Rhythm Apparatus on Overhead

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ABSTRACT

In this paper I present a robotic device that offers new ways of interaction for producing rhythmic patterns. The apparatus is placed on an overhead projector and a visual presentation of these rhythmic patterns is delivered as a shadow play. The rhythmic patterns can be manipulated by modifying the environment of the robot, through direct physical interaction with the robot, by rewiring the internal connectivity, and by adjusting internal parameters. The theory of embodied cognition provides the theoretical basis for this device. The core postulate of embodied cognition is that biological behavior can only be understood through an analysis of the real-time interactions of an organism's nervous system, the organism's body and the environment. The device illustrates this theory because the rhythmic patterns depend equally on the real-time interactions of the electronics, the physical structure of the device and the environment.

Keywords

Analog Robots, Analog Electronics, Embodied Cognition

1. INTRODUCTION

The device I propose as a new interface for musical expression is an apparatus that produces rhythmical patterns and that is placed on an overhead projector to also visualize these patterns. Unlike analog step sequencers or drum machines it is not a programmable device, but behaves mostly autonomous. The core technology is based on analog robotic walking machines as they have been developed by Mark W. Tilden [19]. The most interesting aspect of these analog robots is their organic and very much lifelike behavior [9]. The electronic circuits that drive the rhythmic patterns are inspired by the recurrent neuronal networks in the cerebral spine of vertebrate animals. What qualifies the apparatus as a new interface is based on the complex interaction of the core electronic circuit and the direct current gearbox motors that are driven by the circuitry. Through a direct back-coupling of the motors into the electronics, the motors with attached legs modify the internal patterns. Obstacles hit by the legs or variations of torque during movement modify the timing of the rhythmic patterns. The motors become sensors and actors at the same time. Within the apparatus the dividing line between sensing and acting and control vanishes. This fact also renders the device interesting from a theoretical perspective. A consequence of this vanishing division is that the rhythmic patterns are in constant change, because the motors constantly feed back into the creation of rhythms. In turn the motors are themselves again driven by the rhythmic pattern. Metaphorically one can say that the device is in a constant dialogue with the outside world. The robots interface is this dialogue with the world. The inspiration and theoretical background for the device comes from the theory of embodied cognition.

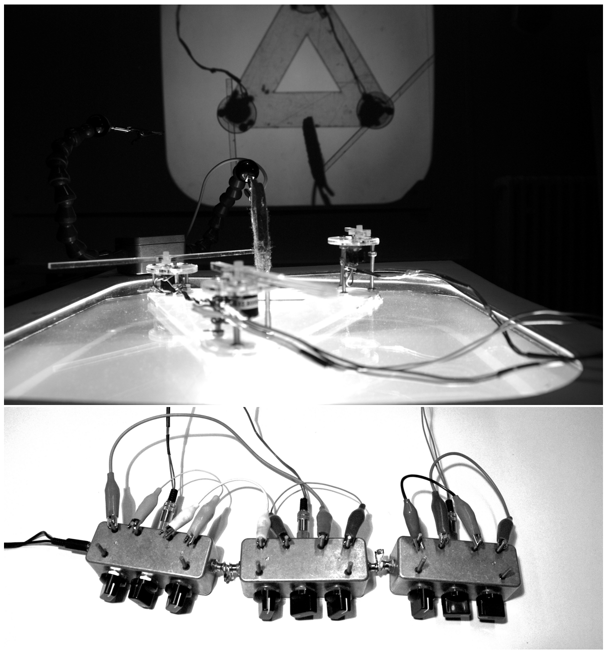

Figure 1: The rhythm apparatus on overhead. The top image shows the robot's body on the screen and the projection, the bottom image shows the controller.

The core claim of embodied cognition is that intelligent behavior in biological systems results from real-time dynamics and interaction between nervous system, body and environment [12, 14, 18]. While computational approaches to cognition focus on the brain as the central information processing device, the embodied cognition perspective denies this single cause explanation. Historically this paradigmatic shift in the understanding of cognition gained momentum in the 1980s with a focus on explaining the cognitive aspects of movement [13, 17]. Recently the field has moved to higher cognition explaining more complex behaviors such

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as spatial working memory [11], object recognition [7].

I consider the rhythm apparatus as philosophical toy because it makes some core concepts of embodied cognition tangible [6]. The device especially demonstrates how behavior emerges from the interplay of a nervous system, the body and the environment. In this paper I go beyond using the device as a philosophical toy by showing that it can be used to create complex rhythmical patterns.

2. THE ANALOG ROBOT

The design of the analog robot is thoroughly minimalist. The robot is build up from modules and can be assembled and reconfigured on the fly. As the focus is to use the robot itself as interface for audio-visual expression, its shape and its design follow a different consideration than that of classical robot. As matter of fact it does not look like a robot or any living organism but has strong graphical component. The base structure is a triangle made of acrylic glass that holds three motors. However because of the analog hardware and the specific couplings of the device the movements even of abstract shapes look very organic and lively. One could say that liveliness comes from within.

2.1 The Electronic Circuit

The pattern generating circuit consists of interconnected threshold devices that have specific timing properties. These are the basic units of the circuit. The smallest working configuration consist of two interconnected basic units.

2.1.1 The Basic Units

Each basic unit alone only acts as a change detector for falling activation at its input. Only when there is significant change of the input voltage an output signal is produced and the duration of the output signal is independent of the length of the input signal. Technically this behavior is realized by combining a capacitor in series with a resistor, and an inverter that is connected in between the capacitor and the resistor (see Figure 2). The capacitor and the resistor form a differentiator or high pass filter. Through the non-linearity of the inverter it only reacts on a falling edge of the input. As the capacitor is being charged up again when the input goes to zero, after some time it passes threshold and the inverter switches back. The timing to switch back depends on the charging time of the capacitor and not on how long the input remains zero.

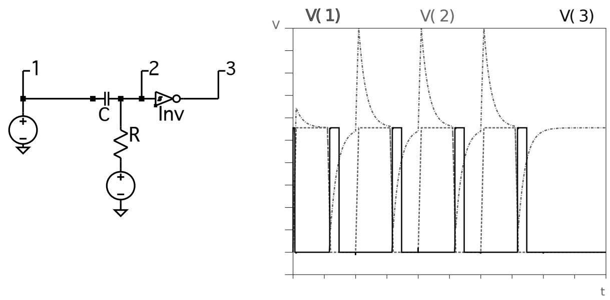

Figure 2: a) Schematic of the basic unit: a capacitor (C) in series with a resistor (R) that is connected to the positive potential. The inverter Inv is connected between Resistor and Capacitor. b) LtSpice-simulation of the temporal behavior of a basic unit: given a periodic input signal at point 1, a positive pulse is produced for every falling edge of the input at point 3.

The behavior in time of such a basic unit is similar to a biological neuron with two functional aspects: First a neuron only produces a spiking output when stimulated to a sufficient level [5]. Second, a neuron adapts to its input: on constant input it stops producing output spikes. The latter property we experience for example when we are exposed to a bad smell: even though the concentration of the molecules producing the odor is constant, after some time we do not smell it anymore [4].

2.1.2 Network and Connectivity

While a single unit does not do much, oscillatory patterns emerge when the units are connected into a loop. Such oscillatory behavior emerges also in neural networks with very simple threshold models of integrate and fire neurons [1, 20].

The simplest recurrent network with the basic units is a loop of two units, also referred as bi-core [10]. In a bi-core a single stable pattern emerges which is actually a traveling pulse (see Figure 3). Four units can also be connected into a single loop, the quad-core. The quad-core allows two complex pattern: A single traveling pulse or two traveling pulses. Six units form a hex-core, that allows for three stable patterns: A single traveling pulse, two traveling pulses or three traveling pulses. The patterns with the larger number of traveling pulses are the more stable ones. With a lot of noise, for example coupling back from the motors, the circuit will automatically switch into the more stable patterns. The other patterns, for example the single traveling pulse, have to be enforced and are less stable. Sometime at some random moment in time the circuit may just switch to two or three traveling pulses.

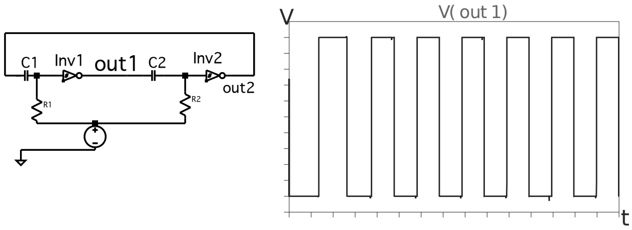

Figure 3: The bi-core circuit: the left image shows the schematic of the bi-core and the right plot shows a spice simulation of the behavior in time.

Besides these single loop networks, it is also possible to build two or three loops and to couple them mutually or with unidirectional connection. For example when two bi-cores are connected with a wire between their outputs, both oscillations will go in phase or in counterphase. A directional wiring is implemented using a diode that connects the output of one loop to the node just in front of the inverter. With this directional wiring the two loops go into a master-slave relationship [16]. The master loop turns the oscillations of the slave loop on and off (see Figure 4).

2.2 The Robot's Body

The robot's body is constructed using a transparent frame made of acrylic glass that is simply scotched onto the surface of the overhead projector. This frame holds three motors. To each motor different type of legs or other shapes may be attached. The motors are directly connected to the outputs of the inverter. It is important to use very efficient dc motors that need very little energy. This allows them to be driven directly from the integrated circuit that can provide up to $150mA$. This is important because the motors are electronically part of the whole circuit. When the motor is for example freely spinning it creates a momentum in the

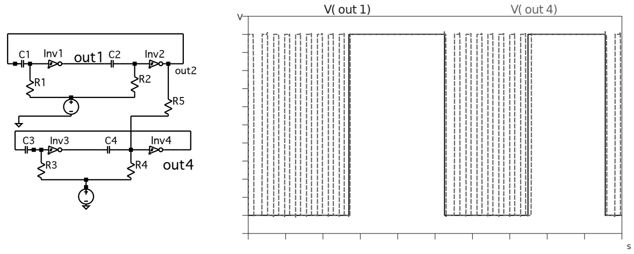

Figure 4: A coupled bi-core circuit, The left plot shows the schematic. The Top bi-core circuit has a connection from its output to the intermediate node in front of the inverter of the second bi-core. The right plot shows a spice simulation of such a configuration. The second bi-core has a higher frequency and only becomes active when the first bi-core's output is inactive.

direction of its rotation. This also induces a current into the circuit that is strong enough to override the internal pattern. When the internal pattern is fully overwritten, the motors do not oscillate any more. Note however that the motors will still reverse when they hit an obstacle. The degree of feedback from the motors into the circuit can be adjusted with an intermediate potentiometer between motor and the circuit. The motors are attached to the circuit using mini-jacks, so that they can be easily swapped or reconfigured.

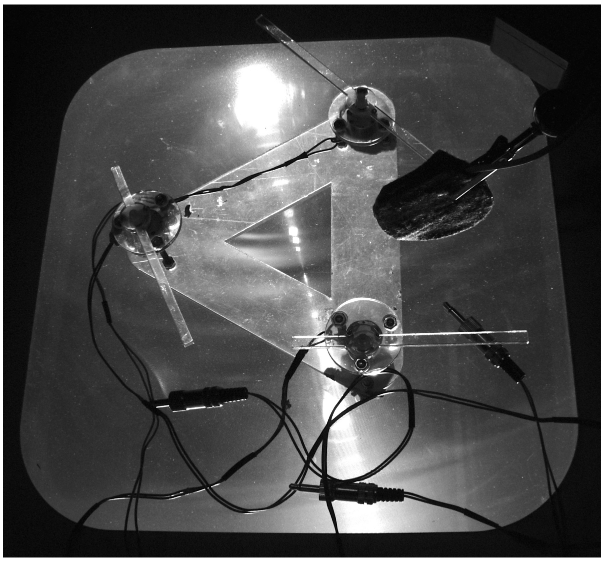

Figure 5: The robots body: three motors are mounted into a triangular frame.

3. INTERFACES

The device offers various interfaces to modify its behavior. It is possible to modify the connectivity on the fly, to create different loops, motors may be plugged or unplugged, internal timing parameters may be tuned or the environment of the robot may be modified.

3.1 Connectivity as Interface

The electronic circuits are housed in die-cast aluminum cases, each case provides two basic-units. It offers an interface for changing the network structure on the fly. The interface is inspired by early instruments from Peter Blasser of Ciat-Lonbarde [2]. It consists of brass sticks that can be connected with simple crocodile clips. The sticks provide access to the three nodes of a basic-unit, the input, the output and the intermediate node. The different network configuration are quickly assembled, Figure 6 shows an example for a bi-core hooked to a quad-core. As the connectivity can be modified on the fly, it is possible to play with different phase relations. Without a coupling cable the oscillating motors will go out of phase. However just linking them with a cable will force them to go in phase or counterphase.

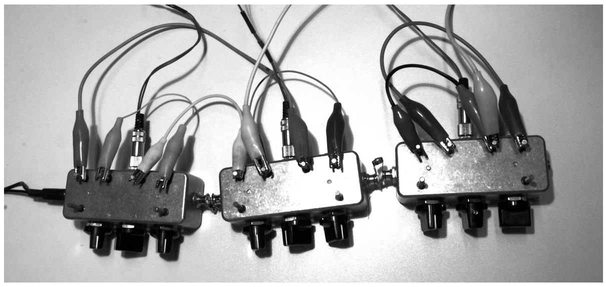

Figure 6: The picture shows three housings. The two on the left are wired up to form a quad-core, and the third on the right is configured as bi-core. A wire between the quad-core and the bi-core couples them.

3.2 Internal Parameters as Interface

The most straightforward interface, very similar to the knobs on synthesizers, are the potentiometers to modify the timing properties of the basic units. But unlike the interface of a synthesizer, the result of changing a parameter depends on multiple factors. For example when the robot is wired up as quad-core and runs in the stable pattern with a single traveling pulse, lowering the resistance of basic unit number one, will shorten the timing of this unit and the associated motor movement will be shorter. If however the robot has the stable pattern with two traveling pulses, this shorter timing will also affect all other timings and the all motors will make shorter movements.

3.3 Interfacing with external devices

As the circuit is fully analog, interfacing it with other analog hardware is straightforward. For example the circuit can be directly coupled to the instrument section of an old analog drum machine, a rhythm ace fr-2l. Or they can be hooked though an intermediate transistor stage to the control voltage input of a simple analog synthesizer. As the connectors are all accessible on the bi-core units it is very easy to try out connecting to all sorts of analog music making devices. The whole design is very much inspired by the circuit bending [8] and hardware hacking approaches [3].

3.4 The robot's body as interface

The most innovative or new interface is the robot's body and its environment. As the motors are sensitive for the environment, they reverse when they encounter an obstacle during rotation. In a quad-core the motors seem to communicate with each other: only when both motors hit an obstacle they will reverse direction. One way to play or interface with the robot is to use ones own fingers as obstacles. When you constrain the legs' movement space with your fingers, the frequency of the oscillations goes up because the motors keep reversing. Instead of using your fingers it is also possible to use piezo pick-up microphones as obstacles. When a leg hits the piezo it reverses direction. When using piezo elements as obstacles it is possible to directly use them as sound source. Using different materials such as felt or paper they can be tuned to sound either deeper or higher. Making a leg heavier also has a direct effect on the movement and the rhythmic patterns.

4. PLAYING WITH THE APPARATUS

Playing with the apparatus using the various interfaces is always an adventure because of the autonomy of the robot. Small modifications in the environment may lead to different rhythmic structures. Sometimes changing internal parameters leads to unforeseeable effects on the physical interaction of the robot with the world. The different patterns that are for example possible with a hex-core have different degrees of stability. The pattern with a single pulse is the least stable, the circuit can be forced to switch into this regime, but it can jump back to other patterns with more pulses at at any time. Because of this sometimes unpredictable and autonomous behavior playing is a constant improvisation. On the other hand playing with the robot is also a sort of dialogue, and an experiment in finding interesting beat structures, by arranging piezo pickups as obstacles. Because of the open structure, adding other analog instruments is lot of fun and gives a wider range of musical expression. I have been developing this type of instrument as part of a performance project called *ray vibration* [15]. With this setup I have performing since 2007 at diverse international media-art festivals and other venues (see Figure 7 for an example).

Figure 7: Performance with ray vibration at the Domicil, a jazz club in Dortmund.

5. OUTLOOK

This paper presented how a network of only six basic units coupled to three motors allows for creating a huge variety of different behaviors and ever changing rhythmical structures. But of course adding more basic units gives even more room to explore what is possible. Part of ongoing research is how to introduce more complex phase relations into the couplings. For example having a fixed delay between tapping motors, for example 30 degree phase difference. Such couplings are possible by using delay lines in between different oscillators. Ultimately the question is whether it is possible to create polyrhythmic and syncopated structures with this approach while keeping the autonomy of the device and while keeping the sensitivity of the device for the environment.

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