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Artificial Intelligence in Building Design Processes and Collaboration in Mixed Teams of Humans and Robotic Agents

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1

1

Content

- **Part 1: AI in design**
  - AI for sustainable FOOD chain from farm to fork
  - Towards Climate Neutral Buildings - Empowering Designers through AI
- **Part 2: AI in planning of mixed teams**
  - Multi-agent (incl. humans) planning, and execution in real-world applications

2

2

Part 1: AI in design

3

AIFOOD - AI for sustainable FOOD chain from farm to fork

- The idea was to show that….

 …transition of existing buildings in a city is possible, and can help to address societal challenges in the context of

- food production
- climate
- sustainable urban development

4

17th December 2019 The Swedish goverment's climate action plan (2019/20:65)

- the AIFOOD project aims at the <u>reduction of greenhouse gas</u> emissions associated with **transportation**, recycling of **energy** and **water**, reduction of N2O from the agriculture, and finally change of behaviour patterns in consumption.

- **Transportation** – Local production and consumption
- **Energy** – LED lights generate heat that is "recycled"
- **Water** – Closed systems

5

Objectives (1/2)

- **Obj1:** To allow data-driven system development for planning and orchestration of complex infrastructures for energy and resource efficiency
- **Obj2:** To facilitate a holistic approach to model design by incorporation of multi-stakeholder perspective, and circular/shared economy aspects

6

AI FOOD

Objectives (2/2)

- **Obj3:** To allow autonomous orchestration of the IVF and its host building for resource efficient operation
- **Obj4:** To support the IVF in creation of mid-term tactical and strategic long-term plans for decision maing.

7

7

AI FOOD

Project targets

- **Precision farming:** Maximum resource efficiency and optimal climate control in the production units to minimize CO2 footprint of produced food.
- **Infrastructure-integrated farming:** Integration of urban farms into host facilities for enabling exchange of energy, water and heat to address sustainability and cost efficiency.
- **Autonomous farming:** Adapt to the needs, minimise food waste and encourage sustainable consumption.

8

8

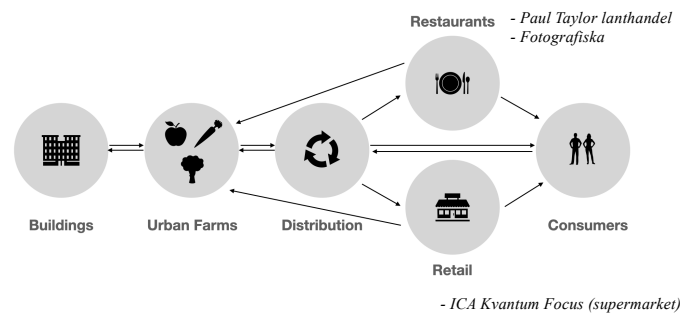## AIFOOD project stakeholders

AI FOOD

- Agtech producers / urban agriculture actors
  - **Swegreen AB**
- Real estate/building facility actors
  - **Areim AB, Bjerking AB, Sweco AB**
- Food retail/industry, logistics and distribution
  - **ICA Supermarkets**
- Restaurants and circular food entrepreneurs
  - **Paul Taylor Sundbyberg, Fotografiska museum**
- Consumers, e.g. housing associations and links to citizen initiatives within Sharing Cities Sweden
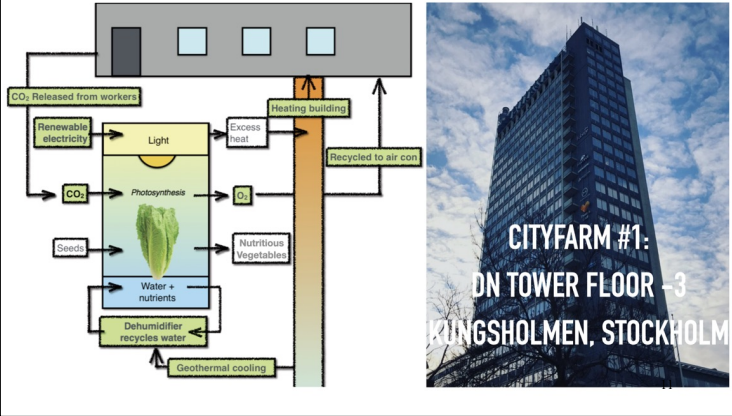
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9

Stakeholders in interaction

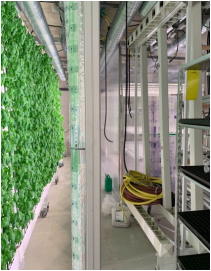AI FOOD

Restaurants — *Paul Taylor lanthandel*
- Fotografiska

Buildings Urban Farms Distribution Consumers

Retail

- ICA Kvantum Focus (supermarket)

10

10

The indoor farm and the host building

11

The "farm", in DN tower (floor -3)

Pics from 2020-2022

12

12

The "farm", in DN tower (floor -3)

CO2 outflux, the CO2 comes from the offices of the DN tower

The band moves slooowely
(It takes 3 weeks)

If not enough people in the offices; tubes are used.
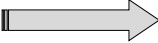
Sepehr & the new closed production unit. It is a moving band.

13

13

The "farm", in DN tower (floor -3)

Time to harvest

14

14

AI FOOD

Al Jazeera interview

- https://www.youtube.com/watch?v=DViTC_2cHWgM

15

15

Towards Climate Neutral Buildings - Empowering Designers through AI (Design4Climate)

- **Worldwide the construction industry represents 38% of carbon emissions**, thus it is of major importance that this industry contributes to the global climate goals by reducing its climate footprint across its activities.

  – Involving this sector in climate adaptation and mitigation actions is of vital importance.

  This was a research application that was not funded

16

16

Design4Climate motivation

Reduce operational carbon

Adhere to sunlight regulations

Reduce embodied carbon

Maximize square metres

Make this a wonderful building

HEEELP!

The task of designing buildings is becoming increasingly challenging. Novel tools are needed to create climate neutral solutions. AI may play a key role in this challenge. [17]

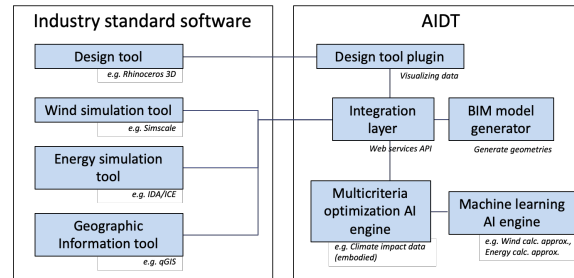*Image by White Architects, Lund Univ, and MDU*

17

Design4Climate solution (1/2)

AI powered Design Tool

Image by White Architects, Lund Univ, and MDU

The AI powered design process concerns concept and spatial coordination design phases according to the RIBA plan of work standard. The design process is orchestrated by the designer (or the multidisciplinary team) and the AIDT empowers re-use of knowledge between projects. [18]

18

Design4Climate solution (1/2)

Industry standard software

- Design tool
  e.g. Rhinoceros 3D
- Wind simulation tool
  e.g. Simscale
- Energy simulation tool
  e.g. IDA/ICE
- Geographic Information tool
  e.g. qGIS

AIDT

- Design tool plugin
  Visualizing data
- Integration layer
  Web services API
- BIM model generator
  Generate geometries
- Multicriteria optimization AI engine
  e.g. Climate impact data (embodied)
- Machine learning AI engine
  e.g. Wind calc. approx., Energy calc. approx.

Relationships between software tools within current state-of-practice (Left) and the proposed AIDT solution (Right). Through the AIDT Design tool plugin the designer can go between AIDT and Industry standard software.

Image by White Architects, Lund Univ, and MDU

19

Part 2: AI in planning of mixed teams

- Let us look at a few robots in the next slides…

20

20

Current research around the world - I

ASIMO, HONDA

NAO, Aldebaran

BigDog, Boston Dynamics (Google)   Kismet, MIT   iCub, http://www.icub.org/
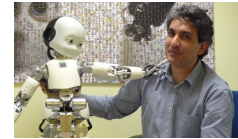
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21

Current research around the world - II

HAL Exoskeleton, Cyberdyne

Bebionic3 prothesis hand, RSLSteeper
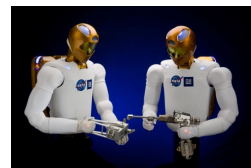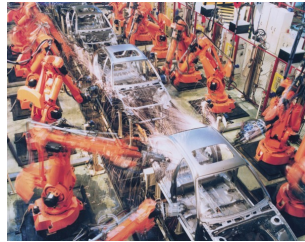
Robonout 2, NASA

22

22

Future of industrial robotics may be different

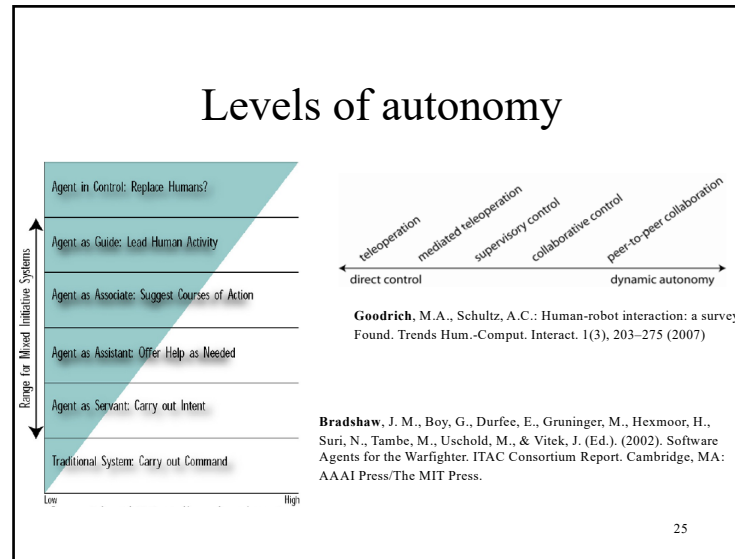Yesterday   Today   Future

23

23

before we talk about "intelligent robots" (to be used in planing) we need to look into autonomous systems, and how they interact with humans.

24

24

Levels of autonomy

Agent in Control: Replace Humans?

Agent as Guide: Lead Human Activity

Agent as Associate: Suggest Courses of Action

Agent as Assistant: Offer Help as Needed

Agent as Servant: Carry out Intent

Traditional System: Carry out Command

Range for Mixed Initiative Systems

Low — High

teleoperation — mediated teleoperation — supervisory control — collaborative control — peer-to-peer collaboration

direct control — dynamic autonomy

Goodrich, M.A., Schultz, A.C.: Human-robot interaction: a survey. Found. Trends Hum.-Comput. Interact. 1(3), 203–275 (2007)

Bradshaw, J. M., Boy, G., Durfee, E., Gruninger, M., Hexmoor, H., Suri, N., Tambe, M., Uschold, M., & Vitek, J. (Ed.). (2002). Software Agents for the Warfighter. ITAC Consortium Report. Cambridge, MA: AAAI Press/The MIT Press.

25

In the next slides we will look at a problem where several drones and tractors/vehicles can be controlled as autonomous units by an AI planning algorithm… Imagine a smart city case with focus on mobility and traffic monitoring.

26

The Mission management tool (MMT) and High-level planning

- Every individual in the population is a candidate solution
- GA produces good sub-optimal solutions in a reasonable time
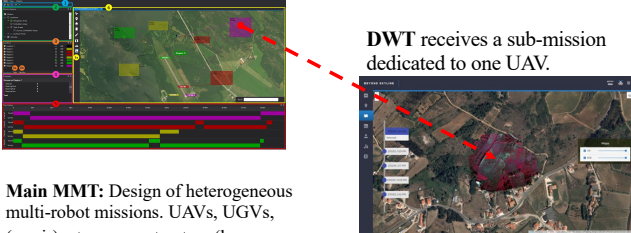- GA based solver, can plan very large missions. Missions are modelled as Extended Colour TSP

27

User interface and human-system interaction solutions

- Drone Web Terminal (DWT) controls the drones in real-time, and can send/receive missions both online and offline

DWT receives a sub-mission dedicated to one UAV.

Main MMT: Design of heterogeneous multi-robot missions. UAVs, UGVs, (semi-)autonomous tractors (legacy systems)

28

29

30

Different project similar AI-based solutions

31

31

The End

Thank you for your attention

32

32