# Self Aware Network

## A Geodesic Sound Sculpture That Interacts With Visitors and the Environment

# Description

## Abstract

The *Self Aware Network (SAN)* is an experiment about the future of architecture. It comprises a system for building structures that *interact and communicate with their environment.*

Eventually structures become intelligent (AI), thereby being able to *understand their environment.* In the final stage, they are robotic and autonomously *adapt to their environment*.

The vision is a *fluid architecture* that constantly reconfigures itself and follows the needs of the people.

For *Eyes of the City* a stainless steel life-size version of the already existing SAN desktop system will be developed. Visitors will be able to manually adapt the network by connecting nodes and edges. The nodes communicate and send information to a central computer, the brain of the network. A projected image visualizes the network's self-awareness. Visitors can connect to the brain from their phones and influence how each node processes signals of information. These signals are made audible via speakers or headphones.

## Network

The architectural structure of the future is comprised of a network.

*Network nodes* have tetrahedral geometry, also known as $sp^3$ hybridization in Chemistry. This geometry is optimal in that the angles between every two connections are identical. It is the basis for the hardest natural structure known to man, that of diamond. The shell of a network node is made of stainless steel. Inside of a node there is a small computer, or microcontroller.

*Network edges* have uniform length. Edges are connected to nodes using stainless steel quick couplers, reliably used in pneumatics. The edges are hollow for optical communication between nodes.

## Self-Awareness

Every change to the network configuration is sent to a central computer, the network's brain. The brain is able to understand the topology of the network. It gains self-awareness. How the network sees itself is visualized and projected.

In addition to being able to sense reconfigurations, the network can sense gravity. Each node contains an accelerometer.

## Visual communication

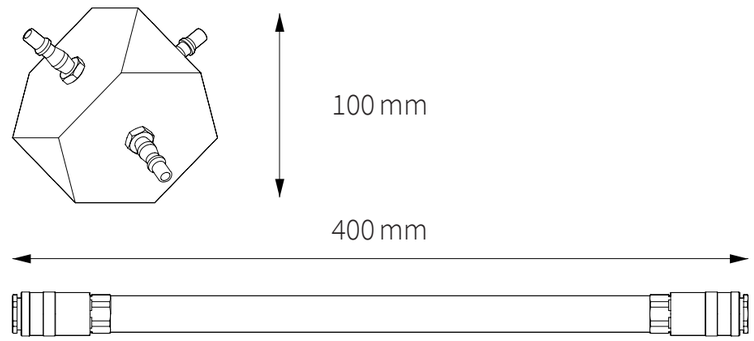
LEDs in nodes communicate their identity by color. This allows visitors to see the duality between the real structure and the projected structure visualized by the brain.

## Auditory communication

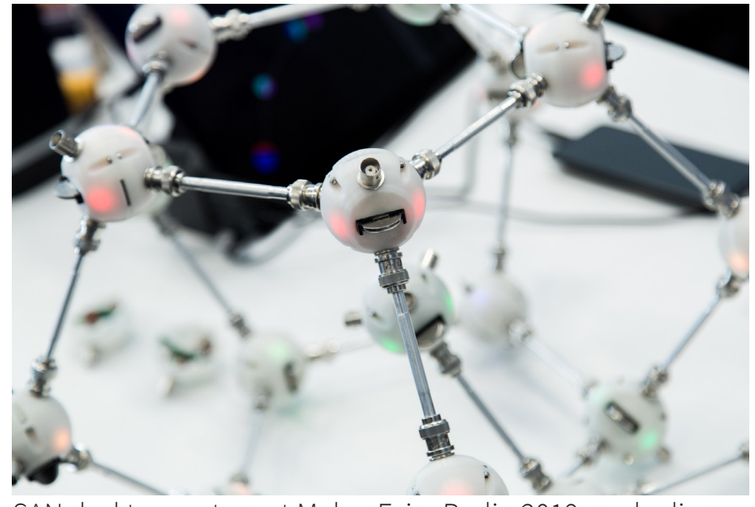
The network forms a modular synthesizer with audio signals passing through nodes. The combined signals propagate to the root node from where they are made audible using speakers or headphones. Modulation depends on the spacial position of nodes. The sound scape reflects the topology of the network.

## Visitor interaction

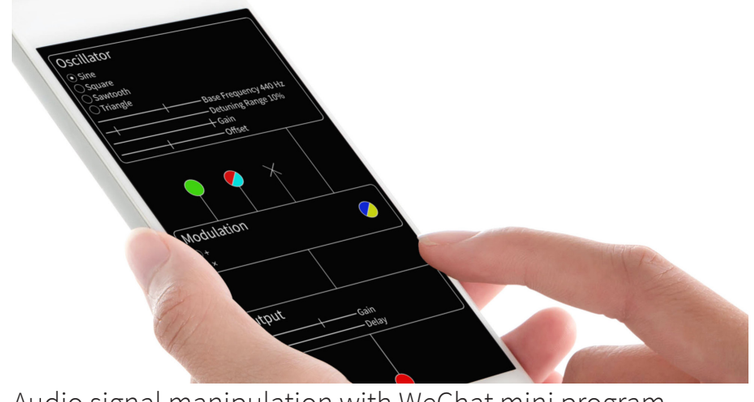
- *Audio:* Visitors scan a QR code. This leads them to a WeChat mini program which allows adjustment of how a node processes an audio signal. The sound scape of the structure adapts immediately. Audio interaction is self explanatory. No supervision is required.
- *Reconfiguration:* Visitors can adapt the network by reconfiguring nodes and edges. Reconfiguration is possible under supervision in scheduled weekly sessions and on demand.
- *Production:* On three weekends, there are hands-on workshops where visitors participate in production. Each participant learns how to solder a circuit board and assemble a node. No prior knowledge is required. At the end of the workshop, the new nodes are connected to the network.




SAN life-size system elements: node and edge



SAN desktop system at Maker Faire Berlin 2019, node diameter 50 mm (photo © 2019 Tobi Giessen)




Audio signal manipulation with WeChat mini program

## On-Site peculiarity

Following the action of visitors, the network organically grows and adapts to its environment. Three dimensional cells compartmentalize space. This process is comparable to a railroad network growing over time and eventually redefining and compartmentalizing the two dimensional space which defines our surroundings.

## Provisional / Durable nature of the intervention

At the end of the Biennale, the network is fossilized. Before it is taken off-line, the network's ultimate state of self-awareness is preserved. A final sound scape is recorded.

The network lives on as a robust stainless steel sculpture. Batteries are replaced by permanent electrical wiring. That way the sculpture can remain lit. It requires little maintenance.

Next to the sculpture there is a QR code. By scanning the code, visitors are able to hear the network and they are able to see its ultimate state of self-awareness.

## Positioning

- *Space:* The network requires a space of at least eight by eight meters. The space needs to be inside. Network elements are not weather sealed.
- *Projection:* A flat surface for projection is needed which may either be a semi transparent surface in the middle of the exhibition space or a wall.
- *Reconfiguration:* For interactive sessions, temporarily additional space is needed to accommodate participants and spare construction elements.
- *Construction elements:* In a busy space, unused nodes and edges may be stored in flight cases.
- *Audio:* For playback of audio during the opening of the Biennale, speakers are mounted. Otherwise headphones hanging from the ceiling are provided.
- *Electricity:* For powering electronics and the projector, electricity is needed.
- *Internet access:* Communication between the WeChat mini program and the network's brain is via the Internet.
- *Workshop area:* For production workshops, a separate area may be used.

## Material

Stainless steel, Electronics, Lighting

## Sustainability

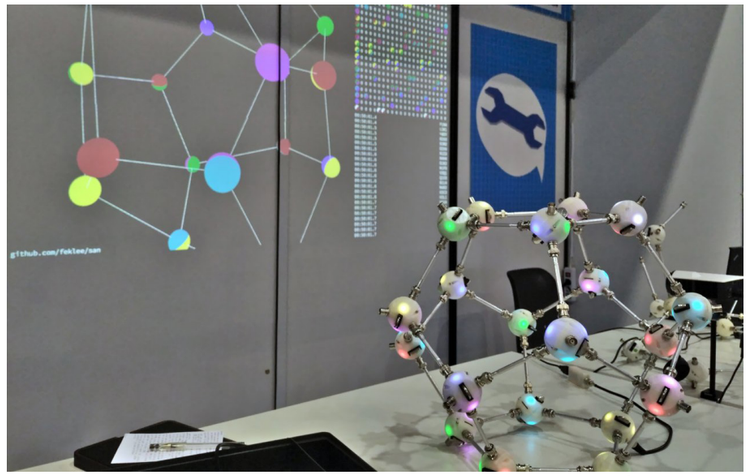
The stainless steel construction is both durable and recyclable. Batteries are rechargeable and will be recycled at the end of the event. Where possible, pneumatic quick couplers that failed quality control for air tightness will be repurposed.

## Sharing

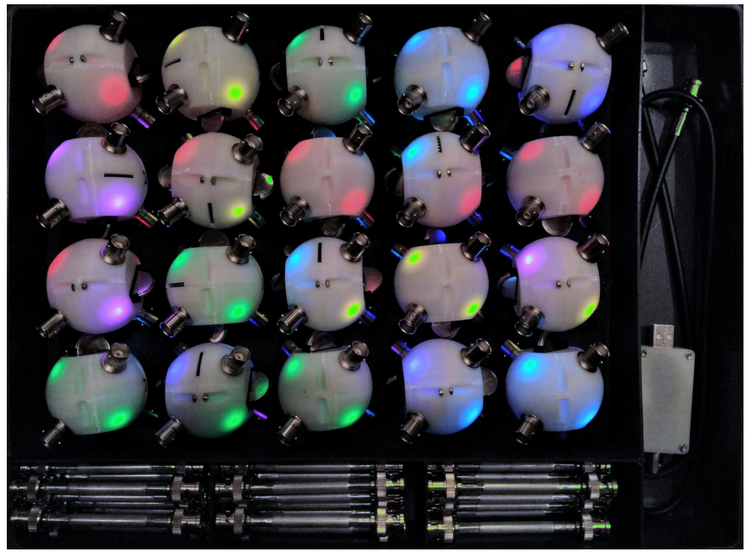
All construction plans for the desktop system as well as all source code is available under the WTFPL open source license at: *github.com/feklee/san*

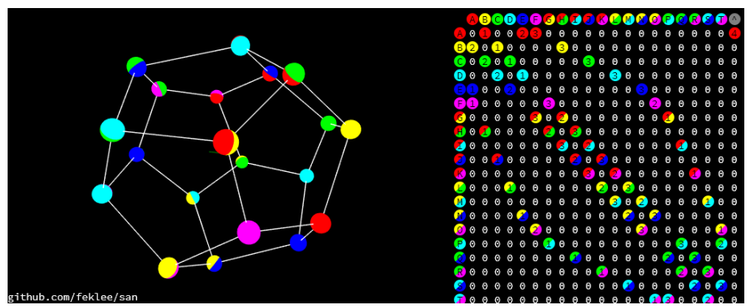
## Outlook

After scaling the network up, the goal is to reach *autonomous housing level 5:* Structures move and self-reassemble without human intervention. A test ground is needed, an architectural makerspace where people of varying backgrounds collaboratively experiment and eventually revolutionize heavy construction and the way architecture interacts with us and with the environment.



Dodecahedron assembled by children at the end of Maker Faire Rome


SAN desktop system complete set



Dodecahedron as perceived by the network's brain

# Feasibility

The desktop version of the Self Aware Network (SAN) has been proven to be robust at busy events since 2018. At Sónar Hong Kong music festival 2019 the artist gave a three hour workshop where each participant soldered and assembled a network node, followed by a collaborative sound experience.

For August 2019, the *Buckyballs summer camp* for children is planned in Shanghai. It will be a stress test of a life-size version of SAN, in that case 3D printed out of plastic.

### Network node

A network node of the life-size version for UABB has the shape of a truncated tetrahedron with a diameter of 100 mm. Two stainless steel halves contain a circuit board (PCB) with electronics and batteries. For attaching edges, pneumatic quick couplers are repurposed.

| Item | Cost / RMB |
|---|---|
| 4 × quick coupler | 80 |
| Electronic parts, incl. LEDs | 60 |
| PCB, produced by SEEED, Shenzhen | 40 |
| 2 × stainless steel shell (laser cut, bent, tapped) | 190 |
| Battery pack and charger | 90 |
| Various (screws, glue, cables, etc.) | 40 |
| Total cost per node | 500 |

### Network edge

| | |
|---|---|
| 2 × quick coupler | 50 |
| Stainless steel pipe with threads, 350 mm | 50 |
| Total cost per edge | 100 |

### Additional items

| | |
|---|---|
| Video projection equipment | 20,000 |
| Sound system | 15,000 |
| Computer equipment (network brain) | 15,000 |
| Accessories (tools, fixtures, lights, etc.) | 15,000 |
| Storage | 15,000 |
| Hosting | 10,000 |
| Shipping | 15,000 |
| Overall contingency | 25,000 |
| Total cost | 130,000 |

### Labor

| | |
|---|---|
| Adaption of software | 50,000 |
| Adaption of electronics | 50,000 |
| Adaption of mechanical design | 50,000 |
| Structural analysis | 50,000 |
| Safety assessment | 20,000 |
| On-site assistance and maintenance | 100,000 |
| Overall contingency | 50,000 |
| Total cost | 370,000 |

### Preliminary budget

Recommended is a set of 500 nodes and 1,000 connectors to assemble a diamond structure made of more than sixty unit cells. Production cost for nodes and edges is: *350,000 RMB*

With cost for additional items and cost for labor, the total preliminary budget is: *850,000 RMB*

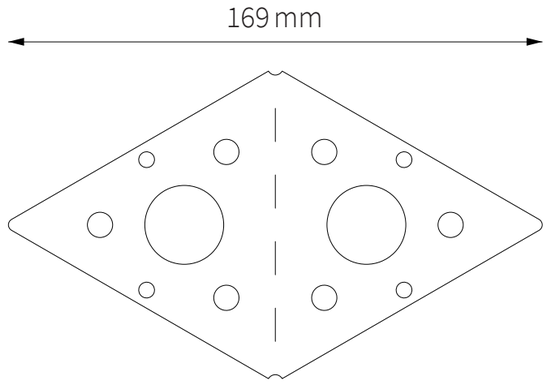
### Schedule

08/2019 Software and hardware engineering
09/2019 Sourcing of parts, production of components
10/2019 Assembly of initial nodes, release of WeChat mini program, stress tests, safety assessment

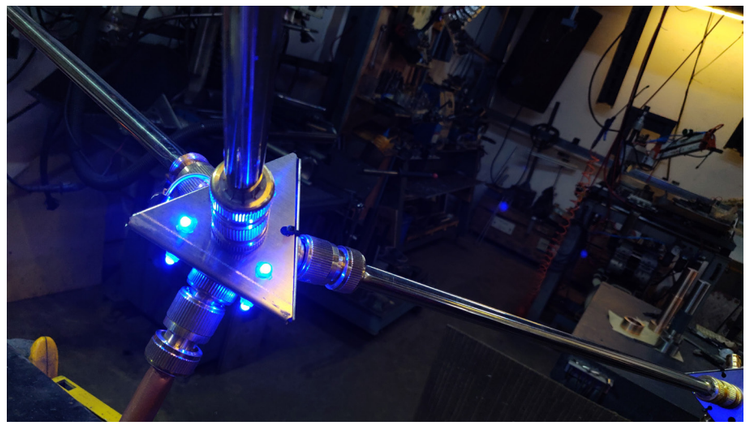
Additional nodes are assembled by visitors during three scheduled workshops at the Biennale.

### Partners

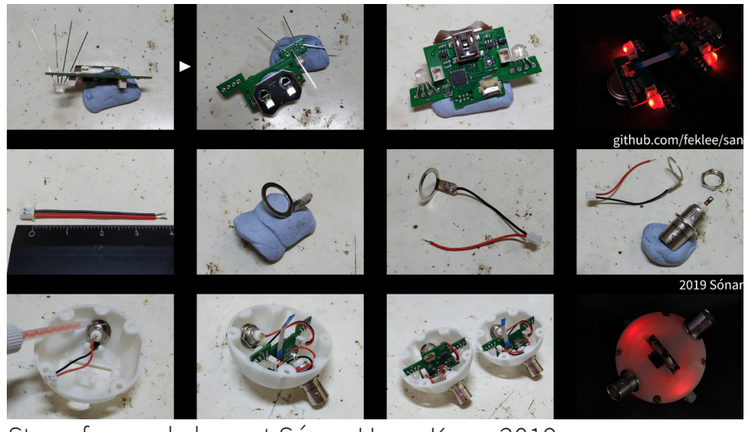
- Cong Nguyen, EE, Sidney: PCB design
- David Mickisch, mathematician, Berlin: Algorithms
- Monica Shen, Seeed, Shenzhen: PCB production
- Michelle Poon, architect, Hong Kong: Workshops
- M. Breidenbach, SE, Berlin: Structural analysis




May 2019 prototype: Template for laser cutting and bending



May 2019 prototype: Stainless steel and brass (500 mm arm length)




Steps for workshop at Sónar Hong Kong 2019

# Artist

## Bio

*Felix E. Klee* has an academic background in architecture and physics. He investigates collaborative construction systems that bridge the real and the virtual. At architectural scale he created the Reality Builder, presented at Chaos Communication Camp 2015 and live streamed to the Internet. At nanoscale, together with P. Silva he created STM, a scanning tunneling microscope wall installation exhibited 2016 at Spektrum Berlin. He is partner in the art production company Rieger & Klee GbR which builds light sculptures. In Berlin he organizes MetaMatter, “a laboratory of research and practice focused on the transformations of matter.”

## Vita

| | |
|---|---|
| 76 | Born on March 8 in Karlsruhe, Germany |
| 82–96 | School in Karlsruhe and Williston Northampton, USA |
| 96–97 | Mandatory community service, Univ. of Karlsruhe |
| 96–99 | Software developer on genetic algorithms for water distribution networks, University of Karlsruhe |
| 97–98 | Student of Architecture, COOP project based learning program, University of Hannover |
| 98–04 | Student of Physics, diploma in quantum information theory (MS equivalent), Universities of Hannover and Konstanz |
| 00–01 | Internships: Bruker Optics, Institute for Nanotechnology, Karlsruhe |
| 04–05 | Volunteer, FFII (EU lobbying organization) |
| 05–07 | Network administrator, Liburg, Karlsruhe |
| 07–17 | Independent consultant and trainer |
| 10–15 | Developer of the Reality Builder, an architecture scale collaborative construction system finally presented at Chaos Communication Camp 2015, live streamed to the Internet |
| 10–15 | Member of team Berlinity (large scale architecture intervention, one million glass elements, based on the Reality Builder, failed for financial reasons) |
| 16 | Nanoscale wall installation STM, shown at “States of Matter” in Spektrum Berlin, collaboration with Philip Silva |
| 16–19 | Partner in the Rieger & Klee GbR art production company making Time Portal, a series of light sculptures developed together with Eitan Rieger |
| 17–19 | Spektrum Berlin’s organizer of the MetaMatter event series, “a laboratory of research and practice focused on the transformations of matter” |
| 18–19 | Developer of the Self Aware Network, shown at Maker Faires across Europe, DMPP boot camp in Bilbao (selected as one of six EU projects), and Sónar Hong Kong (workshop) |

F. E. Klee at Maker Faire Berlin 2019 (photo © Tobi Giessen)