# Austrian Kangaroos
# Team Research Report 2014

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**Abstract**

The *Austrian Kangaroos* are the humanoid soccer robot team of Vienna University of Technology, and University of Applied Sciences Vienna. For both institutions the team serves as a first class teaching environment as much as a test bed for scientific evaluation of new concepts under development. This paper outlines the team's scientific mid and long term goals as much as research conducted over the season 2013/2014.

## 1 General Introduction

RoboCup, especially humanoid robotic soccer, provides an excellent platform for research and education on a wide field of topics. Consequently, research groups of Vienna University of Technology and University of Applied Sciences Technikum Vienna participating in the Austrian Kangaroos are applying their specific research questions and expertise to the Standard Platform League's unified robotic hardware.

The team was founded in 2008 and since then successfully participated in RoboCup events like world cup, and local opens. The first participation in RoboCup world cup took place in 2009 in Graz, Austria, and since then the Austrian Kangaroos have been a active part of the league's community.

Starting with theoretical knowledge in software engineering for cyber-physical systems, scientists and students of both universities jointly gathered a huge amount of practical know-how and expertise within the field of autonomous mobile low-budget robotic devices. Over time, several major cuts in development as much as paradigm shifts have become necessary to reflect team's growing insight in existing real-world problems. Since 2012/2013 the software architecture and its underlying paradigm has been stabilized and hence serves as our scientific test bed.

## 2 Overall Research Goals

Both universities participating in the Austrian Kangaroos have successfully mapped parts of their research agenda to the team's context. The following enumeration provides an overview of the partners' mid- to long-term research agenda.

1. Robust dependable autonomous systems

   One key focus of the *Compilers and Languages Group* of Vienna University of Technology is that of programming and compilation techniques of robust/dependable autonomous embedded as much as cyber-physical systems. Over the last years research related to compiler correctness, engineering methodologies for safety critical systems [9–11, 13, 16], and analyses for worst-case execution times (WCET) [15] in cyber-physical systems has been conducted and applied to the Austrian Kangaroos.

2. Artificial Intelligence and Machine Learning

   AI and ML hav been another focus in research at Vienna University of Technology but also in education at University of Applied Sciences Technikum Vienna where AI and Artificial Life play an important role within the Game Engineering Master. Research on AI and ML has been successfully conducted and applied to the Austrian Kangaroos for Artificial Immune Systems [12], Genetic Programming [14], and Goal Oriented Action Planning.

3. Robust communication in hostile environments

   Rather soon, it became clear that the robots' unreliable WLAN availability at large scale tournaments is a show stopper when it comes to team AI. Hence, a focus on reliable team communication was mandatory. From 2010 to 2012 research efforts have been placed on a wireless time-driven communication bus. The developed system has been implemented and tested at two consecutive world cup tournaments. Results where O.K. but not good enough to solve the team's communication problems. Consequently, research and development efforts have been shifted away from radio towards another channel of communication: acoustics.

4. Robotics in education

   The Austrian Kangaroo team is a learning environment for students that intrinsically motivates. A rotation life cycle was developed at University of Applied Sciences Technikum Vienna and has been implemented for the Austrian Kangaroos [3,4,6–8,17]. It enforces the preservation of knowledge and increases the sustainability of the team. In the EU-project Centrobot a platform for exchange of learning material with robots was developed to share digital content for teachers in robotic classes.

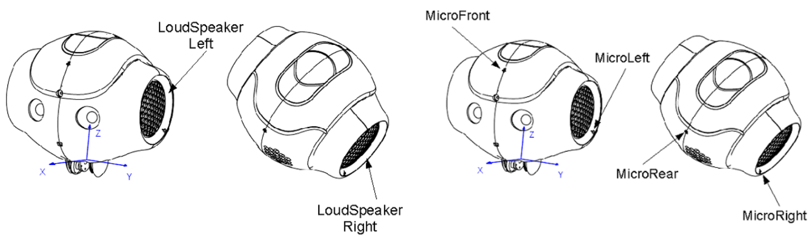
# 3 Results 2013/2014

One long term goal of RoboCup is to raise robotic soccer to a human like level in terms of quality and robustness. Therefore, several challenges exist that have to be overcome. The one our team has focused on for season 2013/2014 is that of robust communication. Previous RoboCup tournaments have clearly shown that communication by WLAN definitively is a show stopper under real world conditions like the world cup. This is mainly caused by radio interference with other leagues, undisciplined usage of the WLAN-resource by several individuals (e.g., video streaming, file sharing, etc.), but also by bad hardware design w.r.t. wireless communication of the NAO robot. Hence, the team's focus of research and development was set to robust acoustic communication without the need of radio signals.

Various approaches to digital acoustic communication have been proposed in literature. The main field of application so far is communication at submarine vessels and underwater sensor networks as sound is much better propagated in water compared to radio signals. However, as radio communication channels at RoboCup tournaments are completely overloaded, some times even jammed, we transpose underwater communication methodologies to over-the-air acoustic communication for the SPL. Limits that have to be overcome are: poor hardware like microphones and speakers of the NAO robot, infeasible design decisions like direction and position of built-in microphones, and finally lots of noise coming from the NAO's hardware as much as from environment. To tackle these issues acoustic communication has to be robust to noise, and adaptive to changes in environmental condition.

## 3.1 Hardware & Audio Framework

The robot used for these results is the "Nao V4 H25" which has four microphones and two speakers mounted on the head. These microphones and speakers are mounted as it can be seen in Figure 1. According to these microphones For the following applications an audio framework based on Advanced Linux



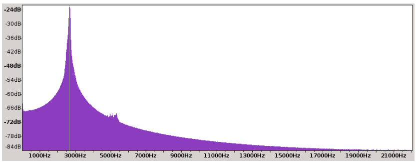

(a) Speaker arrangement. (b) Microphone arrangement.

Figure 1: Nao V4 H25's microphones and speakers. Taken from [1, 2]

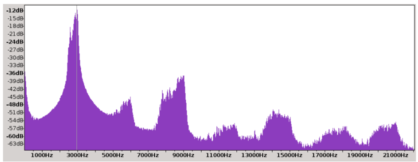
Sound Architecture (ALSA) has been implemented. This audio framework realizes sound reception and transmission with a chosen sampling rate of 8 kHz and 16 bit resolution. The audio reception part also precalculates a Short Time Fourier Transformation (STFT) based on the FFTW3 [5] library with a rectangle window. To increase frequency resolution the windowed audio samples are zero-padded. Although the Nao H25 offers four microphones, only the left and right one have been used because the front and back microphone show different audio characteristics because of different mounting and a fan inside the head.

## 3.2 Whistle Detection

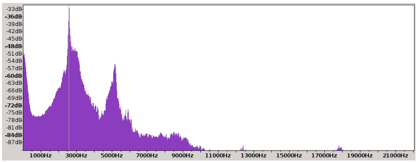
Whistle detection could overcome the problem of starting and stopping a game with the game controller. The biggest challenge with whistle recognition are the varying frequencies depending on the whistle type and the whistle blower. Additionally most whistles have a natural or synthetic cork ball inside which has the task to vary the resulting frequency that humans can better recognize the whistle sound.



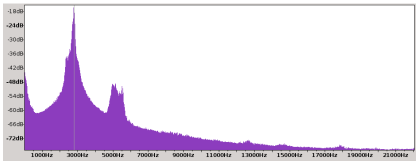
(a) Referee whistle slightly blown. Peak at 2.68 kHz.



(b) Referee whistle normal blown. Peak at 2.96 kHz.



(c) Toy whistle slightly blown. Peak at 2.59 kHz.



(d) Toy whistle normal blown. Peak at 2.78 kHz.

Figure 2: Different whistles blown.

To adjust whistle detection, reference frequencies from real whistles have to be determined. For this purpose two whistles have been measured, one referee whistle made of metal with a synthetic cork ball inside and a second toy whistle made of plastic with a plastic ball inside. The measured frequency distribution can be seen in Figure 2 and clearly shows the effect of the ball inside the whistle. Blowing the referee whistle slightly that the ball will not move results in a clean peak at 2.68 kHz, blowing the whistle stronger shows the frequency variation induced by the ball. Although there is a strong peak at 2.96 kHz. The toy whistle does not have such a clear peak but shows a similar sound profile when blown slightly or strongly.

Since the measured peaks are below 4 kHz (the Nyquist frequency for a sampling rate of 8 kHz) the whistle detection can be realized by searching for peaks between 2.5 kHz and 3 kHz.

For peak detection the mean ($\mu$) and standard deviation ($\sigma$) of the absolute spectrum given from the STFT is calculated. Every value above a threshold of $\mu + c \cdot \sigma$ ($c$ is a configurable threshold constant) is considered as a peak in frequency domain. A whistle event is generated when the amount consecutive peaks in the whistle frequency range lasts for at least 300 ms with allowing misses below a total of 7 ms.

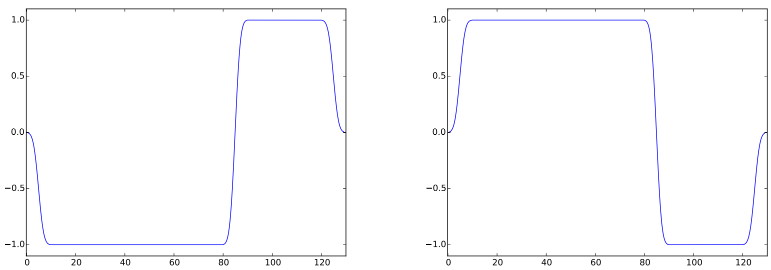
## 3.3 Acoustic Communication

To overcome the limitations of wireless radios (primary the availability in the world cup scenario), acoustic communication is proposed for exchanging basic information like the robot's role. Problems of acoustic communication are air channel pollution by human voice, air condition and other devices, limited bandwidth compared to wireless communication and noise annoyance.

For robot to robot communication Gaussian Audio Frequency Shift Keying (GAFSK) is used for modulation. The selected frequencies are 680 Hz for 'space' (0) and 840 Hz for 'mark' (1) and a bit duration of 40 ms.

For error correction a simple but robust approach has been chosen. Every bit is encoded to a triple-bit sequence. A digital 0 corresponds to $0-0-1$ and a digital 1 corresponds to $0-0-1$, as it can be seen in Figure 3.

For this modulation and error correction a baudrate of 12.5 bit/s is achieved.




(a) Sequence for a digital '0'. (b) Sequence for a digital '1'.

Figure 3: Error correction correspondence.

The demodulation is based on a similar thresholding technique as shown in Section 3.2 observing only the two main frequencies and a cross correlation pattern matching mechanism.

## 3.4 Game Controller Signals

This year also audio signals have been designed for a sound recognition challenge. These signals are a 'start' sequence which is a digital '0' repeated for four times and a 'stop' sequence, a digital '1' also repeated for four times.

In contrast to audio communication, selected frequencies are chosen in lower frequency bands because lower frequencies achieve a higher spatial range and are emitted by public address speakers showing a better frequency response than NAO's speakers. The chosen frequencies are 200 Hz for 'space' and 320 Hz for 'mark'. Even though the NAO documentation [2] claims that the microphone's bandpass has a range of 300 Hz to 8 Hz, enough energy for signal recognition passes through also for the 'space' frequency.

## 3.5 Conclusion

As result for season 2013/2014, our work shows that acoustic communication can successfully be integrated into a soccer playing SPL robot. Data throughput is far away from radio communication due to physical as much as information theoretical limits, but could further be improved e.g., by using multiple orthogonal channels. Experiments at laboratory conditions show good robustness even with presence of music and chatting students. Although bandwidth is very limited, we think our contribution can help to overcome WLAN issues for the SPL.

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