.mit.edu/>.

**16.** Georg Hajdu, *Der Sprung—Beschreibung einer Oper* (score) (Hamburg, Germany: Peer, 2003).

**17.** Georg Hajdu, "Quintet.net—Präliminarien zu einer vernetzten, interaktiven Echtzeitkompositionsumgebung," in Bernd Enders and Joachim Stange-Elbe, eds., *Global Village—Global Brain—Global Music* (Osnabrück: Universitätsverlag Rasch, 2003) pp. 298–303. The Quintet.net homepage, with further references, can be found at <http://www.quintet.net/>.

**18.** The next version of Quintet.net will feature a number of auto-generative processes, which will make it possible to run the program in a stand-alone "installation" mode.

**19.** The MIDI cent scale is based on MIDI key numbers multiplied by 100.

**20.** These maps can be created either manually as text files or automatically with Victor Cerullo's Magic Microtuner utility <http://groups.yahoo.com/group/16tone/>, which can import tunings from a library with well over 1,600 tuning files in scala or mtx formats.

**21.** Chris Brown, personal communication.

**22.** Dean Pawliw, "The Music Is the Message," *mTheory* **3** (2002) <http://www.mala.bc.ca/~soules/mTheory/vol3/pawliw/music.htm>.

**23.** Using an external controller such as CM Lab's motormix, an additional seventh player can perform as a video artist.

**24.** A part consists of a sequence of messages specifying the appearance of one line of music. The code, which has been specifically developed for real-time notation in Quintet.net, can, in theory, also be used for automatic score generation, something I would like to explore in the future.

**25.** Georg Hajdu, "Quintet.net—A Quintet on the Internet," *Proceedings of the International Computer Music Conference* (Singapore: ICMA, 2003) pp. 315–318.

**26.** Carl Sagan, *Contact* (New York: Simon and Schuster, 1985).

**27.** John Cage, *Five* (score) (New York: Edition Peters, 1988).

**28.** Manfred Stahnke, "*Orpheus Kristall*—Opera in Two Media," in Habakuk Trauber, ed., program notes to the 8. Münchener Biennale, 2002.

**29.** Anne La Berge, personal communication.

**30.** See <http://www.medienkomm.uni-halle.de/institut/team/wiss_mitarbeiter/foellmers_pdfs/Netzmusik_.pdf>.

**31.** With the implementation of a few new features, the environment can increasingly be used for solo performances as well. With an open architecture, users will also be able to write their own effects modules.

**32.** Technological advances will eventually allow the use of high-resolution video streaming without noticeable latencies for the creation of virtually unified spaces, along with advanced virtualizations in the audio domain.

**33.** See <http://www.orpheuskristall.net>.

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*Georg Hajdu, born in Göttingen, Germany, in 1960, was among the first composers of his generation dedicated to the combination of music, science and computer programming. After studies in Cologne and at the Center for New Music and Audio Technologies in Berkeley, California, he received his Ph.D. from U.C. Berkeley. In 1996, following residencies at IRCAM and the ZKM, Karlsruhe, he co-founded the ensemble WireWorks, a group specializing in the performance of electroacoustic music, with his wife, Jennifer Hymer. In addition to his compositions, which have earned him several international prizes, Hajdu has published articles on several topics on the border between music and science.*