Les Demoiselles D'Avignon

Interactive Quartet

First performance Reid Hall, Edinburgh, February 1st 2015
by Dimitris Papageorgiou, Emma Lloyd, Clea Friend, Pete Furniss
Duration 11', Dedicated to the Bologna Cello Project

Fig.1 The painting

Live recordings at:

https://youtu.be/Tj1VujA90QM
https://www.youtube.com/watch?v=AD0fknwQjRw&feature=youtu.be

PRESENTATION

MODEL

Le Demoiselles d'Avignon is an interactive quartet for bowed-string instruments.
The quotation of Pablo Picasso's painting refers to the reconstruction of a reality where different points of observation coexist, also because of the deformations of the space due to the implicit action of the physical bodies.
The sculpted representation of the female figures (recalling African styles) resists the classic concept of an objective visual-perceptual organisation. The portrait is not yet Cubist, but clearly anticipates a new spatial order, towards a plurality of dimensions and categories inside one single collapsing surface.

FRAMEWORKS

The musical interaction of the quartet is obtained through five laptops in network: one for each musician, with the addition of one more generating the video in real-time.
The whole set of connections between the gestures and the digital interactions of each single player creates the sound development and the aim of the work. The time-space (the musical form) of the work is not imposed a priori, it emerges as a shared activity from the different points of view of each musician acting as an augmented-instrument performer.
In this work the augmented-cellos are based upon the real-time analysis of the sound as it combines with the bow gestures performed on-stage.

The musicians read the flows of analysis data, performing them as musical functions.
The software mappings are designed in order to build musical structures and to influence the other players (processes, messages and scores), charging the habitual chamber music gestures with interactive extra-meanings.

The conscious feedback between the physical performance, its analytical monitored knowledge, and its compositional use in real-time places the human agents in the conditions to collectively define shared spaces of action, mediation and exchange.
The current digital means allow actions and symbols to be unified in the same environment: in this sense physical actions, scores and messages can be part of a complex digital instrument allowing real-time composition.

The system is conceived in order to recognise music expression by means of spectral sound analysis, note detection and motion tracking (the latter organised for the description and computation of some classical bowing styles).
The aim is to augment the traditional chamber music communication through a texture of functional remote influences and a net of formal mediations between the performers.

NOTES
The work makes use of 5 MAX/Msp applications (one for every laptop).
Each system comprises music processing, scores and monitors, and calibration settings.

An external coordinator of the interaction is suggested, if possible a sound engineer. Due to the interactive character of the composition, the musicians need detailed explanations of their system.
The scores are embedded in the real-time software and cannot be printed.

The musicians are here defined as Cello_1, _2, _3 and _4. The work can be performed by any type of bowed-string ensemble, whether classical or experimental. The performers exploit a small motion tracking sensor (Inertial Motion Unit, IMU) tracing their principal bowing styles *Balzato, Tremolo, Staccato* and some bow dynamics. Cello_4 instead interacts only through sound: if a different ensemble is used, “Cello_4” need not be a string instrument, any other monodic instrument is allowed.

This document consists of:
-presentation
-interaction explanations
-general and individual performance notes
-setting details for the coordinator of the performance
-tech and audio specs

The performers should be aware of the following interaction notes before reading the performance details. An explanatory video support for each performer is included.

INTERACTION

ROLES
Each musician has the responsibility to:
-invent and perform his/her chamber music
-interact with his/her specific digitally-augmented cello
-generate through music gestures messages, scores and sound processing upon the other players
-influence, through the same music gestures, some global shapes of the overall music event.

The improvisation is thus shared, controlled and functional.
All the visual cues are received by the performers on the screen of their individual laptops, positioned in front of them in a "music-stand" fashion.
The final behaviour of the composition is in part pre-designed in the software and in part interactively created by the gestures of the musicians on stage.

These interactive global aspects are the following:

-Cello_1 generates the background colour screen of all the Apps, whose significance regards some modalities of the overall performance, but above all an indication about the densities of playing.
-Cello_2 sends an animated action score to the other musicians, and makes choices upon the video.
-Cello_3 spatialises the electronic sounds produced by the ensemble, and in addition live-selects, records, diffuses and processes sounds played on stage.
-Cello_4 sends a variable chord, as a shared tonal centre.

Other shapes can be preconfigured by the ensemble, a video is processed in real-time responding to the bowing styles and dynamics of the performers.
A full interactive score in pentagram form is received by Cello_4.

AUGMENTED INSTRUMENTS
The sensing system is based on motion tracking and audio analysis, the devices exploited as sensing inputs are small inertial motion units (IMU) positioned under the frog of the bows, and contact microphones on the bridge of the cellos. Each musician performs autonomously a totally different augmented instrument in terms of sensing input, mapping space, kind of output and interactive role. Each musician contributes to the consistency of the overall result through global controls and remote dialogues: the same sound-gestural means (audio analysis and gesture computing-recognition) finalised to global interactions are driven by each musician towards an individual electroacoustic sound palette.

Fig.2 The wireless IMU sensor under the bow frog

-Instrument_1 (Cello_1; Spectral): generates interactions by means of bowing-styles captured by the IMU. The sound output spectrally transforms its acoustic cello sound (freeze of the spectrum, dynamic equalisation, transposition-decomposition of the sinusoidal/noisy partials).
Through bowing-styles it sends variable background colours to the other players (colours are intended as an interactive graphic score).

-Instrument_2 (Cello_2; Artificial): generates interactions by means of a hybrid gestural sensing system (bowing-styles captured by the IMU combined with spectral sound analysis). As output it creates sounds of synthesis (physical models, additive synthesis, frequency modulation synthesis). It sends graphic interactive scores to the other players.

-Instrument_3 (Cello_3; Sampler): generates interactions by means of bowing-styles captured by the IMU. Selects prerecorded files, and record-renders live fragments played by the other musicians, applying transpositions, fragmentations and overlapping on the output materials.
It spatialises the sounds coming from the ensemble of augmented instruments.

-Instrument_4 (Cello_4; Harmoniser): generates interactions by means of the sound expressiveness of the cello performance captured by means of sound analysis computed at a note-level.
The sound output is made of "canonic" transpositions of the input sound (four-voice harmoniser).
It sends variable chords to the other players (shared tonal centre) and receives an interactive score in full common notation (built by the bowing styles of Cello_2).

SENSING SYSTEM

The digitally augmented instruments (hyper-instruments) are based on a motion tracking system aiming to offer the musicians means to interact with the digital composition through the same gestures normally functional to the acoustic outcome: therefore without disturbing the classical (or experimental) techniques.

Cello _1, _2 and _3 mainly interact through motion tracking, Cello_4 only through sound (timbre analysis, note detection and expressiveness pattern recognition).

The former three musicians receive and monitor interpreted bowing styles computing through the interpretation of:
-Angle/Orientation of the bow movements on the Horizontal axis
(from the low to the high string)
-Angle/Orientation of the bow movements on the Vertical axis
(from "full-hair" bow position to "hair plus wood")
-Global bow Energy ("*velocity*")
-Energy of *rotation* (with respect to the instrument strings)
-*Tremolo* intensity
-*Balzato* intensity
(Energy of orthogonal movement towards the string: *Ricochet* or *Spiccato*)
-*Staccato* intensity (*Martelé*, massive "alla corda" style)

The intensity of a bowing style is here intended as a sum of the global amplitude and velocity of the pattern.
Motion tracking applies to performing bowing styles, as like to silent bow movements in the air.

These seven continuous parameters are integrated with three types of impulsive bow motion recognitions (functional to triggering and on/off interactions):
-impulsive *rotations* of the bow
-impulsive Accelerations of the bow
-hybrid system of bow position recognition with respect to the strings

Below is a graphic summary of the principal gestures recognised and computed by the system. The description of the audio-analysis parameters will be reserved to the individual notes for Cello_4.

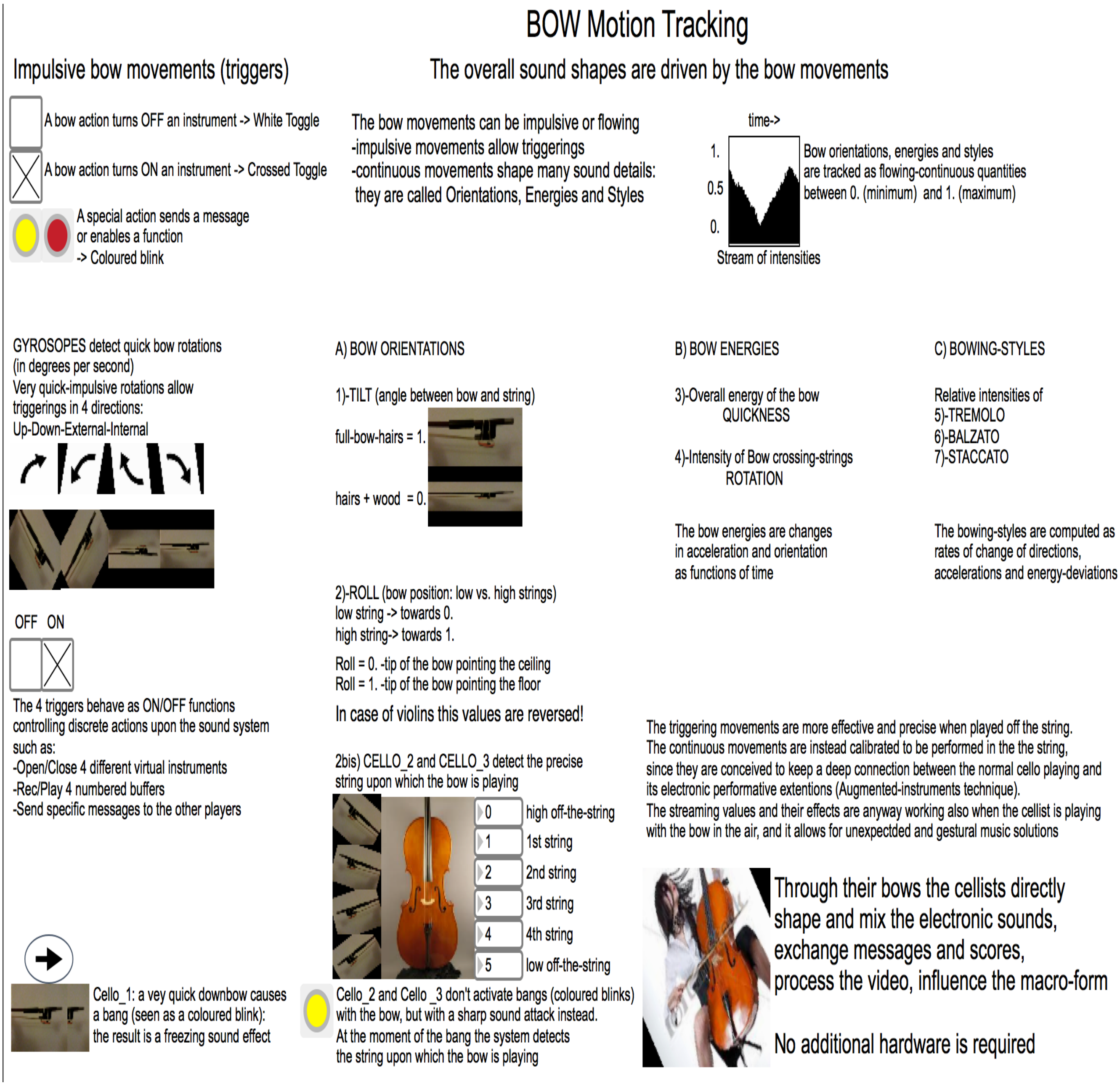


Fig.3 Motion Tracking functions

COMPOSED INTERACTIONS

The augmented instruments have preferential trajectories of dialogue.

-Cello_1 and Cello_3 drive their electroacoustic processes through bowing styles, but the intensities of some styles (*Tremolo, Staccato, Balzato*) are computed either individually or as a reciprocal gradient of similarity between the two performers.
In this way the two musicians (contrasting or imitating each other) strongly influence the sampling processing coming from the electronic sound of Cello_3.

-Cello_2 and Cello_4 drive together a crossed system highly reliant on pitches and notes produced in real-time. Cello_2, through the bowing-styles T*remolo, Staccato, Balzato*, generates pitch and rhythm in one of its virtual instruments, but the same module also generates the polyphony (density, rhythm and pitch transposition) of Cello_4, whose augmented instrument is a four-voice harmoniser; in addition the same module of Cello_2 generates the notes received by Cello_4 in its interactive pentagram.
Part of the sound synthesis of Cello_2, the electronic polyphony of Cello_4, and its score are therefore strictly correlated in terms of rhythm and intervals since they are generated by the same gestures, produced by Cello_2.
On the other hand Cello_4 has the power to activate and mute the four virtual instruments of Cello_2 by means of the melodic intervals of its performance.
Cello_4, through its musical expressivity, can also influence the resonance, intensities and shapes of Cello_2's electronic sounds.

As described above, all four musicians have a role in affecting the global development of the composition:

-Shared tonal centre (interactive variable chord) sent by Cello_4
-Spatialisation driven by Cello_3
-Action score sent by Cello_2
-Background colour (as a graphic animated score) sent by Cello_1

Tonal centre

Cello_4 controls the shared tonal centre through an algorithm defining his/her last most often performed notes.

Spatialisation

Cello_4 has an autonomous fixed quadraphonic output system .

The other three musicians output their sound in stereo; their stereos are individually spatialised by the bowing styles of Cello_3 (see Cello_3 individual notes).
The overall spatialisation can be octo or quadraphonic.

Action score

Through a conventional bow gesture Cello_2 interrupts for a brief period any current activity of Cello_1, _2 and _3. An interactive image appears on their screen in synch which has to be performed by everybody with intensity and impulse.

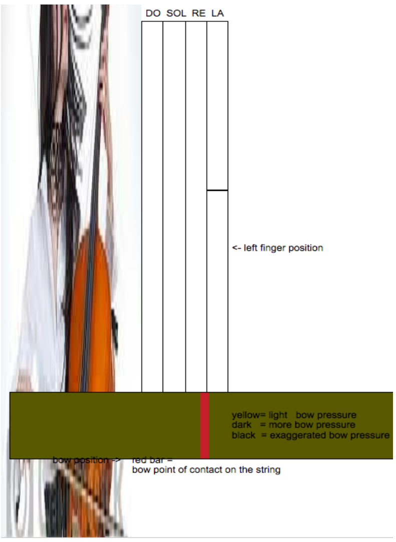


Fig.4 Action score

The image consists in a stylised cellist where:
-A quick moving small segment shows the left hand position on the fingerboard and the four strings
- A coloured bar represents the bow:
black = more bow pressure on the string,
Yellow = light pressure,
Bar movements up and down =
bow from sul-tasto towards near the-bridge,
Red pointer = point of contact of the bow upon the string (between frog and point)

The movements of the score are generated by the real-time sound analysis of each cellist.

Background colours

The background colour of each laptop has a crucial impact on the macro-form.
Each musician receives the same colour sequence at the same time, but with different gradations of brightness. At the beginning all the musicians will receive a black background (with the exception of Cello_1, who receives a white background).

Black = Silence; White = play a solo**.**
The overall length of the work is 10 minutes, preceded by 30” of solo Cello_1.
These default time lengths can be modified before the performance inside the settings of the Cello_1 App (see setting section below).
During the initial solo, some bowing styles of Cello_1 are associated with colours.

After these 30” the ensemble interaction starts, since the musicians receive the colours created by Cello_1: the background colour is a trace indicating how to play.
During the ensemble interaction the temporal development of the colours changes 20 times slower than the original bow gestures of Cello_1, generating them.
The initial 30” are therefore the seed of a macro-formal message, and Cello_1 is aware of that during his/her solo (see individual instructions).

The musical meaning of the colours should be a shared ensemble decision made in advance and regarding character, intensities, mood and techniques of the performance
(but a loose improvised interpretation of the colours could also be appropriate).
The only fixed interpretation regards the meaning of the parameter of brightness vs. darkness.

Bright = increase in the active generation of original musical materials.
Intermediate = short music commentary, accompaniment, dialogue, digital interaction.
Dark = decrease in originality and limiting to the sound gestures only affecting the interaction towards the other musicians and the overall music shapes.

After a few rehearsals the musicians easily learn how different these two detached performance styles are: the first flowing and expressive, the latter discrete, atomised and functional.
The decreasing gradients of activity (solo, dialogue, accompaniment, commentary, single gesture, silence) imply the increase of functional and structuring "compositional" detached sound gestures, and two distinct performance modes emerge:

-1) fluid, improvisatory, individualistic

-2) objective, detached, compositional, influencing the external communications and the sounds of the other people.

The composer has however predefined some internal envelopes of brightness, preserving the colour but differently time-shaping the individual quantity of light for each performer.

All the musicians will therefore be receiving different tonalities of brightness: in this way Cello_1 will be very active at the beginning, Cello_4 predominant towards the end of the piece, Cello_2 and Cello_3 will be performing with some peaks of foreground action in some intermediate points of the performance.

CIRCUIT

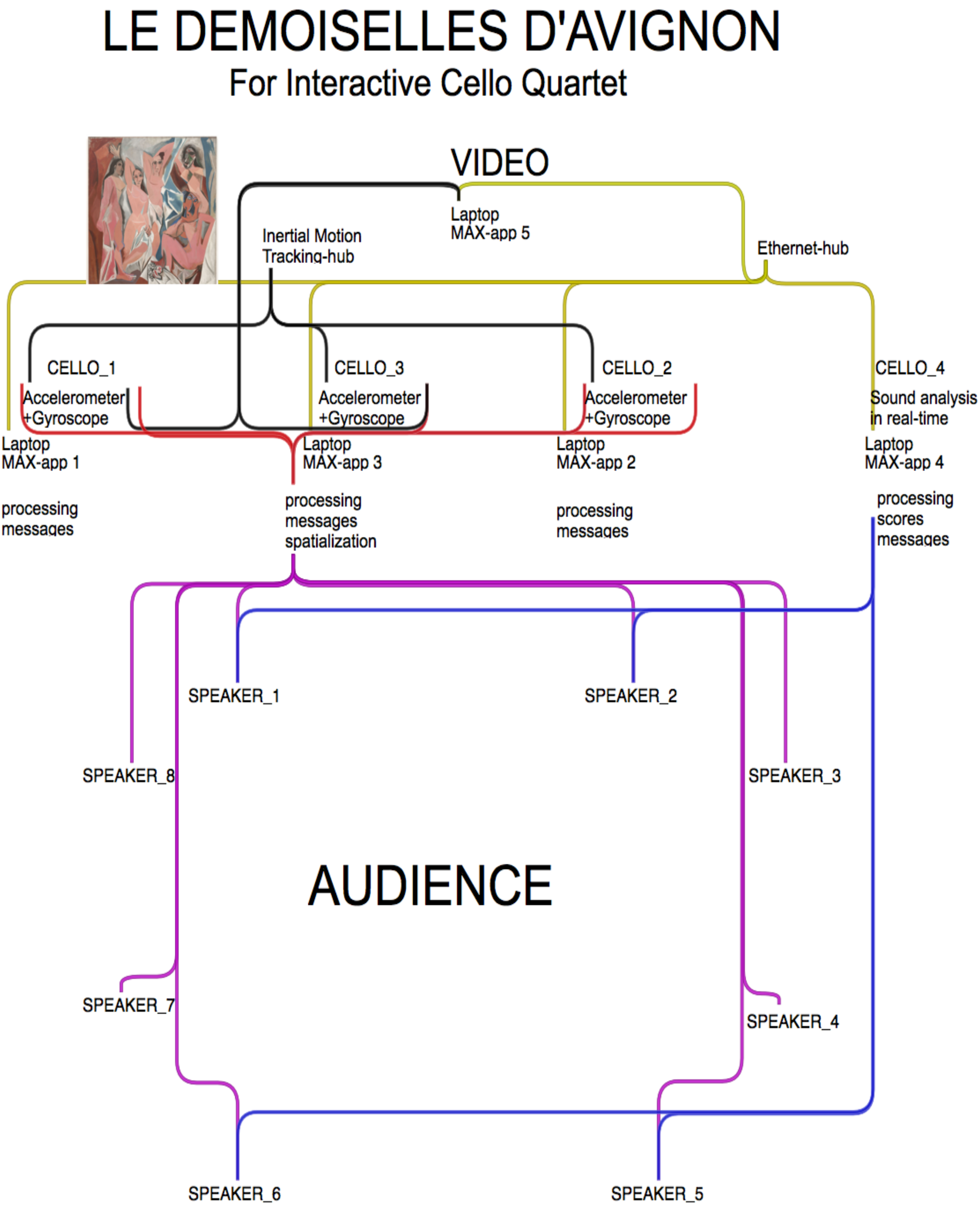


Fig.5 The circuit

GENERAL INSTRUCTIONS FOR THE WHOLE ENSEMBLE

The laptop screen is at the same time a monitor and an interactive score, upon which to model the ensemble improvisation, the reciprocal influences and the technical control.
Each musician is provided with a laptop (containing one individual MAX-Application), one sound card, and at least one microphone (see the final section "hardware equipment").
The laptops are linked via Ethernet.
The performance notes don't include any scores, since the composition is an ensemble interaction, and behaves much more as a collective instrument requiring explanatory details rather than notational instructions. Before starting the performance, a general review of the settings is necessary. The settings are contained inside each App, sometimes accessible as hidden modules by double-clicking the corresponding label.

SETTINGS
Each App contains three setting sections:

1) *Setting*: this section is positioned in the upper-left part of the screen.
   The written labels inside the red and yellow borders can be opened by double-clicking on them (each yellow or red bordered label can be opened with a double-click).
   These interfaces are called: *"p network", "p audio-settings", "nb.bowings*".
2) *Input/Output*: sound monitors and number boxes (filled with default values).
   These numbers set the input and output gains normalised between 0 and 1.
   By typing or dragging the decimal numbers it is possible to modify the gains.
3) *Calibration*: number-boxes (monitors and settings).
   Calibration can be manual or automatic.

A few parameters need to be checked inside these modules before every performance.
-the motion tracking monitors have to show flowing data
-check that the right sound card is active (double-click "p audio-settings")
-the input/output gains should be appropriate
-in case of lack of motion tracking control, a new calibration needs to be performed
See video description.

PERFORMANCE: START!
After organising the settings (the first time it will be a rather complex procedure), the calibrations should be remembered by the Applications, and only a brief checkup is recommended before every new performance (above all the sound card check inside "audio-settings").
The performance starts when Cello_4 presses "Spacebar" on his/her laptop. At this moment Cello_1 receives two off-beat flashes, and then immediately starts the opening solo.
During the solo the background colour of Cello_1 is white, while it is black for the other musicians.
After the time of the solo (30" by default) all the laptop backgrounds start to shift across different colours, and then the ensemble performance starts to evolve. At the end, all the laptops will be black again and the ensemble silent: Cello_4, being the last one to receive a steady black background, turns off the system by pressing "Enter"

CELLO_1. SPECTRAL

Video performance instructions at: https://www.dropbox.com/s/4suc3k9ecm9xcfj/cello1-instructions.mp4?dl=0

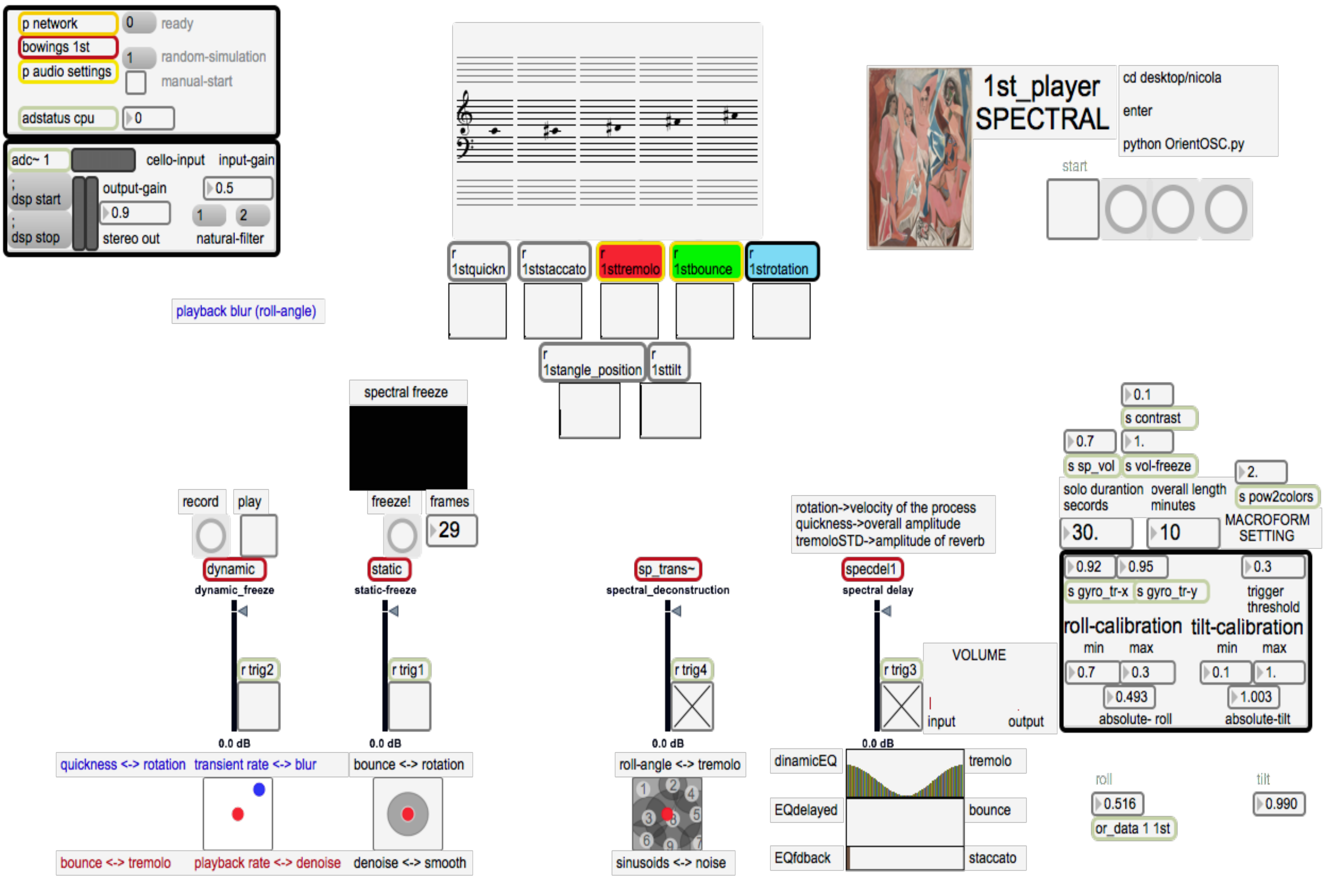


Fig.1-C_1 Cello_1 application

ELECTRONIC SOUNDS AND INTERACTIVE ROLE OF CELLO_1

Cello_1 is the instrument that explores most deeply the cello timbre. This feature is underlined by the foreground role in the initial part of the composition, where the main sound qualities are introduced, and upon which the other players will act by development and contrast.

The electronic sound of Cello_1 involves spectral modulations of the live performed cello, therefore not evolving by contrast, but instead deepening and interleaving the cello acoustics.

Performance could be shaped through:

-a frequent use of bow-wood sonorities: this bow *rotation* amplifies the direct cello sound, meanwhile attenuating the electronics amplitude, in a dry-wet fashion.

Performing with “full hair” on the strings instead increases the electronics presence.

- scraping, noisy and on-the-bridge sonorities induce broad and rich spectral responses, a fuller and more common cello sound will produce more static responses from the electronics, energetic bowing styles, sometimes also performed in-the-air, can help to mix exasperated cello sounds with more dynamic electronics interactions. Timbre is globally oriented to a clear cohesion and intimacy between cello and electronics.

The composition opens with a solo, immediately starting after two off-beat flashes on the screen.

The solo is improvised but it should be prepared in advance taking care of the following responsibilities towards the ensemble:
-exposition role of the sounds (obviously1or 2 virtual instruments are to be immediately chosen and opened by bow triggers)
-development of a tonal centre (freely following the chord sequence written on the screen, which during the solo is fixed with the pitches C, C-sharp, D-sharp, F-sharp, A-sharp)
- choice of a clear sequence of T*remolo* and B*alzato* bowing styles with precise dynamics of *rotational* energy across the strings: as described below, the evolution of the overall background colour macro-form received by the whole ensemble throughout the performance depends on these bowing styles alternating during the initial solo.
The opening solo will be created in order to musically mix these three obligations. The solo is signalled by the white background colour: when some colours start to appear the ensemble music begins. These instructions take for granted that the section "composed interactions" on pp. 4-5 is fully known. The overall time-envelopes of brightness/darkness show the tendency for Cello_1 to fade out from an active foreground role at the beginning towards a final stillness. Bright colours mean production of flowing and original music materials, intermediate colours mean gestural and more detached sound commentaries, performed with full attention towards the ensemble. The darker the colour the more the performance will be involved to focus only on the dialogue with Cello_3 and on its output (similarity vs. diversity in the intensities of T*remolo, Staccato* and B*alzato* between Cello_1 and _3 strongly affects the output sound of Cello_3).

FEATURES AND INTERACTIONS
From the very beginning the performance evolves progressively through these focal sections:
1) Solo, building a macro-form (white background)
2) Active flowing sound interactions (bright backgrounds)
3) Short commentaries and dialogues with Cello_3 through bowing styles (dark backgrounds)
4) Silence (black background)

-1) The solo sets a sound exposition and a melodic-tonal centre. This exposition has to be integrated with a clear sequence and mix of the two bowing styles *Tremolo* and bouncing, performed with different intensities of *rotation* across the strings. The intensities of *Tremolo*, bouncing and bow-*rotation* are recorded by the system, transformed into colour messages, and sent to the backgrounds of all the laptops when the solo is concluded. *Tremolo* generates Red intensity, Bounce *(Balzato*) generates Green intensity, bow-*rotation* generates Blue intensity. Mixed bowing styles generate mixed colours, a single bowing styles generates a pure tonality. Bow stillness creates darkness, and bow hyperactivity brightness. These values are recorded only during the time of the solo, at the precise moment that the solo finishes the system doesn't record anymore, instead it starts to output the background colours for everyone (this is the signal that the ensemble part is beginning).
The output time of the colours is time-stretched and lasts until the end of the work. If the solo lasts 30" and the work 10', it means that the initial bowing styles will produce a flow of colours 20 times slower, affecting the subsequent macro-form messages as a seed (i.e. the background colour happening after two minutes of ensemble performance, is generated and corresponds to the bow movements performed after six seconds of solo).

-2) The more active and flowing-creative sound interaction will happen during the solo and during the first part of the performance (the brightness of the background colour telling how active to be).The sound interaction is afforded by bow-impulsive triggers opening and closing the virtual instruments (see the last section on virtual instruments p.15-17 and the video example).
The internal response of the virtual instruments is played through the bowing movements, by internal mappings that can be visually followed from the laptop screen. The mappings avoid linear parametric approaches thus permitting a global and musical interplay allowed by the complex behaviour of the modules employed (see foot notes for more info) and by mappings oriented to navigation instead of punctual control. The aim is to treat the electronic sound as if it were a "normal" musical instrument whose responses can be logical but highly complex and non-obvious: they have to be mastered through practice and knowledge of the specific character of each virtual instrument. The electronics can be attenuated, and the cello more amplified, when the bow plays with less hair and more wood (tilt towards 0.), producing a slightly scrappy sound: but the same effect happens also if the bow moves in the air with the same tilt value.

-3) As the background darkens the performance starts to reduce to short detached sounds and the bow gestures are no longer oriented to produce a flowing sound but instead to mainly interfere with the sound of Cello_3, by means of reciprocal bow movements. The similarity or contrast of bowing styles *Tremolo, bounce* and *Staccato*) between Cello_1 and _3 strongly affects the sound output of Cello_3, mainly involved in transforming sound files. Cello_1 takes no notice of this collateral effect when focusing on making his/her own music, but as the protagonist role reduces, the aim of interference and bow dialogue starts to be significant.
This bow dialogue is detected as the difference between the bowing intensities of the two performers in relation to S*taccato, Tremolo* and *Balzato*:
-similar *Staccato* (irrespective of being intense, lazy or absent) -> more dense-overlapping sound material from the sound files output of Cello_3
-contrasting *Staccato* (i.e. one performer plays *Staccato*, the other one *Legato*) -> short-intermittent output from the sound files of Cello_3
-similar intensities of *Tremolo* -> the files from Cello_3 are low transposed (and different intensities transpose higher)
-similar intensities of *Balzato* -> the direct sound of Cello_3 is low transposed (and different intensities transpose higher)

-4) Silence when the background is black (the second part of the performance progressively fades out, leaving final prominence to the Cello_4)

-5) Cello_2 sometimes sends an action score, which unexpectedly appears as a window on the screen. The score arrives synchronously to Cello_3 and Cello _2 itself. During these briefs periods stop any previous music activity, and perform the gestural suggestions collectively, with intensity (see above "composed interaction").

Fig.2-C_1 Action score

THE FOUR VIRTUAL INSTRUMENTS

The instruments are open and closed by the four *quick-impulsive triggering rotations* Up, Down, Internal, External, better responding as in-the-air-bowings. If the virtual instruments are closed, no sound at all will be output.

It is possible to keep open more than one instrument mixing the resulting sounds as an example one *freeze* added to one of the *real-time instruments* could result in a dynamic live effect upon a groove.

The internal nuances of each instrument are consequences of the bowing styles live performed, therefore a detailed description of the virtual-instruments internals appears necessary.

<u>Sound characters</u>

The couple of *freezes* shown in the left part of the screen, when active (in the position ON), live-record a tiny portion of input sound just at the moment of the *quick-impulsive down-bow* (the trigger is underlined by the yellow flash). The sonogram builds up the sound representation of the recorded cello input: the more the sound captured is strong and brilliant, the more the sonogram is dark and shaped, and the sound output powerful. A good synchronisation is necessary between the *down-bow impulse* (to be performed on the string or otherwise in the air) and the cello sound the player decides to be captured.

The *freeze* process captures the sound in both the modules at the same time (if they are open in the position ON). Any *freezes* overwrite the previous sound captured, but the sound inside the module still produces sound after having closed the effect, until a new *down-bow impulse* is performed cancelling the recording.

-*Static-freeze* records a very short chunk of sound, whose length is determined by the tilt position of the bow during the *down-bow impulse* (with *tilt* near zero the recorded chunk will be extremely short): the length of the freezing sound is given in number of frames inside the nearby number box.

-*Dynamic-freeze* instead records 2.5” of sound, allowing for a broader interaction whose nuances upon the freezing sound are controlled by many bow gestures together in combination.

The other two instruments, the *real-time instruments,* instead process the live sound directly.

-The third instrument, called *spectral deconstruction*, operates a detachment between the sinusoidal and the noisy components of the instrumental input. When sinusoidal components are enhanced, the effect produces a sort of “Flute of Pan” transformation: few or many sinusoids can contribute depending upon the bow controls of the effect. The noise-component enhancement instead pushes the sound to be aggressive and very responsive: sound can also be transposed and differently modelled. Inside the *spectral deconstruction effect* the final result is highly dependent on the input in the sense of its flat, light, rich or dense timbre qualities.

-Dynamic equaliser (*spectral delay*) is a deep and selective equaliser in 64 bands operating on the cello input. It is designed in order to shift between fixed-EQ states and very dynamic changes sounding as a sort of cascade-EQ. The single bands are prone to delays and feedback in order to mix their individual different persistence.

All the effects are shaped and controlled in their time behaviours by the bowing styles.
The cellist therefore performs a double action upon the acoustic instrument and upon the electronics whose shapes are influenced and mastered by the bow gestures.

<u>Internal nuances and controls</u>
The controls schematically summarised below are visually represented in the *virtual-instrument* monitors of the App, and should be aurally-visually explored.

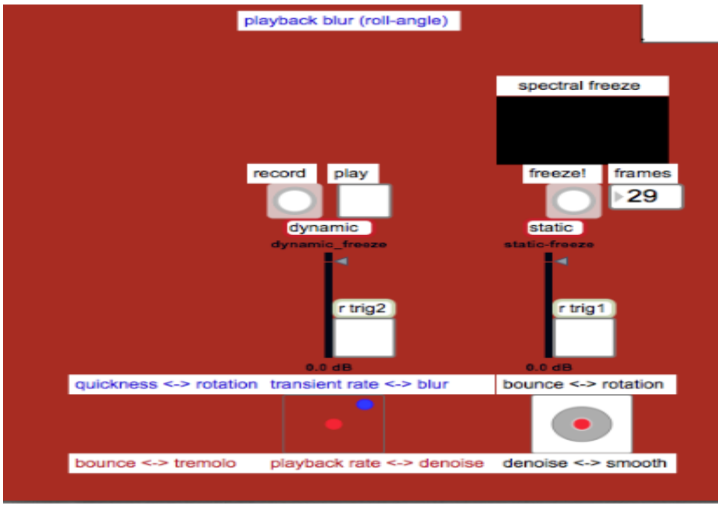


Fig.3-C_1 Action score Freezing spectrum instruments

1) *Dynamic-Freeze*
The sound captured and freezing is dynamically shaped in this way:
-playing low strings the portion of sound output is quite thin , rolling towards higher strings the portion of sound performed is larger, and the output result will sound more blurred and "confused", as shown by the blue zone inside the sonogram.
-the intensity of bouncing (B*alzato*) affects the playback velocity of reproduction of the freezing sound (few-bouncings -> static sound; intense bouncing -> quick playback;
no bouncing> reverse playback).
-the more intense the *Tremolo*, the more artificial and light is the output: the *denoise* effect proportionally selects the most prominent sinusoidal parts of the captured sound. -the bow Energies of *velocity* and *rotation* help to define clear and quick transients, otherwise blurred and slowed down when the bow is slow and moving on the same string.

Two small red and blue balls move inside the visual control space as bow monitors, even if the sonogram returns a more consistent visualisation of the sound processes in action, caused by the bow interactions.

2) *Static-Freeze*
-an intensively bouncing (B*alzato*) bow increases the *denoise* effect
- an intense *rotational* bow activity increases the *smooth* effect, making the sound static and dense. These sound effects are again monitored through a small red ball moving inside the control space, the largeness of the grey circle shows the time length of the tiny *freeze,* even if the aural response and the sonogram diagram should be enough.

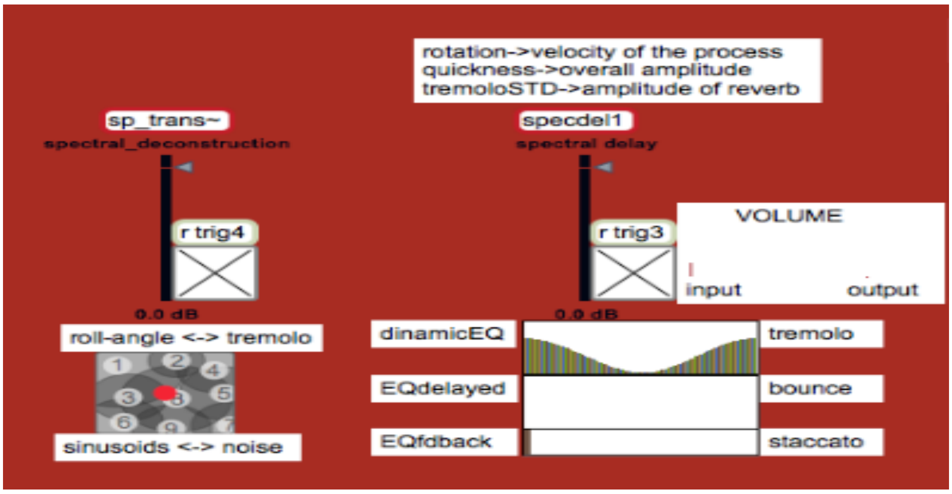


Fig.4-C_1 Real-time spectral instruments (dynamicEQ)

3) *Spectral_deconstruction*
-low vs. high strings bow-position moves the red ball high vs. low,
-*Tremolo* intensity moves it left and right.
It is a visual cue allowing to navigate inside a quite non-obvious control space, intersecting different nodes mapped to specific sound effects of density, transposition, sinusoid extraction, noisiness.

4) *Spectral delay* (dynamic equalizer)
-the intensity *of Tremolo* shuffles the resonance bands of the spectrum moving from high to low (graphically from right to left) in a wave fashion: it is represented in the *dynamicEQ* upper monitor.- by varying the intensities of bow-bouncing, the delay effect operates upon some detected spectral bands: *EQdelayed* middle monitor.
-*Staccato* increases the “feedback” (the tendency of the effect to persist): *EQfdback* lower monitor
-the intensity of *rotation* across the strings makes the equalisation shifts much quicker and dynamic, whereas playing on one same string makes the equalisation fixed and still, as underlined by the monitor shifts.
-bow *velocity* (*quickness*) and the *Tremolo* irregularity increase the volume and the reverb of the effect, as shown by the input and output volume-monitors.

Obviously this detailed support has to be globally experienced inside the aural/visual concrete interaction in order to be effective.

CELLO_2. ARTIFICIAL

Video performance instructions at: https://www.dropbox.com/s/789z2g5lhwccvda/cello2-instructions.mp4?dl=0

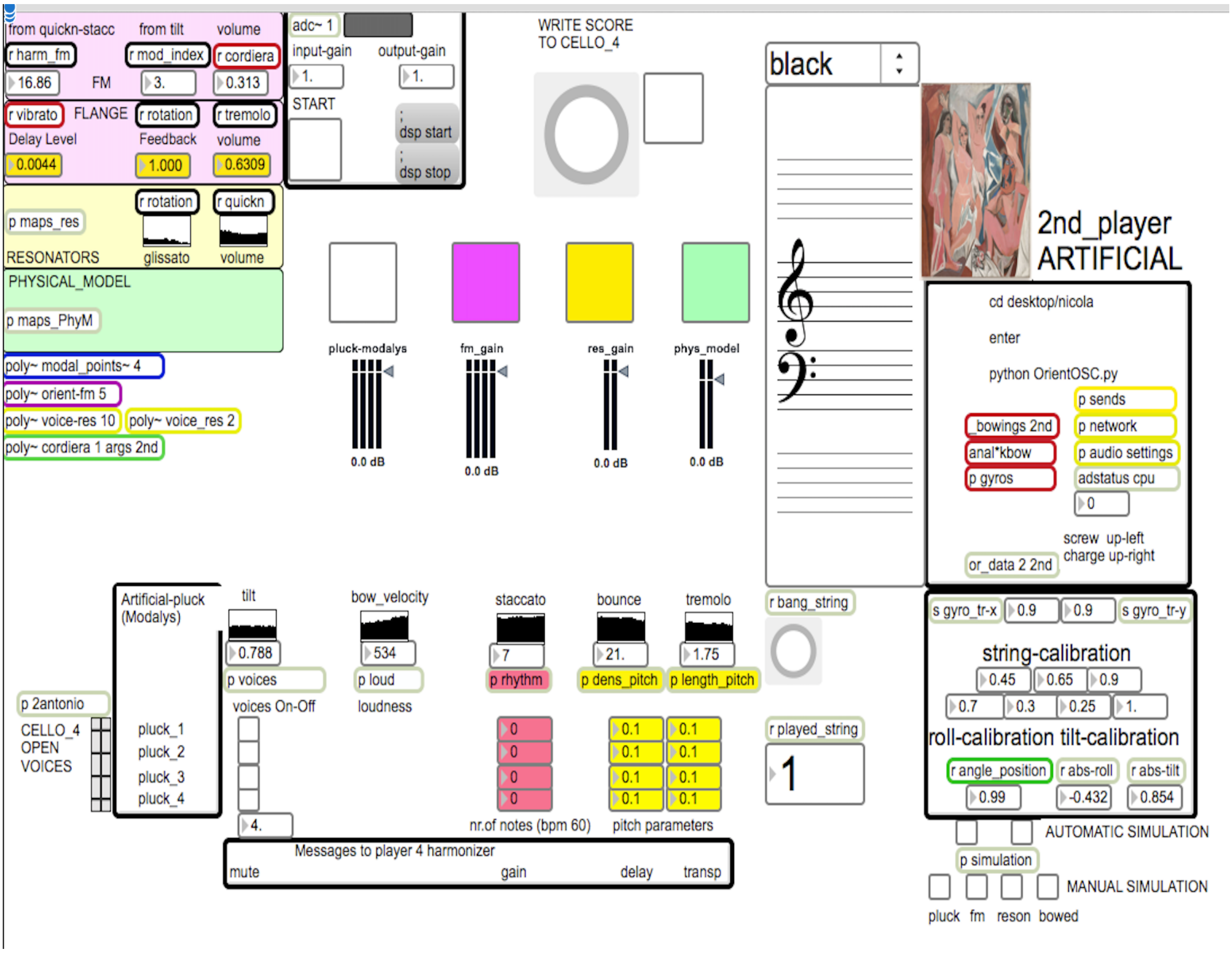


Fig.1-C_2 Cello_2 application

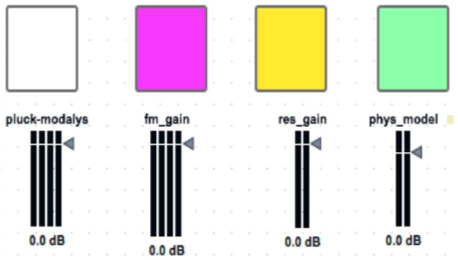
ELECTRONIC SOUNDS AND INTERACTIVE ROLE OF CELLO_2

This system is very gestural, and it generates synthetic sounds. Unlike the other musicians, the electronics act here as a contrast with respect to the cello sound, and the results will be far from obvious. The cello sound, though, is crucial for influencing the artificial sounds, which are mainly generated by the bow movements (on the string as well as in the air).

You can find a good control of the electronics by mixing bowing styles and sounds creatively. Whilst the computer interprets your musical gestures and transforms them into sounds of synthesis, it sends you visual monitors of your movements and of the sounds you are producing. In this way you receive clear feedback about how to invent and organise your performance.

Your electronic sounds are not totally foreseen, and in order to get interesting results you'll have to practise, listen and act intuitively. Notice that the acoustic cello sound sums up the electronic sound, in a sense you are playing two different instruments in coordination and at the same time.

Received messages
A variable chord (created by Cello_4 and sent to all the players) appears on the screen: freely improvise upon this tonal centre.



The electronic sounds are created through four virtual instruments, represented by differently coloured buttons located in the central part of your screen: when the button is crossed the instrument is open and you will see below it green movements representing the amount of sound produced.

Fig.2-C_2 Four virtual instruments

But you don't decide when to open and close these instruments (the choice comes from Cello_4). You can only modulate the sounds internally to the effects when they are opened.
The task is not simply to modulate the electronic sounds of your individual augmented cello: you have at your disposal further techniques interacting with the other musicians, in particular with Cello_4 (whose electronic instrument multiplies and transposes in a "canonic" fashion his/her sound).

Messages to Cello_4
-your bowing styles (*Tremolo, Balzato, Staccato*) determine the kinds of harmonisation upon Cello_4
-you decide how many "voices" are making up the Cello_4 "counterpoint"
-Cello_4 sometimes receives a pentagram score in real-time, whose notes are created by your bowing styles.

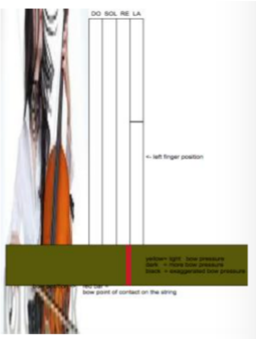
Messages to the ensemble
-when you perform a special bow gesture in the air, an interactive action score appears on the screens of Cello_1 and _3 (and yours too).
-some impulsive bow movements have the function to strongly modify the video.

Timings
As described above in the general instructions, the background colour of the screen has a precise meaning:

-Black (during Cello_1 solo): silence
-Dark (first part of the interaction): rarified sound commentaries, perform some gestures as messages to the ensemble.
-Bright (central part of the interaction): play more intensively; when the colour is white it signals the presence of your solo
-fading to Dark (second part of the interaction) play less intensively, but keep alive the gestures modifying Cello_4 electronics (you will notice that his/her is playing much more in the second part of the work).
-again Black (ending part): stillness

INTERACTIONS

Messages to the ensemble (first part of the interaction)



-*“quick-impulsive horizontal-bow”*.

An extremely impulsive and Horizontal (parallel to the floor) bow gesture immediately triggers an action score for Cello_1, _2 and _3: you will interrupt any current activities in order to play this animated graphic score together. The strength of your impulse has an impact on the length of this performative window, which it will be anyway short lasting.

The performance instructions of this score are explained above inside the general instructions (p. 7).

Fig.3-C_2 Action score

Don’t launch this effect too many times. It will be especially suitable for offering immediate vitality and contrast to the performance: find the right moment, and notice that the effect is active after the initial solo of Cello_1, and it will be disabled in the final part.

-*“quick-impulsive triggering rotations”*.

Four quick impulsive *rotations* of the bow in the air (up-down-external-internal) modify the state of the video:

Internal = Black

External = Colored

Up = visible score

Down = full video

Fig.4-C_2 Message to video

This interaction is active in the first part of the work, after the first receiving of the score by Cello_4 the process will be automatic, and after that you’ll be able to concentrate better on the musical aspects.

MESSAGES TO CELLO_4 (mainly in the last part of the interaction)

Electronic sounds

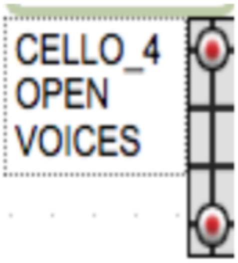
You decide how many voices "harmonise" Cello_4 (and you can change their number).

Each of your four strings is connected with one of the four voices of Cello_4.

When you produce a sufficiently clear sound attack, you'll be able to see inside your screen a yellow flash (named "bangstring"): at this point the system attempts to predict which of your strings you are currently playing; as a consequence the corresponding voice will be opened inside the electronic polyphony of Cello_4. If you put your bow on a string and you pass from the position "full-hair" to the position "hair plus wood", you will close the corresponding voice.

Fig.5-C_2 String recognition

These string positions are recognised by the system both if the bow is upon the string and if it is flying in the air.



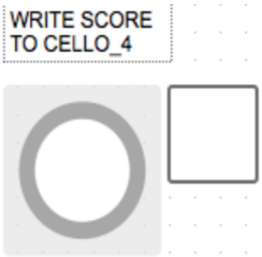
In the bottom-left part of your screen you can find a small monitor showing how many voices are active in the polyphonic system of Cello_4.
Four red buttons = all voices active; no red button = silence.
In this way you can model the density of the electronics of your colleague.

Fig.6-C_2 To Cello_4 polyphony

You can also model the quality of the last opened voice (without excessive worries about the details, the global controls are):
-the intensity of *Staccato* increases the amplitude of that "voice",
-the intensity of *Balzato* transposes it higher (and less or no *Balzato* = lower)
-the intensity of *Tremolo* increases the Delay (intense *Tremolo* = distant repetition until 5" less or no *Tremolo* = close repetition until 1/5 of a second)

It is worth noting that an identical system controls one of your virtual instruments, as will be described later

Score



A red flash in the upper part of the screen signals that the Cello_4 score is building up as a consequence of your bowing styles (it will happen much more frequently in the second part of the performance). A cross inside the white square tells that the process is working, until the cross disappears.

Fig.7-C_2 To Cello_4 score

The Cello_4 score is notated in 4/4 tempo. How to influence the interactive score:

-*Legato* produces long notes (2/4, 3/4, 4/4)
-*Staccato*: the more intense the *Staccato* is, the more quick and irregular the score rhythms will be
-*Balzato*: no *Balzato* = low notes; the intensity of *Balzato* increases the change of pitch register until very high notes in the treble clef
-*Tremolo*: when intense and irregular it increases the variability of the melodic contour.

THE ARTIFICIAL SOUNDS: VIRTUAL MUSIC INSTRUMENTS
After the details about the influences of Cello_2 upon the ensemble, this section describes the internal sound interactions of Cello_2 as an individual augmented instrument. These aspects will be more present in the central part of the performance, and its density will be tuned to the background brightness of the laptop screen.

The musical gestures (sounds and bowing styles) modulate the effects of the Virtual Instruments, only when they are opened (by Cello_4): if several instruments are opened together, the same musical gestures act in parallel, if the all instruments are closed no sound will be audible, except the amplified acoustic cello.

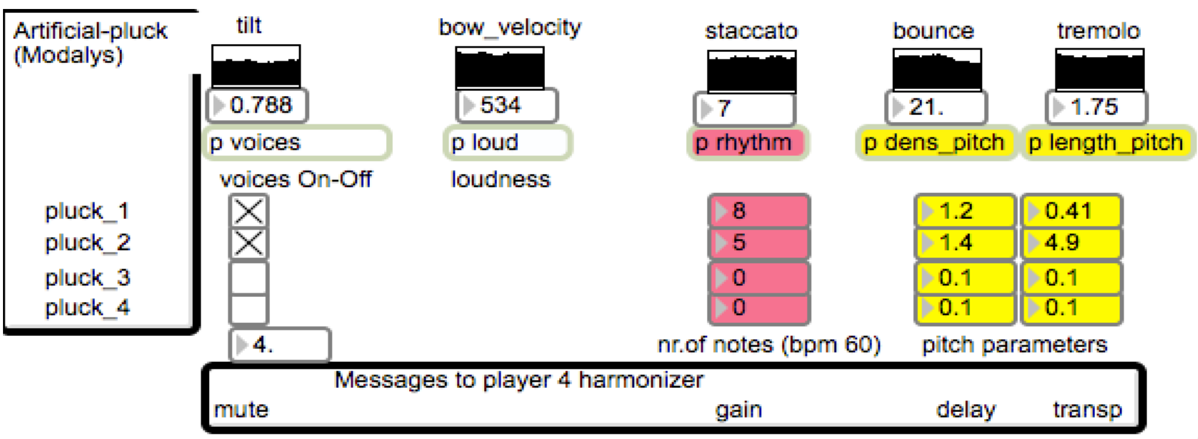


Fig.8-C_2 The instrument "Mandolins"

-White instrument “Mandolins”
The sound is produced by physical models synthesis, simulating an artificial plucked string.
The system is the same as the virtual engine affecting the Cello_4 “polyphony”, and obviously the same gestures affecting the “mandolins” have a parallel influx upon the Cello_4 electronics.

Each cello string is connected to a different virtual mandolin, the actions upon the mandolins work only when the effect is active (white button crossed).
The visual monitor is in the central-bottom part of the screen.

It is the only instrument working through a explicit and visible connection between the bow gestures and the electronic sounds.

Functions:
A clear sound attack produces the yellow flash “bangstring”, signalling that the system tries to detect which string you are currently performing.

The corresponding mandolin starts to play and you can modulate its notes (if other mandolins are active in this moment, they keep steady notes and rhythms as a “bordone”).

In the monitor “voices On-Off” you can see which mandolins are currently playing (crossed or uncrossed buttons); the numbers in the red and yellow boxes are flowing only in correspondence with the currently selected “soloist” mandolin.

You modify the notes of the “soloist” mandolin with the same procedures above described:

-*Staccato* intensity -> quicker rhythms; *Legato* -> slower rhythms -
Tremolo intensity -> the mandolin note shifts down in small intervals
-*Balzato* intensity -> the mandolin note shifts down in larger intervals
If the bow stays still, it shifts the notes very high and at a very slow rhythm.

When a new string is selected (through the “bangstring” process), the last note values of the previous “mandolin” remain unchanged. For this reason it is suggested to cross from one “mandolin” to a new one in a very dynamic fashion, in order to avoid that the last note pattern will stay fixed on high notes because of unconscious intermediate bow rests.

The overall *velocity* of the bow increases the mandolin volume, and the cello timbre has a slight influence on the mandolin timbre.

When you decide to silence one mandolin, place the bow in position “full hair” on the corresponding string, and shift it to the position “hair plus wood” on the same string (the process is only gestural, you can perform it silently without playing).

Violet instrument: “Electric guitar”.

The sound is produced by frequency modulation synthesis (FM), with added flanger and reverb. In this case the cello sound is extremely important as a source of the modulation.

The five carrier frequencies of the FM are the same as your main cello sound partials (sounds on the bridge or very noisy sounds produce high pitch variability, a more conventional cello sound retunes the sounds of synthesis together).

The overall amplitude of the effect is regulated by your cello amplitude.

Cello_4 can increase the timbral density of your effect through his/her expressiveness.

This instrument is complex and it has to be governed more with practice and listening rather than with theories, but it is useful to know that:

-*Tremolo* intensity increases the volume of the flanger (a sort of “Hendrix” effect) if Cello_4 in this moment plays more “espressivo”.

-Playing cello without changing string with the bow, the flanger starts to be massively coloured, but in presence of intensive bow *rotations* across different strings, the flanger effect decreases, and the overall sound colour changes (only the FM remaining active).

The FM is mainly modelled by bow *velocity*, bow tilt (“full hair” vs. “hair plus wood”) and different gradations of *Staccato* vs. *Legato* bowing.

In terms of FM synthesis the result will be:

Slow bow -> much more harmonic sound,

Fast bow -> sound dense and intermingled in timbre;

“Full hair” -> aggressive sound

“Hair plus wood” -> simpler and resonant sound,

Legato -> consonant timbre

Staccato intensity-> inharmonic timbre,

Balzato intensity -> increasing the reverb/resonance of the sound

Therefore a very slow-legato-wood playing style will allow a sort of “spiritual” sound effect (enhanced if the bow is left still in the air with the cello resonating). Conversely energetic bowing styles afford different contrasting effects, all raising artificial copies of the cello sound.

Notice that if you wish to completely silence the effect you need to stop the string with your hand, otherwise the effect will maintain the cello string resonances.

Yellow instrument: “Glissati”

Additive synthesis: also in this case the partials of the cello sound feed the artificial one (resonators), but here there is no audible resemblance between the acoustic and electronic sound.

The timbre oscillates between pitched glides, whistles and light/foggy small bells.

This instrument interaction is also impossible to be described in detail because the musical gestures interlace in a complex fashion; also in this case an “espressivo” performance by Cello_4 contributes to the overall volume and resonance of the effect.

Low notes (especially if dark in timbre i.e. sul-tasto, resonant pizzicatos etc.) make the artificial pitch glides slower and lower in tuning, high cello pitches (especially if *Balzato* in bowing styles) interrupt the continuity of the pitch glides. *Tremolo* intensity raises the volume and the presence of hidden resonating sonorities. Contrasting timbral differences are produced if the bow crosses the strings rapidly rather than playing on a same string.

The overall effect is quite interactive, the artificial sounds respond not synchronously to the cello, and the instrument requires some previous practice exploration.

Green instrument: "Resonant percussions"
It is a double system of physical models synthesis.

A) deformation of the cello sound,
B) resonant percussion (like a huge gong or a beaten piano stringboard),

-every energetic sound attack of the cello (monitored by the "bangstring" flash) produces a percussive output

-a nervous and quick bow conduction builds up selective bands and contrasting spectral zones, as a consequence extreme timbres and intonations arise when the percussion happens

-intensity of *Staccato* and bow-*rotation* amplify and characterise these nodes of resonance, on the contrary legato styles on a same string soften the timbre and make it more changeable.

-playing with a small portion of hair and no *Balzato* increases the resonance of the percussion, the opposite contributes to a less aggressive and detailed sound

- *Tremolo* intensity increases the amplitude of the deformed cello

The overall augmented cello has to be experimented with freedom and focus in order to memorise these new connections between bow gestures and artificial sounds. The only direct and explicit instrument is the first one, called "mandolins", the others are to be understood in an intuitive and instrument virtuosic fashion.

All the electronic nuances depend on the interrelations between the cello sound and the seven bow movement detectors, monitored inside the laptop screen. The intensities of these bow movements contribute together to the artificial sounds and they are organised as bowing styles *(Tremolo, Staccato, Balzato*), Energies (*velocity* and *rotation*), Orientations (Horizontal from the low to the high string, Vertical defining the bow inclination with respect to the string)

CELLO_3. SAMPLER

Video performance instructions at: https://www.dropbox.com/s/h0d0yi83x2pfkbe/cello3-instructions.mp4?dl=0

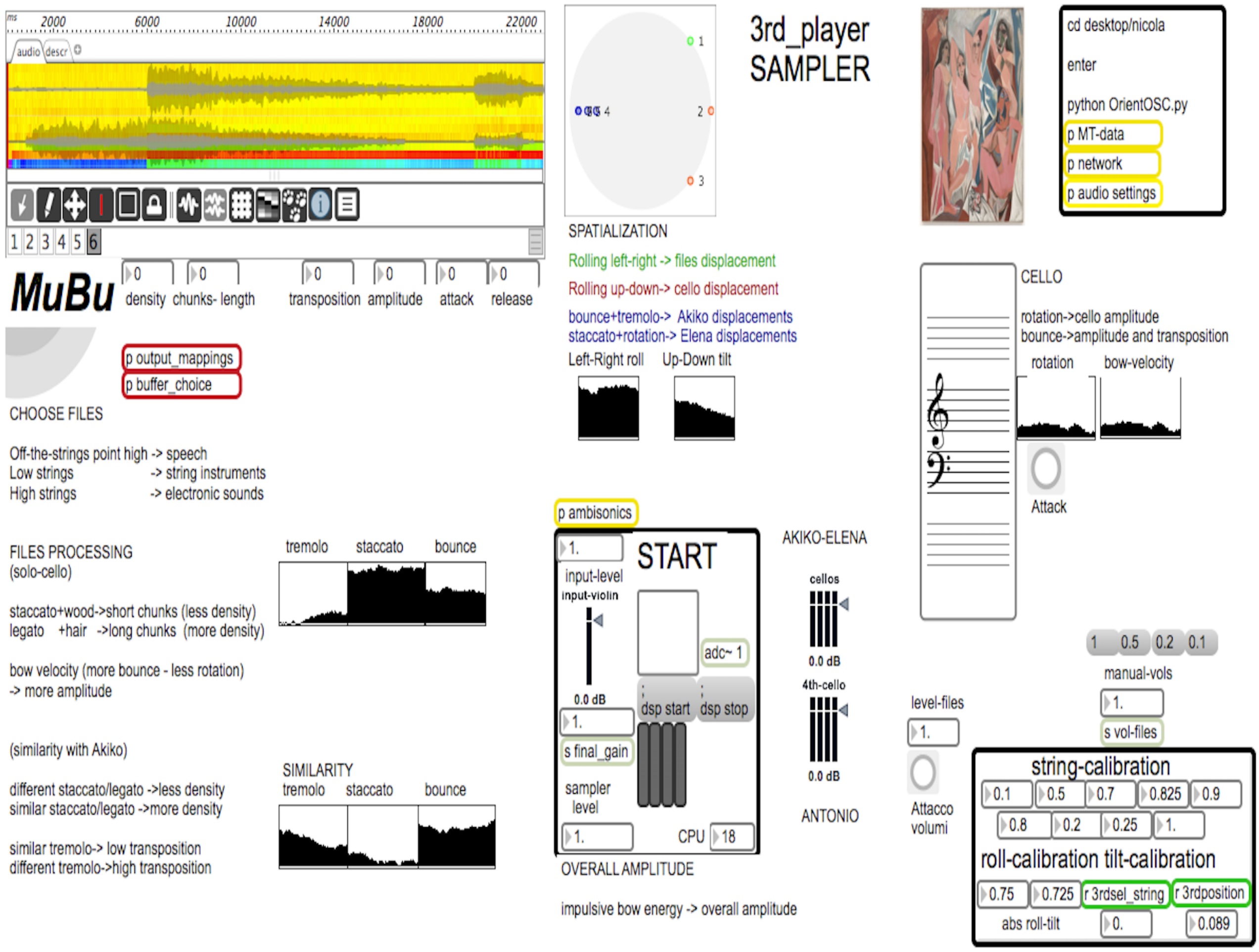


Fig.1-C_3 Cello_3 application

ELECTRONIC SOUNDS AND INTERACTIVE ROLE OF CELLO_3

Cello_3 shares with Cello_2 a developed focus on gesture. The sound of the cello is autonomous from the electronics, which are produced by bowing styles.

The principal role of Cello_3 is to spatialise the sounds of the ensemble: this activity is a principal aim from the beginning (during the Cello_1 solo) until almost the end of the performance (when Cello_4 closes the whole work alone, being the only musician provided with an independent spatialisation).

Cello_3 electronic sounds will be in the foreground especially in the middle part of the performance (following the evolutions in the brightness of the laptop screen). The autonomous electronics of Cello_3 consist in selecting and manipulating prerecorded audio files. In the second part of the performance Cello_3 can record live short portions of the sounds produced on stage by single musicians, substituting in real-time the old files with some of the new ones.

The events created by Cello_3 (the audio files sonically transformed) have the function to create contrast and discontinuity, also in opposition to the unifying activity of spatialisation.

As below described, a preferential dialogue between Cello_3 and _1 regards contrast/imitation patterns in the production of the bowing styles *Tremolo, Balzato, Staccato*.

In addition, together with Cello_1 and _2, Cello_3 will be receiving an interactive action score sent by Cello_2. The score arrives as an improvised and unforeseen window inviting the players to interrupt all previous musical action for a short period. In presence of the action score all three musicians must perform the gestural indications provided (“Interactions”, p. 7) together and with intensity.

Fig.2-C_3 Action score

SPATIALISATION

The spatialisation is driven through the algorithm Ambisonics.

The sound movements are rotatory inside the audience space.

The upward part of the monitor shows the frontal speakers, the downward the rear.

Seven sources are spatialised:

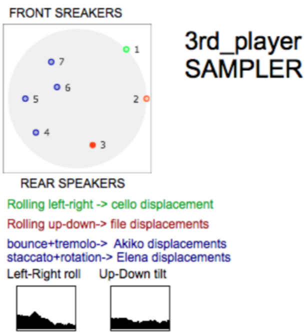


Fig.3-C_3 Spatialisation

-one copy of the player's own amplified cello sound (green source) shifted by the Horizontal bow Orientation (*rotations* between the high and low string of the cello)

-the stereo output of the Cello_3 sampling electronics (two red sources) driven by the Vertical bow Orientation (from “full hair” to “hair plus wood” positions)

-the double stereo of Cello_1 and _2 (four blue sources) respectively shifted by *Tremolo* and *Balzato* (Cello_1 stereo), *rotation* and *Staccato* (Cello_2 stereo).

The overall bow *velocity* contributes to:

-accelerate the global sound shiftings

-increase the distance between the Cello_3 outputs (the red sources).

LIVE RECORDING

Through four *rotational* bow movements in the air (the up, down, internal, external *“quick-impulsive triggering rotations”*) you will get the recording on-the-fly respectively of Cello_1, Cello_2, Cello_3 (Cello) and Cello_3 (Electronics).

Fig.4-C_3 Red_Monitor

The live recording system is active and exploitable from minute 5 after the beginning: the recognition of the four triggering movements (crossed/uncrossed buttons), is visible inside the section “recording” shown in fig.4-C_3. Every new recorded file progressively substitutes the audios stored from the beginning, their waveforms are visible inside the “Mubu” interface (fig.5-C_3). The procedure of file selection in order to output the sampled sounds remains unchanged and it works as follows:

SAMPLING

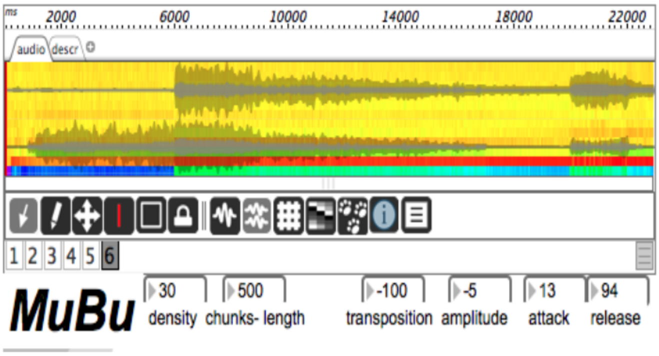


Fig.5-C_3 Sampling

Right from the beginning the system loads six short prerecorded sound fragments: you can select them in this way:

-You have at your disposal six different zones of bow inclination: 0 corresponds to “bow-point towards the floor and frog towards the ceiling”; 1-2-3-4 correspond to your four cello strings; 5 corresponds to “bow-point towards the ceiling and frog towards the floor”.

-Each of these zones of bow inclination relate to the specific inclinations of your strings towards the floor (the zones are detected both if your bow is on the string and if it is flying in the air). A reference number (“sel_string”) shows which zone you are currently occupying.

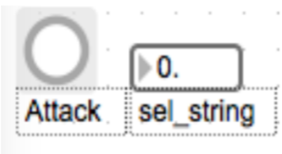


Fig.6-C_3 Choose-file

-In order to put in function the detection you must make a sound with a clear attack (maybe a left hand pizzicato would best fit, so you don’t disturb the bow location): a yellow flash signals that the sound attack is detected and as a consequence the bow-zone number is activated. After one second the corresponding indexed file is selected and starts playing[1].

[1] This latency offers more stability to your musical choices and avoids unwanted file selections. Notice that every detected sound attack produces a new file selection. Therefore you have to play a sharp sound when you wish to change a sound file, otherwise during the course of the overall performance your sound style must be generally soft and smooth.If the machine starts to make autonomous decisions (maybe too many for your taste) don’t be worried: interact with fantasy!

In other words each bow zone tags a different audio file stored in the system; the latency of the system and the need for a triggering sound attack prevent continuous and meaningless file selections, affording stability to the sampling interaction.
-the six files in numeric order contain: spoken voice, cello sounds, string quartet chords, electronic sounds, electrified piano, water mixed with sounds
-after having selected the file, you embed sound transformations upon it through a granular system which splices sound portions in lengths conceivable as “musical notes”: the audio files will be kept more or less recognisable, at least in their timbral aspects.
-the methods of sound manipulations of these “sampled notes” are mainly controlled by your bowing styles, but in part influenced also by the Cello_1 bowing styles: attention and coordination in the reciprocal bowing styles are therefore a chamber music interactive duty.
-the sound manipulations of the files regard: volume, transposition (up and down) and density.
-the density is obtained through the durations and the frequency of occurrence of each fragment: very short fragments output at bigger time distances will produce some sort of rhythmic patterns, long fragments output at high speeds of occurrence will conversely produce overlapping until dense textures. The joint variation of these two parameters (length and frequency of fragments) will produce a high degree of variety in sound emissions.
-further parameters influence filtering and more timbre features of the sampled files
-an internal system of audio analysis allows the software to automatically select the file portions more similar in timbre to the cello sound you are currently performing: you can therefore have an impact upon the sounds you are sampling through your cello sound; the other methods of granular sampling are instead driven by your bowing styles.

CELLO
The amplified copy of the cello sound will be generally soft and it will sometimes be output. Some of your bowing styles increase its presence, some others produce slight gliding transpositions emerging as distant shadows alternating with your sampled audio files.

As with the other musicians, a variable chord is present on your screen: this shared tonal centre is a free point of reference for your improvisation.

BOWING STYLES
Each subtle change of your electronics depends on the set of seven bow detections, whose monitor is visible on your screen. It is pointless to control every single parameter individually without influencing the others, the bow actions will be the results of global activities focusing upon goal oriented interactions (as happens in every musical instrument).

Every single parameter has intensities between 0. and 1. (visually from white to black), the parameters detect:
-Bowing styles (intensities of *Tremolo, Staccato, Balzato*)
-Energies (*velocity* and *rotation*)
-Orientation (Vertical -> “full hair” vs. “hair plus wood”, and horizontal -> from low to high string)

These seven parameters are common to the other players, but your system is provided with three more parameters: the difference in intensity of *Tremolo, Staccato* and *Balzato*, compared to Cello_1: the more your bowing styles are similar and the more the values of difference fall to zero, the more they are different (i.e. one is playing *Legato* while the other is playing *Staccato*, one player is playing *Balzato* and the other one not etc.). The difference value raises until 1. These values are here defined as “Similarity/TR”, “Similarity/ST”, “Similarity/BLZ”.

Below is a list of the bow parameters and their effect upon the electronics (notice that the parameters are affected through bowing styles performed upon the string, as well as in the air).

Amplified cello:
-Bow slow, with *rotations* between the strings-> increasing volume
-Intensity of *Balzato* -> transposition high
-Similarity/BLZ -> low glissato (high glissato if the value is opposite)

Sound files:
-Impulsive bow Acceleration Horizontal or Vertical (with no *rotation*!)
-> loud attack with slow fade out
-Intensity of *Balzato* -> contributes to increase the amplitude
-(*Legato*, Col-legno, Similarity/ST) -> indirect volume increase (more density of sounds)
-Intensity of *Staccato* -> shorter grain fragments
-Bow *Legato* -> longer fragments (more recognisable)
-Col legno -> more density of occurrence of the file grains
-“Full hair” -> rarified and intermittent occurrences of the file grains
-Similarity/ST -> more density of occurrence of the file grains
-Similarity/TR -> lower transposition of the file sound (higher if the value is opposite)
-*Velocity* and *rotation* -> contributes to a clear timbre (in terms of attack/release)
.
You can notice that some bow gestures overlap their functions, and it contributes to a better ductility of the system.

It could be helpful to summarise the most important interactions:

-*Velocity* impulse without any *rotations* = dramatic loud file impulse
-Intensity of *Balzato* = sustain in the file amplitude
-*Legato*, Col-legno = high density-manipulability of the file contents
-Intensity of *Staccato* = file fragmentation
-Slow *rotational* bowing = emergence of the cello
The dynamics of similarity/difference of the bowing styles compared to Cello_1 offer unforeseen variables and the opportunity for a chamber-digital interaction.
Further sound connections can be freely found and explored

CELLO_4. HARMONISER

Video performance instructions at: https://www.dropbox.com/s/l22t12bsv2tpwrd/cello4-instructions.mp4?dl=0

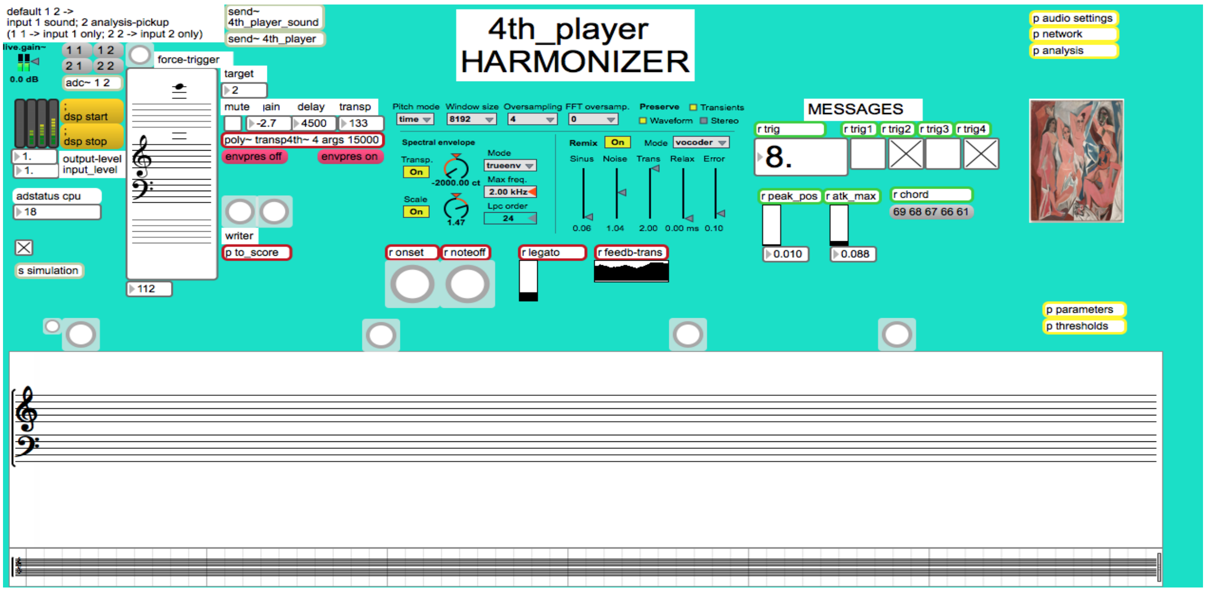


Fig.1-C_4 Cello_4 application

ELECTRONIC SOUNDS AND INTERACTIVE ROLE OF CELLO_4

You are the only musician not exploiting motion tracking. The kind of interaction is therefore different, not gestural, but based on communication with the other players through notes, timbre and music expression. The main part of your interactive system is organised in terms (almost traditional) of notes and models of expressivity.

Your performance will be split into two different modes:

A) interaction (with Cello_2),

B) free performance plus interactive score sight reading.

The mode A will be prevalent in the first part of the piece, the mode B in the second, but the mode A will be also present until the end. The density and the alternation between these two performance modes will be dependent on the colours and brightness of your screen. The brighter your screen (it will happen in the last part of the work), the more free and intense will be your music (mode B). When the screen is dark you will be limiting the performance only to the functions of dialogue and control upon Cello_2 (mode A).

In performing mode A you decide which kind of sonorities are coming out the electronics of Cello_2. On the other hand an important part of your electronics is controlled by Cello_2. Your electronic sound is based on repetitions, accumulations and transpositions of the music as you perform and improvise it. The bowing styles of Cello_2 determine the "harmonisation" and time shifts of your multiplying electronic cello. Sometimes this harmoniser output could recall almost classical ideas of "canonic" polyphonies, which can be distorted, hidden or exasperated by your timbral choices executed during the performance. In fact your cello timbre affects the timbre of your electronic output.

START/STOP
You are responsible for the starting process of the interaction.
-The music starts for everybody when you press “Spacebar” from the laptop keyboard.
-The whole music ends when you press “Enter”, after having closed all the effects of Cello_2 and after a brief fading out musical pause.

INTERACTIONS
-After the start the initial part will be silent (your screen will be black)

-During the continuation (after the Cello_1 solo) your screen begins to be dark coloured and as soon as you see Cello_2 starting to play, you can progressively interact with him/her through brief events of detached notes (this kind of interaction is explained below)

-The intensity of your interaction can increase as your screen starts to be less dark

-A full and fluid performance is foreseen in the last part of the performance, when your screen will be bright, a final solo will happen at the end when your screen will be white

-Never forget to maintain a control upon the sounds of Cello_2.

The influence upon Cello_2 is crucial and consists in:

-Opening and closing his/her sound effects (more effects can be left open in parallel, increasing in this way the overall density of the sounds of Cello_2)
-Contributing to increase volume and resonance of the effects n. 2 and 3 of Cello_2.

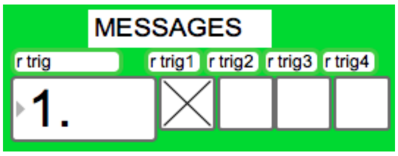


Fig.2-C_3 Interval detection and messages to Cello_2

The activation of the Cello_2 effects is actuated by a system of recognition of your note-intervals. The system responds only when your intervals are higher than one octave:

-The interval of a semitone controls the activation of the effect “Mandolins”

-The interval of a minor third controls the activation of the effect “Electric guitar”

-The interval of a tritone controls the activation of the effect “Glissati”

-The interval of a minor seventh controls the activation of the effect “Resonant percussion”.

A rising interval opens the corresponding effect, a downward interval closes it.

On the screen the interval number is visible as it is recognised by the machine: the effective numbers are: 1, -1, 3, -3, 6, -6, 10, -10, meaning the upward and downward semitone, minor third, tritone, minor seventh.
At this point a cross appears, or disappears, inside a corresponding box (see fig. 2-C_3), the same cross appears inside the screen of Cello_2, signalling the opening or closing of the sound effect.

When your note is detected, if you perform them with more internal crescendos, the system recognises a higher amount of expressivity through the parameters called "peak_pos" and "atk_max".
In this way you can increase the volume and resonance of the effects of Cello_2

It will be useful to detail the system of note analysis and detection.

NOTE DETECTION AND EXPRESSIVENESS

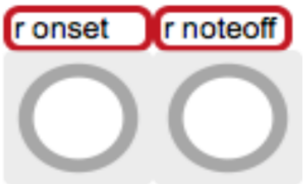


Fig.3-C_4 Note-on/off detection

-1) In advance of the note-interval recognition the system must individuate the beginning and the end of the note ("onset" and "offset"): you can monitor it through a pair of yellow flashes signalling the on-set and the off-set (note-on and note-off).

The system of analysis is able to recognise only one note at every take, and before a clear note release (signalled by a note-off) the machine can never detect a new interval: the release can be a subtle pause as well as a clear decrease in amplitude; two notes in "legato" style cannot be detected. In addition the double-stops are not understood by the system, which is monophonic. Some previous practice will be necessary in order to properly interact, due to these limitations of the system[2].
For this reason the performance style employed for the control upon Cello_2 must be based on single and slightly detached notes. As a contrast the style exploited for playing the solos will be free and fluid. The whole performance is based upon the contrast of these two different styles, which allows two consistently different sound responses from the electronics.

-2) after having time-defined the whole note (after each note-off), the system returns a simple estimate of a few parameters of expressiveness, computing whether the internal of that note contains a sound variable in intensity, provided with crescendos, or it is more or less sustained rather than decaying. Two small monitors in the lower part of your screen show these values (relative to the last performed note), which are mapped to the intensity and resonance of two electronic effects of Cello_2 ("glissati" and "electric guitar").

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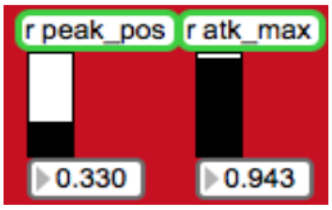
2 Occasionally the machine can make mistakes in predicting the note interval, if this happens it will be simply necessary to perform new notes without breaking the continuity of the music. If too many mistakes occur, a new calibration needs to be done.



This pair of parameters, more sensitive to the evaluation of expressiveness, are “peak_pos” and “atk_max”, respectively indicating:
-where the peak of amplitude is located inside the note (beginning, middle, end)
-how strong the attack is with respect to the maximum peak of the note.

Fig.4-C_4 Expressiveness parameters

TIMBRE

Your electronic system is in turn strongly influenced by the bowing styles of Cello_2, who determines the density, transposition and time shifts of the electronic voices which harmonise your sounds (and as described in a following section, Cello_2 is also responsible, through bowing styles, for the notes filling your interactive score in real-time). You don’t control your own electronic harmony, but you have a crucial influence on the timbre of your electronic voices, controlling it by means of your own cello timbre.

-1) when the monitor “feedb-trans" rises (increasing its black portion), it signals the increase in the amount of transposed repetitions of your sound (increasing feedback) therefore your electronics can become huge; if you lower it, you dry the effect.

Fig.5-C_4 Timbre-expression parameters

In order to increase the feedback, you should produce resonant sounds (i.e. soft low pizzicato double-bass style, or extremely light sul-tasto bowings); bow techniques “on-the-bridge” as well as intense-compressed sound styles lower the feedback, reducing the amount of chained repetitions. This control determines the overall mass of your electronics, but you can gain detail on their timbre.

-2) the “legato” threshold (Fig.28) fixes your electronic timbre at an intermediate default level when you are playing “staccato”. But when you play “legato” (no significant pauses and spaces between your notes) you will be able to model your electronic timbre: at this point you will see some sliders moving, telling you how you are modifying the timbre. In this way the dryer sonorities used to interact with Cello_2 (mode A of performance) will not interfere with your electronic timbre, which can instead be modelled during the free part of your performance (mode B). You can visualise timbre shifts (as an aid to your listening) through three vertical sliders and two rotary knobs.

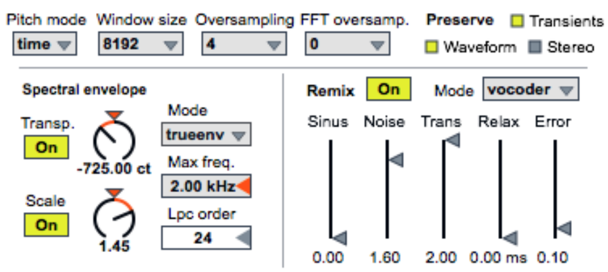


Fig.6-C_4 Tibre interactions

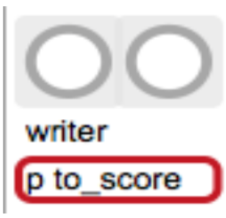
-3) -the two knobs “transp” and “scale” are sensitive to a dark-resonant cello timbre as opposed to a bright-high-compressed-intense one (i.e. resonant pizzicatos or very sul-tasto strokes vs. full tone, on-the-bridge; but also low notes vs. high notes): in other words detecting low vs. high frequency spectral contents. The two monitors will tend to move in opposite directions, but this timbre detection is quite complex and will require experimentation with listening to the timbral causes and effects (varying between deep, light, exaggerated output sounds).

-4) the three vertical sliders are sensitive to:
-extremely still and pure (in timbre, pitch and amplitude) cello sounds -> the parameter "sinus" increases producing a light-spiritual electronic sound
-highly variable cello amplitude -> the parameter "noise" increases producing a more aggressive electronic sound
- variable timbre (fast note changes, and/or quick shifts from ponticello to sul-tasto etc.) -> the parameter "transient" increases producing more clearly defined timbre edges.

Since instrumental timbre is a complex of interleaved phenomena and features, the affection of timbre parameters is a global task: try to experiment, focus and find your own style of performance in order to make a vocabulary of effective timbral influences.

During longer pauses, the sliders could react unexpectedly to the environmental sounds, producing highly deformed timbres: you can exploit this extreme effect. If you decide to include noisy cello sounds you can distort the electronics as well, and it could afford the creation of a wider electronic sound palette.

THE SCORE
The mode of performance B (second part of the piece) includes:
-continuation of mode A (interactions with Cello_2)
-free improvisation (density suggested by the brightness of the background color)
-timbral control upon the electronics (see previous section)
-reading the interactive score (density of score events also suggested by the screen brightness)



You decide when to receive a score. A strong impulsive sound attack (i.e. a Bartok-pizz, or a sharp *Staccato* at the frog) produces a yellow flash near the label “writer”: it activates the score writing process. Cello_2 creates your score through bowing styles (he/her is aware that you have called for your score).

Fig.7-C_4 Calling for the score

-Inside the bottom part of your screen the process of score building (20” long) is visible.
-The score immediately appears, it has to be sight performed, as a unique phrase you have to individuate its character and musical direction on-the-fly
-Tempo is always fixed as 4/4 at 60 BPM
-If it helps you can freely follow the yellow flashes as a visual metronome
-Tempo is not rigorous, but it must not be too enlarged (keep the musical direction)
-A new score can be called for only after the previous one has disappeared
-You are free to call for new scores at will
-Probably the score performance will keep the electronic timbre at its neutral-intermediate level
-Leave room for alternating score-readings with the other tasks of your mode B performance
-Sometimes an unwanted score could appear, a good calibration avoids misunderstandings.

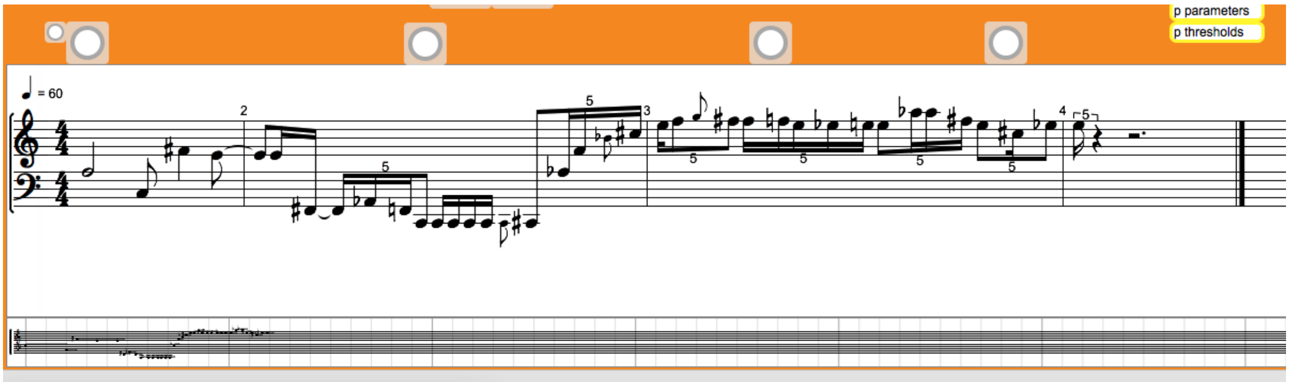
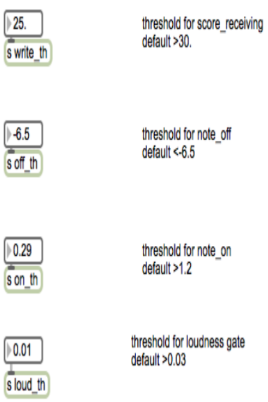


Fig.8-C_4 The score

CALIBRATION

Verifying the parameters of calibration is a task for the coordinator of the performance, but some crucial parameters can be easily rechecked inside the module “thresholds” (accessible by double-clicking its label).

The values are highly dependent on individual features, and calibration has to be rechecked when instrument, player or microphones are different.



1) The main parameter affects the “writer” threshold (how much sound attack you need in order to call for the score)
-lower the number above the label “s write_th” if it requires too much effort
-increase the number if it is too sensitive and generates too many scores
-the minimum-maximum values of the “write threshold” should be between 15 and 35.

2) If too many note-ons are detected you can raise its threshold (or otherwise lower it if you need the opposite): the optimal range of “s on_th” is between 0.5 and 2.

Fig.9-C_4 Calibration parameters

After having changed the calibration number, press the label “write”.
The other calibrations are detailed below inside the technical section.

LAPTOP_5

Laptop_5 is the main hardware connecting the whole circuitry, and upon which the coordinator of the interaction mainly operates.
The MAX application contains:
-the OSC receiver of the Motion Tracking system
-the network module sending the sensor data to the other laptops through Ethernet
-the video processing driven by the three IMUs placed under the bows of the performers

The motion tracking module “rec_orients-D” is setup accordingly to the release 2015 of the Orients system. In case of a different motion tracking system the abstraction “rec_orients-D” has to be substituted with a new one fitting with the referenced motion tracking hardware.

The system receives accelerometer and gyroscopes in three dimension.
By default the system distributes also quaternions, in case they are not available, please tell the three performers exploiting motion tracking to press the “spacebar” before playing, in order to allow an alternative bow-tracking reading.

All the data has to be sent to the performers as already normalised between -1 and +1, in order to be properly read inside any individual applications. In case of different systems or releases, the default values inside the module “p normalise” must be manually changed accordingly to the minimum and maximum values sent by the inertial system.

The laptop_5 patch is designed with MAX 6.1. and Jitter. The only MAX external employed is “o.route” (see “software” section). The images are processed through Jitter, mixed inside the abstraction "final_cut" and rendered through the object *jit.window.*

The video is rendered through Jitter and it processes in real-time an image of Picasso’s painting *Les Demoiselles d’Avignon,* occasionally mixed with images of bows and music scores. The rendering is a process based automation whose engine is preprogrammed by the composer taking the bowing parameters of the performer as dynamic algorithmic parameters. The performers don’t need to be aware of the video processing. The video shifts between four different states: 1) black; 2) coloured; 3) score projection; 4) dynamic video.

In the first half of the performance the shifts between these states are controlled by Cello_2, in the second half they are automatic.

In states 1 and 2 no images are projected, state 3 shows the interactive score as it is received by Cello_4. State 4 is the complete video rendering.

SETTINGS

HARDWARE EQUIPMENT
Five laptops: each musician performs with an individual MAC, one more laptop is required (MAC or Windows) for video and Motion Tracking collecting/distribution.

The system is tested for MAC OS X 1.6 upwards, and built with MAX 6.1For the App Cello_2 the minimum hardware requirement is 2.4 GHz Intel Core 2 Duo, and the same minimum kind of processor is recommended also for laptop_5.
The remaining three applications don't show special CPU heaviness.

5 ethernet cables 1000 Mbit/s (3 meters length), 1 Ethernet Switch.

1 Master sound card 6 inputs, 8 outputs (or 4 outputs as a minimal option), possibly RME or MOTU+ 2 stereo sound cards (outputs plugged as inputs in the master card), + 1 Sound card 2 inputs and 4 outputs.

2 microphones (for Cello_1 and Cello_4) DPA, or condenser cardioids, or directional.2 directional microphones, or cardioid DPA, or contact (for Cello_2 and Cello_3), 1 pickup for the sound analysis of Cello_4 (showing input isolation; external microphones, or piezo-pickups should be avoided).
PA possibly octophonic.

Optionally mixer and more microphones (individual and/or panoramic) for the direct amplification of the instruments.

Cello_1, _2 and _3 augment their acoustic instruments by means of a small IMU (Inertial Motion Unity) developed by the Centre Speckled Computing at the University of Edinburgh.
The current setup is dependent on the current specs and its updates.
Any different Inertial Motion Unit needs the substitution of the abstraction "or_data" with a new fitting abstraction in Laptop_5, as described in the video instructions and in the Readme file.
IMUs must return accelerometer and gyroscope data in the 3 dimensions x-y-z, and possibly also quaternions.

REAL-TIME SENSING AND ANALYSIS
<u>Motion tracking</u>
Each performer (with the exception of Cello_4) positions the sensor under the frog of the bow with the help of tie sets (the power-chip pointing up). Motion tracking data come from laptop_5. When the network is working the performers will see the data flowing inside the monitors (with the bow Vertical the tilt numbers should be higher, and with the frog pointing to the floor the roll data should be lower: in case it doesn't happen the sensor position is to be reversed under the frog).
The module "bowings" contains the MT computations, and cannot be modified.

The wireless Orient Motion Tracking system reads Acceleration, Gyroscope and Quaternion in the three dimensions x, y, z: therefore we access angles and velocities of *rotation*, but no absolute positions. Each sensor sends data to a central router talking with laptop_5, which decodes the values through Python and sends them to the laptop_5 MAX Standalone through the OSC protocol. Data are then distributed in network through Ethernet.
Figure 4 at the beginning offers a general graphic explication of the bow-tracking functions enabled in the present composition. See the video instructions about calibration.
IMUs return raw data concerning bow Orientation ("angle positions" with respect to the floor), angular velocities (in degrees per second) and Acceleration. The system implemented by this composition develops methods of motion analysis in order to extract bow Orientations, Energies and Bowing-styles.

1) Orientation. At a first stage calibration and filtering allow the detection of Orientation in the two dimensions x and y (called here bow-roll and bow-tilt): mean and smooth Acceleration help to detect the bow angle-positions, taking the directions of the cello strings as a hypothetical fixed reference.
2) Energies. Derivatives and delta root mean squares computed on single and global data from accelerometers and gyroscopes allow the extraction of time information about the bow Energies.
3) Styles. Standard deviations and FFT are implemented in order to approximate the detection of specific qualities and intensities of the bowing styles *Tremolo, Balzato* and *Staccato*.
The system globally responds in synchronised and affordable ways. It is at an experimental stage and could be improved in the future.

<u>Sound analysis</u>
Sound analysis is performed by the MAX objects *gbr.yin, mnm.moments, sigmund~, analyzer~.*
Envelope-following and pitch-tracking are computed upon the overall signal and sometimes at the level of the principal spectral partials. Timbre features are extracted by means of periodicity detection, spectral centroid (and its gaussian distributions), and computing some derivatives and deviations upon the signal amplitude and the spectral centroid.
Sound analysis is performed as a sensing system inside the hybrid tracking system of Cello_2 and more in depth inside the sensing system of Cello_4.
The sensing system experimentally implemented in Cello_4 adds to the spectral features extraction, a combined system of note detection and expressiveness description (performed not completely in real time, but on-stage in the time of the performance).

Combining onset detection and pitch tracking the principal notes and intervals are defined on line.
At a note-level some parameters describe and quantify "legato", timbre-stability, and attack/continuation performance styles (some essential details are contained inside the Cello_4 performance instructions and in the calibration video).

SETUP

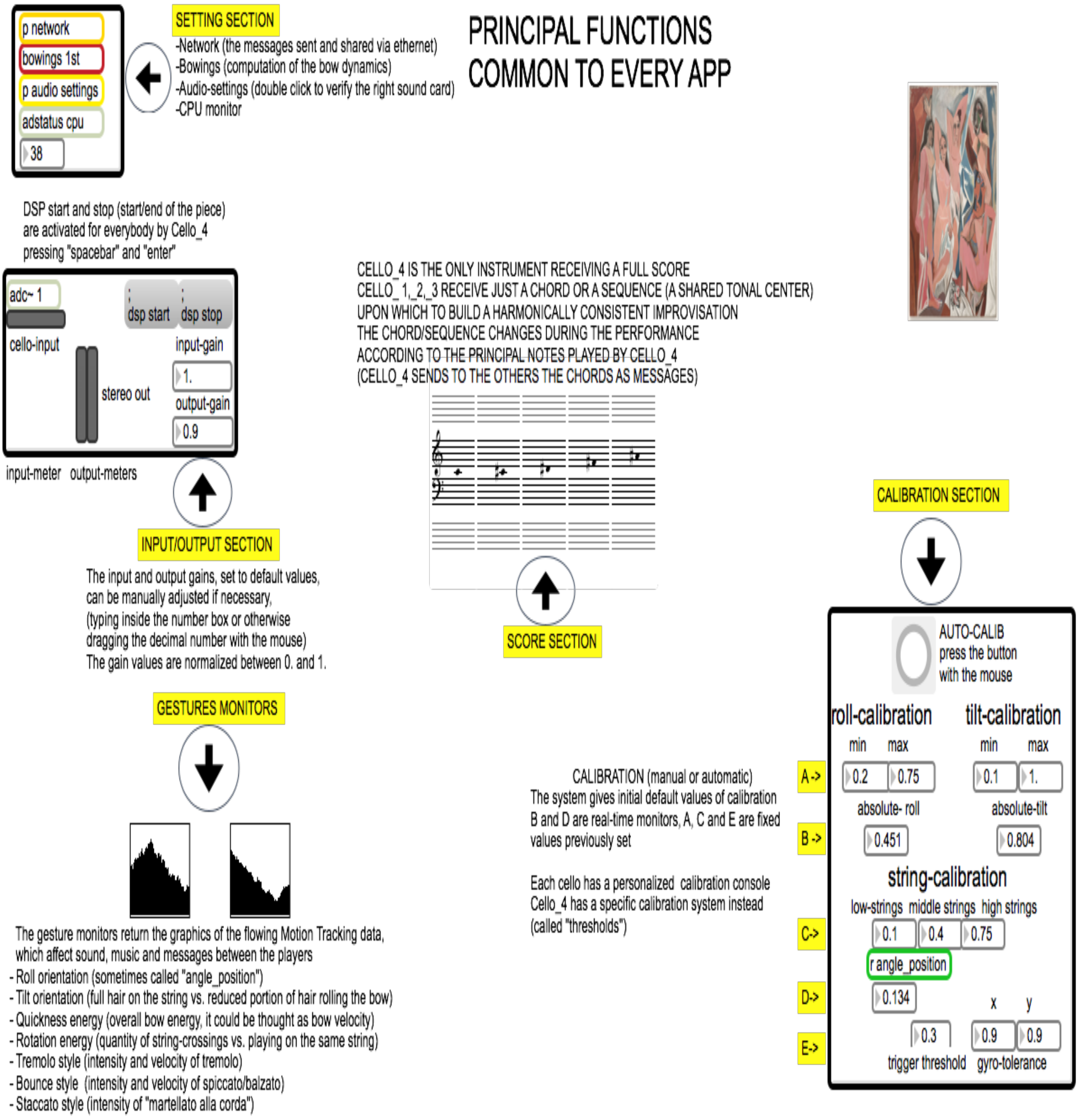


Fig.1-T Graphic interfaces common to any cello applications

Audio settings

Before any performance it is essential to verify the presence of the sound card. Double-click the "audio-settings" icon in order to access the I/O module, if the sound card is not automatically loaded and written inside the yellow menus, it has to be set by dragging the two arrows in the right part of the yellow menus of input and output, as shown below in Fig. 2-T (the three menus should contain the labels " Core Audio" in the upper menu, and the name of the sound card in the other ones).

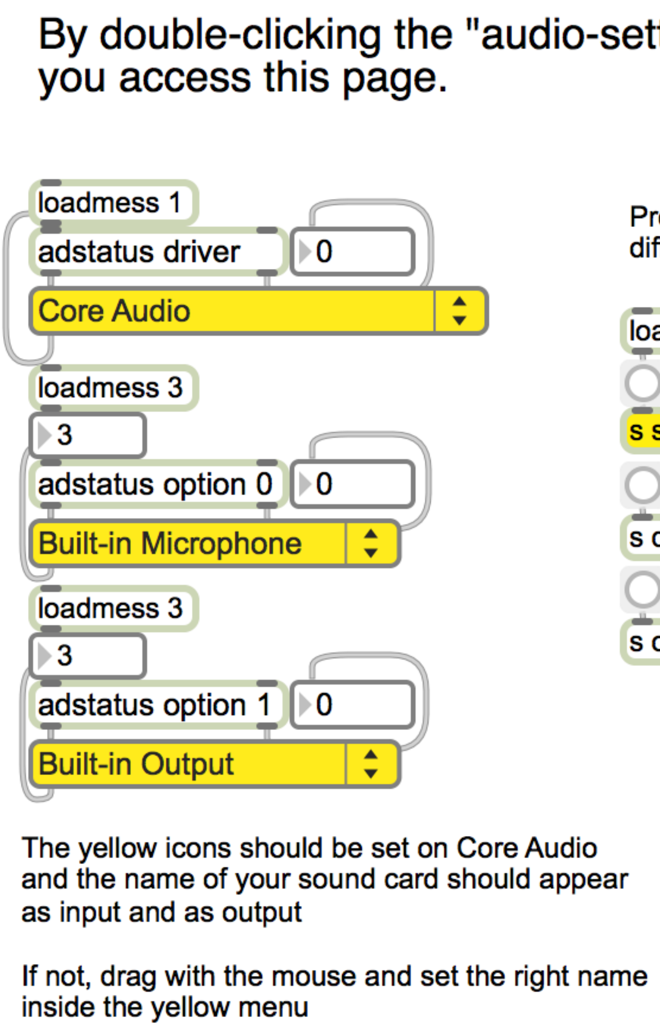


Fig.2-T Audio-settings and sound card

If it should be necessary to modify the input physical channel of the sound card, the option is given to type the number of the modified channel in the yellow number box above the message "s inp_1". The default number of outputs can also be modified by pressing the corresponding button above the options "stereo_set", "quadri_set, "octo_set". The default output architecture previews the stereo outputs for Cello_1 and Cello_2, the quadraphonic output for Cello_4 and octophonic for Cello_3 (which drives the spatialization, receiving the stereos of Cello_1 and _2 as inputs).

Network settings

Instructions:

1) Connect the Ethernet cable from the laptop to the Ethernet Switch
2) Navigate /system preferences /network /ethernet, inside your laptop
3) The Ethernet icon must be green, select it by clicking with the mouse
4) Set the position as automatic
5) Configure the IPv4 as manual, and then type the address and subnet mask as shown below.

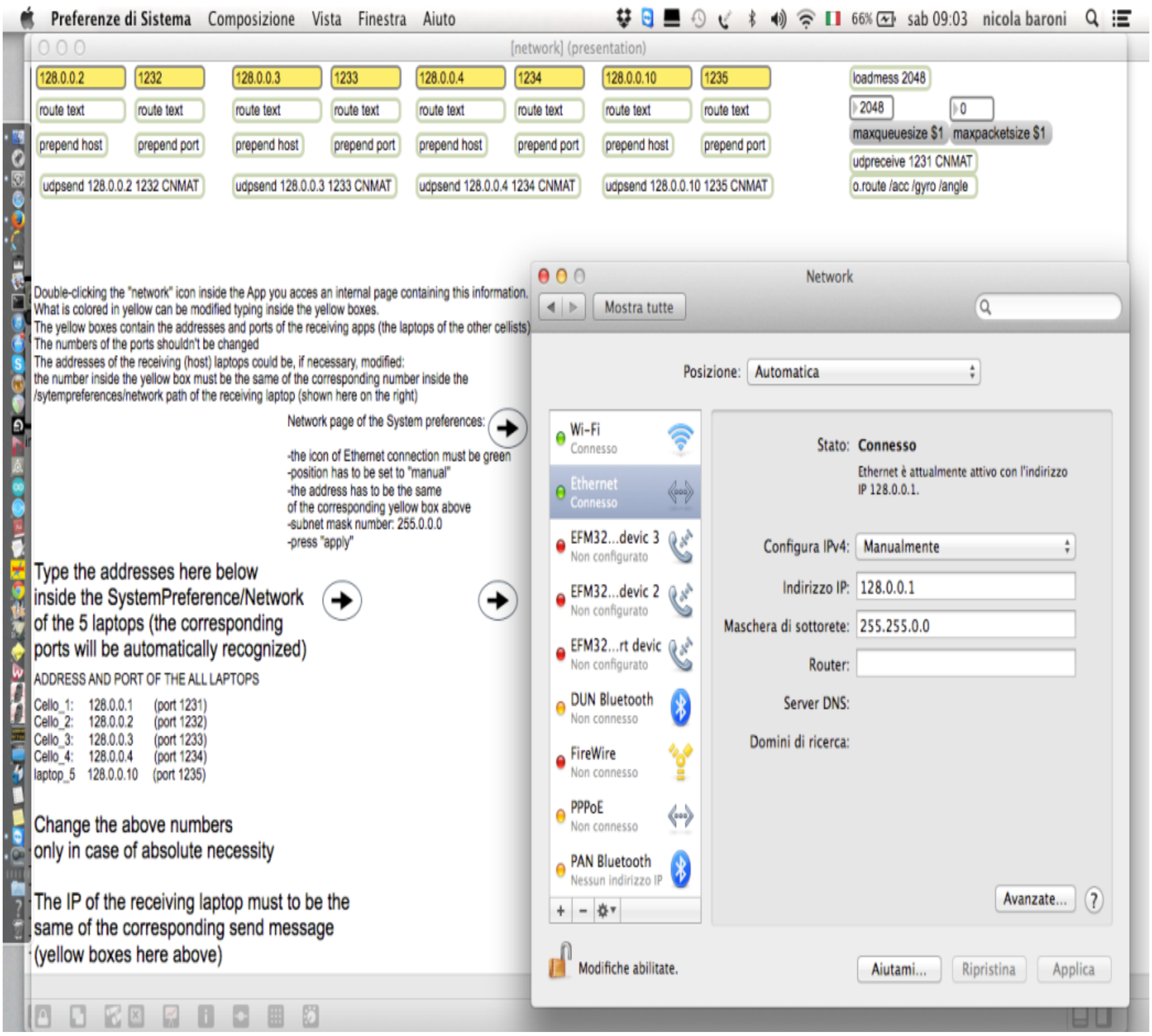


Fig.3-T The network

The default addresses of the laptops are:

Cello_1: 128.0.0.1

Cello_2: 128.0.0.2

Cello_3: 128.0.0.3

Cello_4: 128.0.0.4

Laptop_5: 128.0.0.10

All with subnet mask 255.255.0.0

By double-clicking the icon "p network", you can access the network module of the App: the addresses contained in the yellow boxes can be modified by typing inside (only in case of strict necessity!). The IP addresses and the port numbers obviously must be corresponding among the *“p network”* modules of all the applications, and also inside the system preferences network of each laptop, as shown in Fig.3-T.

Input_output
Each App provides the I/O section in the upper-left part of the screen: by default the input channel from each sound card is number 1 (adc~ 1 in the App), with the exception of Cello_4 which uses two microphones (by default: input 1 for the sound production and input 2 for the internal sound analysis).
As shown in Fig.1-T the I/O section contains visual sound-monitors and a couple of editable number-boxes for a possible modification of the input and output gains (amplitudes between 0. and 1.), in the case the sound card doesn’t allow optimal balance and the default amplitudes don’t fit.

Duration
The overall duration of the work (and also the length of the opening Cello_1 solo) can be differently set from the Cello_1 application.

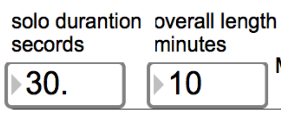


Fig.4-T Durations

CALIBRATION

The motion tracking calibration of Cello_1, _2 and _3 should be verified before every performance, the Application memorises the last calibration settings as default.

Cello_4 instead calibrates only the sound analysis data, which can be left unchanged after the first calibration, unless instrument, microphones or sound card are different.
Cello_4 calibration (onset/offset note detection, spectral description thresholds and parameters) will be described in the Cello_4 instructions.

The first time the calibration must be performed accurately (following the manual or the automatic modality); after that, before any following performances, a manual check should be sufficient.

The automatic calibration starts by pressing the *“auto-calib”* button and following the interactive instructions appearing on the screen.
If something fails during the process, it will suffice to press *“auto-calib”*, and start again from the beginning. Alternatively full manual calibration can be performed.

MOTION TRACKING

Motion tracking calibration is crucial in order to define the "*performance bowing space*" marking the boundaries of the bow positions.

Finding the minimum and maximum points of bow *rotation* in relation to the cello body is the requisite for a precise and meaningful bow interaction.Each value will be normalised within the extreme positions of 0. and 1., which represent the actual extreme points reached by the bow with respect to the cello strings during the performance.

The numbers referred by B and D (shown in yellow inside Fig. 8) are flowing quantities relative to the current Orientations of the bow: *"absolute-roll", "absolute-tilt", "angle_position".* The numbers referred by A and C will be set automatically (if auto-calibrated), otherwise the musician has to write them by typing inside the boxes or dragging the decimal portions with the mouse. The numbers referred by E are further thresholds to be eventually set. Default values are provided by the application, but notice that every further change is memorised when the App will be reopened.

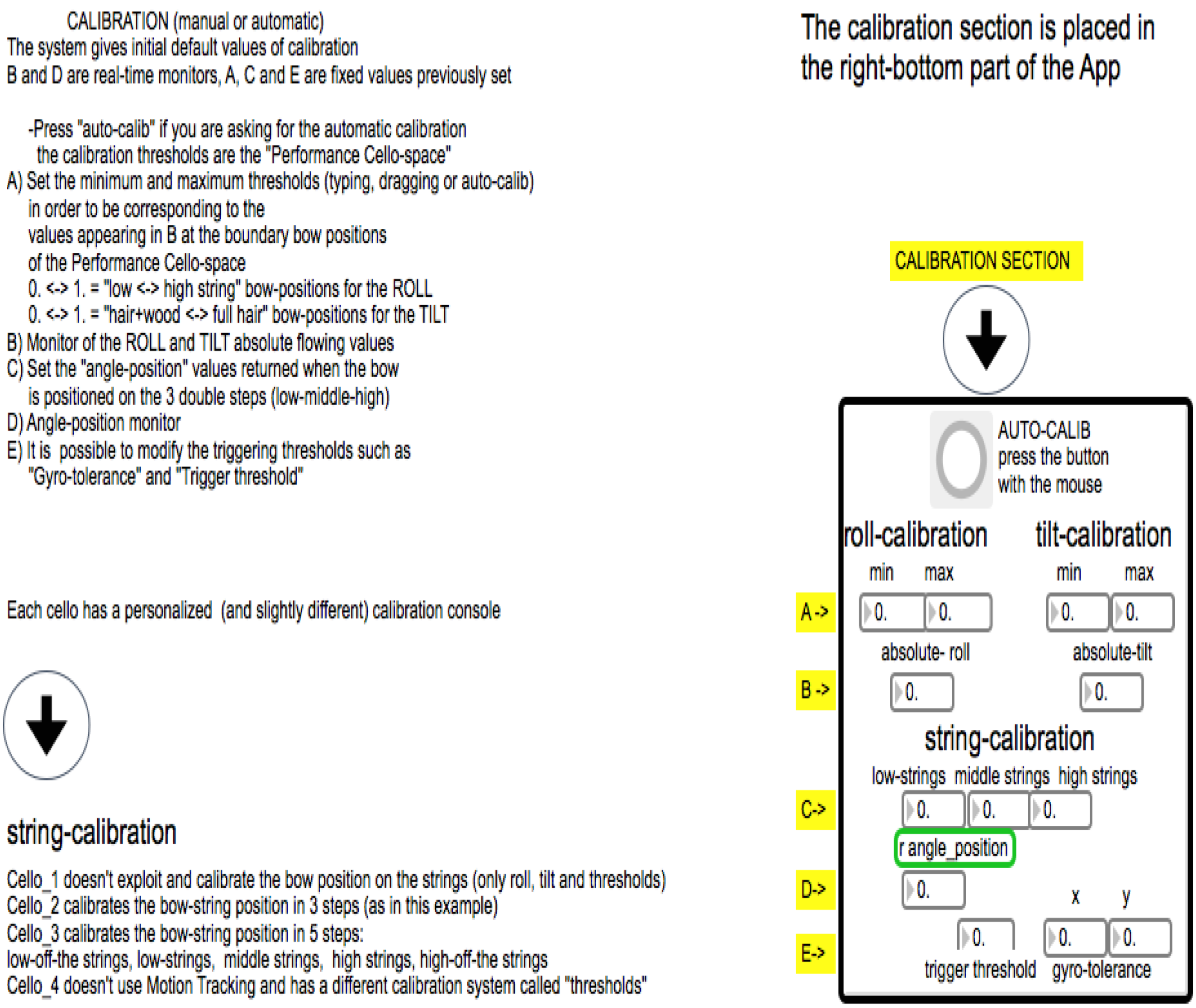


Fig.5-T Motion tracking calibration

Roll and tilt calibration

Absolute-roll and *absolute-tilt* are labels of the bow Orientation with respect to the x and y axis (taking the floor as a point of reference). But the performance point of reference is instead (from the point of view of the musician) the axis of the strings: we will therefore define *"roll"* as the changing value when the bow crosses the strings from the lower to the higher one, and *"tilt"* as the changing value when turning the bow (lying on the string) from "full-hair" position to "wood+hair" position. *Min/max roll-calibration* and *min/max tilt calibration* therefore define the extreme boundaries that will be reached during the performance.

It is useful though, during the *roll* calibration setup, to leave a little portion of room outside the extreme boundaries of contact between the external strings and the bow: some off-the-string downward and upward space, in order to allow some bow *rotations* in the air (especially for Cello_3).

If the musician is instead a violin or viola player, the *roll* values will obviously be reversed, but the low string and high string remain in any case the right points of reference, and the final result will be the same, and in any case *Rol*l calibration defines the bow boundaries of Orientation starting from the low string towards the high string (the boundaries are here intended as the most extreme bow-flexion points outside which the bow loses contact with the string, starting to "scrape" the body of the instrument).

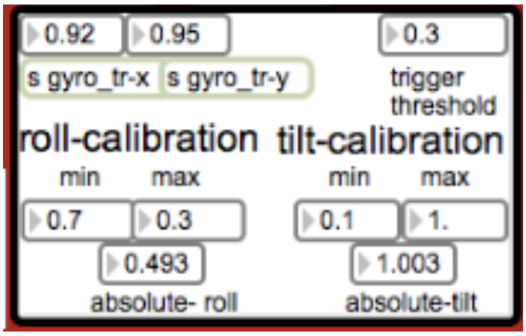


Fig.6-T Calibration box

General instructions

-Place the bow at the frog on the low string (C for the cello, G for the violin) in its maximum external flexion allowing not to loose the contact with the string.

Observe what is the mean flowing number appearing in the *absolute-roll* box, than transcribe it manually inside the *min roll-calibration* number box (typing or dragging with two decimal approximation).

-Place the bow at the frog on the high string (A for the cello, E for the violin) in its maximum external flexion allowing not to loose the contact with the string.

Repeat the same procedure transcribing the *absolute-roll* mean value observed, inside the *max roll-calibration* number box.

-Place the bow (in the middle) on the mid double strings as if playing with "full hair".

Transcribe the *absolute-tilt* mean flowing value appearing, inside the *max tilt-calibration* number box (the number should be very closed to 1.)

-Place the bow (in the middle) on the mid double strings again, as if playing with "wood+hair". Transcribe the *absolute-tilt* mean flowing value appearing, inside the *min tilt-calibration* number box (the number will be closed to 0.)

If the numbers show to be reversed (i.e. the right outcome is high string ->1, low string ->0, hair->1 wood->0), it means that the sensor is probably placed not correctly under the frog of the bow, and it has to be put in the right position.

In this way the bow performance space will be filling the full range of values between 0. and 1.

Check the two number monitors under the calibration rectangle, or otherwise the main graphic monitors.

String calibration (for Cello_2 and _3 only)
After *roll* calibration the "*angle_position*" values will define the *rotational* space between the low and the high string (with a small added lateral space): this *roll* performance space is therefore normalised between 0. and 1.

Some interactions require the string currently playing to be identified. For this reason string calibration is required. This calibration is obtained by finding and fixing the "*angle_position*" values as a reference when the bow is successively placed (at frog position) upon the three double steps low, middle and high. This calibration in three steps is required for Cello_2. Cello_3 needs the string calibration in 5 steps, in order to also detect the low and high off-the-string positions.

During the performance this detection is reached after a perceptible latency, and only as a consequence of a clear sound attack, monitored with a flashing yellow bang: this procedure is due to the need to avoid unstable and too frequent unwanted change-string detections, and to extract only the most relevant changes of strings, monitored with a number tagged as "*choose_string*" (in this way the system suggests leaving room for significant musical passages played on the same string).

Triggerings calibration
The calibration section E offers the possibility to soften or increase thresholds involved in some triggering movements.

-"*gyro-tolerance"* regards quick *rotations* of the bow in the four principal directions Up, Down, Forward, Back.
Softening the threshold below the default 0.92 could help for a more natural style of playing, but risking at the same time to increase unwanted triggering because of a too tolerant threshold.
-"*trigger threshold"* is only for Cello_1 ("*quick-impulsive down-bows")*
-"*sound-attack thresh*" defines the boundary of detection of the sound attack for the "currently played string" function of Cello_2 and _3.

Calibration allows a fine-tuned rendering of the bow controls over the electronics and the interactions. Bow movements are collected following three main typologies: Orientations (*roll* and *tilt*), Energies (*quickness* and *rotation*), Styles (*Tremolo, bounce* and S*taccato*). Triggering involve the detection of four types of "*fast-impulsive-rotations"* (Up, Down, Forward, Back), "*quick-impulsive down-bow"* detection (only for Cello_1), and the "*currently-played-string"* detection for Cello_2 and Cello_3.

AUDIO ANALYSIS (Cello_4 only)

Note analysis

The sound analysis modules involve timbre feature extractions, note detection and expressiveness[3] pattern recognition (as a submodule of the note detection).

-Timbre is continuously monitored through the "*gbr.yin*" external detecting fundamental frequency, overall amplitude, periodicity, spectral centroid, and spectral statistical distributions

-note detection is allowed by amplitude thresholds combined with transient deviation analysis in order to approach a substantially reliable onset/offset system synchronised with fundamental frequency detection

-estimations of "expressiveness" are computed inside the abstraction "expr_perf" which localises the amplitude peak position and its intensity compared to the attack inside each note detected, and computes standard deviation, mean and variance of the amplitude inside each note.

In this way it is possible to compute on the fly some consistent ratios between attack-sustain-decay of the performed notes. In addition every inter-onset-interval (IOI) is compared to the "note length" in order to extract a raw estimation of "legato" playing.

These data are returning immediately after each "note" is completed.

The "expressiveness" estimations inside the time and place of performance show evident limitations, though being interesting and affordable performance subsidiary controls.

On the other hand note detection has to be exploited with some cautions and in relation to special music contexts, as detailed inside the performance notes.

Sound calibration

Calibration is highly dependent on individual features, and must be setup again when instrument, player, microphones or sound card are changed. The system is provided with default values for cello playing. The most crucial calibration regards amplitude threshold and onset detection.

A deeper level of calibration involves offset detection and timbre "density".

When the performing instrument is not a cello a full re-calibration is mandatory.

Sound analysis calibration is accessible inside the "p thresholds" module of Cello_4.

Each label is provided with a number, which can be changed by typing or dragging.

After having changed the calibration numbers, press the label "write" and save.

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[3] Canazza, DePoli, Drioli, Rodà,Vidolin, Proceedings of the IEEE, 92, 4, 2004

Instructions
Note detection needs to be carefully calibrated since it allows the performer to control global aspects of the interaction working on a net of on/off functions.
Timbre detection allows instead a more loose and continuous interactive interplay.

Any sound analysis doesn't happen when the signal is below the threshold "s loud-factor", set by default at -80 Db. You can raise it, if necessary.

A) Note detection parameters

-1. The attack threshold "writer" (see Cello_4 application) flashes when the cellist calls for a score when he/her sound surpasses the threshold through a sharp sound attack
-2. Note-on threshold. Note-on is detected as an increasing amplitude ratio respect the last 50 ms
-3. Note-off threshold. Note-off combines three different decay-tracking methods. Calibration can be set only upon one of them: the decay difference respect the last 100 ms. (in Db)
-4. Loudness gate disables the note-on detection when the cello amplitude is below its threshold, in order to avoid background noise detection.

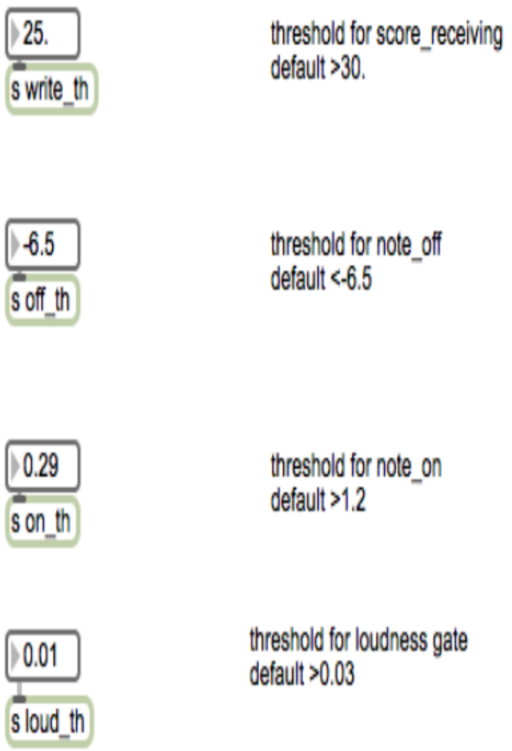

Fig.7-T Calibration parameters

1) score receiving (how much sound attack you need in order to call for the score
-lower the number above the label "s write_th" if it requires too much effort
-increase the number if it is too sensitive and generates too many scores
-the minimum-maximum values of the threshold should be between 15 and 35.
2) If too many note-ons are detected you can raise its threshold (or otherwise lower it if you need the opposite): the optimal range of "s on_th" is between 0.5 and 2.
3) Set an appropriate difference level in Db of "s off_th"
4) Raise the "s loud_th" if the background noise interferes, lower it when the note-on detection cannot be performed playing softly.

The amplitude monitoring is performed through the *peakamp~* MAX object

B) Timbre detection parameters

“Timbre” detection affects the interaction allowing the performer to modify the electronic timbre of his/her augmented instrument (harmoniser).

It needs to be calibrated in deep when the instrument assuming the role of Cello_4 is not a cello. In this case the values involved (amplitude, signal periodicity, spectral centroid, spectral kurtosis) could be dramatically out of range respect the default, needing different kinds of compression and scaling.

It could be assumed that for different cellists and cellos we don’t need a detailed timbre calibration, since the interaction can be learned by the performer through direct interaction.

The most effective timbre calibration, maybe useful also for a cellist, is contained in the “s pow_2feed” message. The referenced module computes the ratio between fundamental frequency and spectral centroid (sounds full of low components will output a value approaching 1., sounds full of high components will output values approaching 0.). The output, after being time-filtered, is directly mapped to the feedback of the harmoniser delay chains.
In this way the performer controls the sound density and quality of his/her augmented instrument.

This ratio can be powered by a coefficient (by default the power is 1, therefore the ratio is left unchanged). If you raise the power ratio inside the “s pow_2feed” module, the values of the feedback will be compressed downward, making it difficult to boost high qualities of delayed repetitions; conversely if you lower the power ratio between 0. and 1. the delay-feedback will be compressed upwards, more easily approaching the maximum value of 1.

All the other timbre calibrations coming from the input sound analysis, dynamically affect the sound parameters of the four voice harmoniser, namely the sinus, noise, formant and transient spectral components of the internal vocoder.

Detailed timbre calibration instructions are contained inside the Cello_4 application (“notes" patcher inside the “p threshold” module).

SOFTWARE

Inertial Motion Tracking is tested with the Orients_15 System, developed by the Centre for Speckled Computing of the University of Edinburgh, [4] running through the orientMac application. This application and the related Readme.txt document are contained in the main folder of this software. The system needs a native Bluetooth 4 Mac version as minimal requirement.
A different Motion Tracking system is allowed by substituting the abstracion “rec_orients-D” with a different OSC udpreceive module, which must contain proper scaling and normalisation.
Details are given inside the Readme text file.

The motion tracking data are collected in Laptop_5 through the UDP and OSC MAX objects.
These data are sent by the Ethernet network to the cello standalones inside the other laptops, where individual modules called “p network” route the messages, decoded inside the “bowings” individual abstractions. The processed data are sent to the main functions of the patches as controllers and interactive agents. All the patches and abstractions rely on the *"pattr"* system for calibration and automatic data recalling.

After processing inside the single cello-applications, the motion tracking data are sent back to Laptop_5 in order to generate the video in real-time.

CELLO_1.SPECTRAL
MAX/Msp 6.1 or *CELLO_1* standalone application

LIST OF EXTERNALS AND ABSTRACTIONS

analyzer~ (Tristan Jehan)
http://web.media.mit.edu/~tristan/maxmsp.html

contrast-enhancement (Michael Edwards)

dag.statistic (Pierre Guillot)
http://www-irma.u-strasbg.fr/~guillot/

dot.smooth, dot.std (Joseph Malloch et al.)
http://idmil.org/software/digital_orchestra_toolbox

ej.line (Emmanuel Jourdan)
http://www.e--j.com

[4] www.specknet.org

expo74 abstraction: readaptation of 04-transit-freeze, 09-adapt-pvoc (Jean Francois Charles)
https://cycling74.com/toolbox/live-spectral-processing-patches-for-expo-74-nyc-2011/#.Vh0sE2A-BE4

f0.distance, f0.round (Fredrik Olofsson)
http://www.fredrikolofsson.com/pages/code-max.html

ftm, ftm.list, ftm.object, ftm.reschedule,
gbr.bands, gbr:fft, gbr.resample, gbr.slice~, gbr.wind=, gbr.yin,
mnm.alphafilter, mnm.delta, mnm.list2col, mnm.list2row, mnm.list2vec, mnm.onepole, mnm.win-filter,
FTM-Gabor library (Norbert Schnell et al.)
http://ftm.ircam.fr/index.php/Download

jg.spectdelay~ (John Gibson)
http://pages.iu.edu/~johgibso/software.htm

msd (Nicolas Montgermont)
http://nim.on.free.fr/msd

multiconvolve~ (Alex Harker and Pierre Alexandre Tremblay)
http://www.thehiss.org/

OSC-route (Matt Wright)
o.route (Adrian Freed)
http://www.cnmat.berkeley.edu/MAX

pipo (IRCAM IMTR)
http://forumnet.ircam.fr/shop/en/forumnet/59-mu.html

quat2car (freeware)
http://www.mat.ucsb.edu/~wakefield/soft/quat_release.zip

sigmund~ (Millar Puckette et al.)
http://vud.org/max/

SpT.ranspose (abstraction)
Spectral Toolbox (William A. Sethares et.al)
http://www.dynamictonality.com/spectools.htm

CELLO_2.ARTIFICIAL
MAX/Msp 6.1 or *CELLO_2* standalone application

LIST OF EXTERNALS AND ABSTRACTIONS

analyzer~ (Tristan Jehan)
http://web.media.mit.edu/~tristan/maxmsp.html

dag.statistic (Pierre Guillot)
http://www-irma.u-strasbg.fr/~guillot/

dot.smooth, dot.std (Joseph Malloch et al.)
http://idmil.org/software/digital_orchestra_toolbox

ej.line (Emmanuel Jourdan)
http://www.e--j.com

f0.distance, f0.round (Fredrik Olofsson)
http://www.fredrikolofsson.com/pages/code-max.html

ftm, ftm.list, ftm.mess, ftm.object, ftm.reschedule,
gbr.slice~, gbr.yin,
mnm.alphafilter, mnm.delta, mnm.list2col, mnm.list2row, mnm.list2vec, mnm.onepole, mnm.win-filter
FTM-Gabor library (Norbert Schnell et al.)
http://ftm.ircam.fr/index.php/Download

jgn.mesh~ (John Gibson)
http://pages.iu.edu/~johgibso/software.htm

modalys~, mlys.force, mlys.mono-string, mlys.point-output, mlys.script
(IRCAM Instrumental Acoustic Team)
http://forumnet.ircam.fr/product/modalys-en/

msd (Nicolas Montgermont)
http://nim.on.free.fr/msd

multiconvolve~ (Alex Harker and Pierre Alexandre Tremblay)
http://www.thehiss.org/

OSC-route (Matt Wright)
o.route (Adrian Freed)
resonators~ (Adrian Freed et al.)
http://www.cnmat.berkeley.edu/MAX

pipo (IRCAM IMTR)
http://forumnet.ircam.fr/shop/en/forumnet/59-mu.html

quat2car (freeware)
http://www.mat.ucsb.edu/~wakefield/soft/quat_release.zip

sigmund~ (Millar Puckette et al.)
http://vud.org/max/

CELLO_3.SAMPLER
MAX/Msp 6.1 or *CELLO_3* standalone application

LIST OF EXTERNALS AND ABSTRACTIONS

ambiencode~, ambidecode~, ambimonitor (Jan Schacher)
http://trondlossius.no/articles/743-ambisonics-externals-for-maxmsp-and-pd

analyzer~ (Tristan Jehan)
http://web.media.mit.edu/~tristan/maxmsp.html

bonk~ (Millar Puckette et al.)
http://vud.org/max/

centroid~ (Ted Apel et al.)
http://vud.org/max/

dag.statistic (Pierre Guillot)
http://www-irma.u-strasbg.fr/~guillot/

dot.smooth, dot.std, dot.timedsmooth (Joseph Malloch et al.)
http://idmil.org/software/digital_orchestra_toolbox

ej.line (Emmanuel Jourdan)
http://www.e--j.com

f0.distance, f0.round (Fredrik Olofsson)
http://www.fredrikolofsson.com/pages/code-max.html

ftm, ftm.list, ftm.object, ftm.reschedule,
mnm.alphafilter, mnm.delta, mnm.list2col, mnm.list2row, mnm.list2vec, mnm.onepole, mnm.win-filter
FTM (Frederic Bevilacqua et al.)
http://ftm.ircam.fr/index.php/Download

imubu, mubu, mubu.granular~, mubu.knn, mubu.process, mubu.record~, mubu.track,
pipo, pipo~ (IRCAM IMTR)
http://forumnet.ircam.fr/shop/en/forumnet/59-mu.html

msd (Nicolas Montgermont)
http://nim.on.free.fr/msd

multiconvolve~ (Alex Harker and Pierre Alexandre Tremblay)
http://www.thehiss.org/

OSC-route (Matt Wright)
o.route (Adrian Freed)
http://www.cnmat.berkeley.edu/MAX

quat2car (freeware)
http://www.mat.ucsb.edu/~wakefield/soft/quat_release.zip

CELLO_4.HARMONISER
MAX/Msp 6.1 or *CELLO_4* standalone application

LIST OF EXTERNALS AND ABSTRACTIONS

analyzer~ (Tristan Jehan)
http://web.media.mit.edu/~tristan/maxmsp.html

bach.roll, bach.score, bach.transcribe (Andrea Agostini, Daniele Ghisi)
http://www.bachproject.net

dot.smooth, dot.std, dot.timedsmooth (Joseph Malloch et al.)
http://idmil.org/software/digital_orchestra_toolbox

ej.line (Emmanuel Jourdan)
http://www.e--j.com

f0.round (Fredrik Olofsson)
http://www.fredrikolofsson.com/pages/code-max.html

ftm, ftm.copy, ftm.list, ftm.mess, ftm.object,
gbr:fft, gbr.slice~, gbr.wind=, gbr.yin,
mnm.list2row, mnm.moments, mnm.winfilter
FTM-Gabor library (Norbert Schnell et al.)
http://ftm.ircam.fr/index.php/Download

lhigh (Peter Elsea)
http://peterelsea.com/lobjects.html

M4L.gain1~, M4L.delay~ (abstractions)
https://cycling74.com

multiconvolve~ (Alex Harker and Pierre Alexandre Tremblay)
http://www.thehiss.org/

o.route (Adrian Freed)
http://www.cnmat.berkeley.edu/MAX

sadam.stat (Ádám Siska)
http://www.sadam.hu/en/software

supervp.trans~ (IRCAM Analysis/Synthesis Team)
readaptation of SuperVP.HarmTransVoice
http://forumnet.ircam.fr/product/supervp-max-en/

LAPTOP_5.VIDEO
MAX/Msp 6.1, Jitter or *LAPTOP_5* standalone application

LIST OF EXTERNALS AND ABSTRACTIONS

o.route (Adrian Freed)
http://www.cnmat.berkeley.edu/MAX

sadam.stat
http://www.sadam.hu/en/software

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