iltur – Connecting Novices and Experts Through Collaborative Improvisation

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ABSTRACT
The *iltur* system features a novel method of interaction between expert and novice musicians through a set of musical controllers called Beatbugs. Beatbug players can record live musical input from MIDI and acoustic instruments and respond by transforming the recorded material in real-time, creating motif-and-variation call-and-response routines on the fly. A central computer system analyzes MIDI and audio played by expert players and allows novice Beatbug players to personalize the analyzed material using a variety of transformation algorithms. This paper presents the motivation for developing the *iltur* system, followed by a brief survey of pervious and related work that guided the definition of the project's goals. We then present the hardware and software approaches that were taken to address these goals, as well as a couple of compositions that were written for the system. The paper ends with a discussion based on observations of players using the *iltur* system and a number of suggestions for future work.

Keywords
Collaboration, improvisation, gestrual handheld controllers, novices, mapping

1. MOTIVIATION
Recent developments in music technology led to a cultural and social transformation in the manner in which we make, perform, and consume music. Music today is more accessible than ever thanks to innovations in recording, compression, and distribution. New developments for the home studio allow more people, novices as well as professionals, access to high quality and affordable equipment to create and distribute their music directly to their audiences. These promising developments, however, are undermined by some byproduct social effects. It has been shown that although music toady is more accessible and ubiquitous than ever, most of the music that we listen to is consumed in an incidental, unengaged and/or utilitarian manner [1]. Furthermore, the home studio proliferation undermines one of the most valuable traits of music – its collaborative and social nature – by promoting private and isolated musical practice where the value of live group interaction is marginalized. The *iltur* system attempts to address these social effects by allowing novices to become actively engaged in rich, thoughtful, and meaningful musical activities as they transform and personalize experts' musical improvisation. The transformation algorithms embedded in the system aim to provide both simple low-level musical control (such as direct manipulation of pitch, timbre, and rhythmic values) and more elaborate control of high-level musical percepts that have been shown to be perceived by novices, such as rhythmic stability and contour similarity [2, 3]. We believe that by altering and personalizing elaborate musical phrases of their choice, novices could be part of a meaningful and expressive musical experience that does not necessarily require prior theoretical knowledge or advanced performance skills. Our system also attempts to use digital communication to create novel interdependent group playing interactions, in contrast with some of the home-studio technologies that undermine music's inherent collaborative social nature. Thanks to these communication lines, and unlike traditional improvisation in a group, Beatbug players can gain direct control over their peers' music. The outcome of the system can, therefore, be seen as a crossbred hybrid musical product, created by the combination of experts' educated virtuosic musicianship and novices' unmediated expressive musicality.

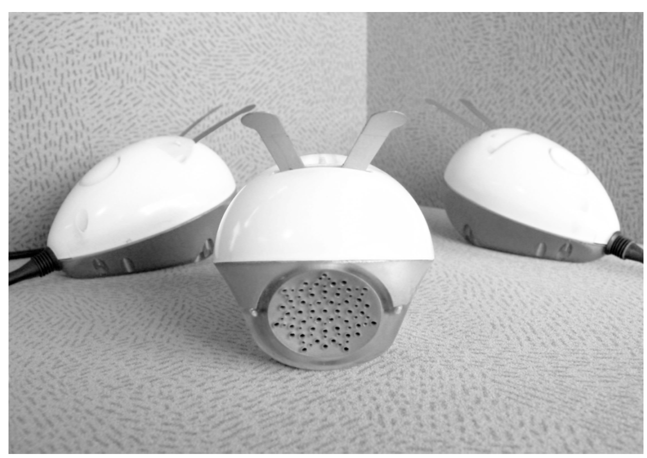

Figure 1. The Beatbugs

2. RELATED WORK
Previous work with the Beatbug controller [4] in the framework of the Toy Symphony project [5] showed that even novices who demonstrated high levels of musicality, expression, and a unique

personal voice, found it conceptually and technically difficult to create and develop their own musical ideas from scratch. It was also clear that novices were imitating instructors before they could express their own unique musical voice. Based on these observations and in order to help learners and novices to quickly connect to expressive and meaningful musical experiences, we decided to expand the Beatbugs' functionality to allow for easy capture of musical phrases and intuitive gestrual personalization through transformation.

The approach we used for algorithmic transformation is informed by the work of researches such as Lewis [6], Rowe [7], Pachet [8], Johnson-Laird [9], and Pressing [10] who developed a variety of theoretical and practical approaches for interactive improvisation. In these works, the computer utilizes transformative, generative and/or sequenced methods and can serve as a playing companion or as an extended musical instrument. In *iltur*, on the other hand, unlike generative computerized improvisation systems that are based on artificial intelligence or machine analysis and synthesis, the central computer is programmed to provide a supporting infrastructure for the interdependent connections among human players. Expert and novice musicians are the ones who are responsible for the musical decisions as they learn to listen to each other and shape their peers' music by creatively manipulating of the system's algorithms. Such multi-user algorithmic collaborations for the creation of artistic artifacts have been explored in other media as well, such as digital graphics and video [11]. In music, composers such as John Cage, The League of Automatic Music composers and the Hub, and a variety of Internet musicians explored similar interdependent interactions [12]. These experiments, however, usually require advanced musical understanding by players and audiences and often lead to inaccessible "high art" musical products. More recent collaborative musical installations for novices on the other hand (see a recent survey in [13]), tend to simplify the musical experience and are not geared to interdependently connect between novices and professionals. In *iltur* we attempt to address both novices and experts by facilitating novel interdependent collaborative group connections among players.

3. GOALS AND CHALLANGES

Based on these motivations and informed by the related work, we identify two main challenges for our software and hardware design. The first challenge focuses on the individual player. Here, the goal is to define and encode the appropriate musical parameters that would allow novices to control intuitive musical percepts that they can relate to, and to create pleasing musical results without compromising their ability to make mistakes and improve over time. The second challenge focuses on the collaboration between novices and experts. Here the goal is to create a coherent multi-player interaction where players can clearly follow and identify their contribution to the collaborative process, while still allowing for an immersive and interdependent experience to emerge.

4. SYSTEM HARDWARE

The original Beatbugs were designed to provide players with discrete control over triggering rhythmic events and continuous control over high-level musical transformations [4]. These requirements guided the sensors selection: a piezoelectric sensor for detecting discreet hits and two bend sensor antennae for continuous manipulation of musical patterns. Similarly to the original Beatbug, the *iltur* Beatbug uses a PIC 16f876 processor to read analog data from the antennae, control the LEDs, and encode/decode MIDI data. An internal speaker and a set of LEDs are used to help convey the interaction to players and audiences; The white LEDs flicker in synchrony with the phrase's notes and the colored LEDs indicate the position of the antennae – the lower the left and right antennae are bent, the brighter the green and orange LEDs become, respectively. Several improvements were made for the *iltur* hardware in comparison to the original Beatbug system in an effort to make it more robust and portable. Since the original Beatbugs' bend sensor antennae were vulnerable targets for twisting, kinking and tear, a new sensing mechanism was implemented in the *iltur* Beatbugs by Roberto Aimi [14], which utilizes Hall effect sensors and magnets mounted under the antennae. This electromagnetic sensing method proved to be more robust, although it provides only 3 bit bending resolution, in comparison to the 7 bit resolution of the older resistive bend sensors.

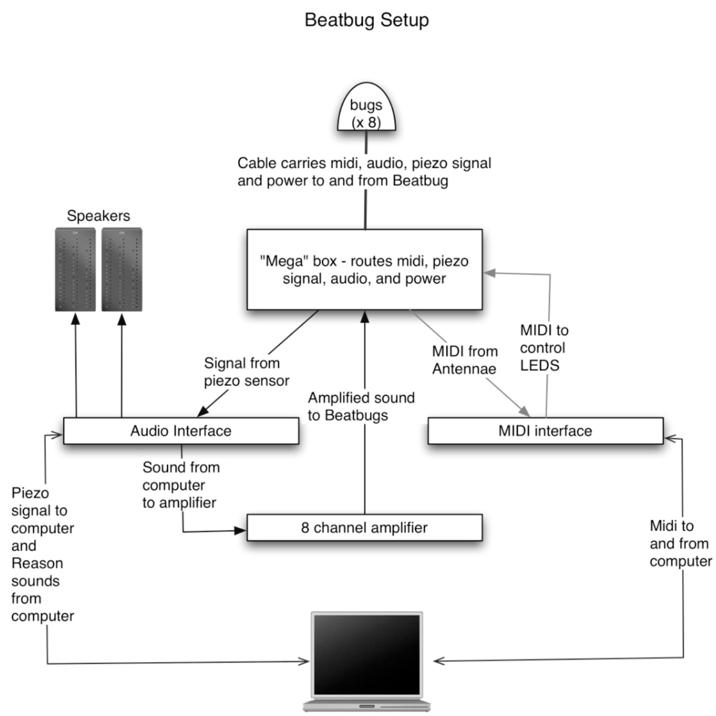

Figure 2. The *iltur* System Schematics

Other hardware improvements addressed the system size and portability. The Toy Symphony Beatbugs were connected to a 18-unit rack that included a desktop computer, a monitor, a mixer, audio and MIDI interfaces, MIDI drum trigger, multi channel amplifier and propriety routing box [4]. The *iltur* system, on the other hand, uses a laptop computer, a software-based mixer, and the piezoelectric sensors are connected directly to the audio inputs (by way of the patch box), which eliminate the need for a MIDI drum controller module. The system, therefore, is housed in a small 6-unit rack, which consists mostly of standard, off-the-shelf equipment including a Mark of the Unicorn 828 audio interface, Emagic AMT MIDI interfaces, and a Lectrosonics PA-8 8-channel amplifier that supports up to 8 internal Beatbugs speakers. The only non-standard device in the rack is the custom patch box, which provides power to the bugs and converts each bug's 10-pin

Neutrik Minicon connector to power, MIDI in and out, and audio in and out. An Apple G4 PowerBook, running Cylcling74's Max/MSP and Propellerheads' Reason, is responsible for the detection, transformation, and synthesis algorithms.

5. INTERACTION AND MAPPINGS

The control functionality in *iltur* is consistent in both MIDI and audio applications. To control the three main interaction functions – recording, triggering, and transformation – players use different combinations of hitting and bending gestures. Recording is conducted by simultaneously bending both antennae while hitting the bottom part of the Beatbug. This action proved to be effective since the sensitive piezoelectric sensor at the top of the Beatbug can easily sense hits at different locations on the Beatbug's surface (see Figure 3.) Hit velocities during triggering are generally mapped to different locations in the recorded buffer. To stop a phrase while it is playing, a strong hit on the top of the Beatbug is used. The continuous transformation algorithms for the MIDI and audio applications are described separately below.

Figure 3. A player taps the Beatbug while bending the antennae to start recording.

5.1 MIDI Transformations

A number of MIDI improvisation algorithms were developed to allow novices access to musical aspects that they can relate to and easily control. Some of the transformation algorithms are direct and simple such as linear pitch shifting of MIDI events or the addition of short notes in between recorded notes in correlation to antennae bending. Other algorithms are more sophisticated in their effort to simulate high-level musical aspects such as contour directionality and rhythmic density. Players can also trigger different permutations of the recorded MIDI phrases such as inversion and retrograde, by hitting the Beatbug while bending only one antenna, left and right respectively. When the system enters recording mode, a Max External titled *mysequence* (written by Alex Powell in an effort to enhance efficiency and time accuracy) starts listening to incoming note events. The external object receives MIDI messages that corresponds to the times, velocities, and pitches of every note. Hitting the Beatbug at any time while recording stops the recording process and starts the triggering/playback mode. In this mode mode, a timer loop in Max is repeatedly sending a playat <time> messages to the external object. When the Beatbug is hit, the hit velocity is measured and scaled to the length of the recorded phase. Soft hits (0-64 is MIDI velocity) starts the phrase at time 0 while harder velocities (65-126 in MIDI velocity) are lineally mapped to different time positions in the phrase. Very strong hits stops the phrase (hits can range higher than the standard 7 bit MIDI resolution since we capture audio from the piezoelectrric sensor.) Before a note is chosen to be played, calculations are made to determine whether its timing and/or pitch should be altered based on input from the antennae. The left antenna controls the rhythmic transformation. Different algorithms were written for this antenna and they are used by different Beatbugs at different parts of the compositions. One of these algorithms is designed to control how similar the rhythm will be in comparison to the original phrase. Stochastic operations are use to control how many notes will be chosen for modification. The lower the antenna is bent; the more notes are chosen to be modified. In order to create surprising variations of the original rhythm, a stochastic decision is made to either remove a chosen rhythmic value or add a new note that would subdivide the given rhythmic value into two. When a new note is created, its velocity equals that of the note from which it stemmed and its pitch value is chosen based on the contour algorithm, controlled by the right antenna. For this antenna a number of stochastic algorithms for pitch and melodic contour transformation were developed and used in different Beatbugs. One of these algorithms is designed to control contour directionality, a musical concept that has been shown to have perceptual significance for novices as well as experts [15]. In one case, it has been shown that novices' ability to retain melodic contour of a semi-known melody is much better than retaining specific pitches [16]. Trehub at al. showed that contour can be perceived by infants as young as one year old, strengthening the assumption that this percept is well ingrained in human cognition [3]. These studies suggest that by providing an intuitive access for transformation of melodic contour we can allow novices to meaningfully improvise by creating variations with different levels of similarity to the original phrase. The right antenna, therefore, is mapped to control the contour of the melodies played by MIDI instruments. The lower the antenna is held; the more are the changes in the original contour direction that are taking place. Contour reshaping is accomplished in the same Max External used for rhythmic transformation. A currentTransposition value is initially set to 0 and is recorded throughout the resampling process. Based on a stochastic process, the function decides how often to change the direction of the contour and whether to change the pitches themselves. The more the antenna is held down, the more often a rising melody will turn lower, keeping the same interval relationship between its pitches. The algorithm can always return to the unchanged melody or to any setting of the antenna despite its reliance on stochastic techniques because of its reseeding policy to the random number generator. All operations that change the sequence are performed on a copy of the data, and an operation will not take place on that copy unless one or more antennae is held down. For other sections of the *iltur* compositions, more direct pitch and rhythmic transformations are used such as linear pitch shifting and the enhancement of rhythmic density using simple value multiplication.

5.2 Audio Transformations

In order to provide novices with intuitive real-time transformation of musical audio we first focused on capturing note onset times and detecting pitch from a particular acoustic instrument chosen for the system - the trumpet. Novices can then use the Beatbug to rearrange and manipulate the recorded notes to their liking. To capture note onset times we used the Max/MSP external bonk~ (written by Miller Puckette), with extensive filtering and trumpet-specific parameter tuning to maximize accurate detection. The attack noise from "tonguing" a note instead of slurring was especially helpful in this regard. In controlled settings we reached a detection level of about 90 percent of staccato notes and about 50 percent of legato notes. In legato sections, therefore, we captured short series of notes instead of individual pitches. In playback, much care had to be taken to avoid clicks and pops by cross-fading audio, but at the same time minimizing delay so that the Beatbug would feel responsive. Several different mapping methods were investigated to allow Beatbug players to control and transform the segmented audio recordings.

Figure 4. Audio transformation schematics. Pitched audio is detected and segmented by the computer. The Beatbug sends control information to trigger and transform the audio.

One of the effective mapping combinations included bending one antenna to control pitch shifting, bending the other antenna to determine playback buffer start location, and striking the piezo sensor to trigger playback using hit velocity to determine volume. We also experimented with real-time combinations of pitch shifting and delay lines to harmonize melodies, a method that was effective mostly with long and slow notes. Another mapping strategy utilized hit strength to control playback start time, while the antennae were used to control delay lines and filter cutoff frequency, providing some control over timbre. We also experimented with higher-level segmentation of phrases, where the recorded audio was divided into three segments that were determined by the largest silent gaps between notes. This mapping scheme allowed players to start playback at a variety of musically sensible times while shaping the phrases via pitch shifting. The pitch-shifting algorithm in all these mappings was restricted to discrete half note step (up to a fifth in both directions) and did not change playback times (by compressing or stretching the audio using the MSP External pitch~ by Tristan Jehan). In another mapping scheme players could select notes for playback based on pitch, playing higher pitches as they bend the antenna further. This scheme allowed players to reorder the recorded notes to form their own new melodic contours. However, an accurate choice of specific notes using a continuous controller such as a bendy antenna was a challenging task for most players. The effectiveness of each of the mapping strategies was dependent on the type of input musical material (staccato, legato, slow, fast, muted, and unmated playing, all led to different results.) The most effective mapping for the Jazz composition "*iltur 2*" (See section 6.2) was controlling pitch shifting and buffer start time with the antennae, and mapping hit strength to control volume.

6. COMPOSITIONS

Two Jazz compositions were written for the system. The first – *iltur 1* – features the MIDI application and the second – *iltur 2* – focuses on audio transformation and manipulation, while improving on the original MIDI application.

6.1 *iltur 1*

In "*iltur 1*" two Beatbug players control two different algorithms for rhythmic ornamentation and transposition of musical material played by a MIDI piano. A rhythm section – a drummer and a double bass player – helps in establishing the piece's Jazz feel. The composition begins with a melody played by the piano and repeated in transformation by the Beatbugs players who control its expressive envelope using hit velocity and antenna bending. The Beatbugs play two different mallet instrument sounds (using Propellerheads' Reason samples), which helps differentiating their sounds from the piano sound, and from each other. The piece then moves to an improvisation section where Beatbug players record short segments of a piano solo on the fly. Players can then trigger different sections and permutations of the phrase and manipulate it by bending the antennae as described in Section 5.1. These call-and-response routines are based on a repeated harmonic structure.

Figure 5. *iltur 1* in concert - International Computer Music Conference, Miami 2004

The next section of the piece is played in a freer manner. The only instructions for the players are to listen to each other, to pick up musical ideas that they like, and to transform these phrases back and forth. In this section the drummer and the bass player are also encouraged to participate by adding variations on the original and transformed material[1]. The piece then returns to the theme section, featuring the same Beatbug variation as at the beginning of the piece.

[1] A movie clip of *iltur1* free improvisation section can be found at http://undertow.arch.gatech.edu/homepages/gweinberg/IlturNweamoFree.mov

6.2 *iltur 2*

In *iltur 2*, one of the Beatbugs improvises and transforms audio recordings of muted trumpet playing while the other Beatbug interacts with the MIDI piano. Here too, a double bass player and a drummer provide the rhythm section. The piece, written in 11/8, begins with the melody section played by the muted trumpet, while one of the Beatbug player capture specific melody notes using a delay line and extend them by manipulating pitch and timbre. In the improvisation section, the audio-based Beatbug player can create his own melodic contour with the captured and analyzed audio material. Other transformations include segmentation and reshuffling of the trumpet solo and effect manipulation such as pitch shift and delay (See section 5. 2 for details). The other *iltur 2* Beatbug interacts with a MIDI piano, utilizing a similarity algorithm based on contour directionality and rhythmic density (See section 5.1). In the Jazz standard tradition, the piece starts with a melody section, goes into a number of improvisation cycles, by the MIDI piano, the Trumpet, and the Beatbugs, and ends with a repetition of the melody[2].

Figure 6. *iltur 2* studio recording

7. DISCUSSION

iltur 1 and *iltur 2* were recorded and videotaped in a number of studio sessions as well as public concerts such as at the Northwest Electro-Acoustic Music Organization Festival in San Diego 2004, the International Computer Music Conference in Miami 2004, and the Listening Machines Concert at the Eyedrum Atlanta 2005. About ten different players, novices and experts, played the Beatbgus in these performances, which led to a number of findings regarding the two main goals for the project: our effort to create rich musical experiences for individual novices through gestural manipulation of intuitive musical percepts and our attempt to form a unique collaborative musical experience for novices and experts, which is interdependent and coherent.

7.1 Intuitive and Expressive Musical Experiences for Novices

A variety of transformation algorithms were developed in an effort to provide expressive and institutive musical control for novices. Some of these algorithms utilized direct mapping between continuous bending gestures and fundamental musical aspects such as pitch and rhythm. Other algorithms used more sophisticated stochastic operations in an effort to allow players to control aspects such as melodic similarity or rhythmic density. Based on observations and discussions with players, we believe that the simple direct mappings were generally more effective than the sophisticated stochastic algorithms since they provided more predictable control for players. A few users, however, preferred to interact with the stochastic operations, stating that these were surprising and encouraged them to concentrate on the "dialog" between their actions and the musical output. The effectiveness of the experience was also closely related to the musical and harmonic context. The first section of *iltur 1*, for example, includes a repeated harmonic structure where the Beatbug players record improvising over a full chord progression cycle before playing the variation back over the same harmony. Here, players could simply bend the antennae sporadically to ornament chosen parts of the phrase, while the default harmonic structure was kept intact. In the second section of *iltur 2*, on the other hand, players record a phrase that is based on a particular harmonic progression, and play it back over a different harmonic context. Here, players had to put more effort in manipulating the melody so that it fits the accompaniment, a task that was further complicated by the irregular 11/8 time signature of the piece. In these sections players were able to improve their playing skills through practice, and some even developed a certain level of "virtuosity" which produced better and more harmonically appropriate musical outcome. In another atonal section of *iltur 1*, a freer and more open experience emerged for both experts and novices. Players who preferred this mode of interaction stated that it posed less boundaries and allowed more creativity and expression. Some players, however, mentioned that the free section was confusing, and that at times it was difficult to predict and control the output of the Beatbugs. In addition to software mappings, another key factor in providing an expressive and intuitive experience for novices was the design of the gestural interaction with the Beatbug. The simple bending and hitting gestures proved to be intuitive and easy for most players to experiment with. Gestural combinations such as hitting the Beatbug while bending the antennae for recording, on the other hand, required more coordination and larger hands (see Figure 6). These combinations made the interaction more physically demanding in compression to the simple interactions with the Toy Symphony Beatbugs.

7.2 Coherent Interdependent Group Interaction

Our effort to create a coherent multi-player experience that allows novices and experts to clearly follow and identify their contribution to the collaborative process was generally successful. Contributing factors were the design of simple sequential interactions based on turn taking as well as to the implementation of visual and localized-audio feedback in the Beatbugs. Of the two modes of visual feedback, the flashing of white LEDs proved to be more useful to the players than the continuous color change LEDs. We believe that the correlation between the sound and flashing light made the discrete feedback more meaningful than the continuous subtle color changes. The flashing also conveyed the more musically critical and potentially acoustically ambiguous information regarding who was playing and when. Also helpful

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[2] A movie clip of a studio recording of *iltur* 2 can be found at http://undertow.arch.gatech.edu/homepages/gweinberg/iltur2.mov

was the design of simple sequential interactions where Beatbug players took turns in communicating with only one player at a time. Both novice and expert players found it easy to follow the interaction and comprehend their contribution to the music. Conveying the interaction to the audiences, on the other, was a more difficult challenge. For example, in our early experimentations the Beatbugs used the same timbre as the instrument they were manipulating (piano and trumpet.) The audience, however, found it difficulty to identify where the sound came from and who was playing at any given moment. We addressed this problem by differentiating the Beatbugs' timbre from the instrumental timbre, by choosing a different MIDI program for the piano Beatbug and implementing filters and other audio effects on the trumpet Beatbug. Another challenge that had to be addressed was that *iltur* had to be performed coherently both in small studios and in large concert halls. To address this challenge we tried to duplicate the output system to the house PA while still playing the sounds through the internal speakers for personal and intimate feedback. However, this amplification scheme made it difficult for audiences to identify the spatial source of the Beatbugs. By mapping the Beatbugs's sound to separate monitors on stage instead of the house PA we were able to better convey the interaction to audience, spatially.

Figure 7. Interdependent group collaboration in *iltur*. Performed at the New West Electro-Acoustic Music Festival, San Diego 2004

8. FUTURE WORK

Several directions for future work, in hardware and software, are currently being explored. Inspired by Aimi's and Young's new Beatbug design [14], we are considering the addition of accelerometers to sense players' arm gestures and the addition of wireless communication to allow freer and less cumbersome operation. We are also working on an improved approach for multiplayer interdependent application that would allow Beatbug players to send phrases to each other, utilizing multi-level transformation algorithms to develop and personalize phrases in sequential steps. For this application we plan to make use of the system's ability to support up to 8 Beatbugs, capacity that was not utilized fully in the applications that are described here.

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