# RoboMusic

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## Abstract

Based on principles from modern artificial intelligence and robotics, we developed the RoboMusic concept. In RoboMusic we use a number of robotic devices as instruments, and the tunes are composed as a behaviour-based system. The music artist composes a baseline behaviour of the robotic instruments and composes the behavioural response to interaction by human musicians. The music artist is transformed from a composer of static music tunes to a developer of robot behaviours – behaviours that are expressed by the robotic system as music pieces. Music compositions are transformed to become robotic behaviours as in a behaviour-based system. A RoboMusic concert is performed with robotic instruments, and changes the concept of live concerts by inviting the audience to interact with the band's instruments themselves and thereby guide the live performance of the music themselves.

## Introduction

Where robotic technology was used mainly in heavy industries in the past, the last decade has shown a widening of the use of robotic technology into the professional and private service sector, including the entertainment sector. For instance, inspired by Brooks' early development of behaviour-based systems, iRobot has developed vacuum cleaning and floor washing robots for the home market, and Wow-Wee has developed toy robots based upon Tilden's bio-inspired bottom up approach to robotics. We have ourselves developed the behaviour-based approach for interactive robot entertainment such as RoboCup Junior [7], I-BLOCKS play in hospitals and developing countries [5], and interactive playgrounds [4].

Here, we will be looking at the possibility of using the behaviour-based robotic approach to develop a new genre of music that we term *RoboMusic*. In this and the above-mentioned robot service and entertainment applications, the robot technology is merging with other developments in artificial intelligence such as ambient intelligence and ubiquitous and pervasive computing. In many cases, however, we observe that developments in such sub-fields seems to build upon (parts of) the general definition of robotics. We use the following definition of a robot:

> A robot is defined to be a programmable machine that by its interaction with the surrounding environment autonomously can perform a variety of tasks, and its behaviour is different from a computer program by the interaction with the environment through sensors and actuators.

According to the definition, we may develop robotic instruments being programmable instruments that by their interaction with the surrounding through sensors and actuators can be used for playing a variety of tunes.

## Related work

Robotics and AI has been used previously to develop music by other researchers and musicians. Most notably, Gil Weinberg [11] and his research group at Georgia Tech have developed a number of robot instruments, such as the Haile drumming robot and other instruments like the beat bugs and squeezables. The robotic drummer Haile is an impressive robotic design made to listen to two live percussionists, analyze their drumming in real-time, and use the product of this analysis to play back in an improvisational manner [11], e.g. as shown at live performances at the Robots at Play Festival in Odense, Denmark in September 2006.

Also, a number of researchers have worked with multimodal interactive environments, including musical environment. Antonio Camurri [2] developed a multimodal environment, in which users were allowed to communicate by means of full-body movement, singing

or playing. In the multimodal environment, the users could get feedback from the environment in real time in terms of sound, music, visual media, and actuators, i.e. movement of semi-autonomous mobile systems including mobile scenography, on-stage robots behaving as actors or players, possibly equipped with music and multimedia output.

Other interactive environments were developed with focus on musical composition with novel interactive instruments, such as the Bubble Bumble and Musical Desk by Zhou et al. [12].

Also, interactive computer music researchers and artists such as Wayne Siegel have explored the possibility of creating real-time interaction with music pieces, as exemplified with Wayne Siegel's "Music for Wind" and "Movement Study" performances in which wind speed and direction control the music and dancer movement control the music [10].

Other artists and researchers have explored similar concepts, developments and performances with interactive computer music and movement control of sound. The work that we present here on RoboMusic distinguishes itself from such related work in the inspiration from and exploitation of different strands of robotics to create intuitive interaction with robotic instruments for both audience and composer, and to create musical compositions as *robotic behaviours* as known from the behaviour-based robotics.

In many cases of related work, a well instructed professional dancer or musician has to control the interactive devices, and the professional musician or dancer has to do so in a precise way in order to create a musical response which is pleasant for the audience. On the other hand, the RoboMusic is taking advantage of the work in human-robot interaction to create a seamless interface for any non-expert human user to make pleasant run-time manipulations of musical pieces.

## RoboMusic

RoboMusic defines a novel genre of music. In RoboMusic, music is composed using robotic instruments, music is recorded based on playing robotic instruments, and concerts are performed with robotic instruments.

According to the definition above, a robot is defined to be a programmable machine that by its interaction with the surrounding environment autonomously can perform a variety of tasks, and its behaviour is different from a computer program by the interaction with the environment through sensors and actuators. Hence, a robotic instrument is programmable instrument that by its interaction with the surrounding through sensors and actuators can be used for playing a variety of tunes. Through communication, robotic instruments can be used together to orchestra an ensemble. If left untouched by human (or environmental) interaction, the robotic instrument will behave with its own performance composed by the music artist. When a human or other environmental subject interacts with a robotic instrument, the instrument may change performance from its normal autonomous behaviour.

The artistic and technological challenge of the music artist is to compose baseline behaviour of the robotic instruments and compose the behavioural response to interaction by human musicians. The music artist is transformed from a composer of static music tunes to a developer of robot behaviours – behaviours that are expressed by the robotic system as music pieces. Music compositions are transformed from being static to become dynamic; music compositions are transformed from being static nodes to become robotic behaviours.

A RoboMusic concert is performed with robotic instruments, and changes the concept of live concerts by inviting the audience to interact with the band's instruments themselves and thereby guide the live performance of the music themselves. The audience is actively engaged in the performance of the music of their concert, and their interaction with the robotic instruments guide the robotic behaviour and thereby creates a unique live concert performance that change from concert to concert depending on the behaviour of the audience. Each RoboMusic concert is a unique live performance. The music artist has composed the baseline, and the audience is manipulating the robotic instruments to allow the robotic behaviour to change, and thereby the music tune to diverge. For the audience, the concert form has changed from passive listening to active participation in playing the concert.

## Behaviour-based RoboMusic composition

Behaviour-based robotics [1] can be used to create easy access and manipulation of complex technology by non-expert users, and therefore becomes an appealing technology for creating RoboMusic, in which both musicians and audience with no robotics/technology

knowledge should be able to manipulate the robotic instruments in an easy and straightforward manner.

Interaction between human and traditional robotic systems can be problematic, as the traditional robotic systems often perform repetitive actions in a restricted environment, whereas human interaction often is characterised by novel ways of interactions, which creates an ever changing environment (which should be the case with RoboMusic live concerts). Therefore, traditional robotic system methods and technologies are often difficult to apply in situations and applications where the interaction plays a major role. So we developed a new kind of *user-guided behaviour-based robotics* (e.g. [3]) and applied this method to many robotic systems, such as manipulative robotic technologies, mobile and humanoid robots, etc. in order to investigate how non-expert users could develop their own complex robot behaviours within very short time (e.g. 30-60 minutes) with no prior knowledge to the robot technology. For instance, the robotic building block concept allows us to develop 'programming by building', which, for instance, allow African school children and African hospitalised children with no a prior knowledge whatsoever about IT, robotics and technology to develop their own electronic artefacts [5].

The behaviour-based robotics approach (and in general the embodied artificial intelligence approach [8]) puts emphasis on placing the robot/system in the real, physical environment and utilise the characteristics of the real world in the development of the intelligent system. The resulting control systems provide a close loop between environmental stimuli and actuation in the environment through the use of primitive behaviours executed in *parallel* and coordinated to provide the overall behaviour of the system. So, the overall behaviour of the system becomes the *emergent effect* of the interaction with the environment and the coordination of the primitive behaviours. The task of the system designer becomes to design the correct primitive behaviours and to set up the primitive behaviours in the right manner to allow the desired, overall behaviour to emerge as the interplay between the primitive behaviours. With the same primitive behaviours, the designer may be given the opportunity to design many different overall behaviours of the system, depending on the designer's selection and set up of the primitive behaviours [4].

Therefore, in RoboMusic, the design challenge becomes to create primitive robotic behaviours and to coordinate these primitive behaviours in order for the music piece to emerge as the coordination of primitive behaviours. Thereby, a music composition emerge from the way the composer, musicians or audience interact with the robotic instruments that provide the primitive behaviours.

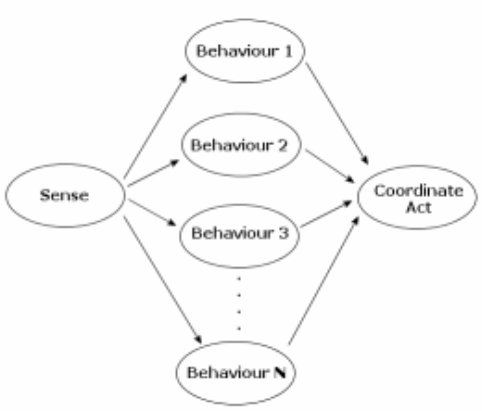


Figure 1. The behaviour based robotics approach.

Each robotic instrument is used to trigger a particular primitive behaviour (Behaviour 1, Behaviour 2, … , Behaviour N on Fig. 1) dependent on the interaction (Sense on Fig. 1) with the instrument(s). In RoboMusic, the primitive behaviours can be anything from a volume or a cut-off to a small sequence of tones. The music composer designs the way in which the primitive behaviours that are triggered should interact with each other (Coordinate Act on Fig. 1).

Hence, as is the case when designing behaviour based robots such as mobile robots, the robot designer (in this case the music composer) designs the primitive behaviours and the coordination scheme. And, as is the case with user-guided behaviour based robotics, if non-expert users (e.g. live concert audience) are supposed to manipulate and become creative with the systems, it is crucial that the designer (music composer) creates primitives on a fairly high abstraction level that allows the non-expert user to understand and have positive feedback from the human-robot interaction within a very short time frame (seconds in the case of live music concerts).

Therefore, we initially created understandable robotic instruments and primitives. The instruments used to play the music include interactive mats that measure touch, rolling pins that measure rotational acceleration, and light&sound cylinders that measure distance (of a person/hand). Such features as pressure, rotational acceleration and distance are used to trigger primitive behaviours which include variations in resonance, cut-off, volume and pan of musical tracks in the musical composition.

## Experimental set-up and test

For the first RoboMusic concert (Robo[rave] in Odense, Denmark on 15/9/2006) and for the recording of the Funkstar De Luxe album "No Man's Planet", we developed three kinds of robotic instruments, primitive behaviours and coordination.

Figure 2. Two Rehab Tiles and a RollingPin used as robotic instruments.

The system we made for this purpose is composed by three elements:

1. Device with MIDI in/out features (E.g. PC with Cubase or Keyboard)
2. MIDI controller box (MCB)
3. Robotic instruments

The robotic instruments communicate with radio communication (Xbee) to the "base station" where the coordination is taking place (see Fig. 3 and Fig. 4).

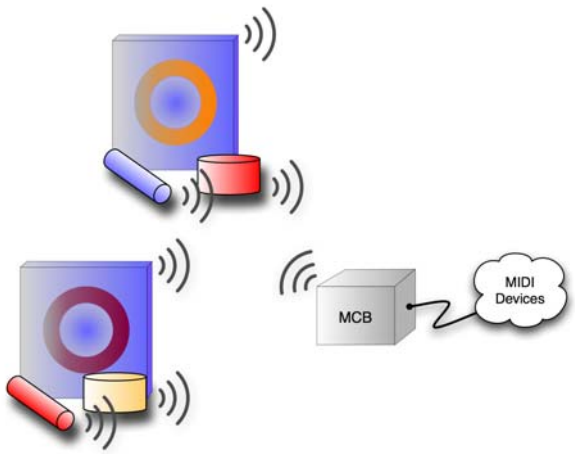


Figure 3. Concert set-up.

For the particular concert, 10 robotic instruments were used: 2 RollingPins, 2 Light&Sound cylinders and 6 Rehab Tiles. The Rehab Tiles were divided into two main groups with the same ID number. This implies that 3 tiles mimic each other. This is mainly done for robustness of the system. There is not implemented any additional transmission reliability or robustness other than the default mechanisms in the Xbee protocol (which may be necessary in future concert environments). The setup used for the Funkstar De Luxe concert is illustrated in Figure 3. The instruments can be activated or deactivated by MIDI control commands. This can be done from any MIDI device connected to the MCB that respects the implemented protocol.

The command control sequence is illustrated in Fig. 4 where a MIDI device[1] activates an instrument by sending a command on a MIDI channel. Furthermore, the MIDI Controller Box defines control numbers for input and output (e.g. 24 and 54 respectively).

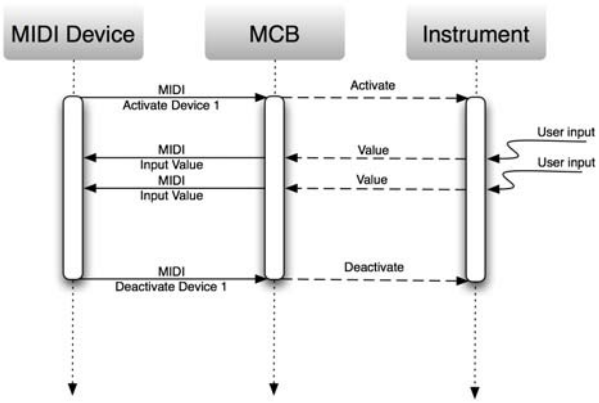


Figure 4. Control flow diagram.

The robotic instruments were developed by modifying modular robotic tools designed specifically for the purpose of supporting dynamic configurations of the environment, initially utilized in physiotherapy with cardiac patients and in dementia treatment [6]. We used inspiration from modular robotics to develop three different kinds of tools, namely the Rehab Tiles, the Light&Sound Cylinders and the RollingPins. According to the robotic building block concept used in some modular robotic work [4, 5, 6], a building block needs to have a physical expression and should be able to process and communicate with its surrounding environment, where the communication with the surrounding

[1] In this particular case the MIDI device is a Laptop running Cubase

environment can be through communication to neighbouring building blocks and/or through sensing or actuation.

The Light&Sound Cylinders and RollingPins were initially developed for the non pharmacological therapeutic treatment and were designed to allow very easy and understandable physical operation by dementia affected patients and therapists (see [6] for details), and likewise the Rehab Tiles were initially developed for physiotherapeutic rehabilitation, e.g. of cardiac patients, with an easy interface for both therapists and patients.

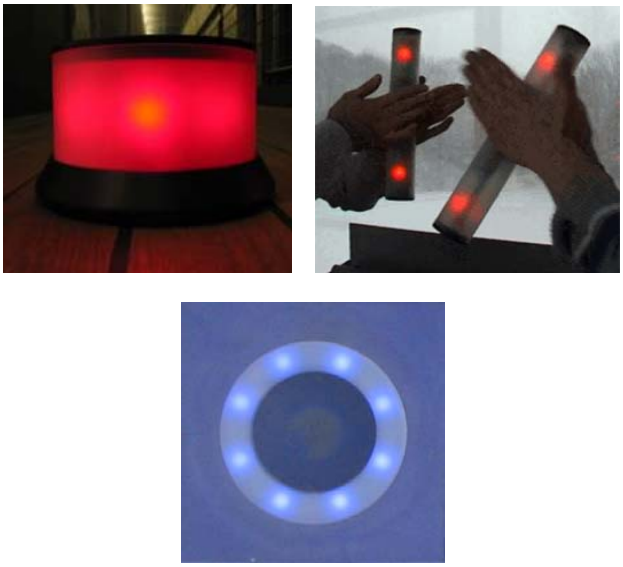

Figure 5. Light&Sound Cylinder, RollingPins and Rehab Tile.

In all cases, the modular robotic units were modified to become robotic instruments by allowing them to use Xbee radio communication to the MIDI Controller Box, see figure 3,4. Hence, the musical composition can radio communicate with the robotic instruments and for instance control the robotic instruments to light up in different colours, patterns and intensities according to the kind of human interaction which may be possible or desirable at a given point in time during the music composition. For instance, the musical composition (or the composer) may send a signal to a robotic instrument to blink in red, which may be understood by a human player as the signal that it is possible to increase a volume by interacting with the instrument.

When a robotic instrument receives an input from a human player, it will trigger a primitive behaviour. The three kinds of robotic instruments developed here have the following possibilities for receiving input from a human player:

1. Light&Sound Cylinders contain a ultrasound sensor that measures the distance to a reflection, e.g. from a hand moving up and down over the Light&Sound Cylinder
2. RollingPins contain an accelerometer and a gyroscope to measure angle and rotational speed, e.g. when a human player is rolling the pin
3. Rehab Tiles contain a force sensitive resistor to measure the force of pressure, e.g. when a human player puts a hand or foot on the tile

And all three kinds of instruments produce output in the form of coloured light in different patterns and radio communication of primitive behaviours to the MIDI controller box for further coordination (see fig. 3).

In general, it is possible to view the standard musical composition as a baseline robotic behaviour, and the interaction with the robotic instruments as triggering deviations from the baseline behaviour. Therefore, the task of the music composer is to create the “standard” behaviour when there is no interaction with the robotic instruments (i.e. the normal “static” music piece), the primitive behaviours of the individual robotic instruments and the coordination that defines the influence of the human players on the “standard” behaviour.

In the case of the first RoboMusic live concert with presentation of the Funkstar De Luxe album “No Man’s Planet”, we (i.e. the artist Funkstar De Luxe) designed when and how the audience could interact with the robotic instruments, the form and limits of primitive behaviours, and how they would be coordinated.

To keep things simple for the first live concert, the robotic instruments would trigger primitive behaviours being volume control, cut-off, pan, and resonance – but only when the robotic instruments were active, as signalled in the standard musical composition with different MIDI signals that would actuate the robotic instruments to turn on and off their lights in different colours and patterns. In those intervals, the audience were allowed to interact with robotic instruments, and the interaction pattern would define parameters in the primitive behaviours, e.g. the volume of a particular channel in the musical composition.

Figure 6. The RoboMusic live concert set-up, with Funkstar De Luxe and his control station in the center, and the robotic instruments on the left and right side of the stage.

The art of the music composer is to design the primitive behaviours and their limits (in time and form), so that the human player (e.g. audience) interactions with the robotic instruments provide deviations from the standard music piece in a manner that is at the same time improvisational and controllable – i.e. *improvisational* in the sense that the human player (audience) should be able to create a unique version of the music piece, and *controllable* in the sense that the deviations provided by the coordination of the primitive behaviours should in all cases manipulate the standard music piece in a manner that it is guaranteed to provide a pleasant music piece according to the art of the composer.

The first RoboMusic live concert was played as part of the Robo[rave] concert during the Robots at Play Festival (www.robotsatplay.dk) in Odense, Denmark on 15/9/2006 – a concert that also featured percussion music by Gil Weinberg, Scott Driscoll and their Haile drumming robot. The RoboMusic performance was the inauguration live concert of the Funkstar De Luxe "No Man's Planet" album, and audience were allowed to enter on both the left side and right side of the stage where the robotic instruments in the form of RollingPins, Light&Sound Cylinders, and Rehab Tiles were placed (see figure 6). Documentation of the effect of the audience interaction with the robotic instruments and the music can be seen and heard on the concert video available on [9].

The same RoboMusic system was used to record several tracks on the Funkstar De Luxe album "No Man's Planet".

## Conclusion

We developed the concept of RoboMusic based upon the use of modern artificial intelligence and behaviour-based robotics to allow live music to emerge as the coordination of primitive behaviours. We thereby transform the role of the music composer to become a composer of robotic/music behaviours. In order to test the concept, we developed three kinds of simple robotic instruments, and tested the system with the development of the Funkstar De Luxe album "No Man's Planet" and the inaugural live concert when the audience was invited on stage to perform together with Funkstar De Luxe by interacting with the robotic instruments.

## Acknowledgements

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**Professor Henrik Hautop Lund** is known for his work in robotics and modern artificial intelligence. His team developed the ATRON shape-shifting robots, which he presented to the emperor of Japan, HM Queen of Denmark, etc. His team has developed playware with the novel intelligent playgrounds, and has won the RoboCup Humanoids Free Style World Championship 2002. Professor Henrik Hautop Lund is engaged also in the development of intelligent artefacts, I-BLOCKS, for the teaching of creativity in Africa, where his team were one of the driving forces behind the first science park in East Africa in Iringa, Tanzania. He is member of the Danish national research council, and numerous international committees. He has produced more than 100 scientific publications in robotics and modern artificial intelligence.

**Funkstar De Luxe** (Martin Ottesen) became world famous for his remix of Bob Marley's Sun Is Shining. The remix sold more than one million copies and won several awards including a World Music Award for the best-selling reggae single of 2000. Besides releasing two albums resulting in several gold plates Funkstar De Luxe has been touring most of the world performing as a DJ and musician. The list of artists remixed is long and includes Grace Jones, Bob Dylan, Mary J Blige and Barry White to name a few. With a characteristic touch in his remixes and original songs Funkstar De Luxe's influence on electronic dance music is significant. With his new album No Man's Planet he continues to push back boundaries of creating and performing electronic music.