Concurrent Engineering Project 2018 :

A robotic platform to study thermoregulation in ant colonies

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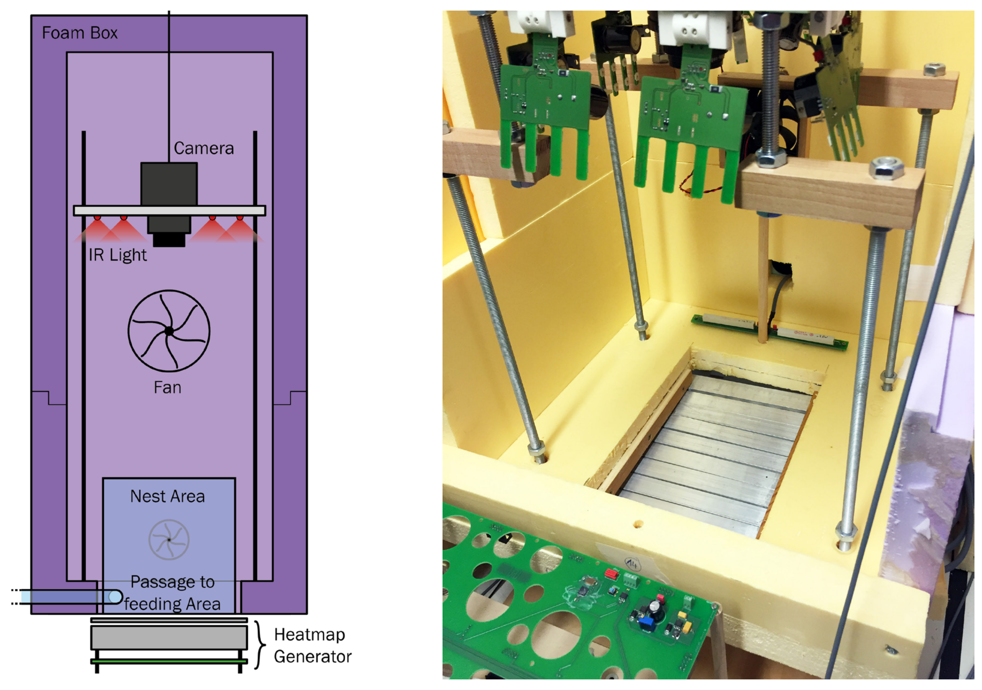
COURSE OF ACTION

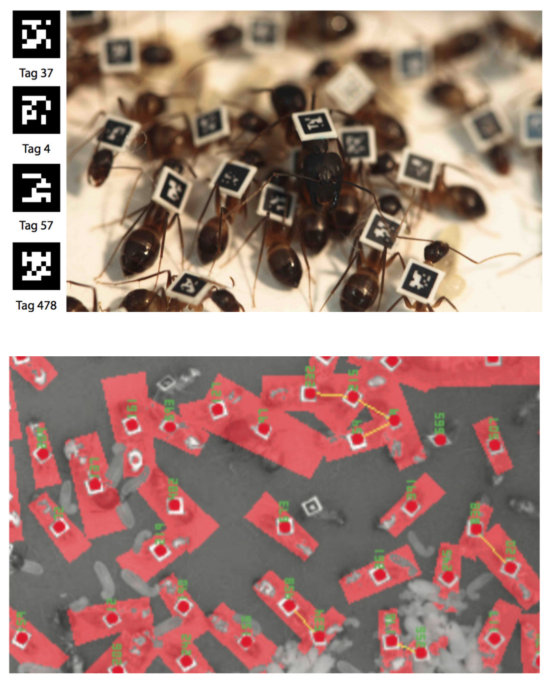
We optimized an existing heat map generator (heat sink and electronics) that is part of an experimental setup (Fig. 1–4) to monitor reactions of ant colonies to nest temperature (T) changes.

SCIENTIFIC PURPOSE

Develop scientific tools that carry out experiments independently and therefore deliver unbiased data.



Figures 1 and 2 : Complete setup to observe thermal-response of ant colonies (left) and implemetation of the setup with the former heat map generator at UNIL



Figures 3 and 4 : Tagged ants and evaluation by the tracking system [1]

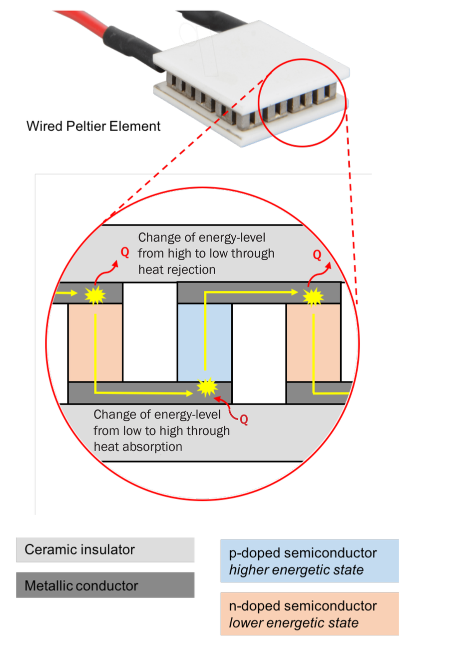


Figure 5 : Working principle of a Peltier element (Joule heating and Fourier effect not shown)

FORMER SETUP

HEAT SINK

The heat sink consists of two distributors and one cooling device (Fig. 6). The cooling water channels are aligned with one control unit (CU) (row of six Peltier elements (PE) Fig. 5).

ELECTRONICS AND COMMAND

Five PID controllers maintain the desired T, each controlling two CUs. Ten thermocouples each measure the T of the first PE of a CU. One PCB to which the cables of the PE are soldered and another PCB linking the PEs of a CU in series.

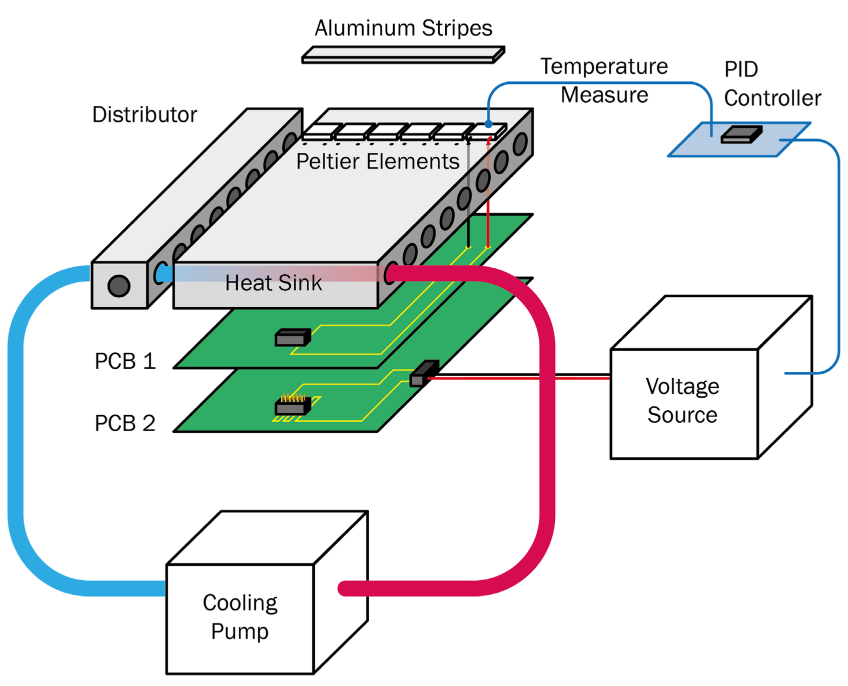
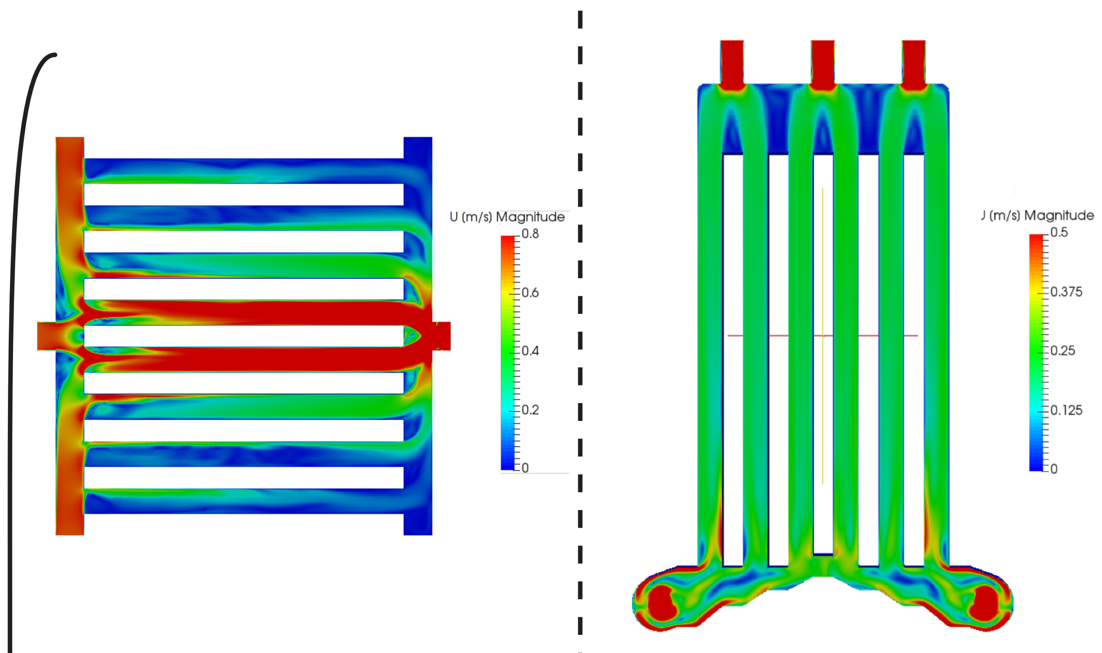


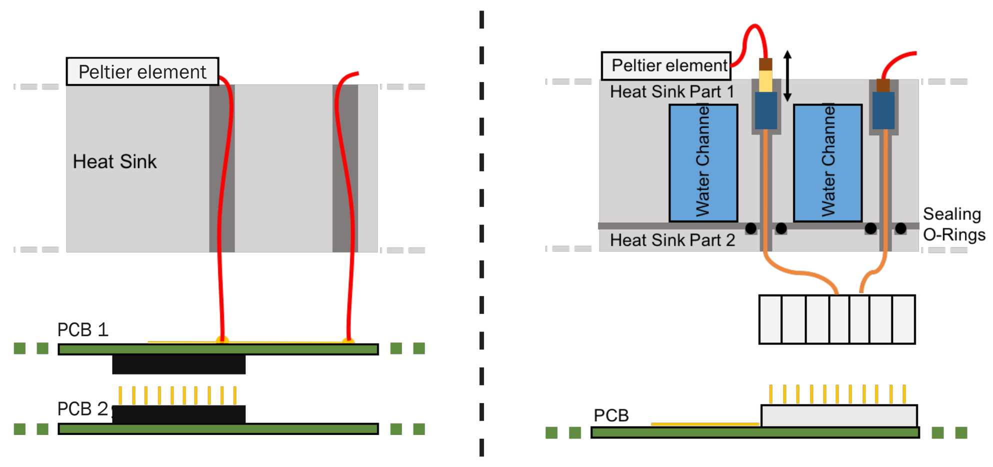
Figure 6 : The former heat map generator (only one distributor and one CU with corresponding PID controller shown)

PROBLEMS AND CONSEQUENCES

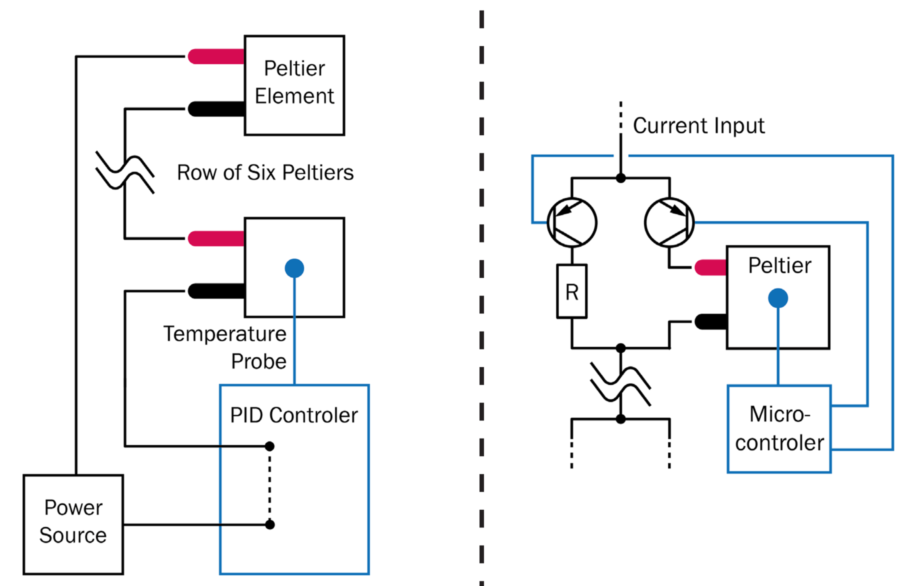
1. Inhomogeneous flow through channels (Fig. 7)
   → Overheating of PEs
2. Flow under PEs heats up
   → Unequal T distribution under a CU
   → Imprecise T control with only one T measurement per CU
3. A PID controller can only handle two CUs
4. PEs soldered to PCB 1 (Fig. 9)
   → Changing an element is very laborious
5. Heat map pattern imposed by PCB 2
   → Need to replace PCB 2 to modify pattern



Figures 7 and 8: Simulation of the flow through the former (left) and the optimized (right) cooling system



Figures 9 and 10: Wiring scheme of the former setup (left) and the optimized version (right)



Figures 11 and 12: Control structure of the former setup (left, only one CU shown) and the optimized version (right, only one PE shown)

OPTIMIZED SETUP

HEAT SINK

Produced in two parts with sealed cable channels. Rectangular water channels normal to the CUs with a two stage distributor. First: break incoming flow [2], second: distribute it homogenously into the channels [3].

ELECTRONICS AND COMMAND

Individual temperature measurement and command possible with microcontroller (MC) and PWM load-switching (Fig. 12) of the PEs.

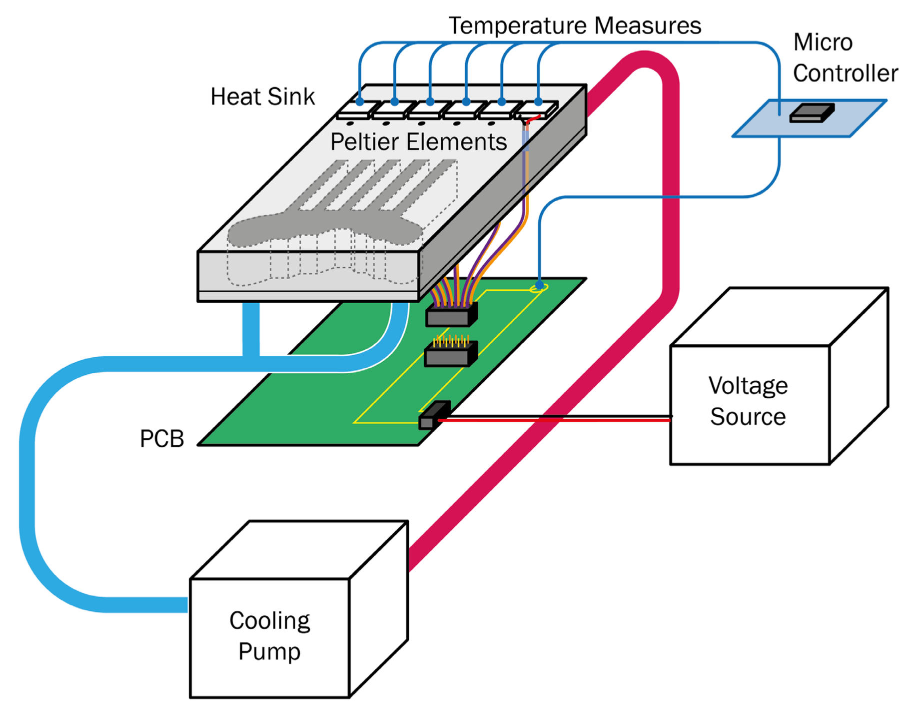
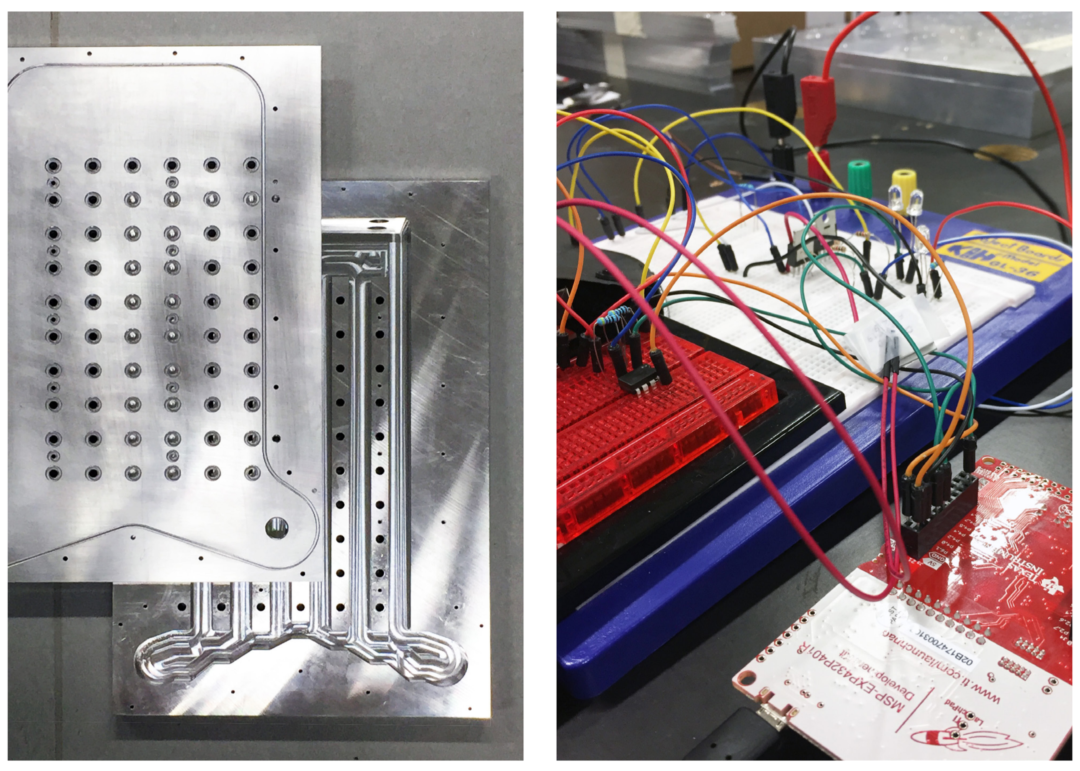


Figure 13: The optimized heat map generator with built-in flow-distributor and individual command

SOLUTIONS

1. New distributor design (Fig. 8)
2. Orientation of water channels normal to rows (Fig. 13)
3. Usage of a MC and load-switching command structure to implement PWM (Fig. 12)
4. Wiring optimized with cable-to-cable and cable-to-board connectors (Fig. 10)
5. Programmable MC to generate different heat map patterns

Note: New heat sink compatible with former electronics and control



Figures 14 and 15: The aluminum made heat sink (left) and the experimental control setup (right)

CONCLUSION

- Individual connectors for each Peltier allow easier replacement in case of need
- A robust cooling system and individually controlled elements result in a flexible system
- Electronic controlling the temperature distribution allows to creat reproducable results

FURTHER IMPROVEMENTS

- Fine-tuning of the programmed PID controller
- Include H-bridge to invert current direction in PE
- Embed control of ant environment (humidity, light, ambient T) also using the MSP432

THANKS

André Decurnex (Feedback on electronics)
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Marc Jeanneret (Technical consulting)

BIBLIOGRAPHY

[1] D. Mersch, A. Crespi, L. Keller: Tracking Individuals Shows Spatial Fidelity Is a Key Regulator of Ant Social Organization, Science (2013)
[2] A. Siddique et al.: Design of a collector shape for uniform flow distribution in microchannels, Journal of Micromechanics and Microengineering (2017)
[3] E. Cetkin: Constructal Microdevice Manifold Design With Uniform Flow Rate Distribution by Consideration of the Tree-Branching Rule of da Vinci and Hess–Murray Rule, Journal of Heat Transfer (2017)

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