



FUTURISTIC BEEHIVES FOR A SMART METROPOLIS

Results

Project Information

HIVEOPOLIS

Grant agreement ID: 824069

[Project website](#)

DOI
[10.3030/824069](#)

Project closed

EC signature date
23 October 2018

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1 April 2019	31 March 2024

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Total cost
€ 6 999 508,75

EU contribution
€ 6 999 508,75

Coordinated by
UNIVERSITAET GRAZ
 Austria

This project is featured in...



CORDIS provides links to public deliverables and publications of HORIZON projects.

Links to deliverables and publications from FP7 projects, as well as links to some specific result types such as dataset and software, are dynamically retrieved from [OpenAIRE](#) .

Deliverables

Demonstrators, pilots, prototypes (9)

[Hive core prototype](#)

This deliverable describes the prototyping of the fully functional central core module and includes the results of tests made using these prototypes to qualify the design of the device

[Dance floor module](#)

This deliverable contains a requirement analysis and a break-down of the final dance-floor module into several component prototypes whose design, construction and evaluation will be described. The evaluation will be limited to the lab to confirm the physical parameters listed in the requirements analysis were met.

[Hive architecture and core design](#)

This deliverable describes the general architecture of hive and the design of the central core

[Gate module](#)

In M39 we are expected to provide a working prototype of the gate module, capable of counting in- and outbound flights as well an option for remote closing/opening of the main entrance.

[Design prototype of an innovative beehive](#)

This deliverable will be a demonstration of the innovative beehive design

[User interface on the individual colony level](#)

This deliverable includes the design and implementation of the various interfaces that the user will need in order to interact with an individual HIVEOPOLIS unit - physically on location and remotely.

[Prototype of the complete system](#)

This deliverable demonstrates a complete HIVEOPOLIS unit with all mechanical and electronic subsystems, interfaces and communication protocols, as well as software systems for data storage and analysis that reside outside the HIVEOPOLIS unit, integrated into a complete coherent system that is ready to house a honeybee colony.

[Power supply and storage system of the hive](#)

This deliverable consists of a hybrid power system that powers the electronics embedded in the hive. It includes energy storage batteries that buffer the energy harvested from various renewable sources: solar, wind, vibrations, etc., and supplies the stored power to the various embedded electronics in order to make the hive energy independent.

[Design and development of the automatic honey harvesting system and storage module](#)

Full schematics of the operational module which extracts the honey through tubes into a storage module located on the outside of the beehive. M30: a working prototype.

Documents, reports (16)

[Models of storage dynamics](#)

Report on mathematical models and computer simulation of storage dynamics, including design of the models, evaluation of predictions, and application to honey redistribution.

[Report on best-practice project](#)

This deliverable will report on the evaluations of the best-practice projects conducted in the project.

[Progress report on community forming procedures](#)

This is an intermediate report on the public outreach and community building efforts and their success metrics.

[Report on the performance of HIVEOPOLIS bio-hybrids](#)

Evaluation results of the performance of the bio-hybrid system based on 1) the unit's sensor systems compared to data from literature and simulations and 2) stress tests performed with a HIVEOPOLIS unit compared to a classical bee-hive.

[Models and simulations of population dynamics](#)

Report on modeling population dynamics of a honeybee colony based on sensor data collected in hives

[Report on core model](#)

This deliverable will report on the computer models that are executed on the central core and that will interact with the specific hive-compartments' locally executed models.

[Final report on community forming](#)

This is a final report on the public outreach and community building efforts and their success metrics.

[Dissemination and exploitation plan](#)

This deliverable will contain a detailed roadmap for all planned scientific and public dissemination activities, as well as a plan to target exploitation activities.

[Specification of external data & programming interfaces](#)

Communication interfaces and protocols for external system connectivity with a biohybrid living system will be specified Several types of interfaces will be considered like machine to machine and machine to human

[Concluding report on project management activities](#)

This report will give an overview over the management activities during the project run-time, in particular the administration and documentation of regular meetings (GAs), distribution of financial contributions, execution of potential amendments to the grant agreement and implementation of the project's software infrastructure.

[Models of interactions of bio-hybrids](#)

This deliverable will report the across-colony models of interaction of connected HIVEOPOLIS units, predictive models and decision making and negotiation model on apiary level as well as mathematical models developed to understand the influence of the environment, beekeeping practices and environmental changes on the bio-hybrid organisms.

[Report on collective decision making models](#)

This deliverable will report the research approaches and the results concerning computational models on collective decision making of bees.

[Report on environmental data fusion platform structure, its operation and developed augmented environmental maps](#) 

In this deliverable we will report the augmented maps that were developed from the collected environmental data, the structure of the data fusion platform and how to operate it.

[Evaluation report of bio-hybrid system integration in urban environment](#) 

This deliverable will contain the evaluation report of bio-hybrid living system operations in urban areas and guidelines for its resilient existence.

[Design of the brood nest module](#) 

This deliverable describes the design of the brood nest module, which includes the design of the mechanical structure of the brood nest module with the integrated sensors, such as cameras and actuators.

[Report on the biological evaluation of the brood nest module](#) 

This deliverable will report on the experiments performed to evaluate the techno-augmented brood-nest module.

Open Research Data Pilot (1)

[Data Management Plan \(DMP\)](#) 

As part of the Open Research Data Pilot we will specify in this deliverable what data the project will generate, whether and how it will be exploited or made accessible for verification and re-use and how it will be curated and preserved.

Other (1)

[Data warehouse with implemented DSS](#) 

Data warehouse for online and offline data collection storage and analysis will be developed Several algorithms and models will be integrated for Decision Support System development Based on DSS recommendations decisions for beekeepers will be provided

Publications

Peer reviewed articles (23)



[Modeling of the Potential Honey Bee Colony Foraging Activity Based on the Agrometeorological Factors](#)

Author(s): Olvija Komasilova, Vitalijs Komasilovs, Armands Kviesis, Aleksejs Zacepins

Published in: Baltic Journal of Modern Computing, Issue 9/3, 2021, Page(s) 280-289, ISSN 2255-8950

Publisher: University of Latvia

DOI: 10.22364/bjmc.2021.9.3.04

[A robotic honeycomb for interaction with a honeybee colony](#)

Author(s): Rafael Barmak and Martin Stefanec, Daniel N. Hofstadler, Louis Piotet, Stefan Schönwetter-Fuchs-Schistek, Francesco Mondada, Thomas Schmickl, Rob Mills

Published in: Science Robotics, Issue 8 (76), 2023, Page(s) eadd7385, ISSN 2470-9476

Publisher: AAAS

DOI: 10.1126/scirobotics.add7385

[Social networks predict the life and death of honey bees](#)

Author(s): Benjamin Wild, David M. Dormagen, Adrian Zachariae, Michael L. Smith, Kirsten S. Traynor, Dirk Brockmann, Iain D. Couzin, Tim Landgraf

Published in: Nature Communications, Issue 12/1, 2021, ISSN 2041-1723

Publisher: Nature Publishing Group

DOI: 10.1038/s41467-021-21212-5

[Application of the internet of things in precision beekeeping in Latvia](#)

Author(s): Aleksejs Zacepins, Vitalijs Komasilovs, Jans Jelinskis, Niks Ozols, Armands Kviesis

Published in: Agrofor International Journal, Issue 7 (3), 2022, Page(s) 101-111, ISSN 2490-3442

Publisher: University of East Sarajevo, Faculty of Agriculture

DOI: 10.7251/agreng2203101z

[GIS-based interactive map to improve scheduling beekeeping activities](#)

Author(s): Daniels Kotovs, Aleksejs Zacepins

Published in: MDPI Agriculture, Issue 13, 2023, Page(s) 669, ISSN 2077-0472

Publisher: MDPI

DOI: 10.3390/agriculture13030669

[Can Biomimetic Robots Change a Hivemind to Guide Honeybees' Ecosystem Services? !\[\]\(08a82c22d89d6b027ff69762ad096586_img.jpg\)](#)

Author(s): Dajana Lazic, Thomas Schmickl

Published in: Bioinspiration & Biomimetics, Issue 18, 2023, Page(s) 35004, ISSN 1748-3190

Publisher: IOP Publishing

DOI: 10.1088/1748-3190/acc0b9

[I.N.S.E.C.T. Wall Twin: Designing With and For Insects, Fungi, and Humans !\[\]\(83f22ed94ec5517769dd76d702c6bfd8_img.jpg\)](#)

Author(s): Dan Parker, Asya Ilgün, Ariel Cheng Sin Lim, Hana Vašatko, Dan Vy Vu, Natalia Piórecka, Svenja Keune

Published in: Temes de Disseny, Issue 39, 2023, Page(s) 228–247, ISSN 2604-9155

Publisher: ELISAVA Barcelona School of Design and Engineering

DOI: 10.46467/tdd39.2023.228-247

[Enhancing migratory beekeeping practice using digital flowering calendar !\[\]\(d0262bbe9d2356661a2e89321dfcc781_img.jpg\)](#)

Author(s): Olvija Komasilova, Daniels Kotovs, Vitalijs Komasilovs, Armands Kviesis, Aleksejs Zacepins

Published in: Baltic Journal of Modern Computing, Issue 11, 2023, Page(s) 1-14, ISSN 2255-8950

Publisher: University of Latvia, Institute of Mathematics and Informatics

DOI: 10.22364/bjmc.2023.11.1.01

[Biohybrid Superorganisms—On the Design of a Robotic System for Thermal Interactions With Honeybee Colonies !\[\]\(f219cfc00b8db0cd1a81ae1fc9afaf28_img.jpg\)](#)

Author(s): R. Barmak, D.N. Hofstadler, M. Stefanec, L. Piotet, R. Cherfan, T. Schmickl, F. Mondada, R. Mills

Published in: IEEE Access, Issue 12, 2024, Page(s) 50849-50871, ISSN 2169-3536

Publisher: Institute of Electrical and Electronics Engineers Inc.

DOI: 10.1109/access.2024.3385658

[Evaluation of the honey bee colonies weight gain during the intensive foraging period !\[\]\(465772ce2fc0e39b7001e2580b915cc2_img.jpg\)](#)

Author(s): Aleksejs Zacepins, Niks Ozols, Armands Kviesis, Janis Gailis, Vitalijs Komasilovs, Olvija Komasilova, Viktorija Zagorska

Published in: Agronomy Research, Issue 20 (2), 2022, Page(s) 457-468, ISSN 1406-894X

Publisher: Estonian Agricultural University

DOI: 10.15159/ar.22.017

[Status of Urban Beekeeping in Latvia !\[\]\(6b6d798a1e19654494a6892c667d44da_img.jpg\)](#)

Author(s): Aleksejs Zacepins, Olvija Komasilova, Vitalijs Komasilovs, Armands Kviesis, Janis Kronbergs

Published in: Bee World, Issue 100, 2023, Page(s) 75-79, ISSN 2376-7618

Publisher: Taylor & Francis
DOI: 10.1080/0005772x.2023.2247915

[Self-complexification through integral feedback in eusocial paper wasps of various levels of sociality](#)
[↗](#)

Author(s): Thomas Schmickl, Istvan Karsai
Published in: Heliyon, Issue 9/9, 2023, Page(s) E20064, ISSN 2405-8440
Publisher: Elsevier
DOI: 10.1016/j.heliyon.2023.e20064

[Mycelial Beehives of HIVEOPOLIS: Designing and Building Therapeutic Inner Nest Environments for Honeybees](#)
[↗](#)

Author(s): Asya, Ilgun; Thomas, Schmickl
Published in: Biomimetics; Volume 7; Issue 2; Pages: 75, Issue 3, 2022, ISSN 2313-7673
Publisher: MDPI
DOI: 10.3390/biomimetics7020075

[Social Integrating Robots Suggest Mitigation Strategies for Ecosystem Decay](#)
[↗](#)

Author(s): Thomas Schmickl, Martina Szopek, Francesco Mondada, Rob Mills, Martin Stefanec, Daniel N. Hofstadler, Dajana Lazic, Rafael Barmak, Frank Bonnet, Payam Zahadat
Published in: Frontiers in Bioengineering and Biotechnology, Issue 9, 2021, Page(s) 612605, ISSN 2296-4185
Publisher: Frontiers
DOI: 10.3389/fbioe.2021.612605

[Behavioral variation across the days and lives of honey bees](#)
[↗](#)

Author(s): Michael L.Smith, Jacob D.Davidson, BenjaminWild, David M.Dormagen, TimLandgraf, Iain D.Couzin
Published in: iScience, Issue 9 (25), 2022, ISSN 2589-0042
Publisher: Elsevier
DOI: 10.1016/j.isci.2022.104842

[Comparing weight dynamics between urban and rural honey bee colonies in Latvia](#)
[↗](#)

Author(s): Komasilova, O.; Zacepins, A.; Kviesis, A.; Komasilovs, V.; Ozols, N.
Published in: Agronomy Research, Issue 21, 2023, Page(s) 471-481, ISSN 1406-894X
Publisher: Estonian Agricultural University
DOI: 10.15159/ar.23.019

[Model for finding the number of honey bee colonies needed for the optimal foraging process in a specific geographical location](#)
[↗](#)

Author(s): Olvija Komasilova, Vitalijs Komasilovs, Armands Kviesis, Aleksejs Zacepins

Published in: PeerJ, Issue 9, 2021, Page(s) e12178, ISSN 2167-8359

Publisher: PeerJ

DOI: 10.7717/peerj.12178

[Model for the bee apiary location evaluation](#)

Author(s): Olvija Komasilova, Vitalijs Komasilovs, Armands Kviesis, Nikolajs Bumanis, Heinrich Mellmann, Aleksejs Zacepins

Published in: Agronomy Research, Issue 18(S2), 2020, Page(s) 1350-1358, ISSN 1406-894X

Publisher: Estonian Agricultural University

DOI: 10.15159/ar.20.090

[Effects of Sinusoidal Vibrations on the Motion Response of Honeybees](#)

Author(s): Stefanec Martin; Oberreiter Hannes; Becher Matthias A.; Haase Gundolf; Schmickl Thomas

Published in: Frontiers in Physics, Issue 2296424X, 2021, ISSN 2296-424X

Publisher: Frontiers

DOI: 10.3389/fphy.2021.670555

[Animal-robot interaction - an emerging field at the intersection of biology and robotics](#)

Author(s): Donato Romano, Maurizio Porfiri, Payam Zahadat, Thomas Schmickl

Published in: Bioinspiration & Biomimetics, Issue 19/2, 2024, Page(s) 020201, ISSN 1748-3182

Publisher: Institute of Physics Publishing

DOI: 10.1088/1748-3190/ad2086

[Architecture of a decentralised decision support system for futuristic beehives](#)

Author(s): Vitalijs Komasilovs, Rob Mills, Armands Kviesis, Francesco Mondada, Aleksejs Zacepins

Published in: Biosystems Engineering, Issue 240, 2024, Page(s) 56-61, ISSN 1537-5110

Publisher: Academic Press

DOI: 10.1016/j.biosystemseng.2024.02.017

[Simple physical interactions yield social self-organization in honeybees](#)

Author(s): Martina Szopek, Valerin Stokanic, Gerald Radspieler, Thomas Schmickl.

Published in: Frontiers in Physics, Issue 9, 2021, ISSN 2296-424X

Publisher: Frontiers

DOI: 10.3389/fphy.2021.670317

[Bee colony remote monitoring based on IoT using ESP-NOW protocol](#)

Author(s): Armands Kviesis, Vitalijs Komasilovs, Niks Ozols, Aleksejs Zacepins
Published in: PeerJ Computer Science, Issue 9, 2023, Page(s) e1363, ISSN 2376-5992
Publisher: PeerJ Inc.
DOI: 10.7717/peerj-cs.1363

Conference proceedings (10)

[Control of collective behaviours through artificial feedbacks](#)

Author(s): Stamatios C. Nicolis, Mariano Calvo Martín, Alexandre Campo, Jean-Louis Deneubourg
Published in: The 2021 Conference on Artificial Life, 2021
Publisher: MIT Press
DOI: 10.1162/isal_a_00403

Simulation and Decision-Making In a Bio-Hybrid Beehive

Author(s): Volha Taliaronak, Heinrich Mellmann, Verena V. Hafner
Published in: Abstract Book of International Congress on Bee Sciences, 2022
Publisher: Organizers of the International Congress on Bee Sciences

[Can Robots Inform a Honeybee Colony's Foraging Decision-Making?](#)

Author(s): Dajana Lazic, Thomas Schmickl
Published in: The 2021 Conference on Artificial Life, 2021
Publisher: MIT Press
DOI: 10.1162/isal_a_00397

[A Minimally Invasive Approach Towards “Ecosystem Hacking” With Honeybees](#)

Author(s): Martin Stefanec; Daniel N. Hofstadler; Tomáš Krajník; Ali Emre Turgut; Ali Emre Turgut; Hande Alemdar; Hande Alemdar; Barry Lennox; Erol Şahin; Erol Şahin; Farshad Arvin; Thomas Schmickl
Published in: Frontiers in Robotics and Ai, Issue 9, 2022, Page(s) 791921, ISBN 9781003023555
Publisher: Frontiers
DOI: 10.3389/frobt.2022.791921

[Anticipation as a Mechanism for Complex Behavior in Artificial Agents](#)

Author(s): Heinrich Mellmann, Benjamin Schlotter, Lea Musiolek, Verena V. Hafner
Published in: The 2020 Conference on Artificial Life, 2020, Page(s) 157-159
Publisher: MIT Press
DOI: 10.1162/isal_a_00314

A Novel Mobile App for the Next Generation of Beekeepers

Author(s): Eugen Puzynin, Heinrich Mellmann, Verena V. Hafner

Published in: CEUR Workshop Proceedings, CS&P 2021: 29th International Workshop on Concurrency, Specification and Programming, Issue 2051, 2021, Page(s) 113-116

Publisher: CEUR Workshop Proceedings

Simulation of Interactions between Beehives

Author(s): Volha Taliaronak, Heinrich Mellmann, Verena V. Hafner

Published in: CEUR Workshop Proceedings, CS&P 2021: 29th International Workshop on Concurrency, Specification and Programming, Issue 2951, 2021, Page(s) 106-112

Publisher: CEUR Workshop Proceedings

[Bio-Hybrid Systems for Ecosystem Level Effects](#) 

Author(s): Asya Ilgün, Kostadin Angelov, Martin Stefanec, Sarah Schönewetter-Fuchs, Valerin Stokanic, Jutta Vollmann, Daniel N. Hofstadler, Martin H. Kärcher, Heinrich Mellmann, Volha Taliaronak, Armands Kviesis, Vitalijs Komasilovs, Matthias A. Becher, Martina Szopek, David M. Dormagen, Rafael Barmak, Erol Bairaktarov, Matthieu Broisin, Ronald Thenius, Rob Mills, Stamatios C. Nicolis, Alexandre Campo, Ale

Published in: The 2021 Conference on Artificial Life, 2021

Publisher: MIT Press

DOI: 10.1162/isal_a_00396

The Queen and her Robotic Court: A Minimally-Invasive Form of Ecosystem Hacking

Author(s): Thomas Schmickl, Martin Stefanec, Daniel Hofstadler, Tomáš Krajník, Ali Emre Turgut, Farshad Arvin

Published in: Proceedings of the INTERNATIONAL SCIENCE FICTION PROTOTYPING CONFERENCE 2021, 2021, Page(s) 5-12, ISBN 978-94-92859-15-0

Publisher: EUROSIS

Addressing modern challenges for bees through a novel mobile app

Author(s): Eugen Puzynin, Heinrich Mellmann, Verena V. Hafner

Published in: Abstract Book of International Congress on Bee Sciences, 2022

Publisher: Organizers of the International Congress on Bee Sciences

[Non-peer reviewed articles \(1\)](#)



[Autonome Roboterschwärme stabilisieren gefährdete Ökosysteme](#) 

Author(s): Martina Szopek, Ronald Thenius, Martin Stefanec, Daniel Hofstadler, Joshua Varughese, Michael Vogrin, Gerald Radspieler, Thomas Schmickl
Published in: Navigationen, Issue 21, 2021, Page(s) 150-181, ISSN 1619-1641
Publisher: Univ.-Verl. Siegen
DOI: 10.25819/ubsi/9913

Book chapters (1)

[Towards an Anticipatory Mechanism for Complex Decisions in a Bio-Hybrid Beehive](#) 

Author(s): Heinrich Mellmann, Volha Taliaronak, Verena V. Hafner
Published in: Concurrency, Specification and Programming: Revised Selected Papers from the 29th International Workshop on Concurrency, Specification and Programming (CS&P'21), Berlin, Germany, 2023, Page(s) 145-173, ISBN 978-3-031-26651-5
Publisher: Springer International Publishing AG
DOI: 10.1007/978-3-031-26651-5_7

Datasets

Datasets via OpenAIRE (6)



[A robotic honeycomb for interaction with a honeybee colony](#) 

Author(s): Barmak, Rafael; Stefanec, Martin; Hofstadler, Daniel N.; Piotet, Louis; Schönwetter-Fuchs-Schistek, Stefan; Mondada, Francesco; Schmickl, Thomas; Mills, Rob
Published in: Zenodo

[Data used in Machine learning reveals the waggle drift's role in the honey bee dance communication system](#) 

Author(s): Dormagen, David M; Wild, Benjamin; Wario, Fernando; Landgraf, Tim
Published in: Zenodo

[Effects of Sinusoidal Vibrations on the Motion Response of Honeybees - datasets](#) 

Author(s): Martin, Stefanec; Hannes, Oberreiter
Published in: Zenodo

[Dataset for: Biohybrid superorganisms - on the design of a robotic system for thermal interactions with honeybee colonies](#) 

Author(s): Barmak, Rafael; Hofstadler, Daniel H.; Stefanec, Martin; Piotet, Louis; Cherfan, Raphaël; Schmickl, Thomas; Mondada, Francesco; Mills, Rob
Published in: Zenodo

[Will Biomimetic Robots Be Able to Change a Hivemind to Guide Honeybees' Ecosystem Services? \(dataset\)](#) 

Author(s): Lazic, Dajana; Schmickl, Thomas
Published in: Zenodo

[Simple Physical Interactions Yield Social Self-Organization in Honeybees - datasets](#) 

Author(s): Szopek, Martina; Stokanic, Valerin; Radspieler, Gerald; Schmickl, Thomas
Published in: Zenodo

Software

Software via OpenAIRE (3)



[A robotic honeycomb for interaction with a honeybee colony](#) 

Author(s): Barmak, Rafael; Stefanec, Martin; Hofstadler, Daniel N.; Piotet, Louis; Schönwetter-Fuchs-Schistek, Stefan; Mondada, Francesco; Schmickl, Thomas; Mills, Rob

Publisher: Zenodo

DOI: 10.5281/zenodo.7671290; 10.5281/zenodo.7671291

[Effects of Sinusoidal Vibrations on the Motion Response of Honeybees - Exemplary software](#) 

Author(s): Martin, Stefanec; Hannes, Oberreiter

Publisher: Zenodo

DOI: 10.5281/zenodo.5674948; 10.5281/zenodo.5674947

[Architecture of a decentralised decision support system for futuristic beehives](#) 

Author(s): Komasilovs, Vitalijs; Mills, Rob; Kviesis, Armands; Mondada, Francesco; Zacepins, Aleksejs

Publisher: Zenodo

DOI: 10.5281/zenodo.11191437; 10.5281/zenodo.11191438

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