

# ***ROBOTIC ARCHITECTURAL SPECIES***

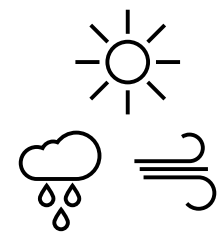
*DYNAMIC ARCHITECTURAL AND INTERACTIVE SYSTEM:  
AGGREGATE STRUCTURES AND SWARM ROBOTICS*

# DYNAMIC ARCHITECTURAL SYSTEM: DESIGNING A "SPECIES"

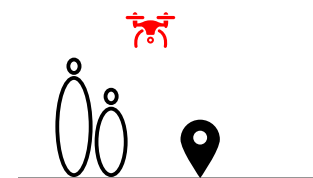
## ARCHITECTURAL CONCEPT

Use swarms of UAVs as architectural "bricks" to deploy and self-assemble temporary shelters and structures in urban space.

## INTERACTION CONCEPT



Environmental modulations

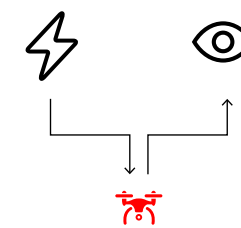


Urban nav. helper

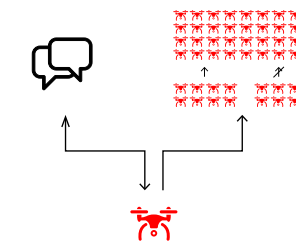


Playfulness and delight

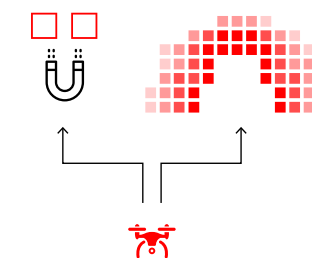
## DESIGNING AND CODING BEHAVIOURS



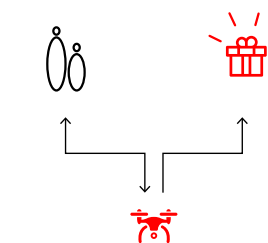
Neutral / Personal



Inter-Swarm



Construction



Human Interactions

# SWARM INTELLIGENCE & SWARM ROBOTICS

## INSPIRED BY NATURE

- Social animals building complex structures
- Simple Individuals
- Emerging Intelligence as a group or swarm

## SELF-ORGANISATION

- Goal-oriented collaboration
- Open-ended result (to some extent)

## SWARM

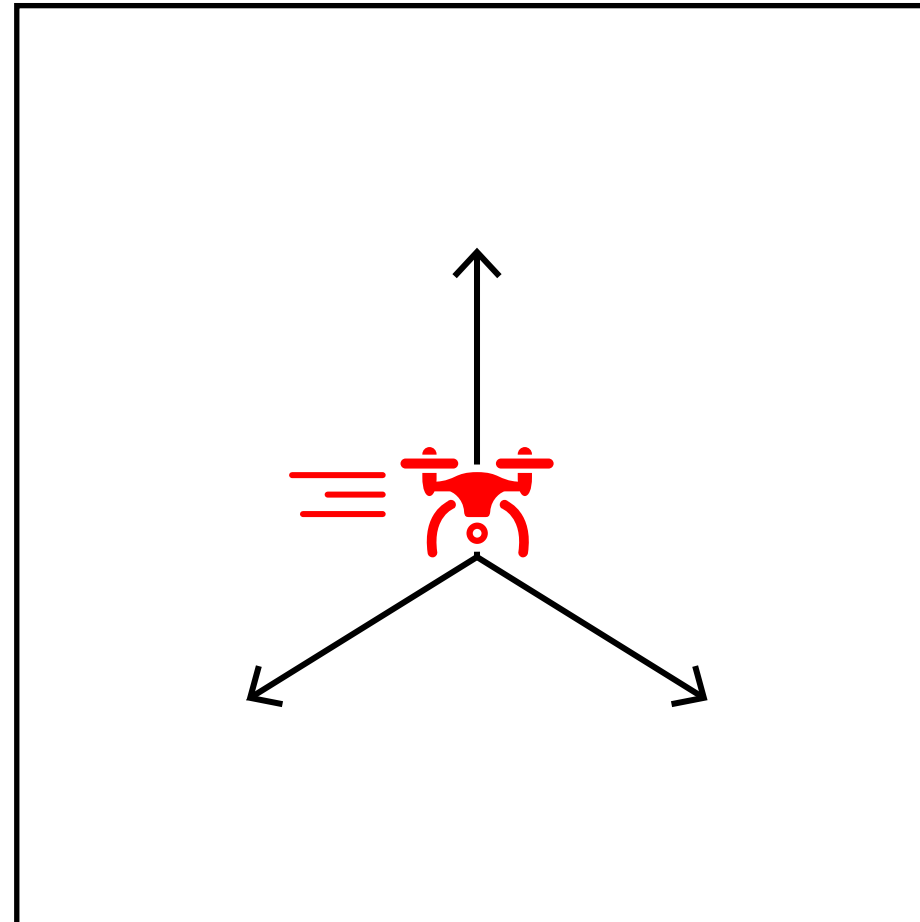
- 1 BRAIN**  
PROGRAMMED BEHAVIOURS AND SENSING APPARATUS
- 2 BODY**  
MATERIALS, GEOMETRY,
- 3 COLONY**  
EMERGING ARCHITECTURE/INTERACTIONS

# UAV AND SWARM ROBOTICS IN ARCHITECTURE

## REQUIREMENTS

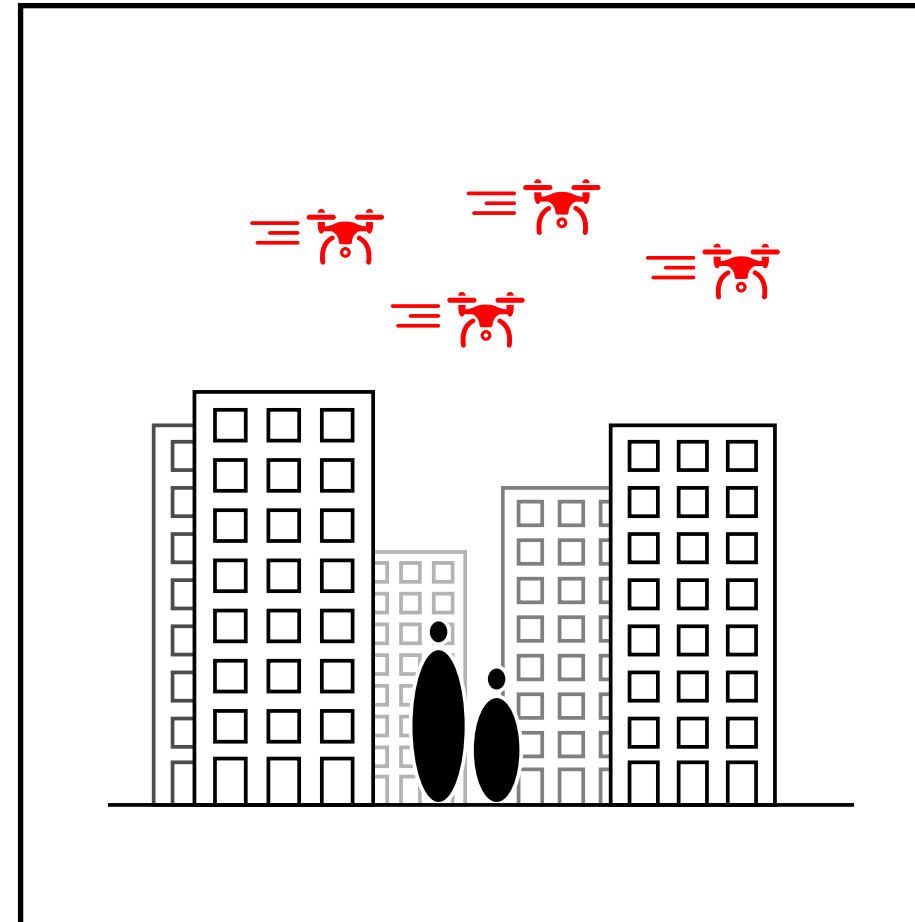
Navigation of urban space  
Inter-swarm collaborations  
Short temporality of the structures

## UAV BENEFITS



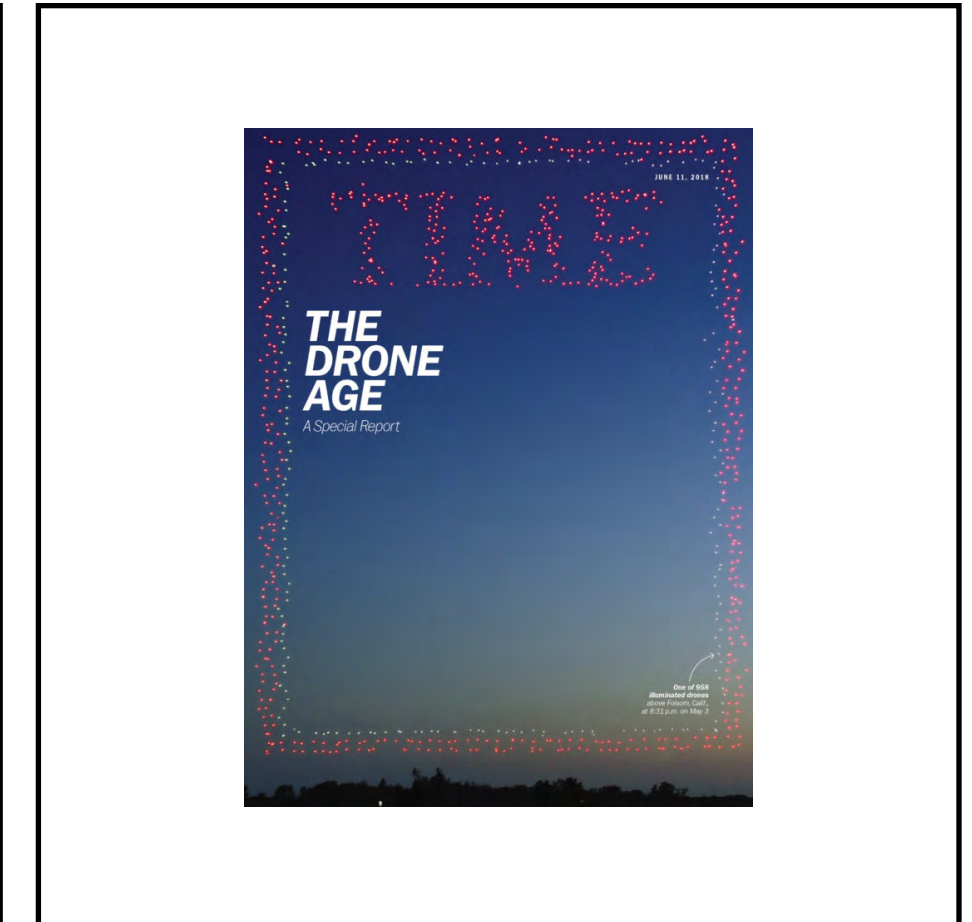
### **FAST, FLUID, FREE MOVEMENTS IN 3D SPACE**

Compared to other, more static robots, UAVs are very versatile in their movements



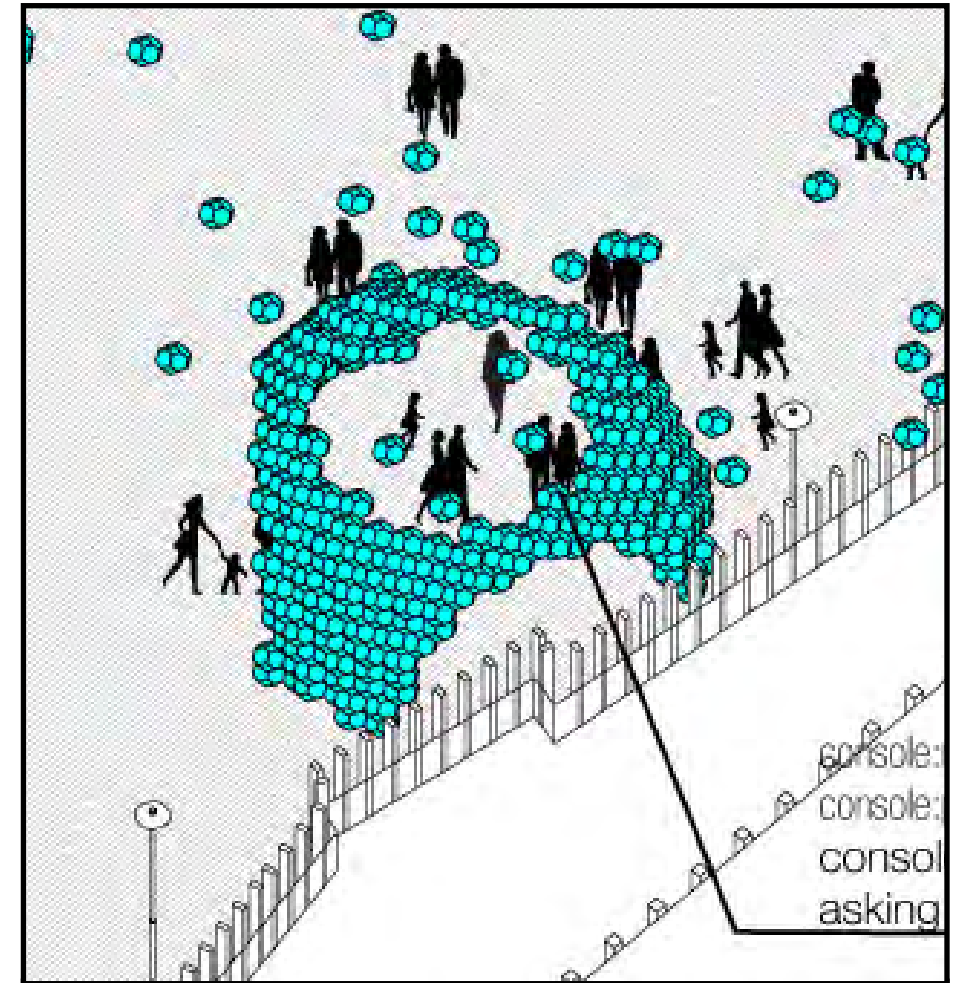
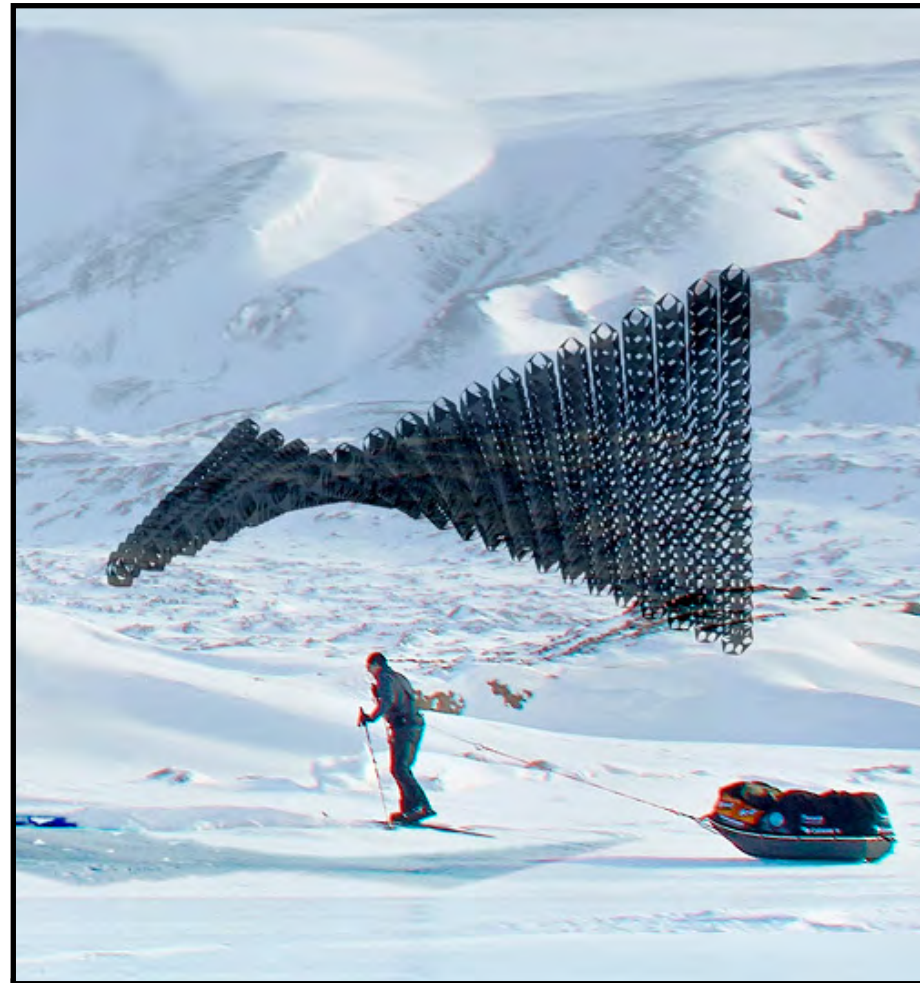
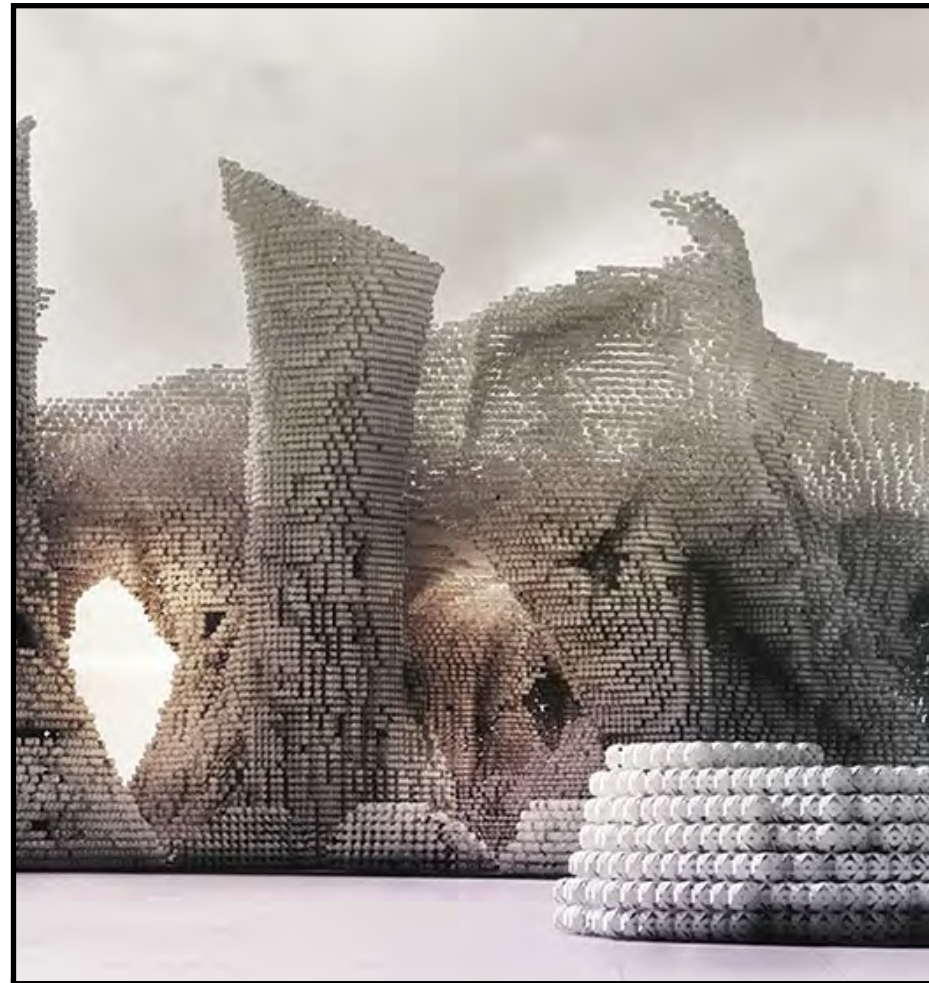
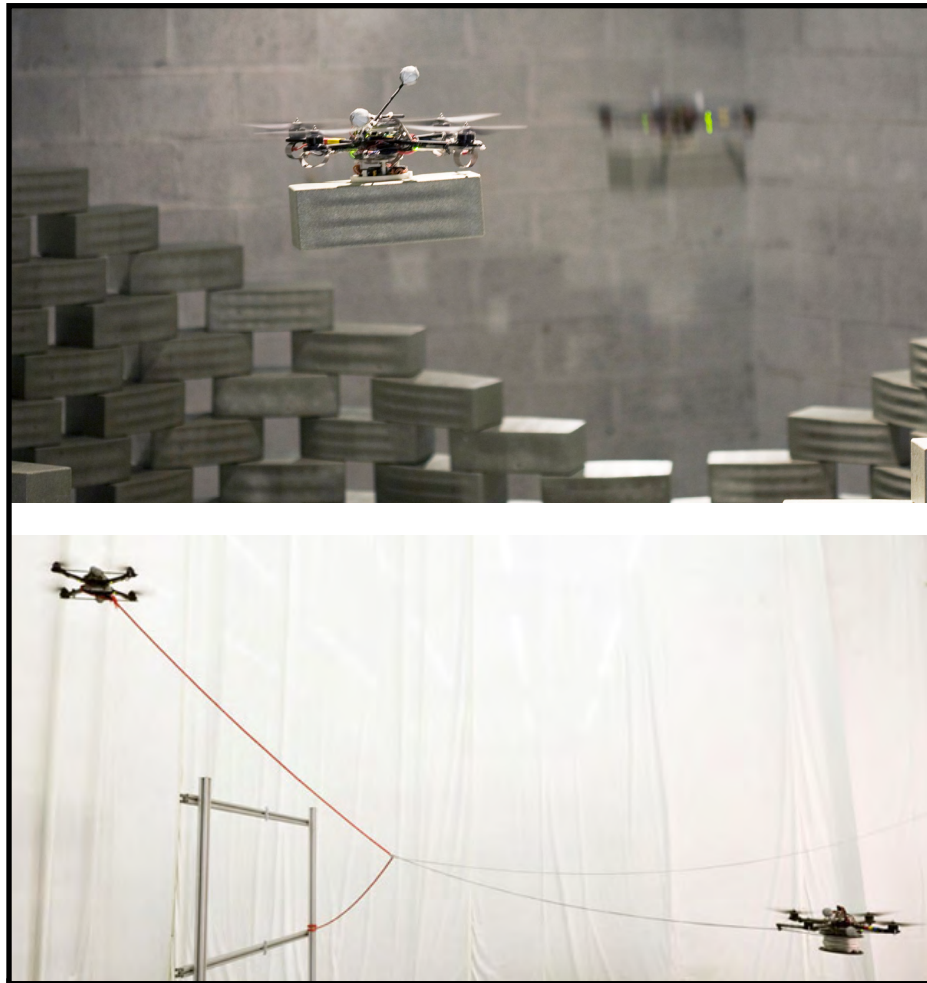
### **LESS INTRUSIVE IN AN URBAN CONTEXT**

Their ability to fly and their speed allow them to “disappear” from sight quickly and easily navigate the urban landscape



### **AUTONOMOUS AND SWARMING BEHAVIORS**

From drone shows by Intel to Drone Swarms assembling buildings or weaving tensile structures



**FLIGHT ASSEMBLED ARCH.**  
Gramazio+Kohler Research, ETHZ  
Zurich, 2011 - [\[link\]](#)

**HYPERCELL**  
AA-DRL  
London, 2015 - [\[link\]](#)

**DRONOLOGY**  
McGill  
Montreal, 2016 - [\[link\]](#)

**OMNIPRESENCE**  
TUDelft  
Delft, 2016 - [\[link\]](#)

Flight Assembled Architecture is the first architectural installation assembled by flying robots, free from the touch of human hands. It consists of over 1.500 modules which are placed by a multitude of quadrotor helicopters, collaborating according to algorithms that translate digital design data to the behavior of the flying machines. In this way, the flying vehicles, together, extend themselves as “living” architectural machines and complete the composition from their dynamic formation of movement and building performance.

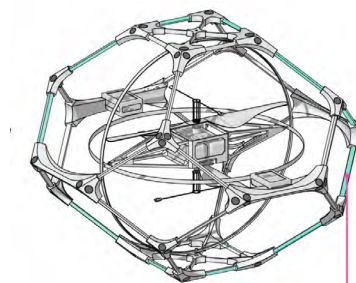
Architectural installation built from low-grade granular material and constructed by robotic machines. It brings forward a new category of random packed, potentially fully reusable,



The workshop introduced participants to the notion of designed granular materials and taught robotic construction techniques, which are gentle and non-invasive to the material system and



In the context of Expo 2025 in Rotterdam, this student project looks at drone swarms serving as assemblable urban material and urban helper in space (speaker system, lost and found, urban furniture and more).



# AGGREGATE STRUCTURES



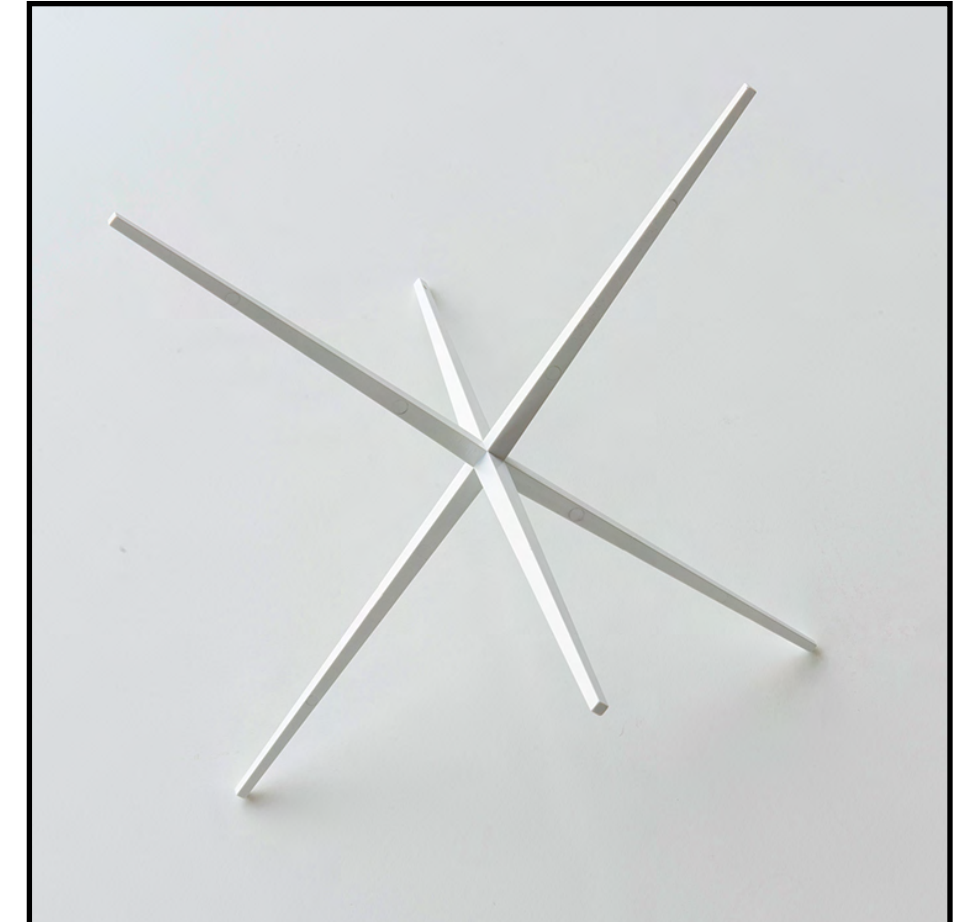
## FROM SIMPLE GRANULES TO COMPLEX ASSEMBLIES

Multitude of particles with only contact forces acting between them



## INFINITELY RECONFIGURABLE

Because the particles are not actively bound together, the assemblies can be reconfigured in time



## "DESIGNED MATTER"

*"If the individual particle is designed, the behaviour of the overall system can be calibrated to specific performative effects."*

- Karola Dierichs, Achim Menges  
ICD Stuttgart - [\[link\]](#)



## ***AGGREGATE STRUCTURE***

ICD Stuttgart, Achim Menges  
Stuttgart, 2018 - [\[link\]](#)

## ***HYGROSCOPIC AGG.***

ICD Stuttgart, Achim Menges  
Stuttgart, 2016 - [\[link\]](#)

## ***ROCK PRINT***

Gramazio+Kohler Research  
Chicago, 2015 - [\[link\]](#)

## ***PNEUMATIC MASONRY***

Pneuhaus  
Houston, Unknown - [\[link\]](#)

The ICD Aggregate Pavilion 2018 constitutes the first fully enclosed architectural space entirely constructed from designed granules, which lie only in loose frictional contact. Such unbound granular materials show the unique property to obtain both the stable character of a solid and the reconfigurability of a fluid. When deploying designed granules, granular materials can form self-supporting spatial enclosures while remaining reconfigurable and reusable. 70.000 star-like particles made from recycled plastics are poured by a rapidly deployable, large scale robot system.

The workshop introduced participants to the notion of designed granular materials and taught robotic construction techniques, which are gentle and non-invasive to the material system and the surrounding environment.

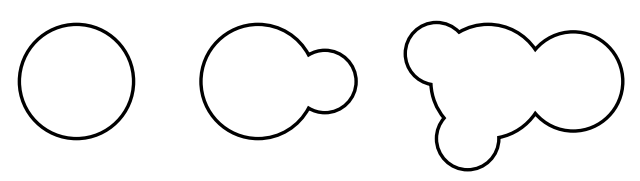

Participants have worked with both matter and robots. On the matter side they designed with hygroscopic particles and locally sourced materials, which were considered and treated as a granular material. On the robot side they have been accustomed with cable- and aerial- robots.

Architectural installation built from low-grade granular material and constructed by robotic machines. It brings forward a new category of random packed, potentially fully reusable, poly-dispersed jammed structures that can be automatically fabricated in non-standard shapes. The installation exhibits distinct features, such as full material reversibility and reusability; structurally active interlocking, differentiated structural performance, and high geometric flexibility and articulation.

Pneumatic Masonry is a lightweight construction system designed around the ideal of an atomic building block. It builds off of traditional masonry techniques with some major twists: air replaces stone and net replaces mortar. The system uses modular geometric units to combine and recombine to configure spaces and forms of different shapes and sizes.


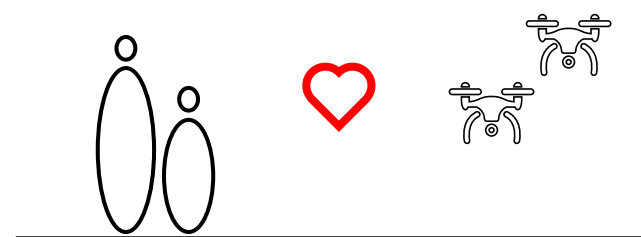
# HUMAN-CREATURE INTERACTIONS

## FUNCTIONAL INTERACTIONS      PLAYFUL INTERACTIONS



Environmental modulation  
(light, wind, rain >> Workshop 1)

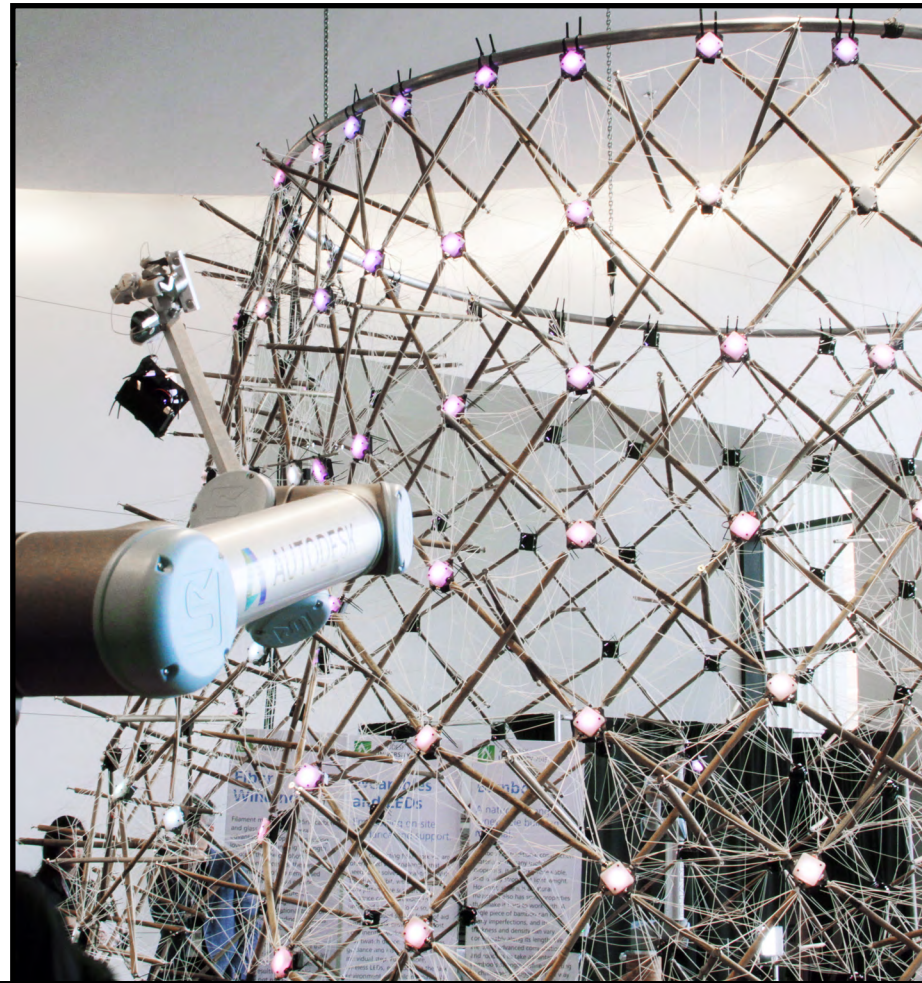
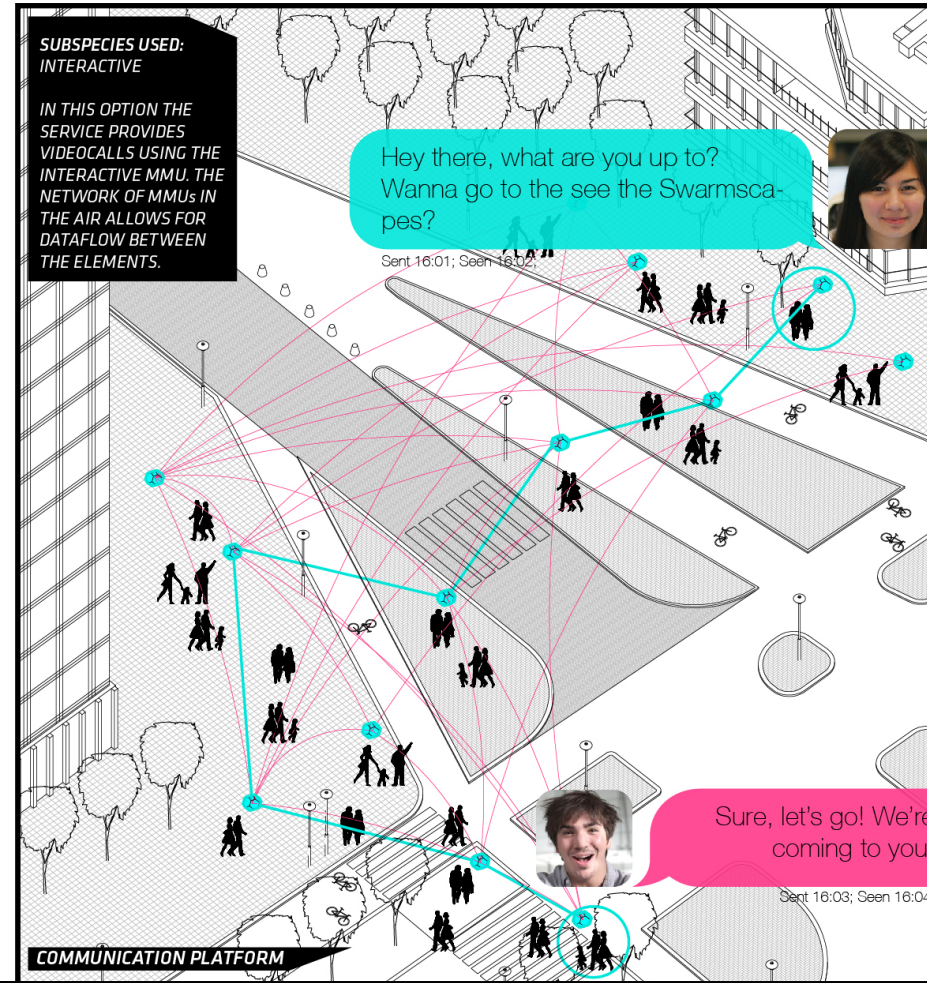
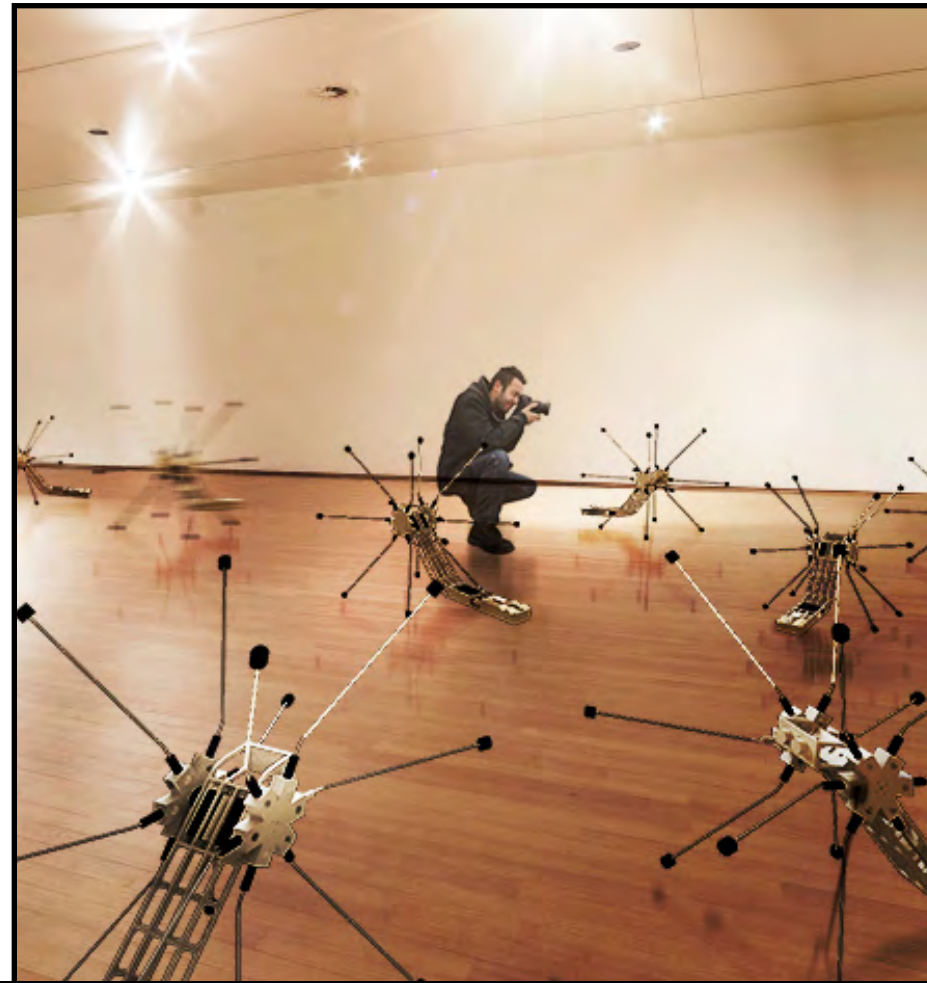
Material configuration



Builds humans' confidence in  
interacting with the creatures

Touch, movement, speech,  
screen-based interfaces...  
(>> Workshop 1)





## ROBOZOO

TU Delft  
Stuttgart, 2018 - [\[link\]](#)

## OMNIPRESENCE

TU Delft  
Delft, 2016 - [\[link\]](#)

## HIVE

Autodesk, ICD Stuttgart  
USA, 2015 - [\[link\]](#)

## WORKSHOP 1

TU Delft  
Delft, 2019 - [\[link\]](#)

RoboZoo aims at establishing the artificial environment of the interactive swarm of robots. Synergetic integrity with such a substance is the subject of our interest. Investigation of models of behaviours plays a paramount role in the presented concept. The possibility of shaping the environment by artificial creatures bring about the potential for dynamic system and its adaptability to the outer and inner changes.

In the context of Expo 2025 in Rotterdam, this student project looks at drone swarms serving as assemblable urban material and urban helper in space (speaker system, lost and found, urban furniture and more).

The visitor to Autodesk University 2015 were invited to work with a robot through wearables and IoT technologies to help build a 12' high pavilion using bamboo. The hive will be created from 224 tensegrity units. Each tensegrity unit is composed of three bamboo rods held together with string that is wound by robotic arms. Each tensegrity unit is unique due to the bamboo rods having differences in length and diameter. They are connected together with LED units that help the builders place the pieces and will create a light show.

Students developed a prototype for an interactive shading system for the TU Delft Bouwkunde Faculty. The installation proposed a more localised approach to lighting/shading optimisation, responding both to highly local environmental conditions as well as to user presence, movements and posture

# ARCHITECTURAL DESIGN: IMPLICATIONS & APPLICATIONS

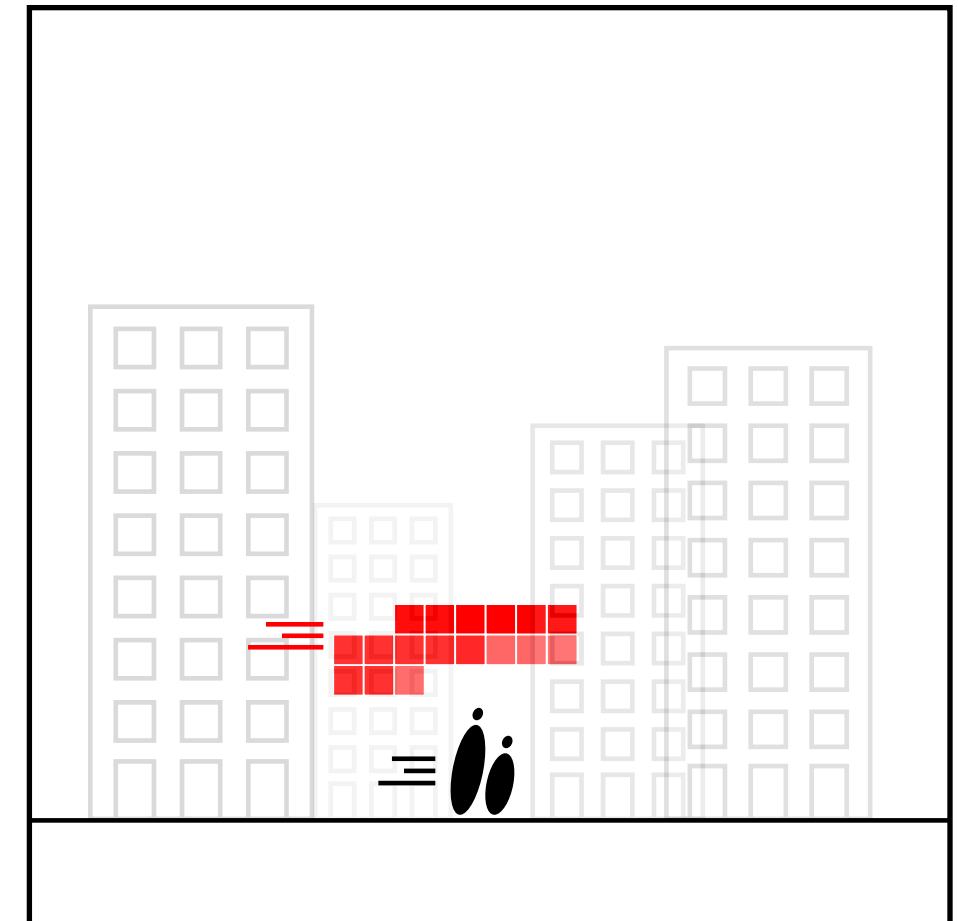
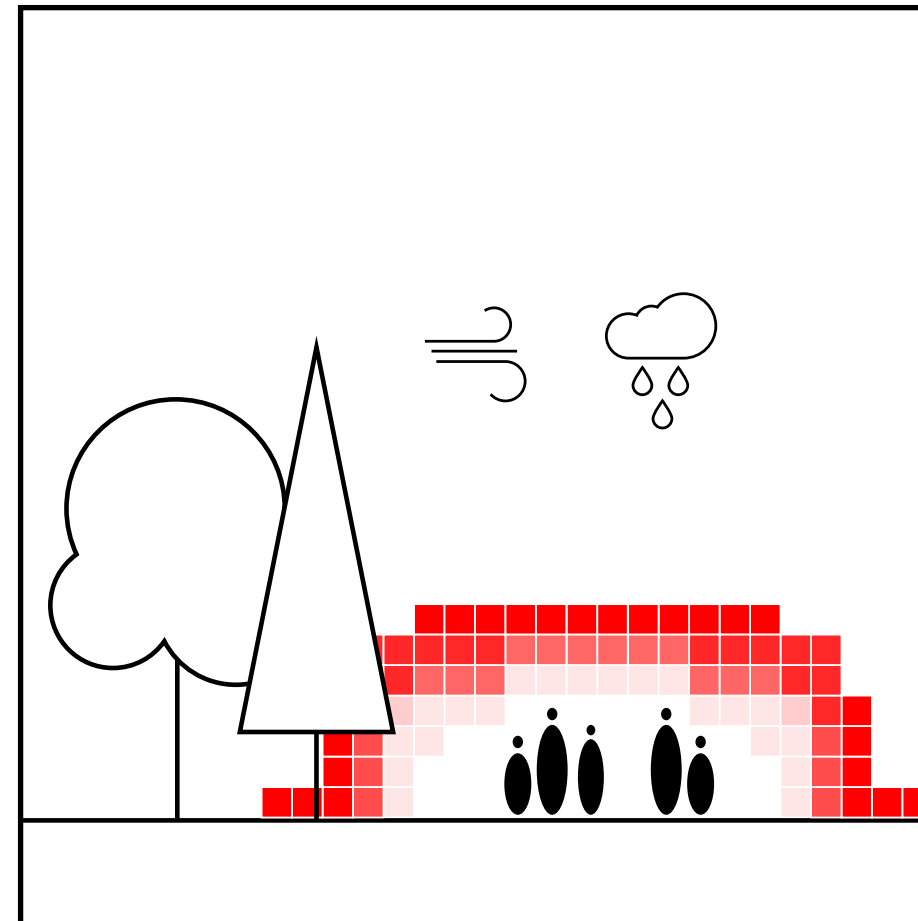
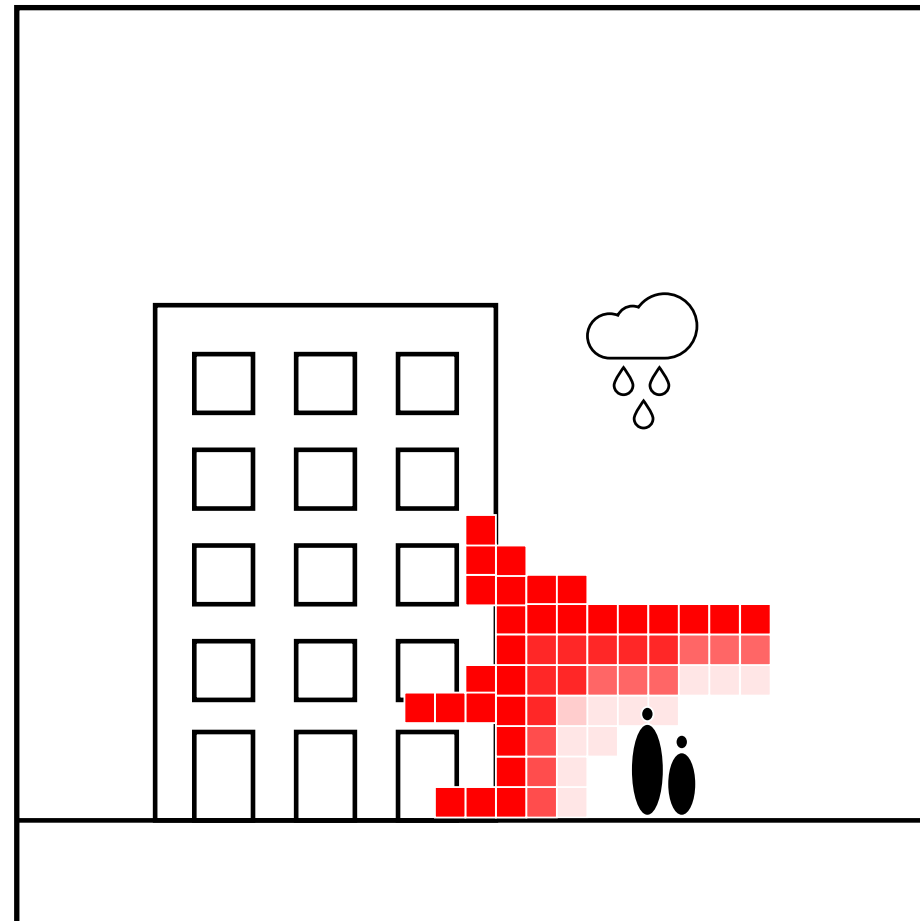
## IMPLICATIONS

Hovering layer of "living matter"

Temporary structures

Reconfigurable

- multiple functions
- responsive and adaptable
- environment+human interactions



## APPLICATIONS

### PARASITIC ADDITIONS

Responding to environmental conditions (rain/wind protection or shading) in the urban landscape

### COVERED SHELTER IN PUBLIC SPACES

Enclosed or Semi-Enclosed sheltered areas in parks, festivals, or other large public spaces

### FOLLOWING STRUCTURES

Assemblies can track and follow a person or group of people

# ***FROM CREATURE TO SPECIES***

## ***BODY:***

*CREATURE MATERIALITY*

## ***BRAIN:***

*CREATURE SENSING APPARATUS*

## ***COLONY:***

*SPECIES BEHAVIOUR*

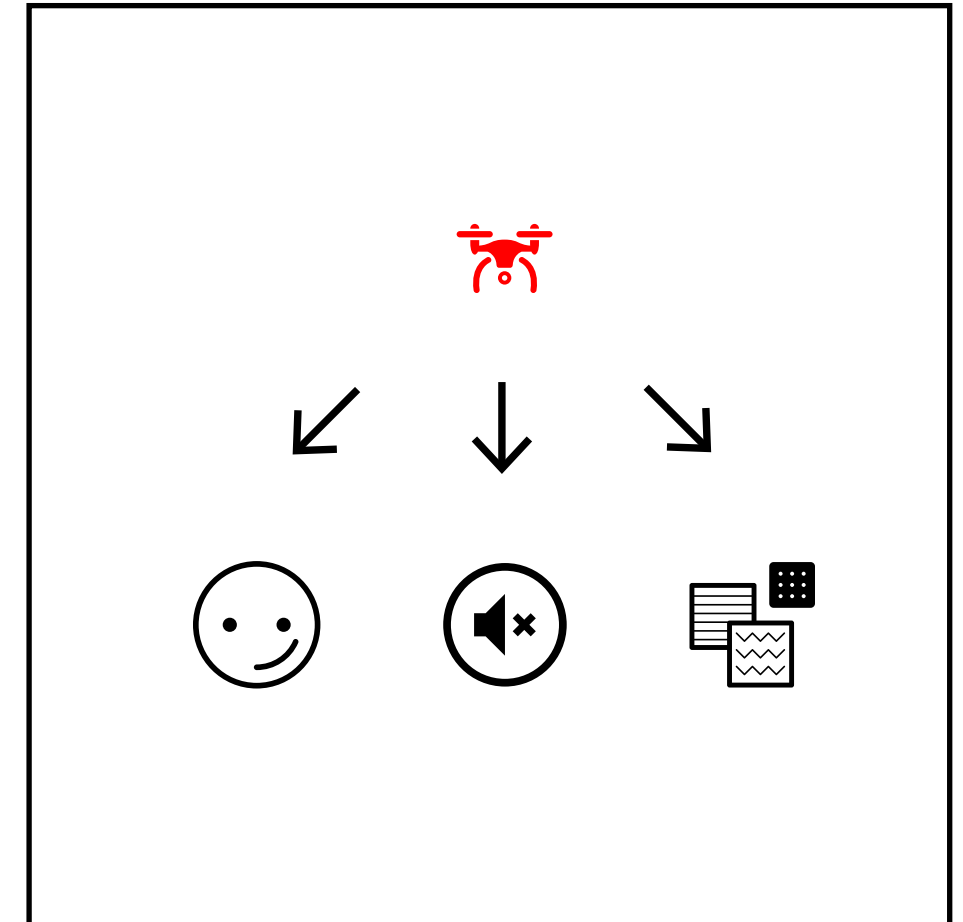
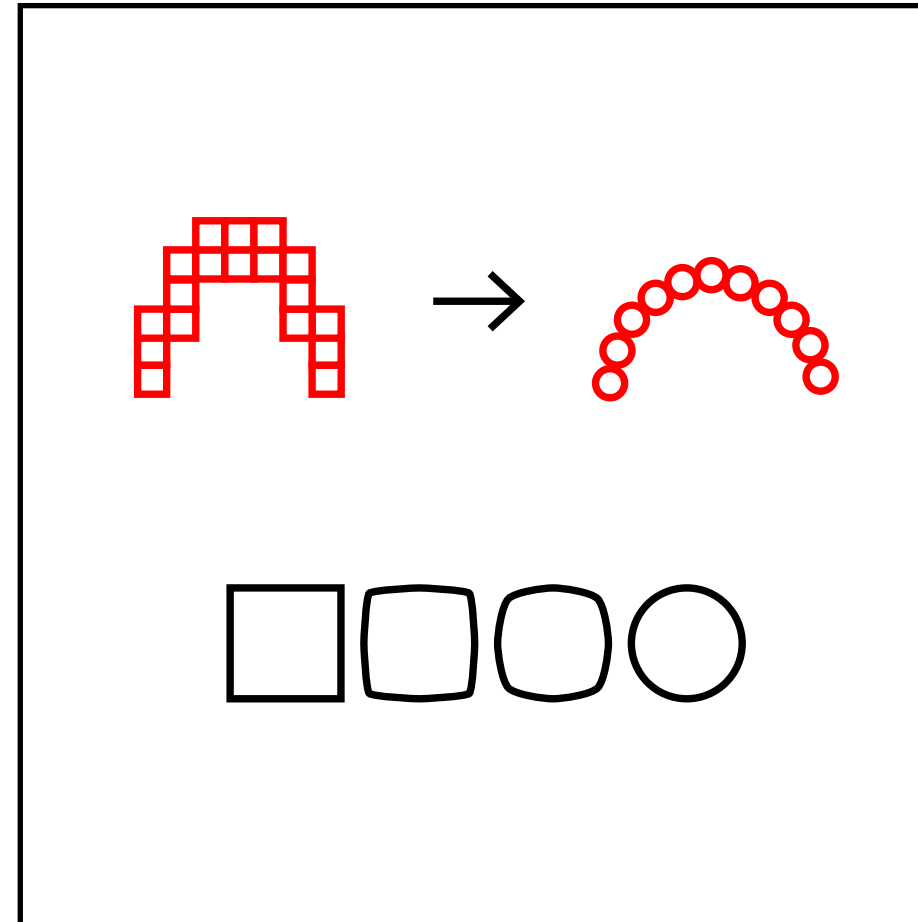
# **BODY:** *CREATURE MATERIALITY*

## **URBAN CONTEXT**

People+Building density  
Mostly hard surfaces

## **ROBOTIC REQUIREMENTS**

Connect to other "creatures"  
Aerodynamic flight  
Safe operation



## **DESIGN IMPLICATIONS**

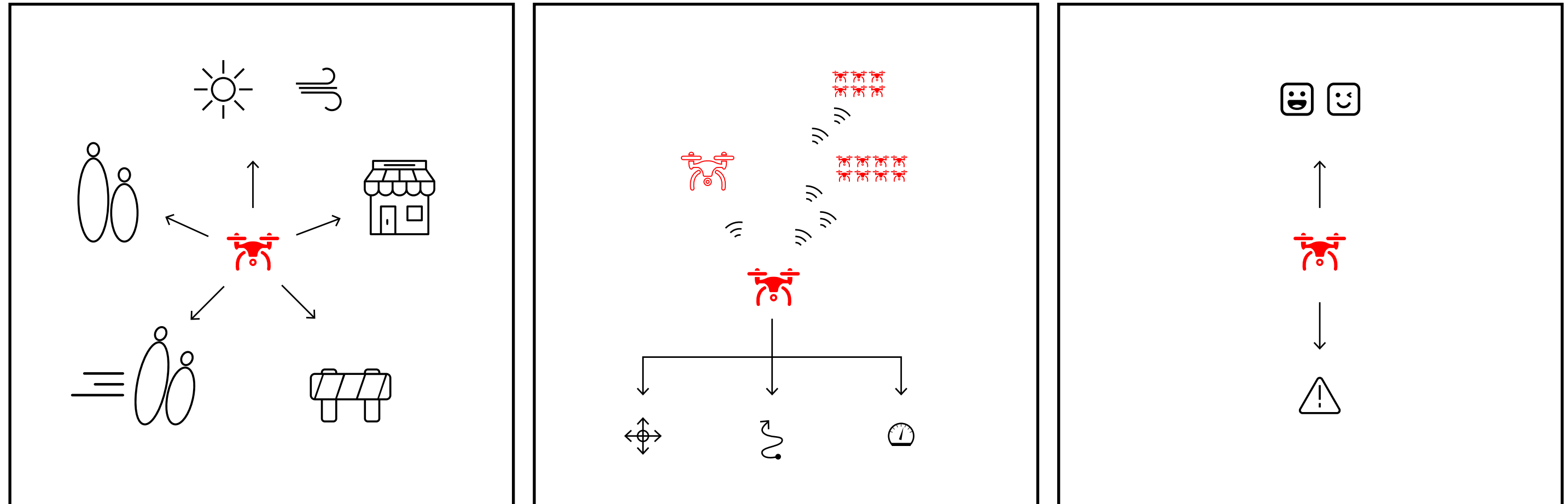
## **GEOMTERY**

## **APPEARANCE**

- determines the type of structures
- quick/safe connections btw creatures
- aerodynamism
- balanced weight (stability, flight time, safety)

- approachable and friendly
- quiet operation
- soft materials

# BRAIN: CREATURE SENSING APPARATUS



## TYPE OF BEHAVIOUR OR INTERACTION

## ENVIRONMENTAL CONDITIONS

## ROBOT-ROBOT INTERACTIONS

## HUMAN-ROBOT INTERACTIONS

- Identify "creatures", humans, POIs
- Identify ground and obstacles
- Identify obj movements and speed

- Position, movement, speed and intention of creatures
- Inter-creatures (near) and inter-swarm (long) communication

- Delight and approachability (appearance, lifelike behaviours)
- Safety (obstacle avoidance, speed adaptations)

## SENSING APPARATUS

*Kinect-like vision, GPS, etc*

*Bluetooth, RFID, GPS, Accelerometer, etc*

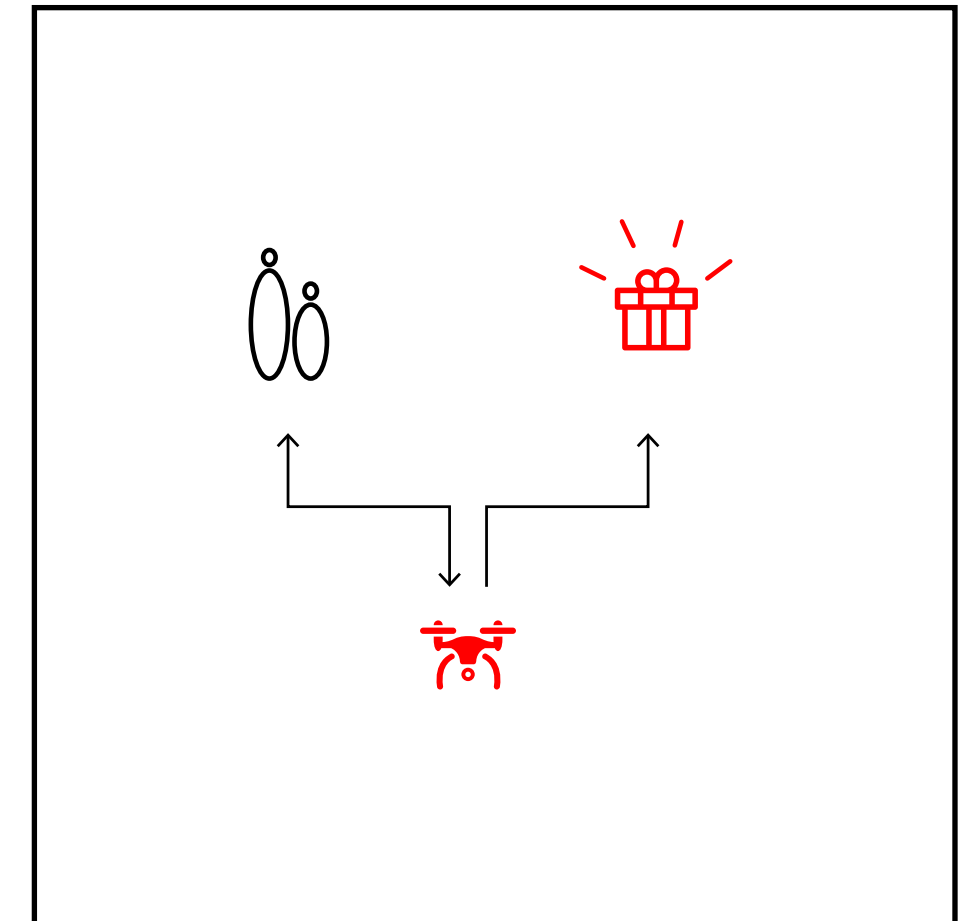
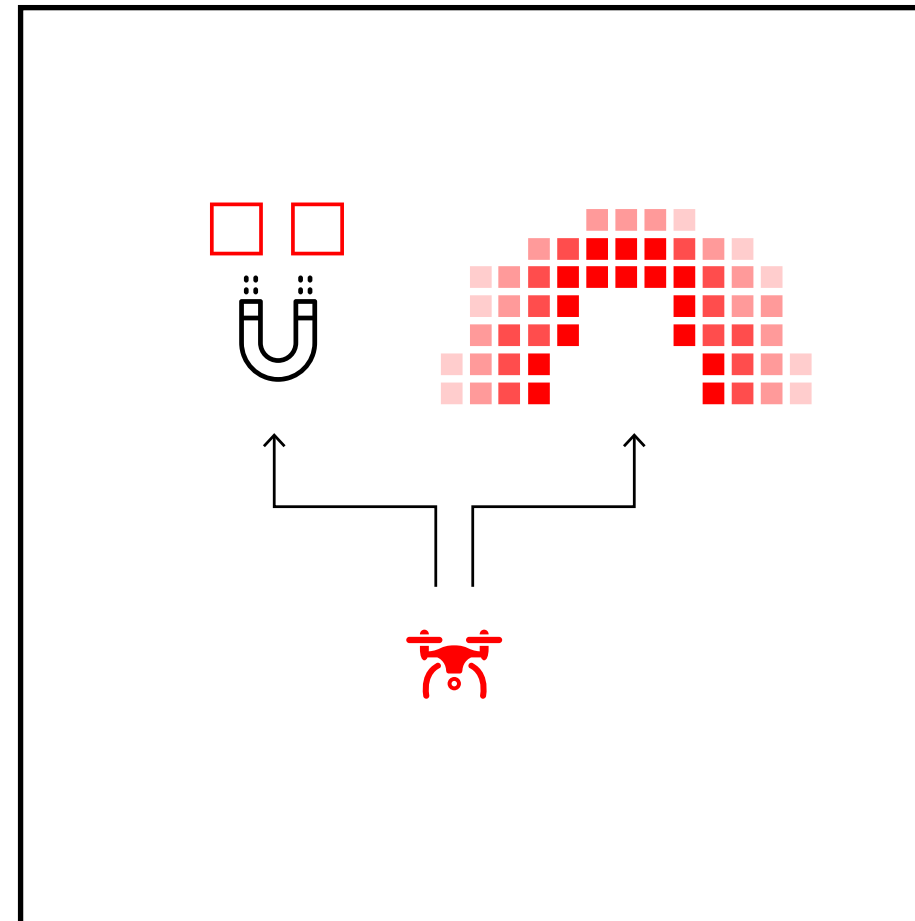
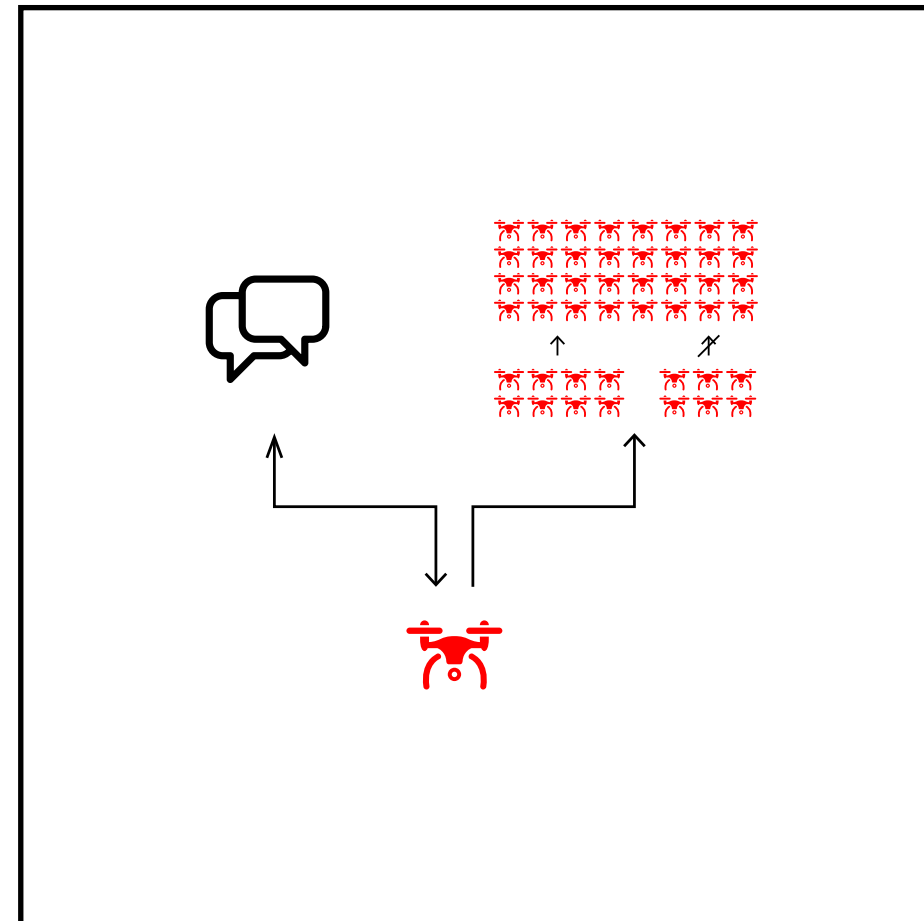
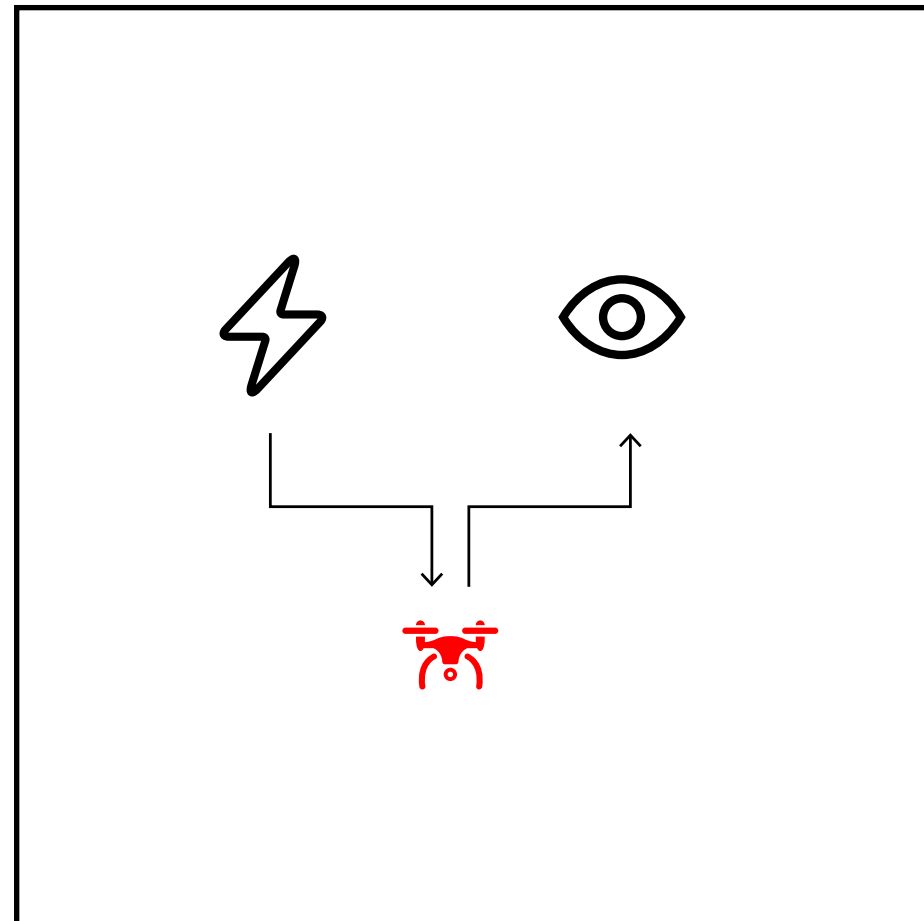
*Kinect-like vision, speaker, light, screen*

# COLONY: SPECIES BEHAVIOUR

## DRIVERS AND EXPRESSION

**Desires** (drive or goals) vs  
**Actions** (expression or sequence)

The quantity of behaviors and their intercrossings increase the complexity of the system but also its life-likeness



### NEUTRAL / PERSONAL

### INTER-SWARM

### CONSTRUCTION

### HUMAN INTERACTIONS

- neutral: "resting" or "scouting"
- personal: charging, need fixing

- communicate their activities
- adapt (enlarge/reduce) swarm size in specific area

- connections between "creatures"
- structures' growth logic
- environmental/artificial modulation (wind/rain/light)
- manipulating objects (textiles)

- environmental/artificial modulation overrides (wind/rain/light)
- assembly configuration override and interactions
- speaker, furniture, etc.