EXPOSÉ
ROOTARCH - Plant Root Growth for Bioinspired Architectural Design

Introduction
The project ROOTARCH aims at translating growth principles of plant roots to new solutions in architectural design by developing new digital design and production methodologies.
The project takes on the method of bio-inspired design to look at biology for innovation in human design [11,14,38,39]. The proposal stands in the tradition of the author's arts-based research projects Biornametics, GrAB - Growing as Building, and BIOCOOL, that were carried out at the University of Applied Arts in the past [12,15,16,17,21,22].
Tree root systems are multifunctional plant elements that serve as role models for bioinspired solutions in architectural design and engineering [35,36]. Specifically, structural systems of buildings, anchoring and supply systems, but also novel fiber based material systems, entangled or integrating aggregate substrates, are of interest [3,29,30,34,37]. At the same time, bio-based structures and materials hold promise for a more sustainable building practice of the future [7,41,42].
Data of a previous study on tree root systems serves as starting point and base for the ROOTARCH project. Due to their underground existence, research on root morphology is largely based on time-consuming and tedious manual or semi-automated processes. In a reverse biomimetic approach, the methods of photogrammetry and parametric design were applied to the morphological analysis of coarse tree root systems, to produce 3D models to reliably extract design principles. 10 different root specimens across 4 different tree species were imaged in the field and reconstructed virtually through photogrammetry. A parametric algorithm was created to extract their skeleton to access the system's topology and morphological traits (such as volume, surface area, radius, curvature, branching angles), informing about key strategies for root performance [18,20]. Also, an analogy framework for the design of building foundations and coastal resilience in engineering was established [35]. Based on the abstracted design principles, functional transfer to concepts of novel bio-inspired infrastructure was proposed and basic principles tested in a pull-out study in granular medium [19,24].

Goals
In the ROOTARCH project, this research will be taken further by the following steps:

- The basic research on root attachment will be extended by exploring fine root growth in a biolab setup, and experiment with co-design and integration for "living architecture" proposals.
- Further analysis and interpretation will be carried out on the available 3D models of root systems to increase knowledge on biological traits, abstracted information on topology and growth principles.
- Conceptual ideas will be developed and explored in use case studies and prototypes.
- Simulations and 3D printing will be applied to explore the design opportunities with complex morphologies in customized and adaptable designs.
- The framework on root-inspired infrastructure will be extended for application scenarios in architectural design.
- A circular approach will be applied to all proposed designs.

State of the art and innovation potential

The innovation potential of this bio-inspired approach lies in the transfer of characteristics of biological structures to architectural solutions, such as for example multifunctionality, resilience, adaptability and circular design on material, building as well as urban and ecosystem scale [11,12,25, 39]. Showcase projects in this field include the experimental pavilions at the University of Stuttgart in the cooperation of ITK and ICD [26].
Integrating biological organisms into technological developments and processes is the characteristic of biodesign approaches, that have been applied in "living architecture" projects by many research groups [9,17].
The "Baubotanik" approach by Ferdinand Ludwig at the TU Munich and projects of Mitchell Joachim use grafted plants as main construction elements [23,27,28]. Projects led by Rachel Armstrong, the HBBE (Hub for Biology in the Built Environment) group around Martyn Dade-Robertson, make use of microbial technologies for design purposes, and artistic projects by Philipp Beesley and Diana Scherer [4,5,10,33] and many more show a growing interest in hybridization of biology and technology, exploring co-design and multispecies design [6,8,13].
Among other additive production technologies, 3D and 4D printing are explored to generate dynamic structures that adapt to environmental triggers such as for example temperature or humidity [40]. The new digital simulation and production technologies allow for customized on site and adaptable design processes, that can integrate complex grown morphologies into standardized production flows [1,2,31,32]. ROOTARCH aims to take those methods further to develop novel root-inspired designs to contribute to solving our current planetary challenges.

Consortium and workplan

The project will be carried out by a consortium consisting of the Department of Building Construction (BC), the Departments of Digital Simulation and Digital Production as project partners with a highly experienced and motivated team with complementary expertises: Petra Gruber BC (Biodesign, Biomimetics, project management), Camille Breuil BC (Landscape Design, Circular Strategies), Daniela Kröhnert (Digital production, 3D printing, sustainability) and Clemens Preisinger (Digital Simulation, structural engineering). External experts include Thomas Speck University of Freiburg (Biology, Botany, Bionik), Anita Roth-Nebelsick Museum of Natural History Stuttgart (Botany, Paleontology, Bionik) and Thibaut Houette CEEBIOS Paris (Architecture, Biomimicry, Root research).
Additional Departments from the University of Applied Arts (Ceramics, Design, Experimental Game Cultures, Science Visualization Lab) and students will be invited to participate in an open workshop.
The majority of project participants are female. Diversity aspects will be considered in the selection of research assistants.
The project will be carried out in a regular rhythm of consortium meetings and four intensive workshops with dedicated themes of two full days each (11/2024, 01/03/05/2025). A kick-off meeting will be held in October 2024 and a final public presentation and exhibition in June 2025. The project duration includes a documentation and publishing phase in summer 2025.
Project tasks include: Literature and project review, review of 3D data and definition of digital workflow, starting laboratory setup and first experiments, setup of 3D printing environment, setup of biology experiments, framing of research and design workshops, inviting additional external experts for open workshops for input and review, processing of ideas and concepts, making and evaluating the designs, prototyping, documenting and publishing, coordination.
The project will use the facilities of the Departments and a temporary Biolab space.

Best practice principles will apply to all research activities, especially in the biolab ethical standards will be applied to minimize potential harm arising from working with living organisms.

Impact

The project will take existing research results further into applicable prototypical solutions, serving as case studies for further research projects and funding (FWF, FFG, EU Horizon2020). The root-inspired solutions will innovate architecture and the building industry, improving sustainability, efficiency and resilience of contemporary designs.
ROOTARCH will allow interdisciplinary collaboration of this consortium in a first biodesign project, and pave the way for a planned continued cooperation in the field.
For the participants, it will be a chance to embark on new knowledge and further the respective scientific careers with results and publication. For the University of Applied Arts, ROOTARCH will serve as an opportunity and a showcase project for a more permanent establishment of biodesign at the school.

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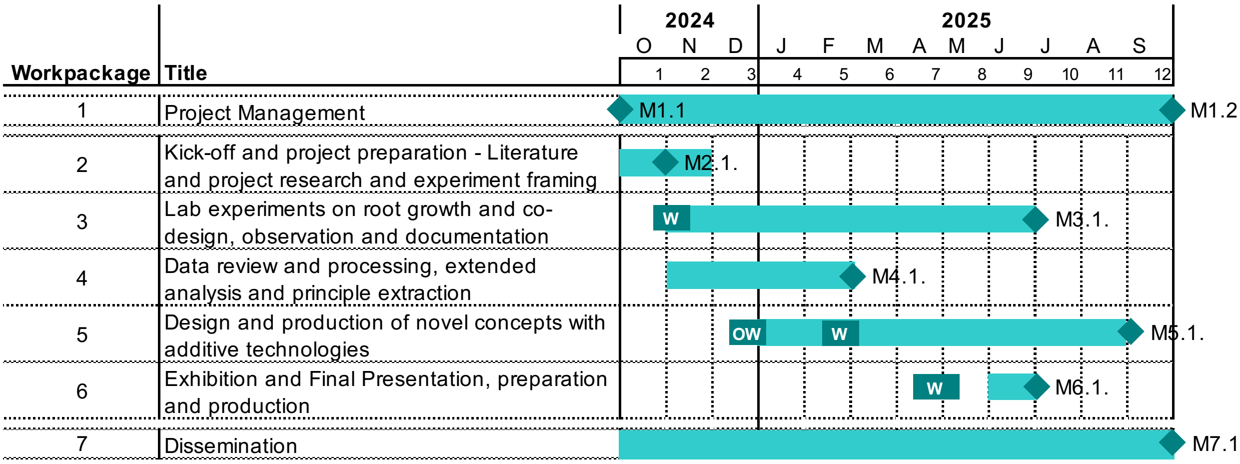
WORKPLAN AND SCHEDULE



W	Workshop
OW	Open Workshop with other Departments
M1.1	Project start, Budget and Personnel available
M1.2	Final project documentation report
M2.1	Kick-off Meeting
M3.1	Laboratory experiments for research and production concluded
M4.1	Data review and analyses concluded
M5.1	Desing concepts and prototypes done
M6.1	Exhibition prototypes and designs ready
M7.1	Dissemination carried out