Beehives [report from la Molina talks, february 2013]

Robustness of the sensor network

Annemie has issues with one of her sensor networks which continuously stops working. This is a key issue we have to tackle for P2P Food Lab and BEE-O-ICT : if the sensor networks are not robust enough, the users may lose heart and all the participative aspect of citizen science may collapse.

Electromagnetic radiation

The bees do not like the PC boards. They left a super (une hausse) empty between their broodcase and the super hosting the PC board. They may be disturbed by the clock frequency ? Luckily, they do not feel visibly disturbed by the sensors.

Monitoring

The main objective is to monitor the health of the beehive, not to produce more honey. We want to monitor when the beehive collapses, and when to intervene – and hopefully, how to do it correctly. The monitoring should be as little intrusive as possible. Every disturbance costs the bees energy and it may take them a day before there are back into their normal activities after the beehive has been opened. The goal of the intelligent beehive is not necssarily to understand the bees but to help them and to detect when there are problems.

Annemie faces problems with robustness of the Arduino sensor solution. The Arduino has to be (very) regularly rebooted. It is not clear why. The best solution will probably require some trial and error. The Arduino may have to reboot automatically using a timer.

For exterior, we should work with professional sensors. The current sen- sors are suited used for hobby projects only. The sensor in the OKNO beehive are currenlty not wokring. They may be broken, or there may be problems with the wiring. Because of the conditions (ouside, diculty to replace broken sensors) is is probably wise to use simple and robust sensors.

1. Temperature outside and distribution of temperature inside. This al- lows us to locate the kernel through interpolation, and get a value of the average temperature, reflecting health of the colony (optimal is 35 C). [(o)] Temperature sensors grid with a natural comb shape ?
2. Humidity : This is also a health parameter, as bees keep normally humidity at a constant 60% in the hive.
3. Visual stream : Camera at the front of the beehive
4. Bee counter : See also this instructable, [todo : link], and this company, http ://users.telenet.be/lowland.
5. Weight of the beehive : to measure the weight of the bees and the weight of the honey. Precision expected : 100 g. (see also www.beewise.eu).
6. Audio : the beehive in Barcelona measure the sound intensity (deci- bels). Annemie is not sure about the usefulness of this measure. A more interesting sound analysis is measuring the frequency band of the bees' sound. A higher pitch may indicate a healty colony. A low pitch may indicate the preparation of a swarm. (see the Apidictor, http ://www.instructables.com/id/iphone-apidictor-for-acoustal-beehive- swarm-detect/).
7. CO_2
8. An e-nose in beehive to categorise the honey is dicult because the

   bees will cover it with propolis. Seems like another research axis.
9. Chemical analysis of honey, beewax and propolis : this will be done by external labs.

Design principles for a biomimetic bee-hive

1. Form : Ideal capacity is around 35-38 L. When you leave Apis Mellifera (Europe) in the wild, they

usually install themselves in a hollow tree, whereas Apis Dorsata (Asie) directly builds its comb on a tree branch outside. When you leave Apis Mellifera in a box without structure, they build their combs in function of their relative position to the sun, together with design elements from their previous beehives. In human- designed beehives, we can distinguish to types of frame alignments : perpendicular to the entry, or cold type, as it allows an ecient air circulation; or parallel to the entry, or warm type, as it reduces air circulation and increase thermal inertia of the hive. We have to find a trade-o↲ between an organic, natural shape which bee-hives refined over the years, and an ergonomic shape allowing us to monitor eciently what we want. Annemie sees a beehive imitating the natural shape of comb - elongated semi-spherical shape - hanging from a tree with an entry from the top.

2. Materials : Annemie sees a mix of beewax and propolis. This material, easy to melt and therefore to print, would allow us to have a great liberty in shape. My only concern is with mechanical strength, and the relative precious character of this kind of material, which may be ”wasted” in such a structure. However, combs are made of wax, so a beehive made of bee-produced materials would be elegant. According to Annemie, beewax and propolis do not have a signature of a specific bee colony, so we can easily recycle propolis and beewax from other bee- hives. We could also support some of the shape with textile - based on locally grown hemp and linen. Annemie’s hypothesis is that a beehive in wax/propolis/resine is better for well-being of bees.

3. Equipment : A self-sustained thymol-based (or other) varoa repulsive system.

Annemie’s main objective through Bee-o-ICT. Help bees to survive, and find new ways to support them.

Apis mellifera specialize on one plant type. They get all the pollen from one specific plant before switching to another one.

<u>Non-invasive temperature sensing</u>

In a minimalistic beehive, where bees build all the structure by them- selves, we have to insert sensors afterwards. A way could be to use catheter- based systems to insert chirurgically sensors in the structure with minimal destruction/influence.

<u>Temperature monitoring grid design</u>

It may be possible to observe the position of the bee nucleus using only a few sensors combined with a temperature conduction/convection/radiation model. However, before we can be sure what the appropriate density is of the sensors, we will use a set of sensor on a 3D grid. From this data we can extract the appropriate model/sensors for a simplified monitoring system, and we may observe other interesting phenomena.

For a fine integration of sensors, we can take inspiration from previous work on smart textiles.

On each frame, four sensors on each corner, then four sensors in a smaller square in the middle of the frame, and then one sensor at the very center of the frame (see Fig. 2) Sensors are thermistors, a small resistive element whose resistance varies with temperature, encapsulated in glass. Such sensors are more robust than more sophisticated ones, with a small circuit allowing the conversion of resistance in voltage information. We will let them naked on the frame, and let the bees cover them with propolis. We will just assume a given response time due to this thermally insulating layer. We will connect the sensors to the ground through cables structuring the frame, so that we can power them with only one wire – which already makes 12⇥9 = 108 wires for the whole broodcase.

The wires will be selected to be as thin as possible – only a single copper wire coated with (bee-compatible) polish. Each sensor will be connected to a analog multiplexer so that they can be measured one at the time. A Wheatstone bridge is used to convert resistance information in voltage information (see Fig. ??). This Wheatstone bridge will be installed out of the frame, and connected to a multiplexer allowing to read the 108 sensors using a single Arduino chip. The thermistor resistance range will be selected so that the wire resistance can be neglected. Electro-magnetic fields generated by the grid should not be a problem, as only changes in current and tension generate them. If we monitor at very low frequency, we should not produce disturbing electro-magnetic fields for the bees.

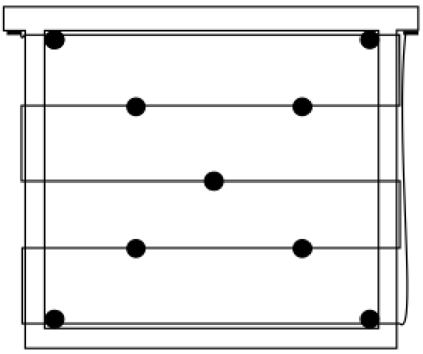


Figure 1 – A frame of the beehive with nine thermistors on the metal wire.

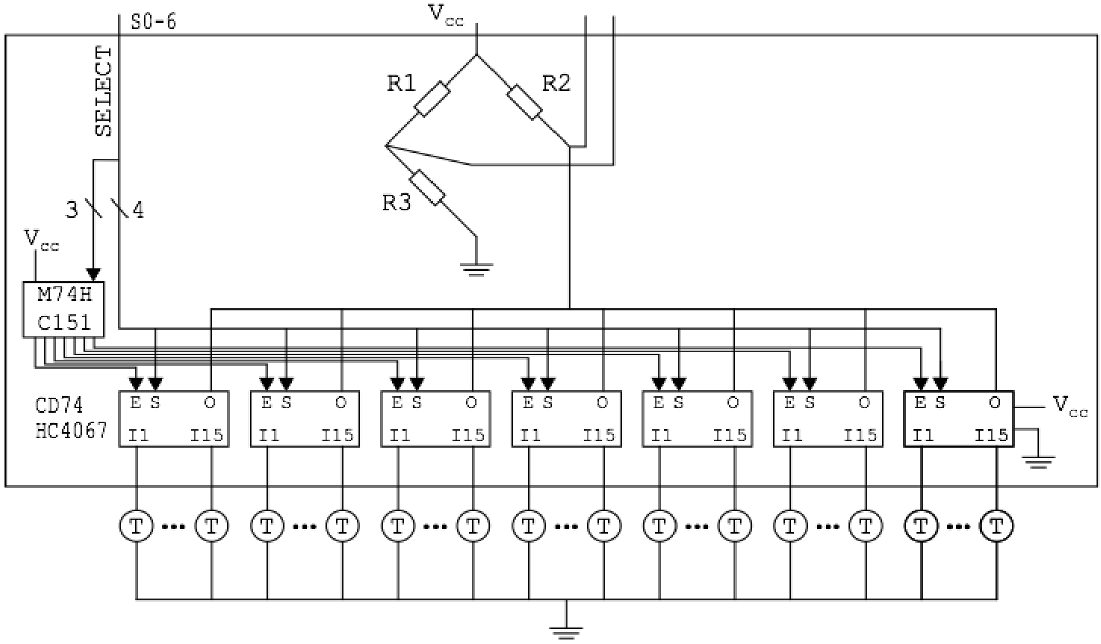
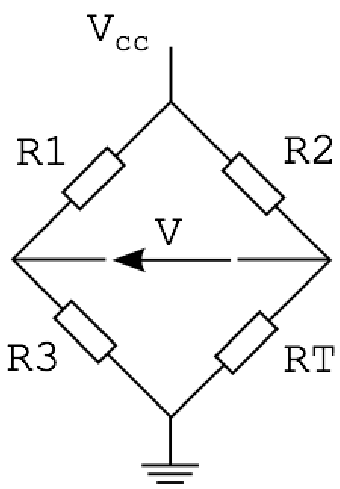


Figure 2 – The multiplexer board and Wheatstone bridge.

Component	Specs/number	Quantity
R1	100k	1
R2	100k	1
R3	560k	1
Analog multiplexer	CD74HC4067	7
Digital multiplexer	M74HC151	1
Thermistor	EPCOS B57560G104F	108

Figure 3 – Wheatstone bridge



Setup 1

– Wheatstone bridge, R1=R2=R3=100k.

– Output voltage : -1.348 to 1 V.

T (°C)	RT (kΩ)	V (V)
0	333.964	-1.348
10	201.659	-0.842
25	100.000	0.000
35	64.759	0.535
45	42.951	0.998

Setup 2

– Wheatstone bridge, R1=R2=100k, R3=400k.

– Minimum temparture : approx. -4 degrees.

– Output voltage : 0.152 to 2.5 V.

– With an amplifier this can be brought to a voltage range of 0.3 to 5 V.

– Using a 10-bit ADC between 0-5V, this gives 962 discrete temperature

T (°C)	RT (kΩ)	V (V)
0	333.964	0.152
10	201.659	0.658
25	100.000	1.500
35	64.759	2.035
45	42.951	2.498

Setup 3

– Wheatstone bridge, R1=R2=100k, R3=560k.

– Minimum temparture : approx. -9 degrees.

– Output voltage : 0.395 to 2.740 V.

– With an 1.82⇥ amplification this can be brought to a voltage range of 0.73 to 5 V.

– Using a 10-bit ADC between 0-5V, this gives 874 discrete temperature readings.

T (°C)	RT (kΩ)	V (V)
0	333.964	0.395
10	201.659	0.900
25	100.000	1.742
35	64.759	2.277
45	42.951	2.740

Setup 4

– Voltage dividor, R1=100k.

– Output voltage : 1.502 to 3.448 V.

T (°C)	RT (kΩ)	V (V)
0	333.964	3.448
10	201.659	3.342
25	100.000	2.500
35	64.759	1.965
45	42.951	1.502

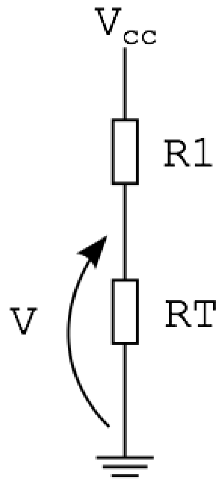


Figure 4 – Voltage division.

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