Algorithmic Music with Linkchained Robotic Musicians as Internet of Things - Art

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Abstract. The Internet of Things (IoT) allows objects that communicate via internet technologies to collect data and control devices, thus expanding our world and human perception of it. As the IoT grows, promising a shift in our culture and an augmentation of our world, it also expands the potential of artistic works that deploy the IoT devices for which it was originally postulated and implemented. When considering music, particularly computer music and composition the "artistic research question" to be answered is: What if a new IoT-art itself arose, does IoT art exist as a self-contained art, meaning art conceptually different from others und specifically in the field of computer music composition ?
In this paper the outcome of the artistic research project of "whether there is an IoT-art? ",using the art-work "IoT-bells" as research object for investigation is shown, and within this focus a further exploration of the artistic potential of the Internet of Things (IoT) discussed. This artwork was originally meant to use IoT devices as autonomous interconnected systems for algorithmic composition and for implementation in sound installations. However, a shift to forming a self-contained network of things, much like a swarm of autonomous robots, seems to be in contrast to the primary goals of IoT, to deliver information with sensors and control the motion of elements with actuators. This misuse of IoT in such autonomous networks in the arts, could allow the IoT with self-contained entities to be watched and explored by an audience.

Keywords. Automatic Music Composition, Musical human-computer interaction, Robotic

1 Introduction

The exponential growth of networked devices, also known as Internet of Things (IoT), in recent years (2017) has triggered a lot of hype, with many manifestos having been written, but the role of the networks and sub-networks of machines with similar functionality in the arts in particular has not been overly discussed. There have been some attempts to postulate that IoT will change art completely[1]-[4]. The inclusion of IoT in

artworks has been done mostly utilizing IoT for data acquisition or actuators as controllers, sometimes as IoT handycraft, but not as artwork with networked machines artistically joining the IoT, per se.
The outcome of research on art, lately conducted in the fields of "IoT" at the IEM during a seminar[1] exploring new media in arts, lead to the artistic research experiment "IoT-bells" as a follow up of the project "power flower bells"[5][6]. The IoT-bells (Fig. 1) experiment explored the artistic potential of net-worked bells as 'automata', which interpret rules of algorithmic compositions using IoT technology [7] for autonomous devices and wireless network.
The new concepts drawn from it and used for this work will be outlined in the next sections.

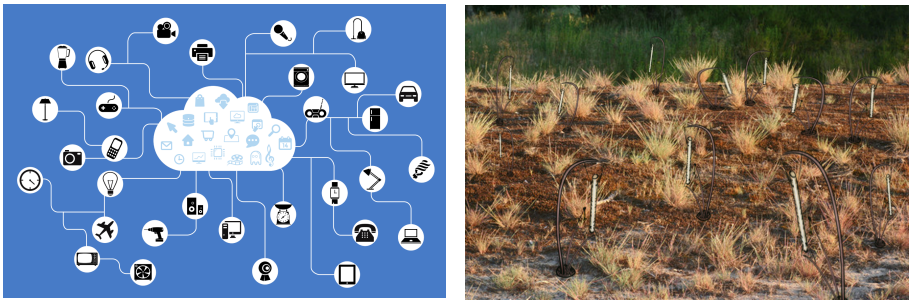

Fig. 1. "Internet of Things" as new serendipity - Vision of a IoT-Bell meadow

2 New aspects within IoT

So why is this artwork different, showing as well a new aspect of IoT as art ?
Communication is a basic requirement for humans and the prerequisite for "machine intelligence." The material of communication is the information itself. Communication as an exchange of information in the age of the computer networks is increasingly handled automatically.
The IoT depends on a network of connected sensors and actuators embedded in physical objects, such as appliances and devices providing people, businesses and governments with real time online access to the state of things and their locations. In order for the IoT to become a reality, the sensor and actors networks, which form its backbone, should provide dependable real-time information all the time, on time and should be locatable. This connectivity will result in a wide range of new services, applications and data, leading to smart cities, electricity grids and health care services for example and, a new culture living in fusion with IoT devices is envisioned. Cultures need art as indicator of being a culture. To be part of this new culture, the IoT-art has consequently to be part of those networks.

[1] See 6

To perceive the devices as part of the IoT, we need to establish a set of requirements that these things must have:

1. each thing is individually addressable, it can be both identified and localized.
2. each thing has various states, which could be queried or is transmitted
3. things are autonomous nodes, which utilize information from outside

But, what if some of these things intercommunicates and form a subnetwork to be recognized as a unity, as a swarm of individuals, one object made of many objects? The difference between a massive amount of anonymous sensors, actors and IoT devices is that they are addressable and therefore can be named. This name individualizes each thing and traces it as unique, but also as part of a greater entity such as musicians in an orchestra.
Looking in the field of computer music it is appropriate to take the parable of "individual musicians forms an orchestra" to find new criteria for IoT-art. As musician, it is normally essential to communicate with others, at least with the musicians besides within a hearing range and adding all up to music. To play with one another in a setting, at least a conductor, a common master plan, a sheet of music as score or, a sort of agreement on rules is needed for the way music will be played. Therefore we include an additional criteria that an IoT art in computer music can have:

4. things communicate with each other and knows at least their neighbourhood
5. each thing knows about a greater concept, a (kind of) score as common rules.
6. each thing has its specific concept and role in the network.

Thus behaving like a swarm of IoT objects[8] is in contrast to the role of "smart instruments" as used in other computer music research [9], where music performance uses data from IoT devices in the composition. Their "things" are not on the same network level as a network of musicians should be and the composition process is done from outside.
To guarantee the uniqueness of a thing in the network, so that every other thing can differentiate itself from others, various methods can be used to access the addresses and index of these things. A Thing in IoT can be seen as a kind of repetition and difference at the same time.[2]
Since each thing relies on others, this dependency must also be part of the capacity to pull needed information. An algorithm, one defining their identities within a context such as their neighbourhood, including their position in a communication network has been found.
The sum of identities forms an imaginary list of members, a database of nodes. This database or parts of it, have to be distributed and the database can be segmented but should be retrievable as a whole. The identity of each node should also be unique, even if the things are not directly connected or not at the same time. So each node knows

[2] In music each repetition is different, since the time differs and so the perception of the repeated material over time. Here difference is meant to be different in localization.

about the map of things in the well- known environment. This concept named “map of known world” (MOKW) from the media-artwork “the house of sounds” where sounds formed a swarm of “soundlives“[10], is introduced and will be used throughout the remaining of the text. This can be seen as another additional aspect IoT-art can have:

7. each thing knows its own neighbourhood, having a map of unique identities

Considering a group of things as a group of musicians, one will need a composition for it to originate music. Both the musicians playing in interaction with their neighbourhood and the composition have to be adjusted. The number of players within a changing topology of the network and other information can induce modified and varied composition outcomes. This information interacts with the composition and things distribute this interaction. Using algorithmic compositions allows an easier implementation. Since things are mostly machines hosting computers, algorithm can be distributed easily. The idea here was that each thing can trigger a composition spreading its algorithm.So it starts a composition or parts of it distributing the score in form of an algorith.

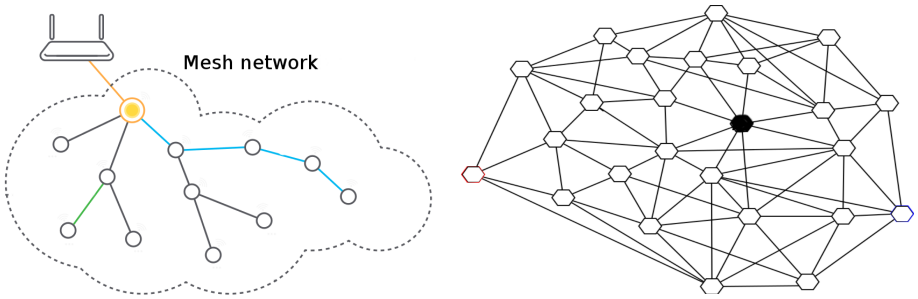

Fig. 2. Mesh network and ”map of known world” calculated from link chained data.

3 Artistic research experiment

The “IoT-bells” experiment was set up with following hypothesis in order to play with these aspects and form interoperable musician objects:

> An artificial area of interacting bells should be created. It should be as independent as possible from its audience’s direct intervention. Pre-defined laws in form of code should exist, creating an sociology of IoT-bells of its own. Humans will constitute the audience of this music world.

The IoT-bells network should be perceived as an aquarium with fish representing a limited area of life, so recipients are pleased to hear and watch. Human audience’s role will be limited to the nursing and observing. In contrast to interaction with IoT devices serving humans, IoT-bells are self-sufficient objects, fulfilling the vision of a self-sustaining machine world.

Autonomously distributed automata as hardware and software have been prototyped for the experiment: low power IoT micro-controller playing bells and using WiFi for networking, to form a dynamic expandable network of instruments and improvising together as a distributed music ensemble. Therefore concepts have to be invented on how these devices operate as a music ensemble and as networked composition. Acting autonomously, these automata are powered by batteries with optional solar cells for continuous operation, and join the performance depending on the power state. Aspects of this concept are described in the following text.

4 Networked Composition

Connecting such things with the Internet, different kinds of network infra-structures can be chosen such as “client on Access Points”, “ad hoc networking”, “wire-less mesh” or else. The mapping of these devices themselves within the “musician’s space” has to be made.

A IoT-bell can be uniquely identified by a chip ID contained in most IoT chips.[3] Also the MAC-address of the Ethernet-node could be used for unique numbering. In order for our concept to be valid and feasible, all that is needed is that neighbourhood nodes communicate directly which each other. To retrieve all nodes connected in the local network, a trace request should be forwarded to neighbours and retransmitted, so all the nodes in the network can be traced back by a host. This brought us to the idea of using the concept of “map of known world” as mentioned above.

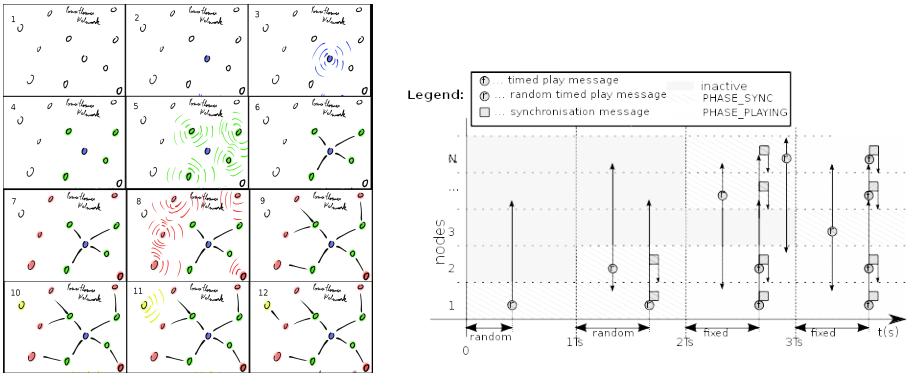

Fig. 3. Distribution of a play impulse for a sequence - Timing for Communication.

4.1 Map of known world

Each node holds a map of neighbours and sends it with his info messages so that other nodes can connected this with the own. After some time all active nodes should be known and after a timeout - ”time to live“ - of the known nodes these links should be renewed. An chain of identities, signed by the nodes, is formed. This algorithm is a

[3] It can retrieved from the ESP8266 microcomputer.

version of the block-chain technology used nowadays also by virtual currencies. Since this temporary block-chain can be renewed by the link structure, we'd better name it link-chained identities (link of chains of identities).
The issue is therefore to find out a way of indexing things to enable a meaningful compositional interaction with the neighbours. An additional parameter is needed to represent the distance between the nodes for a virtual localization. The strength of the received signals from other nodes is used here as well as can be. The playing indexes have to be recalculated each time an additional node appears or one existing disappears.
In order to synchronize, a time signal should also be broadcast over the net. This was provided by using the structure of the mesh network.

4.2 Distributed algorithmic composition

Since the number of musicians and the "map of known world" are first unknown, the musicians should be able to operate autonomously, the code has to be distributed over the net and the composition should be calculated in real time, therefore a distributed composition algorithm, using interpreters was chosen and a script of the language for the algorithmic composition remains needed:
Each node should be able to receive, to script, to execute and then to forward the information to its neighbours, as copy or as modified version. Notes are thus defined, but each robotic musician can interpret them individually, depending on its possibilities. Each node has a limited set of possibilities, what it can play just like a musician with a specific instrument. So we can divide this script in three parts:

- Playing the script
- Modifying the script
- distributing the script

Since most microcomputers are equipped with at least a simple "python", this has been chosen as the computer music programming language for the composition. An algorithm that can be devided and distributed was needed. Based on the properties of distributed autonomous musician machines, the composition is the result of the sum of all algorithms of the individual nodes.
As a first experiment, the goal for the overall compositional idea for each bell can be outlined as follows:
The nodes being automates, it was obvious to use "cellular automata" (CA) as the composition algorithm.
For this artistic research we chose to implement a CA with each thing operating as a cell, and each cell can be an initial player, dirstributing a given limited number of life cycles of the distributed rules.
Playing spontaneously from time to time, the bell player catches the attention of listeners as audience. Whilst they are supplied with energy from the environment, such as accumulated sun energy for the power supply, they can reflect this available energy in their play and each interpretation of a sequence of play can be individualized. They have additionally to play less if they have less energy left, and interrupt if power is too low

thus, disappearing in the network. The relationship between the bells should be recognizable as a musical (rythmic) pattern.
A node can initiate a play phase randomly according to the energy parameter.
One critical aspect is the timing for the musical play, since the IoT-bells can create unique rhythms and a synchronous time for the communication, since the nodes can also sleep between their playing pulses to save energy.

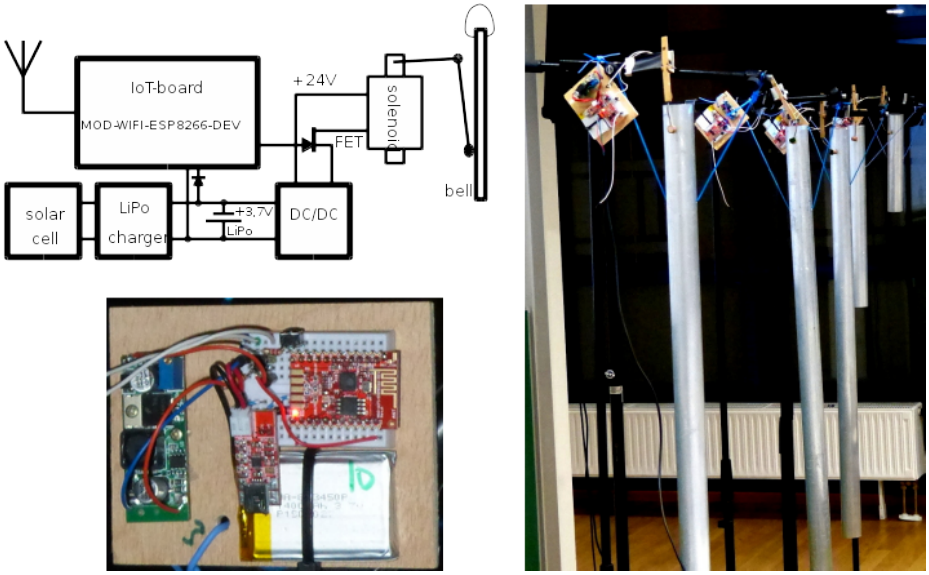

Fig. 3. IoT-bell block schema - IoT prototyp board - IoT-Bells Quintett.

5 Intermediate Result

The hardware was prototyped and a first testing application written as firmware with a matching PD-Patch. 7 bells were implemented and installed in the campus on a field. Additionally a simulation of larger networks in action has been realized, so the composition could be virtually heard.
The main research questions were:

- Are the IoT-bells perceived as IoT objects playing together?
- Are the objects dependable?
- Is IoT essential for these kinds of art-works?

Among several results, the one which reflects the art concept using IoT is outlined: An important aspect is that each IoT-node seen as robotic musician is a singular object with its own identity, linked within a group and part of an ensemble. Everything can therefore be uniquely identified within the net and acoustically identified individually. Each thing has to be self-aware and aware of its own ranking in the network, so it is hard to control and predict the composition.
Each thing contributes equally to the behaviour of the system as a whole, and the final result is accordingly the consequence of all the interactions taking place between all the

objects over the network during time. Thus, the important concepts of network, individuals and interaction play a central role in the definition of the IoT and are well developed in the IoT-bells project, leading to an interesting and inspiring installation which shows the artistic potentials of the many concepts involved.
For the recipient listening to the bells playing in an ensemble, the internal communication is hidden. Trying to decode the composition, the observant listener may be able to find the pattern, especially if little information about these nodes is previously provided. After all the discussions and manifestos for IoT, one question is remains unanswered. Should there be an ”IoT art manifesto“ at all or is this counterproductive?

6 Acknowledgments

The project “IoT bells” can be seen as a further step in the art series ”social machines”, which is a series of art installations started at the Medienkunstlabor Graz at the Kunsthaus Graz 2008 under the leadership of Winfried Ritsch, followed up by some other artworks of Atelier Algorythmics which deal with networked musical machines. This work has been discussed and prototypic realized with the lecture ”Kunst und neue Medien“ during winter semester 2015/161 at the Institute of Electronic Music and Acoustics. Many thanks for the support there and the stimulating discussions with the students, which brought in also the critical notes about hypes of IoT, since digital natives see this with less Argus eyes. Many thanks to Atelier Algorythmics1 for providing the hardware and workshop.

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