IROS 2011 Standard Platform Demo: More cowbell! A musical ensemble with the NAO thereminist

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Abstract— **In this demo, we propose the first live performance of our interactive robot thereminist. The robot plays the theremin using feed-forward arm control, and listens to a co-player's rhythm to stay in sync. Alongside tempo detection, a Kuramoto coupled oscillator model is used for phase synchronization, to stay "together" even in the face of tempo changes. This system has been implemented on three full-size research humanoids, and we now adapt it to the widely-available NAO robot. Audience members will be invited to play a cowbell to lead a band comprised of a human guitarist and robot thereminist.**

Keywords: music-playing robots, robot accompanist, nao

I. Introduction

Music is a promising way to improve human-robot symbiosis, especially when the music is played together. Synchrony is used to form bonds and increase trust between people, whether they are rowers [1], marching army soldiers [2], or choir members [3]. Creating music together can by enjoyed across cultures and by the young and old alike, and we suggest that it can improve relations between humans and robots too.

On a practical level, music robots are also useful for musicians to practice ensemble music anytime, at any place. In contrast with computer accompaniment, robot embodiment provides a 'presence' [4] that can increase the entertainment factor in performances. Our previous interactive music robots [5], were implemented on research systems such as Kawada Industries' HRP-2 and HIRO. Due to their size and price, they were impractical for day-to-day use.

For this demonstration, we port the "musical co-player" system to the NAO humanoid. We confirm that despite its compact size, it can still play a human-sized theremin without physical modification. This result provides a promising outlook, showing that personal companion robots can help us enjoy hobbies such as music.

II. System Overview

The theremin is an electronic instrument with two antennas: a vertical one for pitch and a horizontal one for volume (Fig. 1). A theremin player can change the pitch and volume by moving closer or farther from the antenna. Due to its non-linear pitch dynamics, it is a difficult instrument to master.

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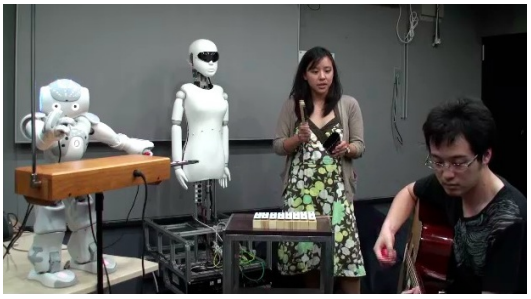

Fig. 1: Proposed demonstration setup with the NAO robot thereminist, percussionist with cowbell and guitarist.

A. Theremin player module

We implement a theremin player module on the NAO humanoid from Aldebaran Robotics. The NAO robot first calibrates itself with the theremin's pitch by recording a sweep of points with its right arm (4-DOF) and performing pitch detection using subharmonic summation [6]. Along with a relatively long frame width of 8192 samples, we found the detection was robust to the noise from NAO's head-mounted microphones. Once pitch detection is complete, two interpolations methods [7] were implemented to retrieve the pose corresponding to a particular pitch: 1) parametric interpolation requiring approximately 12 recording points, and 2) a look-up table with linear interpolation between points, needing approximately 50-70 recording points. Method 1) gives fast, reasonable results most suited to solo play and 2) takes longer to calibrate, but results in finer tuning more suited to ensemble play. In this demo, we will use method 2.

B. Interactive co-player module

We summarize here the interactive co-player system presented in [5]. The co-player module uses a Kuramoto coupled oscillator model, often used to describe synchronization phenomena in biology, to synchronize a human and a robot musician (Fig. 2). The model assumes accurate, real-time beat tracking. This part of our subsystem performs beat-tracking using a Sobel filtering technique over the mel-scale spectrogram, for onset detections robust against robot motor noise. Beat intervals and predicted beat times are sent via TCP/IP to the theremin player which updates its own values accordingly.

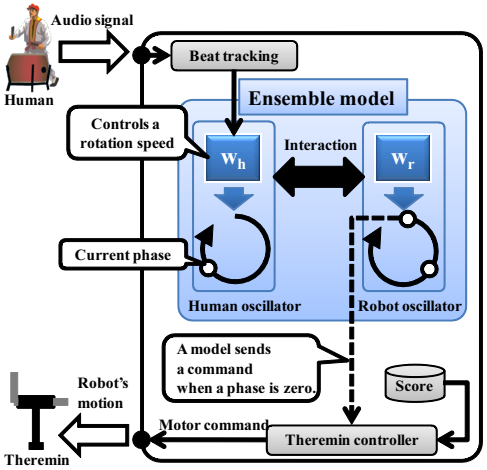

Fig. 2: Block diagram of interactive co-player module. A complete explanation can be found in [5].

C. Innovations of the system

Few interactive music robots have performed in public because the reliability of perception must be high. One way to avoid this problem is to use symbols, but this limits playable instruments to MIDI-compatible ones such as keyboard [8]. Our system performs robust signal processing so that the system may eventually be extended to perceive a wide range of non-MIDI acoustic instruments. In the demo, a cowbell, glockenspiel and shaker (maracas) will be available for use, and we are currently extending beat-tracking to other instruments such as guitar [9] and flute [10].

The system will also reveal the capabilities of a standard robot platform to play a musical instrument. Music robots have long been customized to play a target instrument; for example, Haile had a wooden arm to beat a drum [11], WAS-2 had lungs to play a sax [12], and WF-4RIII was given lips to play a flute [13]. This will be the first standardized robot to perform publicly in a human-robot band, exposing both the versatility and limitations of current humanoid robot platforms.

Indeed, compared to our previous platforms, the NAO system has produced the most sophisticated play thus far. Compared to HRP-2, NAO's arms are much lighter, and can thus change notes quickly. This dexterity allows for a wider range of musical repertoire, such as rock music. Music is an aesthetic experience, so details such as the look of the NAO robot, its polished movements, and smooth sequencing of behaviors also greatly enhance the robot's performance.

III. Demonstration Details

A. Live and interactive aspects

The NAO robot will perform popular music on the theremin along with a human guitarist and audience member playing the cowbell. For each performance, an audience member (or demo support member, if audience members are unavailable) will lead the song with several beats from the cowbell. Robot start and stop will be controlled by a human technician (automated start and stop have been discussed in [10] but will not be included in this demonstration). During the song, the participant can change the tempo by beating the cowbell slower or faster. A shaker and glockenspiel will also be available for participants to use, if desired.

B. Additional material

Please refer to `http://winnie.kuis.kyoto-u.ac.jp/~angelica/musicrobots/` for a demonstration of NAO interactively playing The Beatles' song "Hey Jude" along with two humans, as well as a solo ("Theme from Star Trek") and demos on other platforms.

C. Equipment we will bring

We will bring our own:

- theremin, theremin stand, theremin speaker and cables
- stool for NAO
- acoustic guitar, cowbell, shaker and glockenspiel
- laptop and microphone for off-board beat tracking
- laptop for control

D. Special requirements

We plan to use the NAO standard platform provided by IROS. No additional sensors are required. Since the theremin's pitch is affected by conductive objects nearby, we should ensure approximately 1.5m radius of open space around it. Alternatively, partitions directly behind and to the sides of the robot could be used to avoid interference from guests.

E. Number of people expected to support the demo

Three people are expected to support this demo: Angelica Lim (NAO support), Takeshi Mizumoto (signal processing) and Tatsuhiko Itohara (guitar accompanist).

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