Towards Music Performing Humanoids

David Grunberg[1,3], Alyssa Batula[1,3], Daniel M. Lofaro[1,3],
JunHo Oh[2,4], Paul Y. Oh[2,3], and Youngmoo E. Kim[1,3]
[1]*Electrical and Computer Engineering* [2]*Mechanical Engineering*
[3]*Drexel University* [4]*Korea Advanced Institute of Science and Technology (KAIST)*

Participation in live musical performances requires a multitude of sensory and physical capabilities. The participant must first use hearing and sight to determine features of the music that will enable a logical reaction, and then must respond to the music, such as by gesturing or by playing an instrument. Our main objective is to enable Hubo (Figure 1), an adult size humanoid robot, to participate in live musical ensembles. To this end, we have focused on enabling it to extract information from live music using sight and sound, and on developing algorithms to produce motions in response to audio.

The ability to listen to music and extract relevant features, such as rhythm and pitch, is crucial for participation in musical performances. We developed algorithms to enable a robot to hear and analyze music, such as an audio beat tracker, which autocorrelates the subband energies in audio to calculate the tempo and then beat locations, and a pitch detector, which determines if a note was played correctly by evaluating the spectrum of the note and analyzing the strongest frequencies. Our algorithms are accurate for a variety of popular music (for the beat tracker) and piano notes (for the pitch detector). We also developed techniques that use sight to determine additional musical information, such as a conducting tracker, which uses optical flow techniques to identify a moving baton. This algorithm can identify baton motions in multiple time signatures. All of these algorithms run in real time.

Hubo must be able to move appropriately based on the musical features that it detects. Because of Hubo's fragility and high cost, however, it is risky to use for prototyping. As a result, we are testing our algorithms on a smaller humanoid, the Robonova (Figure 1), which is more rugged and less expensive. This allows us to test motion algorithms without risking damage to Hubo.

We prototyped both dance and piano-playing motions on the Robonova. Regarding dance, we have enabled the Robonova to make arm and leg motions based on beats predicted by the audio beat tracker. The robot currently has a gesture corpus of 30 motions which it can execute in any combination. We also developed motion algorithms to allow the Robonova to play piano notes, and have modified the robot's hands to enable more accurate performances.

By combining these developments, we can enable Hubo to react to music. This robot would be an ideal platform to study human musicianship and musical creativity. Development of the robot's motions will enable us to quantify motion parameters in a manner that is impossible with human performers. Because Hubo can repeat motions with more precision than a human can, we will be able to adjust the parameters and evaluate the resulting performances on human audiences. This data could lead to conclusions about which parameters influence human perception of musical performances.

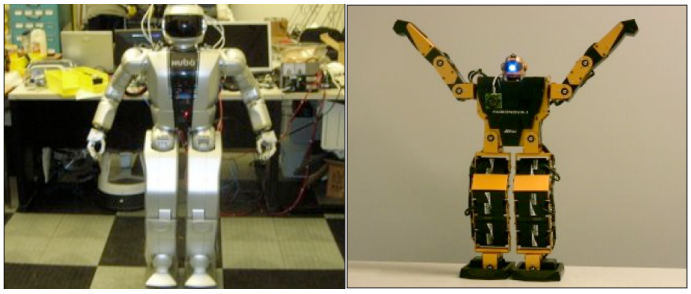

Fig. 1. LEFT: Hubo. RIGHT: Robonova