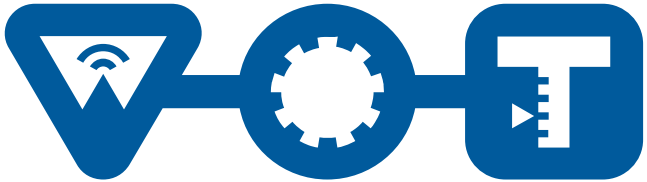
IntellioT

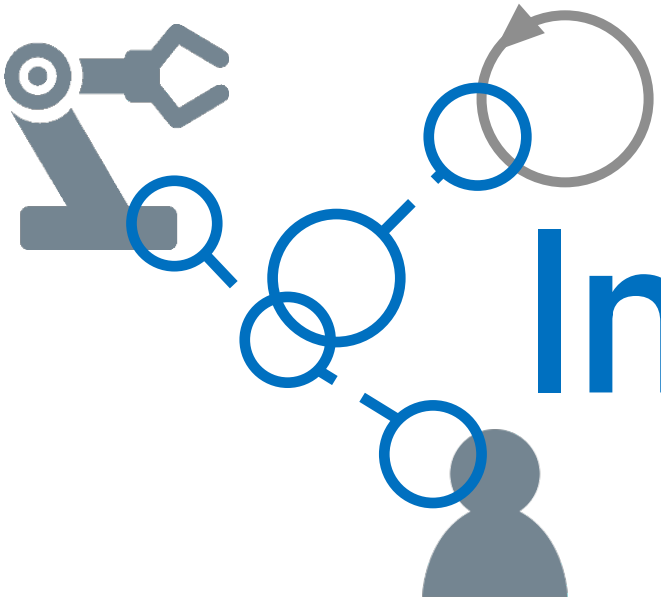


University of St.Gallen

Simon Mayer, Jérémy Lemée, Andrei Ciortea, Danai Vachtsevanou, Samuele Burattini

Interactions Research Group, https://interactions.ics.unisg.ch

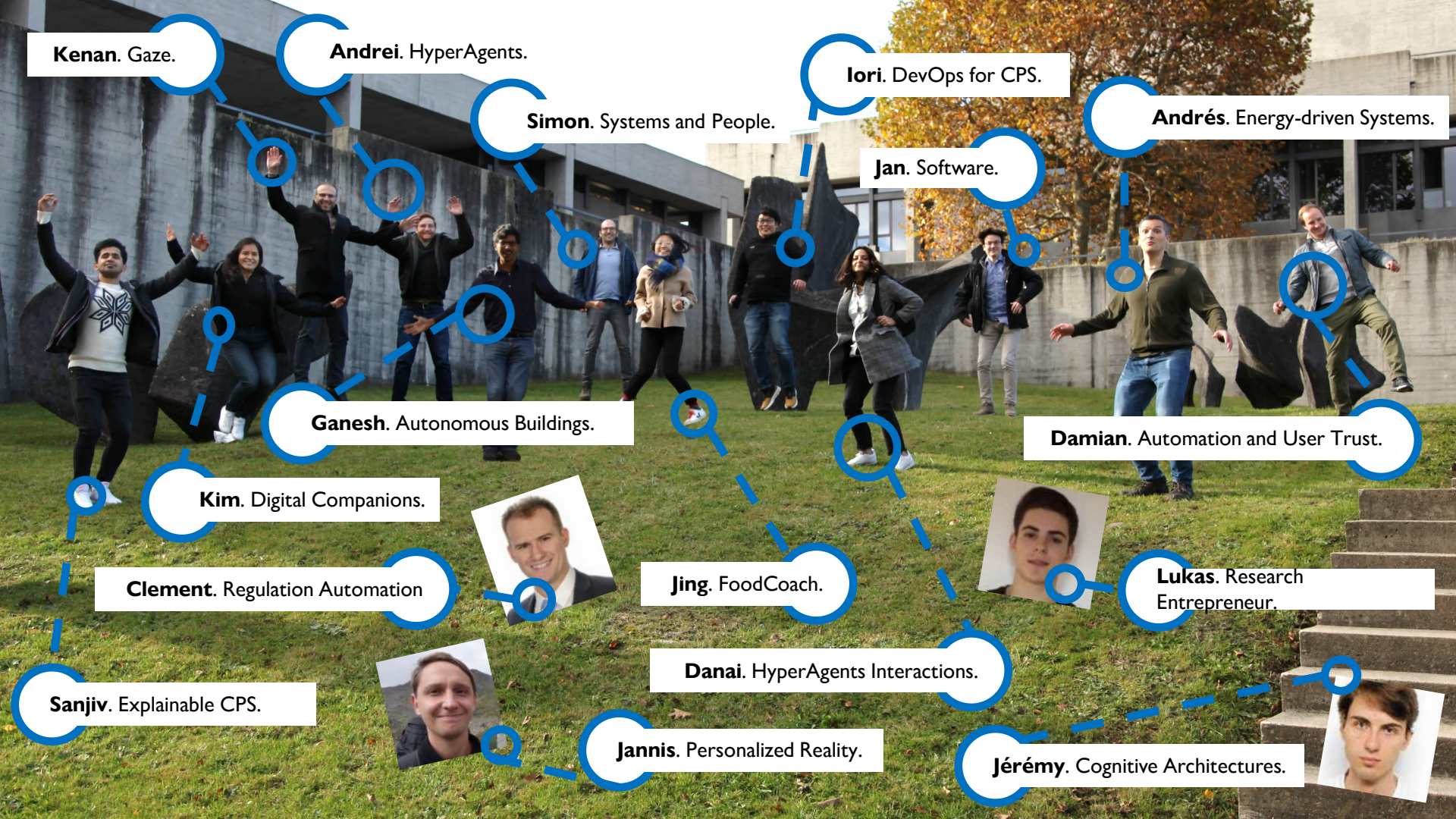
University of St.Gallen



Interactions

interactions.ics.unisg.ch

Pervasive Computing with a focus on **autonomy, interoperability,**
and on **human/system interactions** and **relationships**


Kenan. Gaze.
Andrei. HyperAgents.
Simon. Systems and People.
Iori. DevOps for CPS.
Andrés. Energy-driven Systems.
Jan. Software.
Ganesh. Autonomous Buildings.
Damian. Automation and User Trust.
Kim. Digital Companions.
Clement. Regulation Automation
Jing. FoodCoach.
Lukas. Research Entrepreneur.
Danai. HyperAgents Interactions.
Sanjiv. Explainable CPS.
Jannis. Personalized Reality.
Jérémy. Cognitive Architectures.

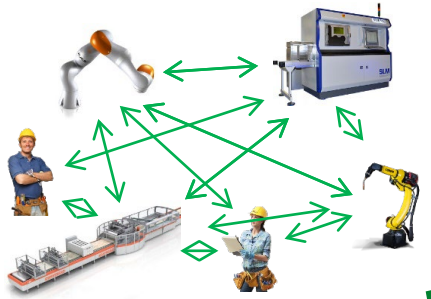
Interactions: Topics

Systems and People in Ubiquitous Computing Environments

- Novel user interfaces for pervasive computers
- Pervasive nutrition and health support
- Explainability and Reasoning in Ubiquitous Computing Environments
- User trust in pervasive computing systems
- Legal context of ubiquitous computing

World-Wide Autonomous Systems

- Hypermedia Multi-Agent Systems
- Interactions of Autonomous Agents with each other and their environment
- Embedded and low-power autonomous agents
- Interoperable and autonomous Web of Things systems



Interactions: Recent Publications

Systems and People in Ubiquitous Computing Environments

- Right to Customization: Conceptualizing the Right to Repair for Informational Privacy. Annual Privacy Forum 2021
- The Effect of a Future-Self Avatar Mobile Health Intervention. Journal of Medical Internet Research 2022
- An Overview of the Explainability of Cyber-Physical Systems. FLAIRS 2022
- SOCRAR: Semantic OCR through Augmented Reality. IoT 2022
- Human-Like Movements of Industrial Robots Positively Impact Observer Perception. Journal of Social Robotics 2022
- GEAR: Gaze-enabled augmented reality for human activity recognition. ACM ETRA 2023

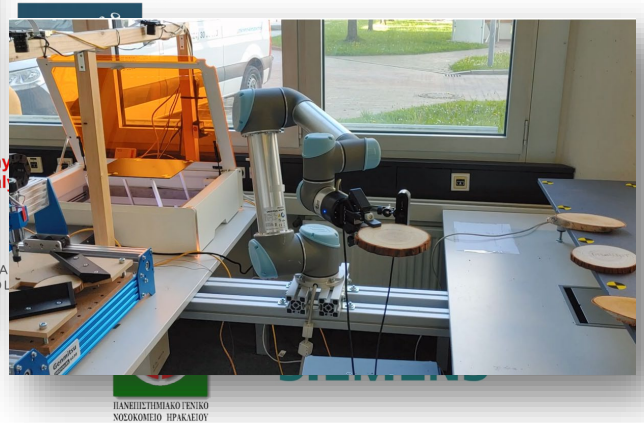
World-Wide Autonomous Systems

- A Decade in Hindsight: The Missing Bridge Between Multi-Agent Systems and the World Wide Web. AAMAS 2019
- Increasing the Intelligence of Low-Power Sensors with Autonomous Agents. SenSys 2022
- Semantic Knowledge for Autonomous Smart Farming. Agricontrol 2022
- Signifiers as a First-class Abstraction in Hypermedia Multi-Agent Systems. AAMAS 2023

Talk Abstract

In the **IntellIoT Project** (https://intelliot.eu/), we used W3C WoT TD for **integrating Web-enabled industrial devices and Autonomous Agents within Multi-agent Systems**

We successfully deployed two use cases: **Autonomous Agriculture** and **Industrial Manufacturing**



Drive **Interoperability**!

Enable **Decoupling**!

Enable **Autonomy**!

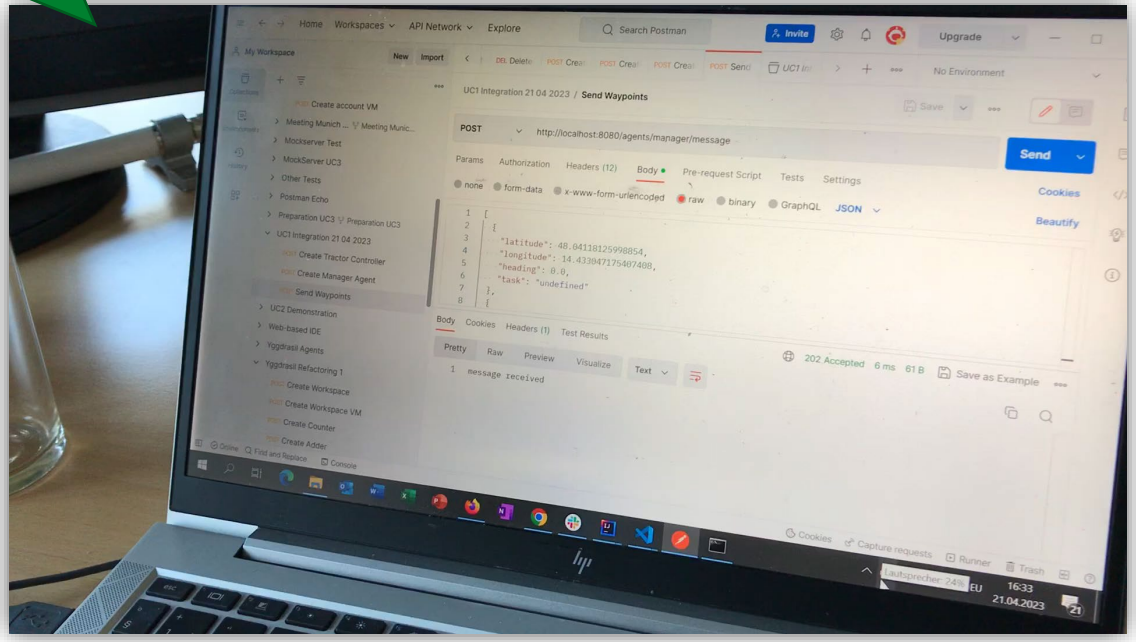
An **autonomous agent** drives a tractor **through W3C WoT TD**

Things expose WoT TDs (tractor controller, waypoint service, AI service, journaling service, human-in-the-loop service,…)

TDs are exposed via yggdrasil, a **platform for agents and artifacts**

TDs are discovered by a **no-code development environment.** A domain expert **programs an agriculture agent** to achieve operator goals

An **operator issues goals** (“Harvest field 5”) at run time using a domain-specific interface



All IntellIoT TDs: https://github.com/Interactions-HSG/example-tds/tree/intelliot/tds
Tractor TD: https://github.com/Interactions-HSG/example-tds/blob/intelliot/tds/tractor_controller.ttl
Example TD on yggdrasil: https://yggdrasil.interactions.ics.unisg.ch/environments/61/workspaces/102
Paper on no-code Development Environment (EMAS 2022): https://emas.in.tu-clausthal.de/2022/papers/paper3.pdf
Extended abstract on architecture (AAMAS 2023): https://www.alexandria.unisg.ch/269570/

An **autonomous agent** manages a robot **through W3C WoT TD**

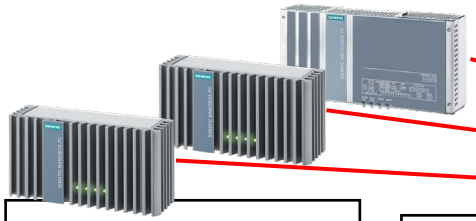
Things expose WoT TDs (robot controller, engraver, grabspot service, journaling service, human-in-the-loop service,…)

TDs are exposed via yggdrasil, a **platform for agents and artifacts**

TDs are discovered by a **no-code development environment.** A domain expert **programs a manufacturing agent** to achieve operator goals

An **operator issues goals** (“Engrave the text IntellIoT at location x/y”) at run time using a domain-specific interface

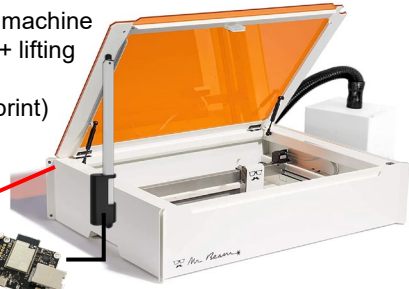
All IntellIoT TDs: https://github.com/Interactions-HSG/example-tds/tree/intelliot/tds
Robot TD: https://github.com/Interactions-HSG/example-tds/blob/intelliot/tds/uc3_robot.ttl
Example TD on yggdrasil: https://yggdrasil.interactions.ics.unisg.ch/environments/61/workspaces/102
Paper on no-code Development Environment (EMAS 2022): https://emas.in.tu-clausthal.de/2022/papers/paper3.pdf
Extended abstract on architecture (AAMAS 2023): https://www.alexandria.unisg.ch/269570/



Industrial Edge infrastructure (HW+SW) - Siemens Industrial Edge Apps (HSG, Eurecom, UOULU, AAU, TSI, Siemens)

Security Assurance Platform (HW?) - SANL+TSI

Laser Engraver machine (Laser cutter) + lifting table +SW (Octoprint)



ESP32 Ethernet Brick to control cover, start button

5G infrastructure (HW+SW) - Eurecom

TSN infrastructure (Controller + switches) - Siemens and TTTech

"Machine Controller" HW (Microbox PC + TTTech NIC)

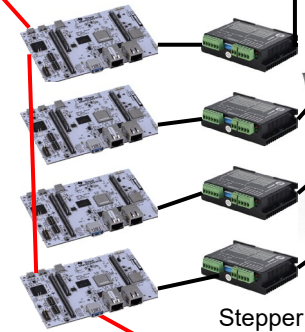
AR Infrastructure - Hololight

Industrial camera

PC UR5 Controller

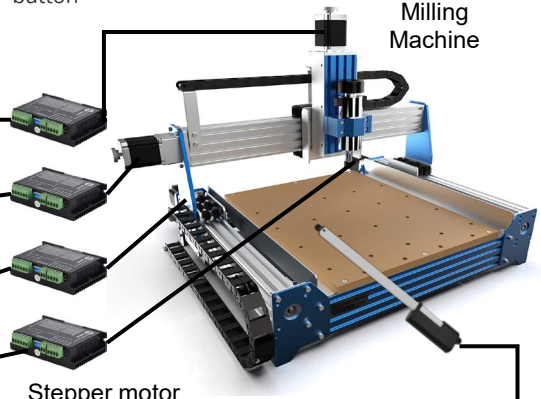
UR5 Robot

Industrial Edge Orchestrator (min 32GB RAM)



Eval boards for controlling 4 motors of Milling machine + SW

Milling Machine



Stepper motor drivers

ESP32 Ethernet Brick

actuators for fixing workpiece

University of St.Gallen

2023. 04. 28.

Talk Abstract

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We successfully deployed two use cases: **Autonomous Agriculture** and **Industrial Manufacturing**

I cover these core components and approaches:

1. Management of W3C WoT TDs in the **Yggdrasil Hypermedia MAS Infrastructure**
2. W3C WoT TD-based **No-Code Development for Multi-agent Systems**
3. **W3C WoT TD Negotiation** for lazy deployment and binding of edge services
4. W3C WoT TD-based Journaling of Agent-Artifact Interactions
5. W3C WoT TDs in the context of Affordance Theory

Drive **Interoperability**!

Enable **Decoupling**!

Enable **Autonomy**!

(similar for the Agriculture use case)

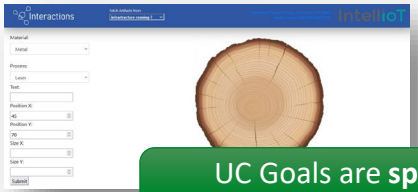
Interactions of Agents with Devices are **journaled** in a DLT

Some services are only **deployed lazily** / some device interfaces only **become bound at run time**

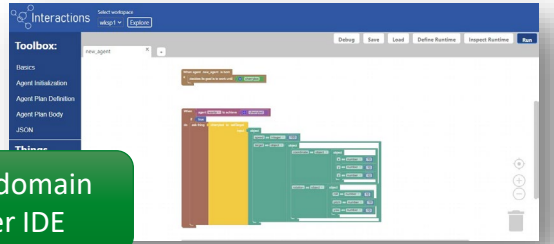
The Agents **interact with** Things/Services/Artifacts including Tiny Devices

The Agents **run** here

Devices and Services **register** here

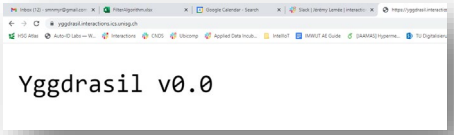


UC Goals are **specified** through a dedicated Web front end per Use Case



The Agents are **configured** by a domain engineer in a no-code end-user IDE

Aspect #1: Management of W3C WoT TDs in the **Yggdrasil Hypermedia MAS Infrastructure**



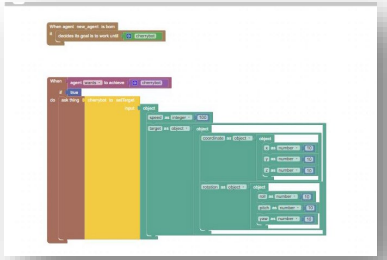
https://www.alexandria.unisg.ch/256718/

- Supports creation of **Hypermedia Multi-Agent Systems** following the JaCaMo meta-model
- Supports the execution of computational artifacts, allows agents to instantiate artifacts, exposes HTTP interfaces for interacting with the artifacts, and generates W3C WoT TDs for the instantiated artifacts
- Yggdrasil-internal artifacts are complemented by W3C WoT TDs for **external devices or services**
- Resulting hypermedia environment is represented in RDF
- Infrastructure is compatible with a search engine for the W3C WoT

https://link.springer.com/article/10.1007/s00779-020-01415-1

Proposal: Yggdrasil can be a blueprint for W3C WoT TD-based systems that may include Autonomous Agents

Aspect #2: W3C WoT TD-based **No-Code Development for Multi-agent Systems**

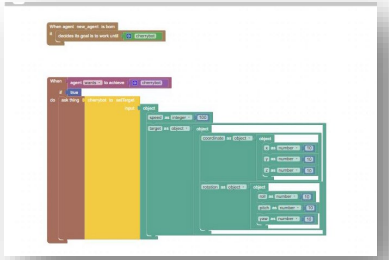


- W3C WoT TD-based **visual programming system for agents** (AgentSpeak language)
- Configure and deploy Hypermedia Multi-agent Systems (extended to MAS organizations)
- Block language based on Blockly. Functional blocks are **automatically generated** from W3C WoT TDs
- **Web-based IDE fetches W3C WoT TDs from Yggdrasil and generates functional blocks**
- Configured agents are **deployed** to Yggdrasil
- Agent behaviors can be implemented against W3C WoT TD affordances while **resolving protocol binding only at run time**

Proposal: This Web-based Agents IDE can be used to create agents based on W3C WoT TD

https://emas.in.tu-clausthal.de/2022/papers/paper3.pdf

Aspect #2: W3C WoT TD-based **No-Code Development for Multi-agent Systems**



Agent-Oriented Visual Programming for the Web of Things

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Danai Vachtsevanou [2] Jeremy Lemee [2] Andrei Ciortea [2]
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27th April, 2022

https://emas.in.tu-clausthal.de/2022/papers/paper3.pdf

Aspect #3: W3C WoT TD Negotiation

- Partners desire deploy services/things **as late as possible for optimization of industrial edge** (“Edge Orchestration”)

- Usage of W3C WoT TD Templates (W3C WoT TD Version 1) and **W3C WoT Thing Models** (W3C WoT TD Version 1.1) for permitting late binding of edge-orchestrated services

- **IntellIoT Edge Orchestrator** emits W3C WoT Thing Models (i.e., Thing Descriptions without protocol binding)

- Agents are programmed (using the Web IDE) **against these Thing Models**

- Deployed agents request services from Edge Orchestrator. EO supplies protocol-bound W3C WoT TD

Proposal: W3C WoT TD Negotiation
- Parameters of machine-learning systems (capabilities)
- Security parameters
- **Any non-functional parameter of a service/thing can be used in this sense**

Aspect #4: W3C WoT TD-based Journaling of Agent-Artifact Interactions

- Implementation of prototype for **journaling of W3C WoT TD-based interactions** in a distributed ledger
- Purpose: Monitoring, auditing, root-cause analysis, possibly payments
- Recording of concrete exchanged messages (according to TD-binding)
- Recording of the service descriptions that are effective at run time
- In IntellIoT implemented using a distributed ledger; any other (trusted) journaling infrastructure may be used

Aspect #5: W3C WoT TDs in the context of Affordance Theory

https://www.alexandria.unisg.ch/269015/

- Collaboration with the HyperAgents project https://hyperagents.org/
- Investigation of **Affordance Theory** in the context of the guidance of interactions of autonomous hypermedia clients
- Introduction of **signifiers as a first-class abstraction** in Web-based MAS
- Differentiation between signifiers and affordances to allow **run-time adaptation of exposed IDLs**
  - To agent goals
  - To agent abilities (including cognitive abilities)
  - To agent … ?

Listing 3: A customized signifier for agents that implement a BDI architecture based on the PRS.

```
...
<#sig> a hmas:Signifier ;
 hint:signifies <#close-gripper> ;
 hint:recommendsAbility [ a prs:PRSAbility ] ;
 hint:recommendsAbility [ manu:OperatorAbility ] ;
 hint:recommendsContext <#env-context>, <#prs-context> .

<#prs-context> a hint:Context; sh:targetClass hmas:Agent ;
 sh:property [ sh:path prs:hasDesire ;
  sh:minCount 1 ; sh:qualifiedMinCount 1 ;
  sh:qualifiedValueShape <#desire-shape> ] .

<#desire-shape> a sh:NodeShape ;
 sh:class manu:PickAndPlace;
 sh:property [ sh:path prs:hasInputList
    ... ] .

<#item-shape>  a sh:NodeShape ;
 sh:class manu:Item ;
 sh:property [ sh:path manu:hasLocation ;
   ... ] .

<#location-shape> a sh:NodeShape ;
 sh:class manu:Location ;
 sh:property [ sh:path manu:inRangeOf ;
  sh:minCount 1 ;
  sh:hasValue ex:leubot ] .
```

Listing 4: A customized signifiers for agents with a STRIPS planning ability.

```
@prefix pddl:
<http://www.cs.yale.edu/homes/dvm/daml/pddlonto.daml#>.
...
<#sig> a hmas:Signifier ;
 hint:signifies <#close-gripper> ;
 hint:recommendsAbility [
  a strips:StripsPlanningAbility ] .

<#close-gripper> a hint:ActionSpecification;
...
 a a pddl:Action ;
 pddl:action-label "closeGripper";
 pddl:parameters [ a pddl:Param_seq ;
  rdf:_1 <#param1> ];
 pddl:precondition [
  ... ] ;
 pddl:effect [
  ... ] .

<#param1> a pddl:Param ;
 pddl:name "?gv" ;
 drs:type manu:GripperValue ;
 :hasSchema <#gripper-schema> .
```

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Drive **Interoperability**!

Enable **Decoupling**!

Enable **Autonomy**!

I introduce the new W3C Community Group on **Autonomous Agents on the Web** (https://www.w3.org/community/webagents/)

Towards World-Wide Autonomous Systems

Autonomy of different components in IoT systems is becoming **more and more relevant across domains**!

Traditionally fragmented communities (Web of Things, Web Architecture, Autonomous Agents, Multiagent Systems, Semantic Web)

Dagstuhl Seminar and new **W3C Community Group on Agents on the Web** integrates these communities

Let's join forces to drive interoperability and autonomous behavior on the Web of Things!

https://www.w3.org/community/webagents/

https://www.dagstuhl.de/en/seminars/seminar-calendar/seminar-details/23081