

Human Control in Daily Environment Automations

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Consiglio
Nazionale
delle Ricerche

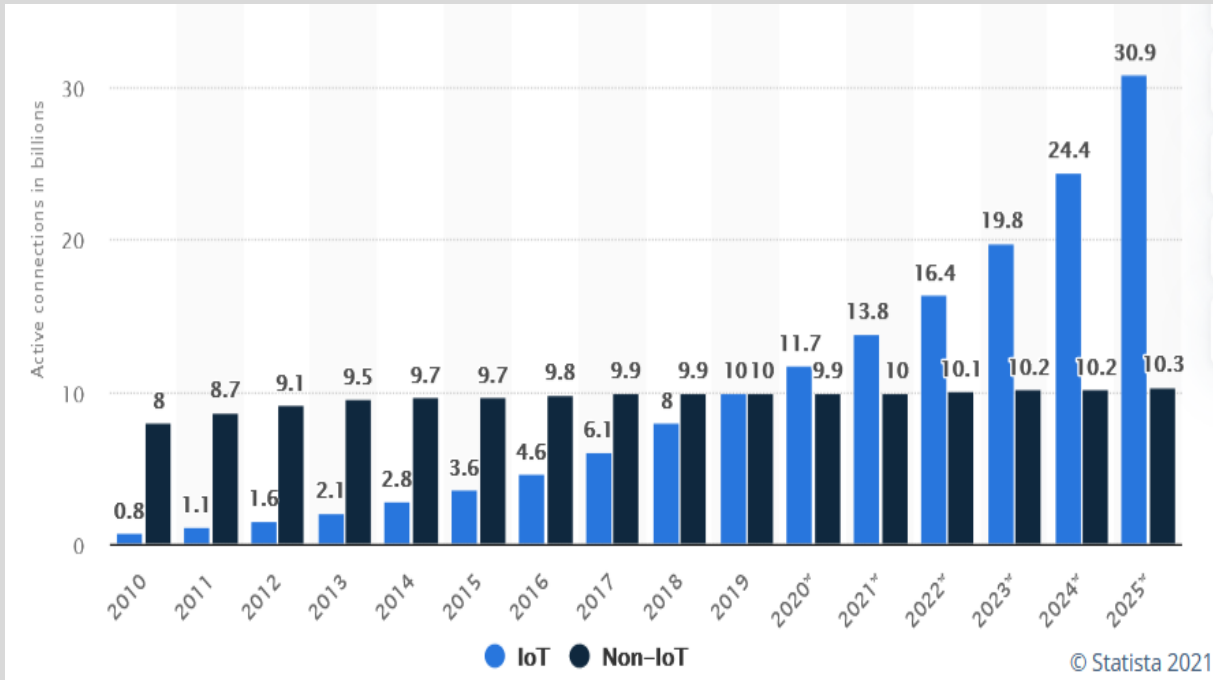


ISTITUTO DI SCIENZA E TECNOLOGIE
DELL'INFORMAZIONE "A. FAEDO"



Technological trends in the digital world

Examples of IoT connections include connected cars, smart home devices, and connected industrial equipment, non-IoT connections include smartphones, laptops, and computers



Recent statistics suggest that there are currently: over 258 million “Smart Homes” worldwide
40% of US households have adopted some Smart Home technology

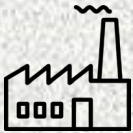
Examples of possible daily automations



- In a store, automations for sending personalized ads to customers' smartphones based on the movements and interactions with store products



- In an older adult residence, automations for sending personalized messages to the older adult to promote healthy behaviour: for example, a warning on the preferred device (eg TV) to encourage them to exercise more, based on the activities detected in the morning



- In an industrial site, automations to activate safety alerts to workers on their smartwatch based on the dynamic presence of some potentially dangerous equipment

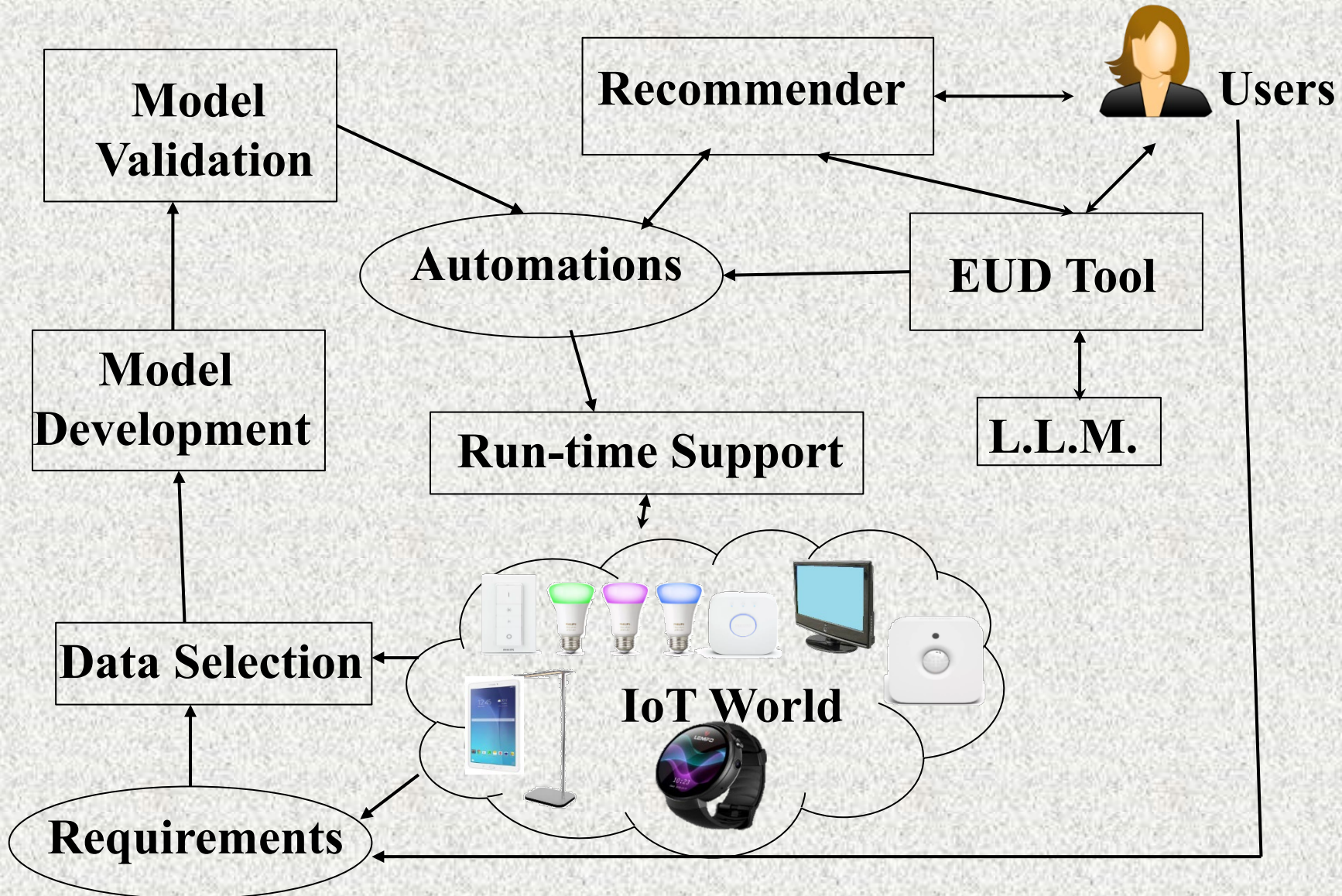


- In an interactive learning system, automations can personalise course material presentation based on real-time info on user's knowledge, emotional state and level of attention

Internet of Things & Artificial Intelligence

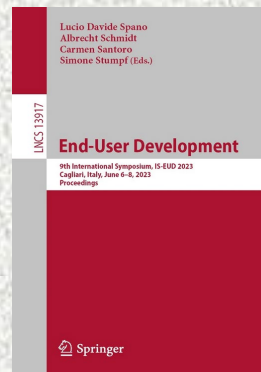
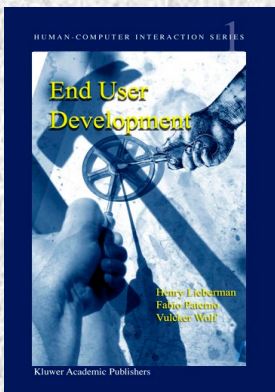
- Great opportunities, new possibilities
- but there are also risks and new problems
 - There can be intelligent services that eventually generate actions that do not match the real user needs
 - The introduced automations can generate unwanted effects
 - People may have difficulties in understanding how to drive the automatically generated automations
- How to design and provide tools that allow people to control and configure smart environments consisting of hundreds of interconnected devices, objects, and services ?
- Tools that allow us to obtain "*humanations*"
 - *automations that users can understand and modify*

People Role in Daily Automations Creation



End-User Development

- Easy to use is not enough for obtaining human control !
- In automated environments sometimes there is a need for human intervention
- End User Development is a set of methods, techniques, and tools that allow people who are not professional developers to create or modify a software system
- For example low-code programming models (citizen developer is an amateur programmer) see recent paper on Communication of ACM
- End users often do not have algorithmic approaches to problem solving
- Various generations of contributions based on main technological trends over time, the last generation is EUD at the IoT+AI time



**Next IS-EUD Symposium in
Munich 16-18 June 2025 !
<https://iseud2025.ubicomp.net/>**

Trigger-Action Programming

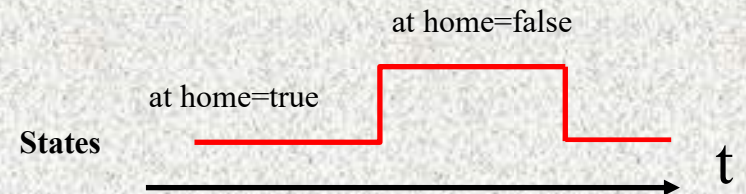
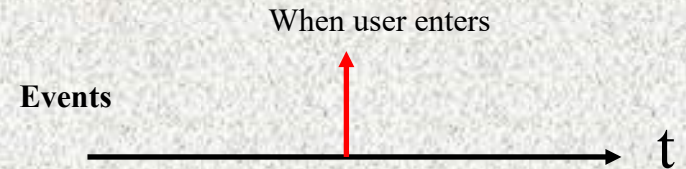
- Useful connection point between the wide variety of technologies and implementation languages considered and people without programming experience
- Personalization rules: when something happens (trigger) something must be done (action)
- They do not require particular algorithmic skills or knowledge of complex programming structures



- Dealing with temporal aspects associated with triggers and actions that may not execute as the user expects
- Configuring smart environments with multiple active automations with unexpected effects
- Security and/or privacy issues from the resulting automations

Time needs to be carefully considered !

- An event happens in a point in time (a state change or given time):
 - when user enters a room,
 - when it starts to rain,
 - when kitchen temperature exceeds 30 degrees,
 - at 8 o'clock
- A condition is a state that lasts for a longer period of time:
 - while user is inside a room,
 - as long as it's raining,
 - if kitchen temperature is over 30 degrees,
 - between 8:00 and 11:30



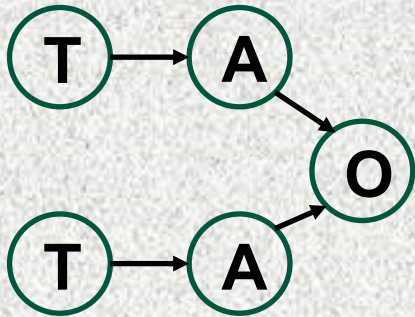
These two rules have different effects:

- When I get home the bell rings
- If I'm at home the bell rings

Time needs to be carefully considered !

- Use of explicit different representations to help users to differentiate them !
- The term “when” couples with the idea of an exact point in time in which the change of state occurs
- The terms “if” or “while” better indicate the Boolean condition to be checked
- Also actions can have different temporal dimensions:
instantaneous, prolonged, sustained
- Temporal aspects must be considered when composing elements for an automation, e.g. avoid composing :
 - two events with AND operator
 - or condition trigger and instantaneous action (e.g. if I am at home send a message to John)

Possible problems with multiple automations

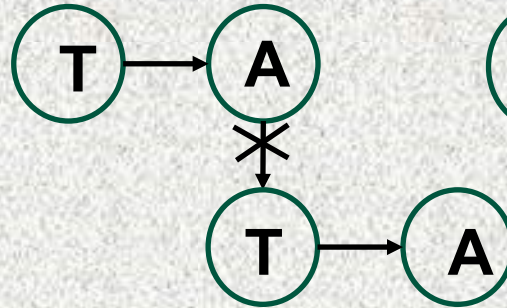


Rule Conflict

Rule 1 "when there's smoke in the kitchen, open the window"

Rule 2 "if it's dark outside, close the window."

What happens when there is something burning in the oven and it is night ?

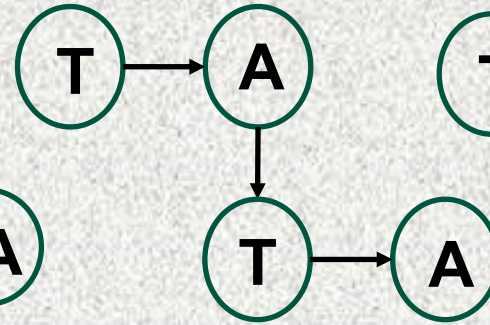


Rule Prevention

Rule 1 "if no one is home, turn off the smart plugs"

Rule 2 "when it's 10 a.m., turn on the animal feeder."

If the pet feeder is powered from one smart outlets and nobody is home at 10AM, the pet will not be fed !

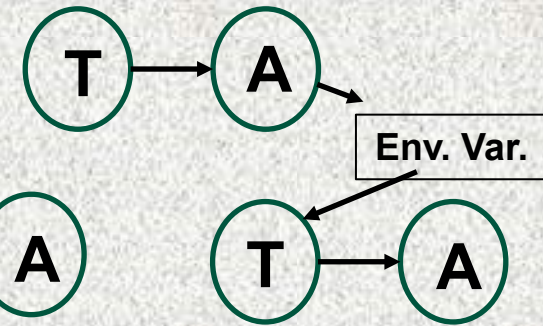


Direct Rule Chain

Rule 1 "when there is a gas leak open the window"

Rule 2 "when you open the window turn off the heating".

After the first rule, the second is immediately carried out, even if it was not the expected behavior



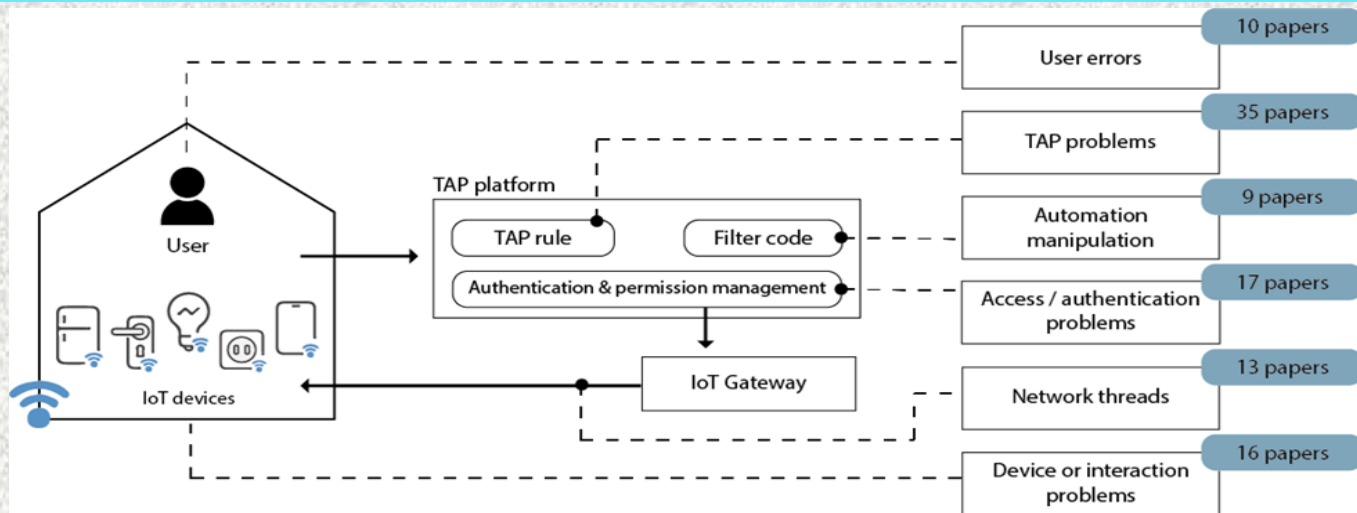
Indirect Rule Chain

Rule 1 "if the temperature in my room is below 20°C, turn on the heating in my room"

Rule 2 "if the temperature in my room is above 25°C, open the window".

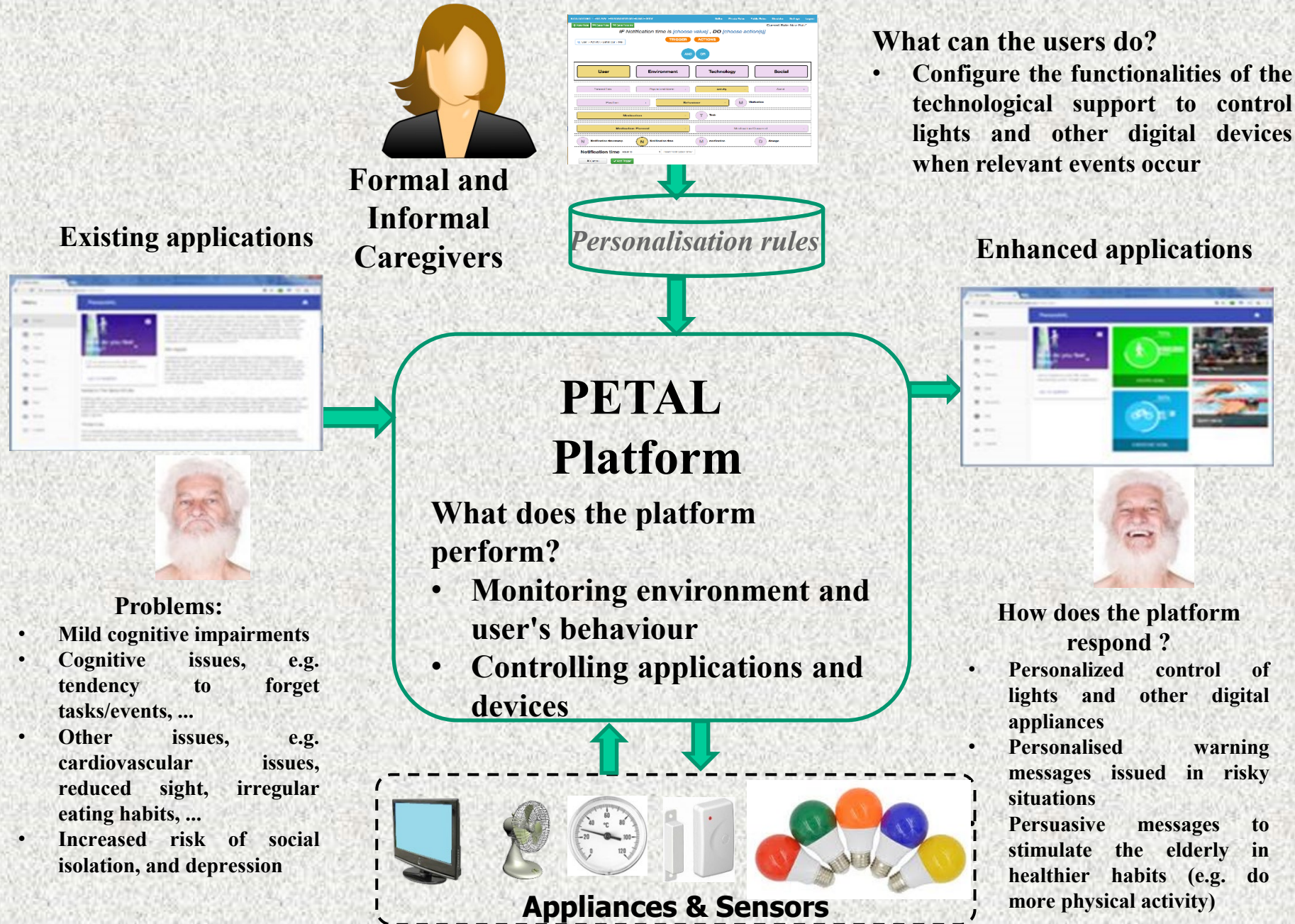
After executing the first rule, the temperature might rise above 25C and activate rule 2, which can cause the window open unexpectedly

Privacy and Security Issues



- **Object or interaction problems**, which can lead to miscommunication between the user and the object, causing unintended actions or leaving the system open to external attacks
- **Network sniffing** by monitoring the state of a network and the traffic of IoT devices connected to it, it might be possible *for an attacker to detect the state of connected devices, identify patterns to predict user routines and speculate on the user state remotely* (e.g. it's highly possible that a house is empty when the air conditioner and lights are off) or acquire personal user data by manipulating communication between the TAP and the IoT devices.
- **Privilege escalation attack**: *An adversary can leverage a mistakenly granted permission* caused by an over-privileged vulnerability on the TAP platform, for accessing the IoT devices that the adversary is not supposed to access.
- **Malicious automation**: *An adversary who is experienced in TAP development may create a malicious TAP rule* for leaking sensitive user data or manipulating the settings of IoT devices (e.g. unlocking the door overnight)
- **Rule logical attack**: An adversary who is experienced in IoT automation programming and is *capable of manipulating the TAP rules made by the victim* could possibly insert a known logical error in the TAP rules to harm the user, to cause damage in the physical environment, or to facilitate a real-world crime. (e.g. uploading personal pictures in the wrong server)
- **Unintentional rule logical attack**: when the TAP rules made by the user include a logical error that could possibly harm the user or cause damage in the physical environment where the IoT devices are deployed.

Daily Automations in Real World: AAL



What can the users do?

- Configure the functionalities of the technological support to control lights and other digital devices when relevant events occur

Examples rules execution in home



Experiences in AAL Projects and Trials

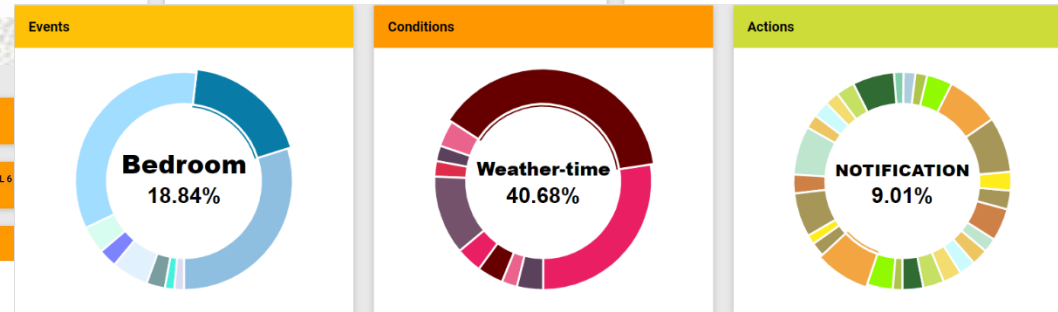
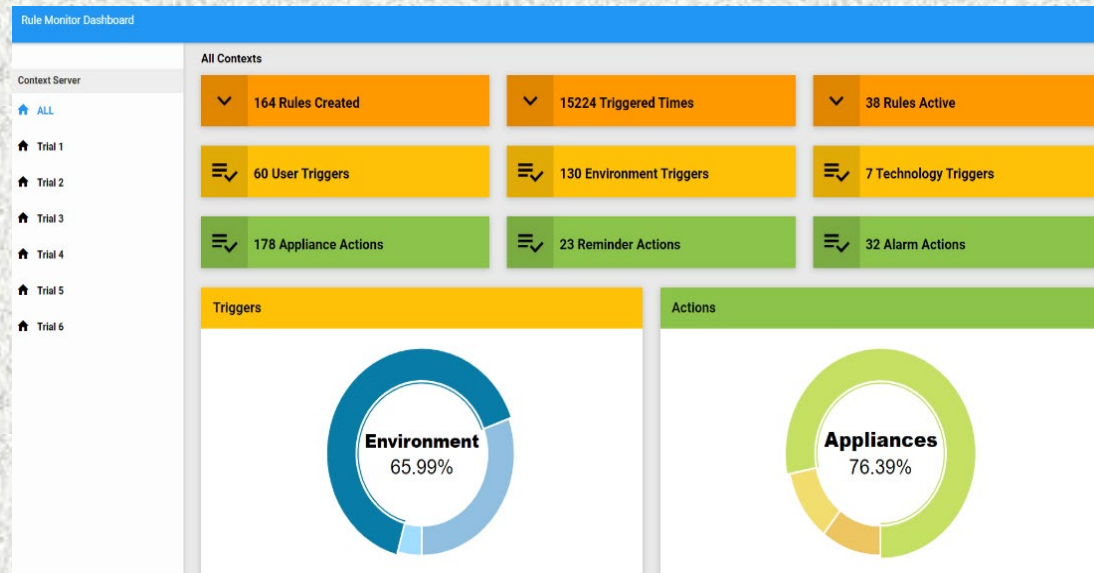
Remote Monitoring of End-User Created Automations in Field Trials M.Manca, F. Paternò, C.Santoro, Journal of Ambient Intelligence and Humanized Computing, 2022



- **Safety.** WHEN the user falls down AND then it does not move for one minute DO send a text message to the caregiver
- **Comfort.** WHEN move from bedroom AND IF time is between 11 p.m. and 6 a.m. DO turn on lights to go to the bathroom
- **Wellbeing.** IF the training time is less than 30 minutes AND WHEN the time is 6 p.m. DO send a reminder
- **Health.** WHEN NOT(taken medicine) between 08:00 and 09:00 DO send one alarm by text to caregiver
- **Energy saving.** IF user is in bed AND time is between 11:00 p.m. and 06:00, DO turn off all lights in the bedroom
- **Socialization.** If tomorrow's forecast is good DO remind the user to call a friend to plan for a walk together tomorrow

Supporting Remote Analysis/Monitoring

- # Created Rules
- # Active Rules
- How many times rules have been triggered
- Distribution of occurrence of trigger types in the set of created rules
- Distribution of occurrence of action types in the set of created rules
- Time interval when the rules have been active



Trigger Events

User		
User Name	Context Attribute	Number
Test-user	Heart Rate	8
	Time Inside Bathroom	6

Environment		
Env Name	Context Attribute	Number
Bedroom	Motion	23
	Temperature Level	3

Trigger Conditions

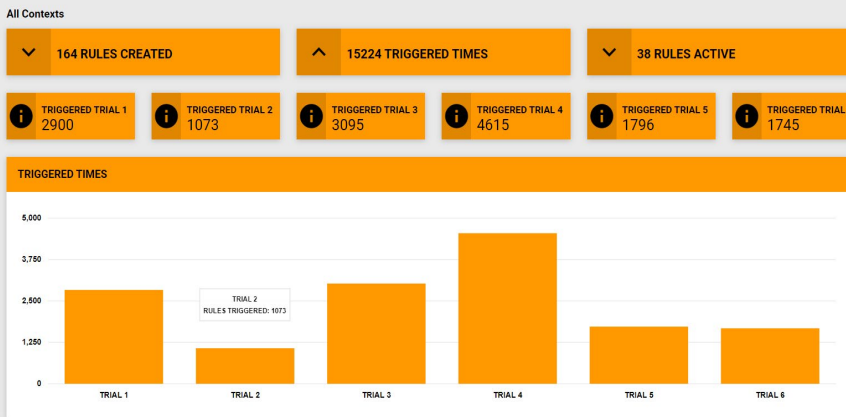
User		
User Name	Context Attribute	Number
Test-user	Point Of Interest	7
	Training Time	1

Environment		
Env Name	Context Attribute	Number
Weather-time	Local Time	20
	Local Date	4

Actions

Appliances		
Target	State	Number
Corridor Light Color state	on	7
Corridor Light Color color	Dark Orange	1

Reminders		
Target	Recipient	Number
NOTIFICATION		17
SMS	+1234567890	2



Dynamic Information on Rule Execution

Rules (select one to get more information)

Show 5 entries

Search: _____

Rule Name	Natural Language	Context	App Name	User Name	Triggered Times	Creation Date	is Active?
Motion During Night	WHEN Bedroom motion sensor becomes active AND IF time is between 22:00 AND 06:00, DO Turn on the Light Strip in the Corridor and set color to Orange for 5 minutes	context_trial_1	trial1	user01	41	2019-10-10 15:43:53	true
Reminder Aspirina	WHEN Time becomes 14:52 minutes, DO send one	context_trial_2	trial2	user02	35	2019-10-08	false

Rules (select one to get more information)

Show 5 entries

Rule Name	Natural Language	User Name	Triggered Times
Motion During Night	WHEN Bedroom motion sensor becomes active AND IF time is between 22:00 AND 06:00, DO Turn on the Light Strip in the Corridor and set color to Orange for 5 minutes	user01	41
Reminder Aspirina	WHEN Time becomes 14:52 minutes, DO send one notification AND Turn on the Light Strip in the Corridor and set color to Red	user02	35
Time Inside Bathroom	WHEN user03 is inside the Bathroom for 5 minutes, DO send alarm	user03	1
Gas Leak	WHEN Kitchen Gas Leak sensor becomes active, DO notify the caregiver by notification	user04	0
Emotional Status	WHEN emotional state becomes sad, DO turn on the light AND set color to Red	user05	3

Rule Emotional Status

- Events >
- Conditions >
- Actions >
- When it has been triggered ▾

2019-10-08 14:52:38

2019-10-06 11:20:50

2019-10-01 16:32:00

17 OK

Rule Emotional Status Info

- Events >
- Conditions >
- Actions >
- When it has been triggered >
- Activation Intervals ▾

Start 2019-08-24 --- 10:52:33

End 2019-09-02 --- 17:05:13

Start 2019-09-12 --- 09:51:32

End 2019-09-12 --- 20:55:25

Start 2019-09-24 --- 12:30:57

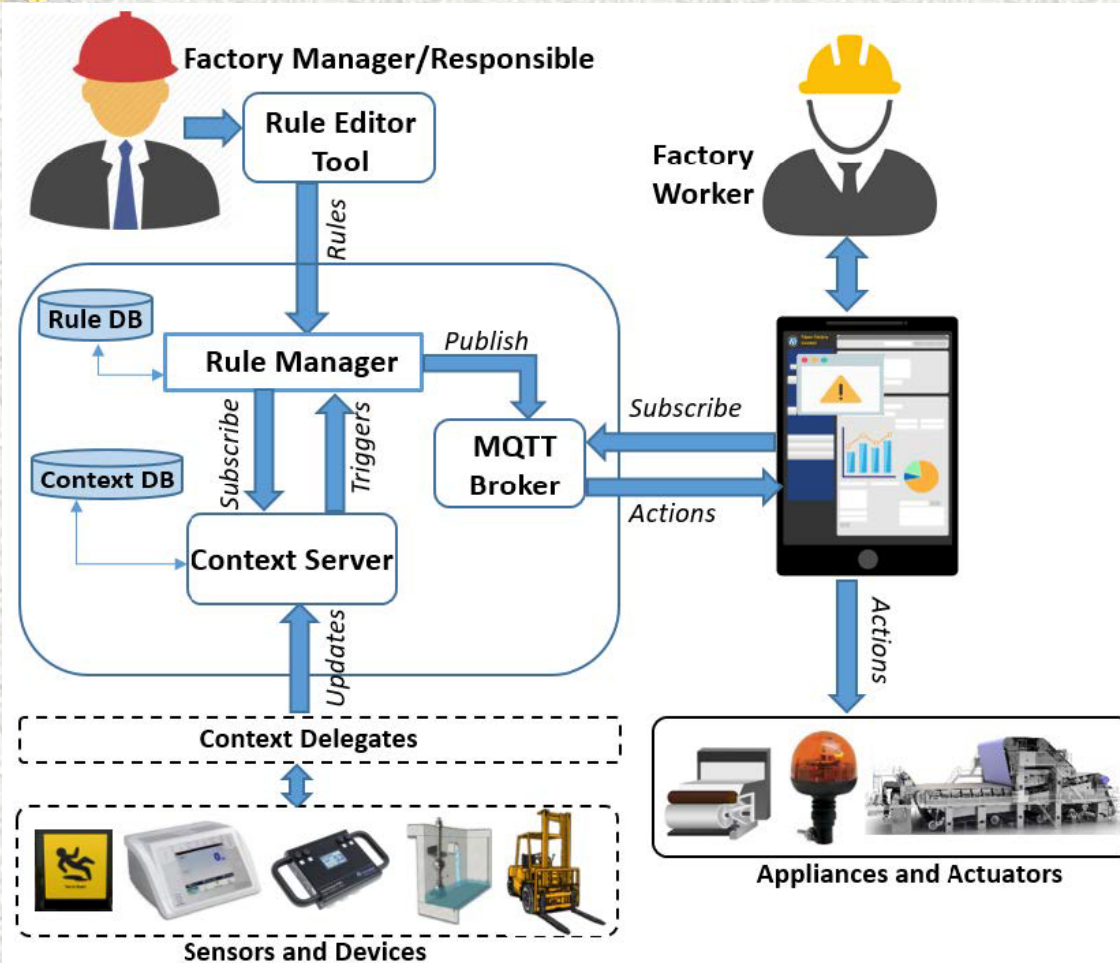
End 2019-09-30 --- 16:03:32

OK

Personalization in a Paper Factory



M Manca, F Paternò, C Santoro, End-user development in industrial contexts: the paper mill case study, Behaviour & Information Technology, 2022,



- **Goals:**
- Efficiency
- Safety of workers
- Quality of production
- Predictive Maintenance

When and What Explaining in Automations

- Often an explanation is an answer to a question
- Typical questions in AI domains customised for trigger-action daily automations
- **Why/Why not**, which can be raised to explain why an automation is triggered or some automations are in conflict in a given context
- **What if**, to investigate whether changing some contextual attributes or some parts of the rule the automations considered would be triggered, or some specific goal would be achieved
- **How to still be this**, how to modify some parameters of the automation but still maintaining the current goal (e.g. home warm but with less energy consumption)
- **How to be that**, how to modify the considered configuration in terms of contextual values or automations in order to achieve some user goal (e.g. security or warming) or avoid conflicts

End-user Automation Debugging

M. Manca, F. Paternò, C. Santoro, L. Corc, Supporting end-user debugging of trigger-action rules for IoT applications, International Journal of Human-Computer Studies, 2019, Vol.123, 56-69

The screenshot displays the 'The AAL Personalization Rules Editor' interface. At the top, there is a navigation bar with 'Editor', 'Private Rules', 'Public Rules', 'Simulator', 'Settings', and 'Logout'. Below this is a toolbar with buttons for 'Save Context Profile', 'Load', 'Simulate Rule', 'Reset Simulator', and 'Conflict Analysis'.

The main configuration area is titled '- User' and is divided into several sections:

- Personal Data**: Includes 'Age' (value: 81) with a diagram showing a step function and 'BECOMES' transition.
- Physical and - Mental**:
 - Physical**: Includes 'Heart Rate' (value: Number) and 'Respiration Rate' (value: 29), both with similar diagrams.
- Activity**
- Position**: Includes 'Relative - Position' with 'Type of Proximity' (value: dropdown menu) and a similar diagram.

On the right side, the 'Rules List' shows five rules (R1-R5) with their descriptions and status indicators:

- R1** (Conflict): **IF** Age is more than 80 **AND WHEN** Respiration Rate becomes less than 30 br.pm, **DO** Turn Off Living Room light colored
- R2** (Conflict): **IF** Age is more than 80 **AND WHEN** Respiration Rate becomes more than 28 br.pm, **DO** Turn On and set Living Room light color to Snow
- R3** (Why Not?): **WHEN** Date becomes equal to sunday **AND IF** Temperature is more than 30 °C, **DO** Close All blinds in the house
- R4** (Why Not?): **WHEN** User leaves home, **DO** send alarm by sms to user
- R5** (Why Not?)

Explainable End-User Automation Debugging

The screenshot displays the 'The Personalization Rules Editor' interface. At the top, there is a navigation bar with 'Editor', 'Private Rules', 'Public Rules', 'Simulator', and 'Settings'. Below this, there are two buttons: 'Back to Simulator' and 'Simulate Rule'. The main area is divided into two sections: 'Context of Use' and 'Analysis of the selected rule'.

Context of Use:

- User**
 - Personal Data**
 - ✓ Age**: Set to 77. The condition is 'Is' (selected) and 'Becomes'.
 - Physical and Mental**
 - Physical**
 - ✓ Respiration Rate**: Set to 27. The condition is 'Is' (selected) and 'Becomes'.
 - + Environment**
 - + Technology**

Analysis of the selected rule

R2 [Edit] [Why Not?]

IF Age is more than 80 AND WHEN Respiration Rate becomes more than 28 br.pm , DO Turn On and set Living Room light color to Snow

Why Not?

- Because in the rule **Age** value is **more than 80** and in the context **Age** is set to **77**.
- Because in the rule **Respiration Rate** value is **more than 28** and in the context **Respiration Rate** is set to **27**.
- Because In The rule **Respiration Rate** refers to a **Event (Becomes)**, while in the context you have selected **Is (condition)**.

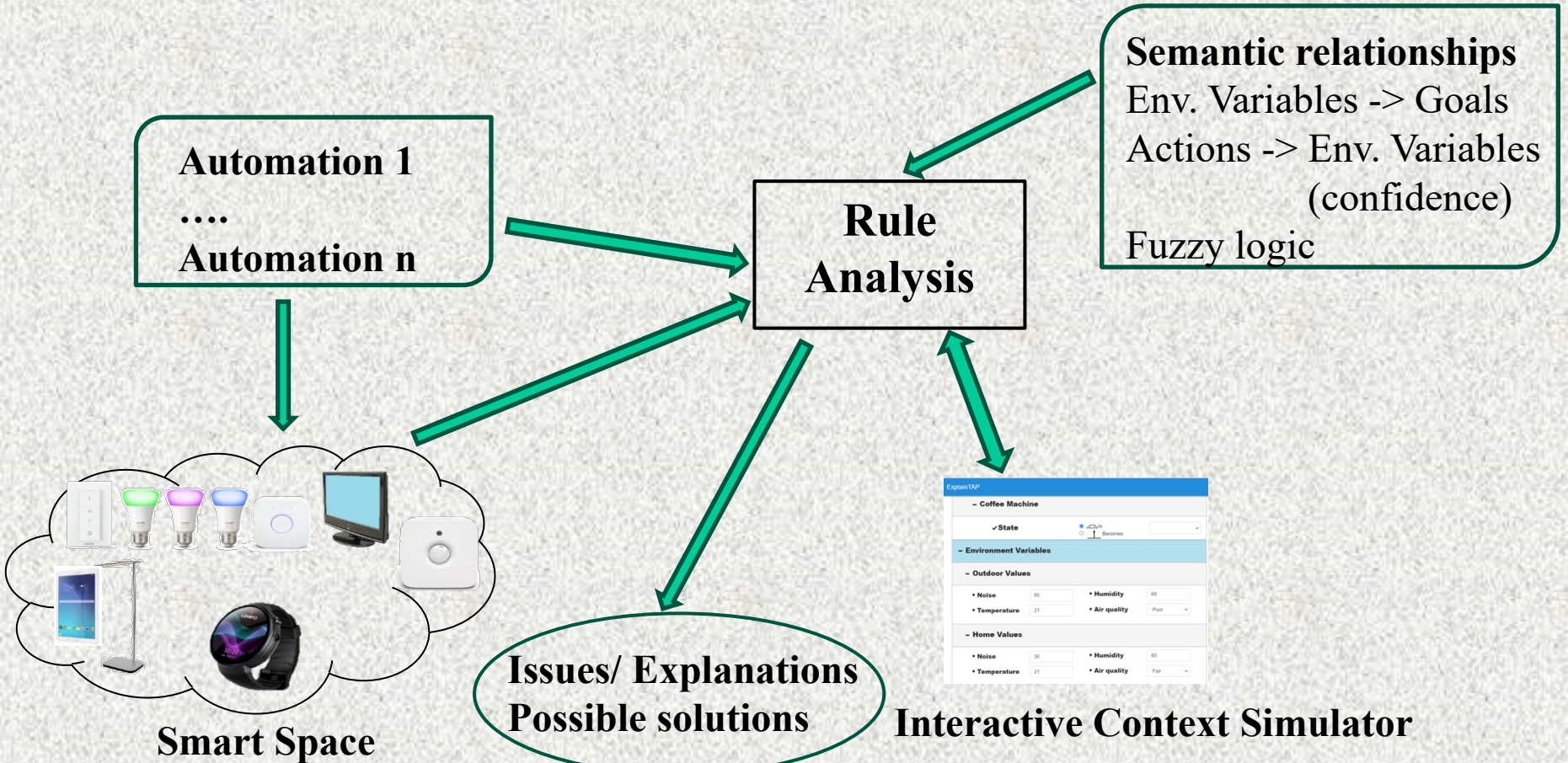
Issue: The specified rules could not result in the user's intended behaviour

How to support users:

- Rule execution in a simulated context of use (what/if)
- Why/Why Not explanations for interactive debugging
- Support for detecting and resolving conflicts between rules

ExplainTAP

Maenza, S., Mattioli, A., Paterno', F. (2024). An Approach to Explainable Automations in Daily Environments. In: Proceedings IHSI 2024



User

Suggestions For Your Goal "Well Being":

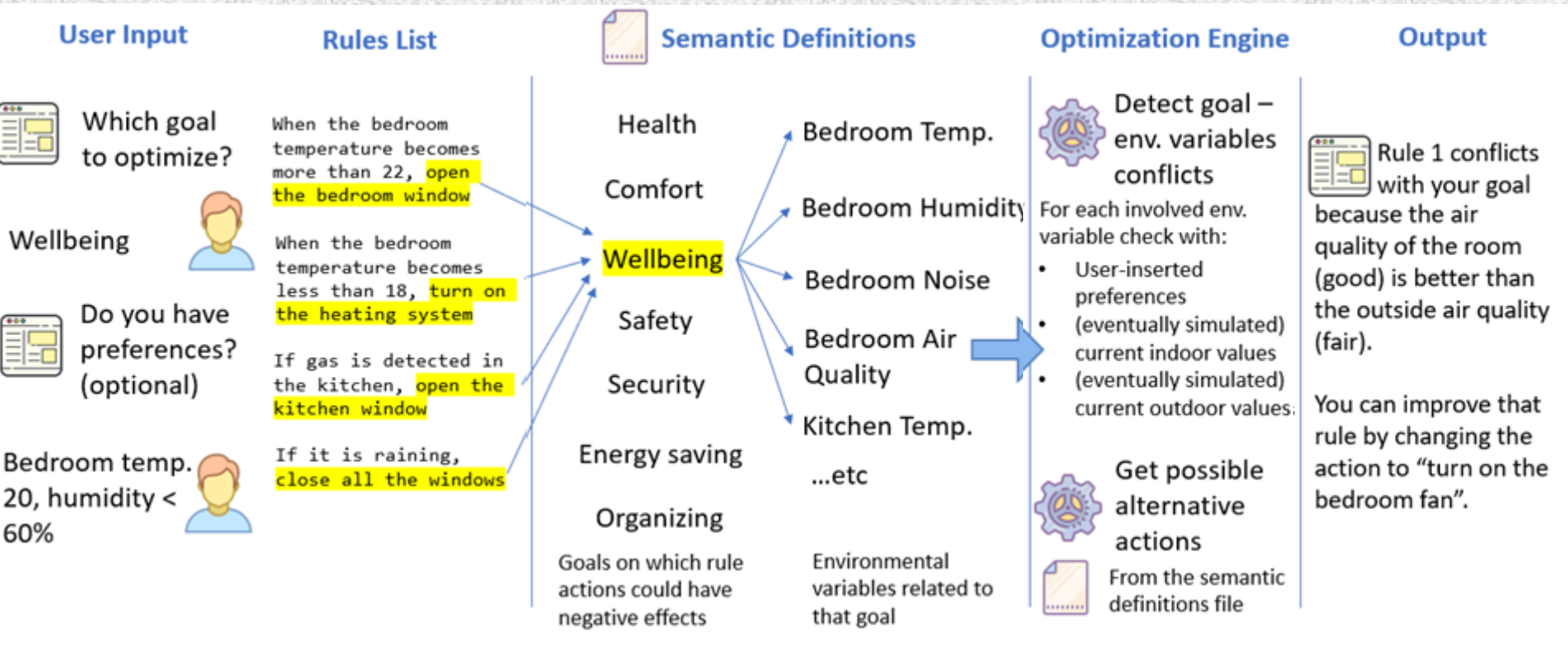
- rule2_Coffee
- rule3_OpenDoor
- rule6_MicrowaveOn
- rule7_TouchHumidity
- Living Room

The action of opening the window in the living room of the rule7_TouchHumidity may be problematic with the well-being goal because the external noise level (60) is more than the current living room noise level (30) and the external air quality (poor) is worse than the current living room air quality value (fair) and it does not protect against weather events.

- set on close all windows in the living room because the external noise level is more than the noise level inside the home and the external air quality value is worse than the current bedroom air quality value.

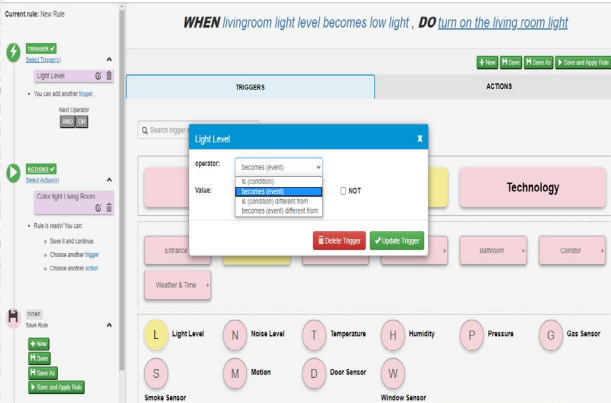
Goal-based Explanations with ExplainTAP

Project on End-User Development of Automations for Explainable Green Smart Homes
<https://giove.isti.cnr.it/eud4gsh/index.html>

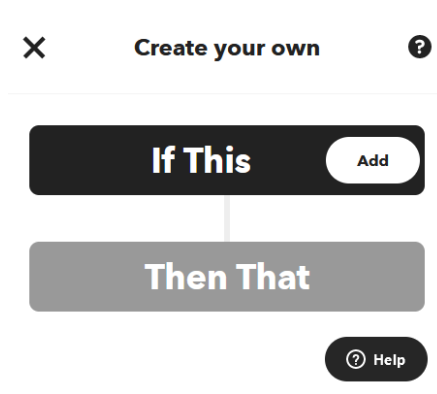


Current Practise: Visual Approaches

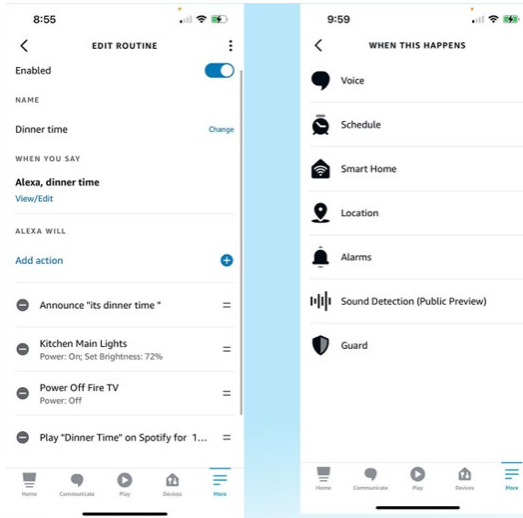
Wizard - TAREME



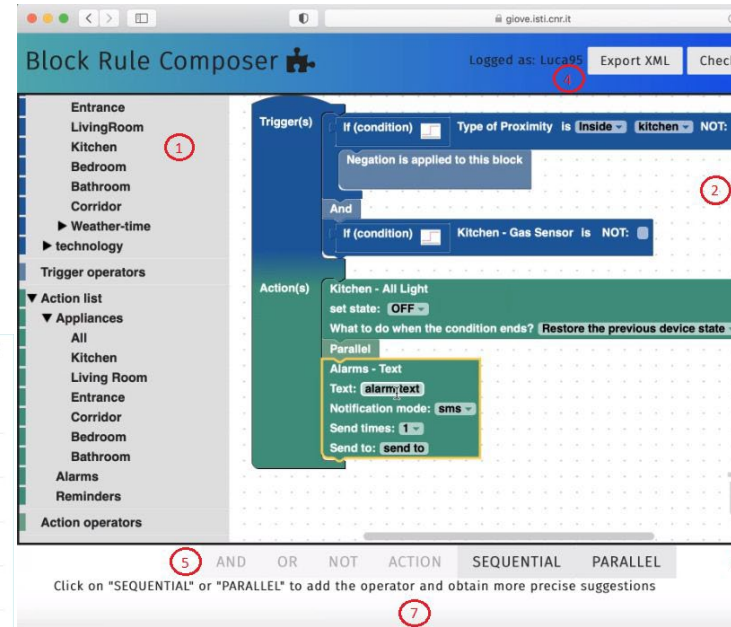
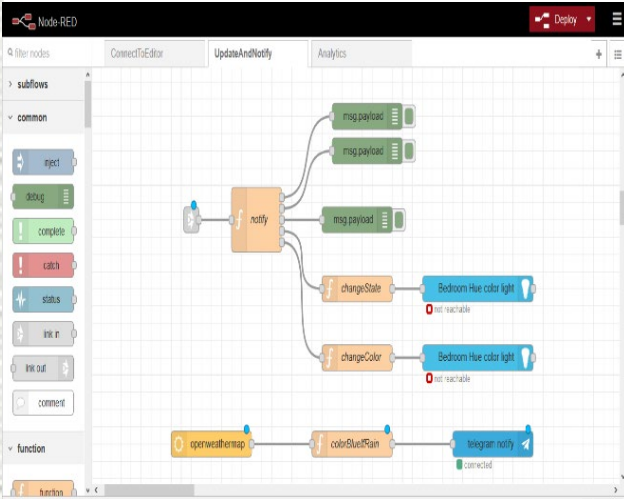
IFTTT



Alexa



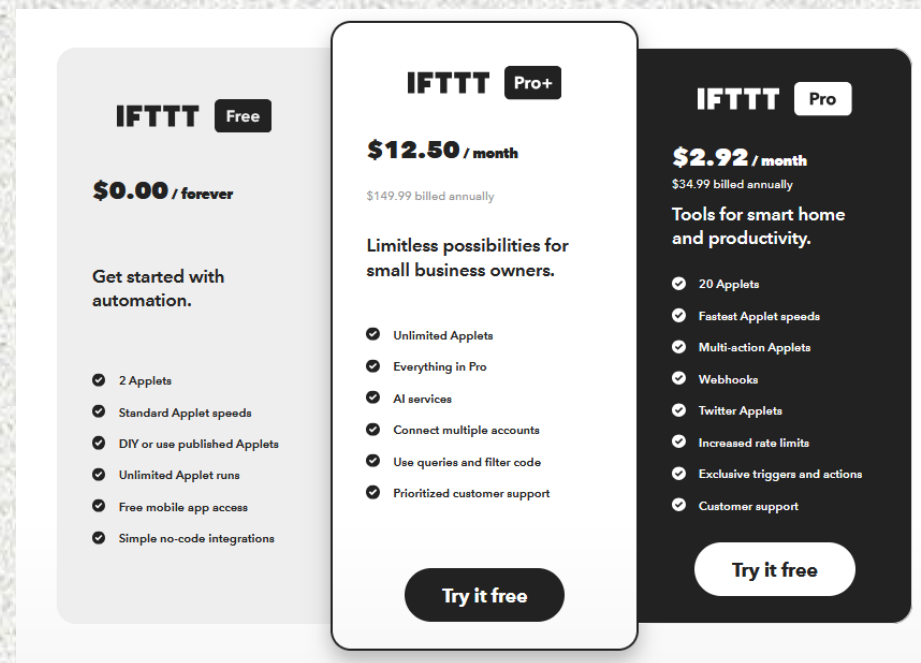
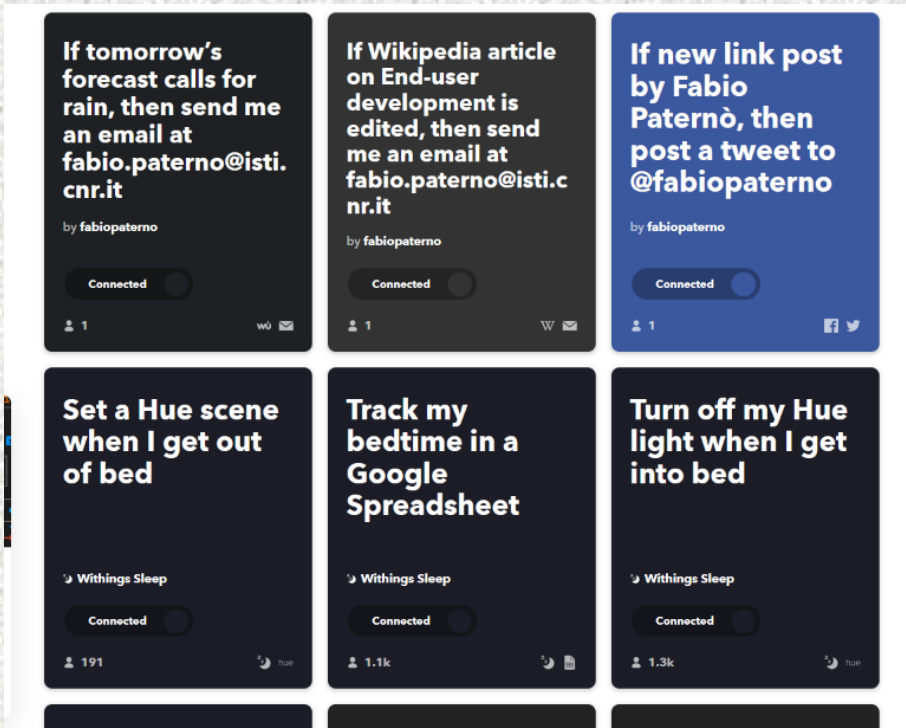
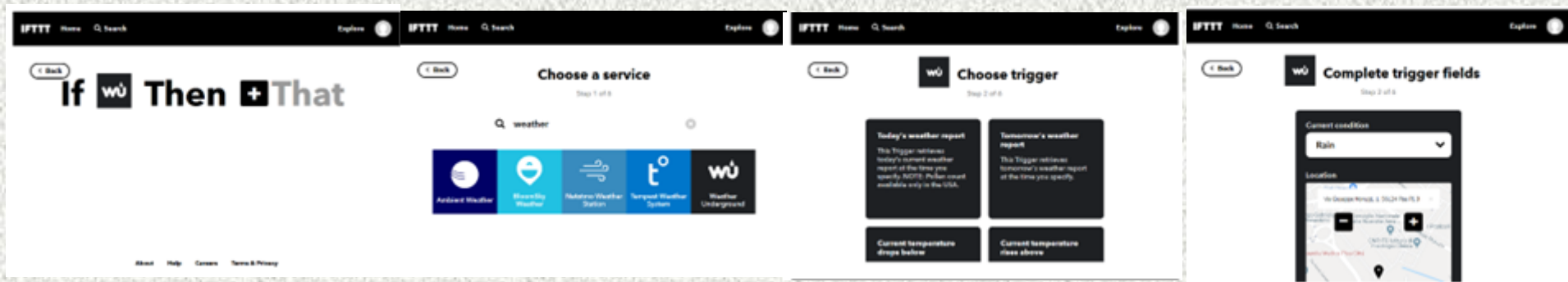
Data Flow - NodeRED



Block-based - BlockComposer

Current Practise: IFTTT

<https://ifttt.com/explore>



- Cloud-based
- Large datasets available but mainly single trigger/single action rules

Current Practise: Home Assistant

<https://www.home-assistant.io/>

- Versatile open-source smart space hub with more than 340,000 active installations on May 2024
- Designed for managing a wide range of sensors and objects from different manufacturers (it works with over 1000 brands and integrations) allowing the creation and execution of automations
- It can work on a local device
- Large community of users with technical amateur experience
- Technical users also encounter conflicts and gives importance to detect and resolve them even if the platform does not provide direct support
- Key themes: energy-saving automations (Heating and cooling efficiency, Smart lighting and appliance management, Optimization of load and consumption)
- Even advanced users acknowledge that reaching optimal outputs requires significant efforts, knowledge, and engagement
- Concerned about the lack of intuitive UI and adopted standards

Current Practise: Home Assistant

<https://www.home-assistant.io/>

alias: Intrusion alarm

trigger:

- **platform:** state
- entity_id:** binary_sensor.movimento_ingress to: 'on'

condition:

- **condition:** or
- conditions:**
 - **condition:** state
 - entity_id:** device_tracker.cellulare
 - state:** 'not_home'
- **condition:** and
- conditions:**
 - **condition:** state
 - entity_id:** binary_sensor.presenza_letto
 - state:** 'on'
- **condition:** time
- after:** '00:30:00'
- before:** '06:00:00'

action:

- **service:** notify.mobile_app_cellulare
- data:**
 - message:** "Alarm ! Detected movement at entrance"
- **service:** media_player.play_media
- entity_id:** media_player.riproduttore_audio
- data:**
 - media_content_id:** allarme.mp4

Triggers

Entrance Motion Sensor started detecting motion

Device
Entrance Motion Sensor

Trigger
Entrance Motion Sensor started detecting motion

Duration (optional)

hh mm ss
0 : 00 : 00

+ ADD TRIGGER

Conditions

Test if any of 2 conditions matches

Smartphone Simone is not home

Device
Smartphone

Condition
Smartphone Simone is not home

& Test if 2 conditions matches

Confirm the time is after 0:30 and before 5:30

Bed Sensor is occupied

+ ADD CONDITION

+ ADD CONDITION

+ ADD CONDITION

Actions

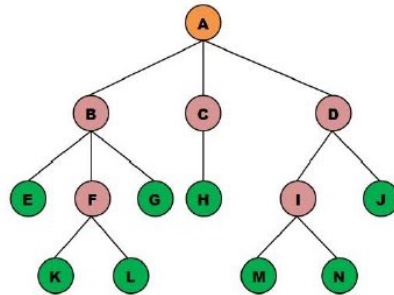
Play media on Home Speakers

Send a notification

+ ADD ACTION

State of the Art - Limitations

- Visual editors with conceptual representations of possible automation elements
- They tend to be large, comprehensive, static, abstract EUD tools with long lists of objects and associated functionalities or abstract representations detached from the user's real context
- It may not be straightforward to understand how to navigate the large number of elements and find the relevant elements
- Understanding the elements and to what real element they refer sometimes requires technical knowledge
- Need for more narrowed, situated, interactive, dynamic representations associated with the physical objects available in the current user's context !



Conversational Interfaces in IoT ecosystem: Where We Are, What is Still Missing

S Gallo, F Paterno, A Malizia, Conversational Interfaces in IoT Ecosystems: Where We Are, What Is Still Missing, Proceedings MUM 2023, ACM

- Systematic Literature Review – Overview – May 2023 - Papers search
- A total of 3,177 articles from ACM Digital Library (2,337) and IEEE (840)
- The articles were obtained by running queries with keywords addressing both the conversational aspect and the smart IoT context (e.g., «conversational agent» AND «smart spaces»)
- The remaining 50 articles were analysed for conducting the review

1. Methods and Tools

- + Rule-based (18)
- + AI-based (32)
 - Frameworks (23) (Dialogflow, Rasa...)
 - Custom Implementations (9) (Transformers, Reinforcement learning...)

2. Application domains

- + Smart **home** (37)
- + General smart **environment** (5)
- + Smart **agriculture**, smart **building**, smart **health**... (8)

3. Interaction modality

- + **Text** based (17)
- + **Voice** based (16)
- + **Text and Voice** (8)
- + Other multimodalities (9)

4. Interaction interfaces

- + Custom **Web** (10)
- + **Smartphone** App (8)
- + Custom **hardware** (e.g., Raspberry Pi) (6)
- + **Alexa** or **Google Assistant** (6)
- + **Desktop** App (5)
- + Other (e.g., Robot, Telegram, Line...) (15)

5. Breakdown Resolution Strategy

- + Command **rephrasing** (7)
- + List of **alternative intents** (1)
- + Help message (1)
- + Rasa Fallback policy (1)
- + Custom **disambiguation strategy** (1)
- + Automatic **Google search** (1)
- **Not defined** by the authors (38)

6. UX Evaluation Methods

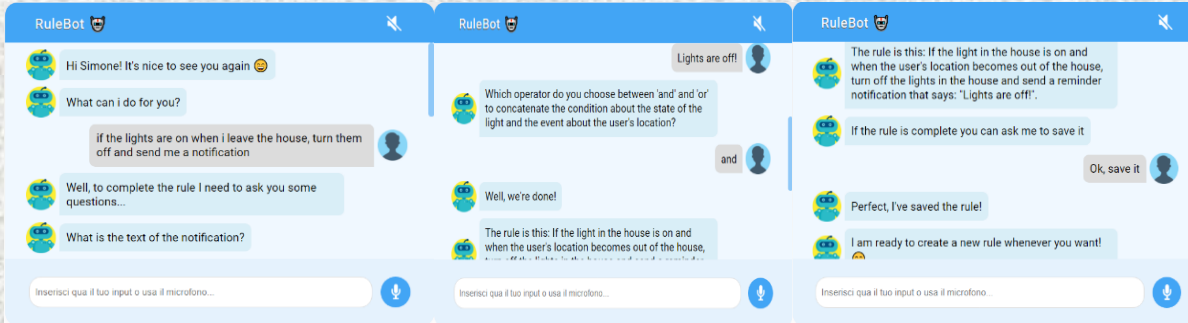
- + Custom questionnaire (6)
- + SUS, NASA-TLX, UEQ (8)
- + **Task** time, success, failure, completion time, errors (8)
- + N. of **conversational turns** (2)
- + Thinking aloud (1)
- + Open questions (1)
- + **No UX evaluation** (41)

Systematic Literature Review

- Artificial Intelligence methods are the primary technology used to develop conversational systems (e.g., Reinforcement Learning, Transformers).
 - Until May 2023, no studies employed recent LLMs (e.g., ChatGPT, which became public in November 2022).
- The majority of studies focused on the smart home domain, the one with the most immediate impact on people's lives, but also other domains were considered such as smart agriculture, smart buildings, smart health
- Limited capability in handling complex commands and in creating and managing complex automation (i.e., trigger-action rules).
- The need for breakdown resolution strategies is often ignored since most studies do not even mention it.
- Only a small number (about 20%) considered user-based evaluation, using *general* evaluation metrics unrelated to conversational aspects.
 - Need for evaluation methods tailored for conversational systems (e.g. chatbot usability scale)
 - All the tests were conducted in controlled environments

A First Attempt: RuleBot

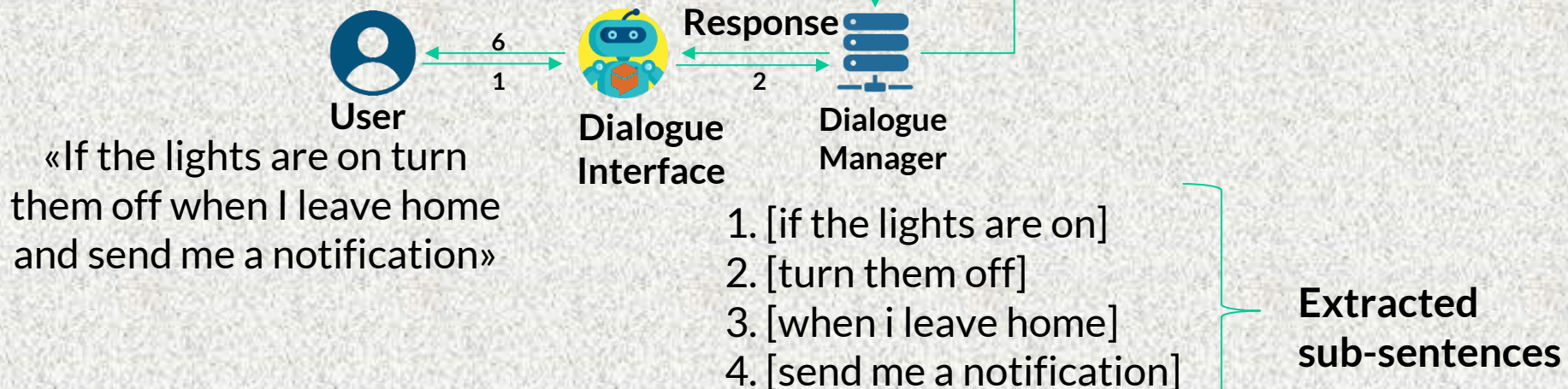
S. Gallo, F. Paternò, A Conversational Agent for Creating Flexible Daily Automations, AVI 2022 Conference



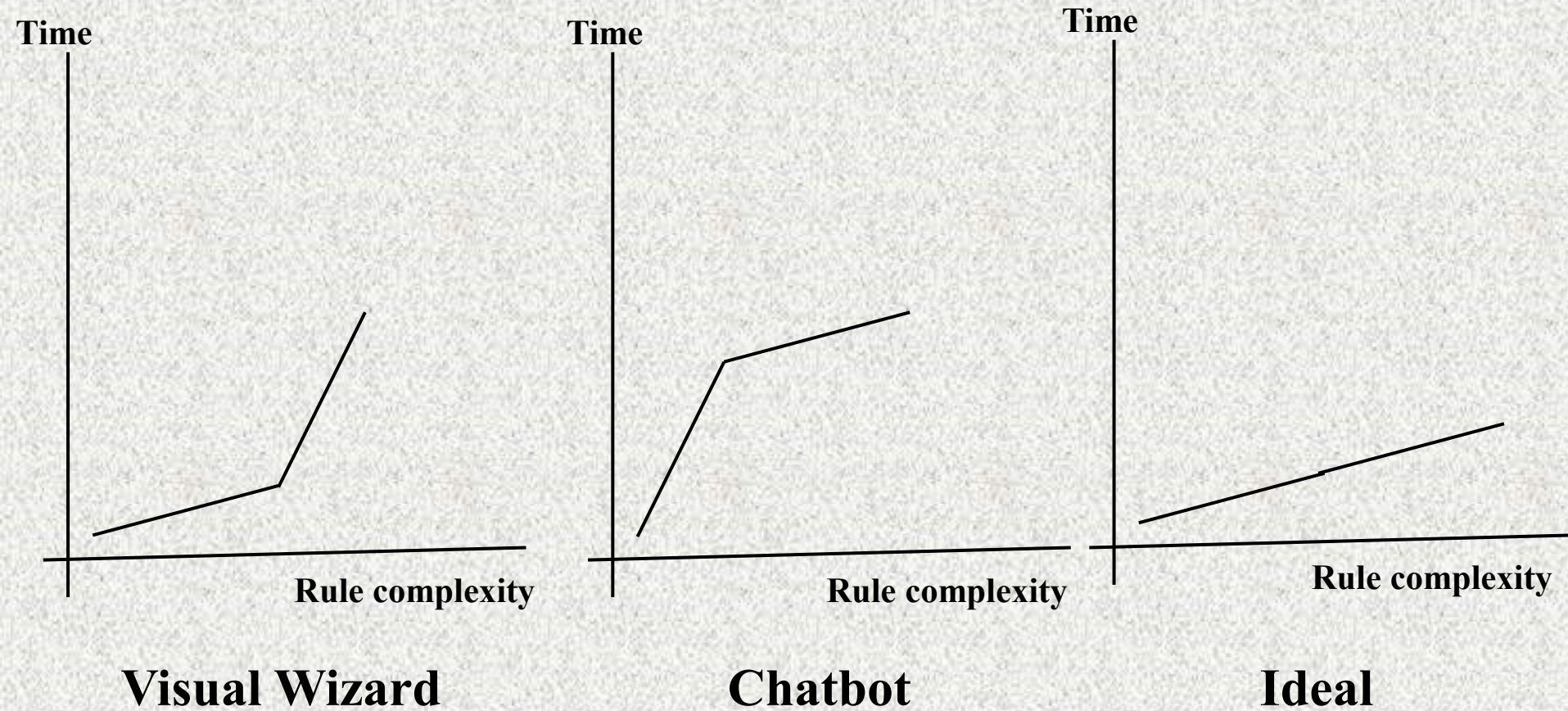
Intent Classification - Parameters

1. trigger_light: [isOn]
2. action_light: [turnOff]
3. trigger_position: [outside, home]
4. action_reminder: [notification]

Intent Classifier



Usability Curves in Automation Creation



Augmenting RuleBot with ChatGPT

Ciao, Simone

[Update Rules List](#)

Start Coffee Machine When Wake Up (ID: 1)

Intrusion Alarm (ID:2)

When the motion sensor at the entrance detects presence, if you are not at home or if it's night (from 12.30 AM to 05:30 AM) and you are sleeping, send a notification to your phone and start an alarm sound

[Logout](#)

Rulebot

Hello! I'm RuleBot, your virtual assistant for managing sensors and smart objects in your smart home. I can help you create automations, modify them, and provide you with information about the sensors in your intelligent home. How can I assist you today?

Hi, I don't have an alarm system at home, but I'd like to set up an automation that alerts me in case of intrusions

Rulebot

Great, in your smart home, you have motion/presence sensors that we can use to detect intrusions.

We can set up an automation that, when it detects motion in a specific area of the house while you're not there, sends you a notification on your phone and, if you want, can also activate the alarm.

To proceed, I need to know in which area of the house you want to detect

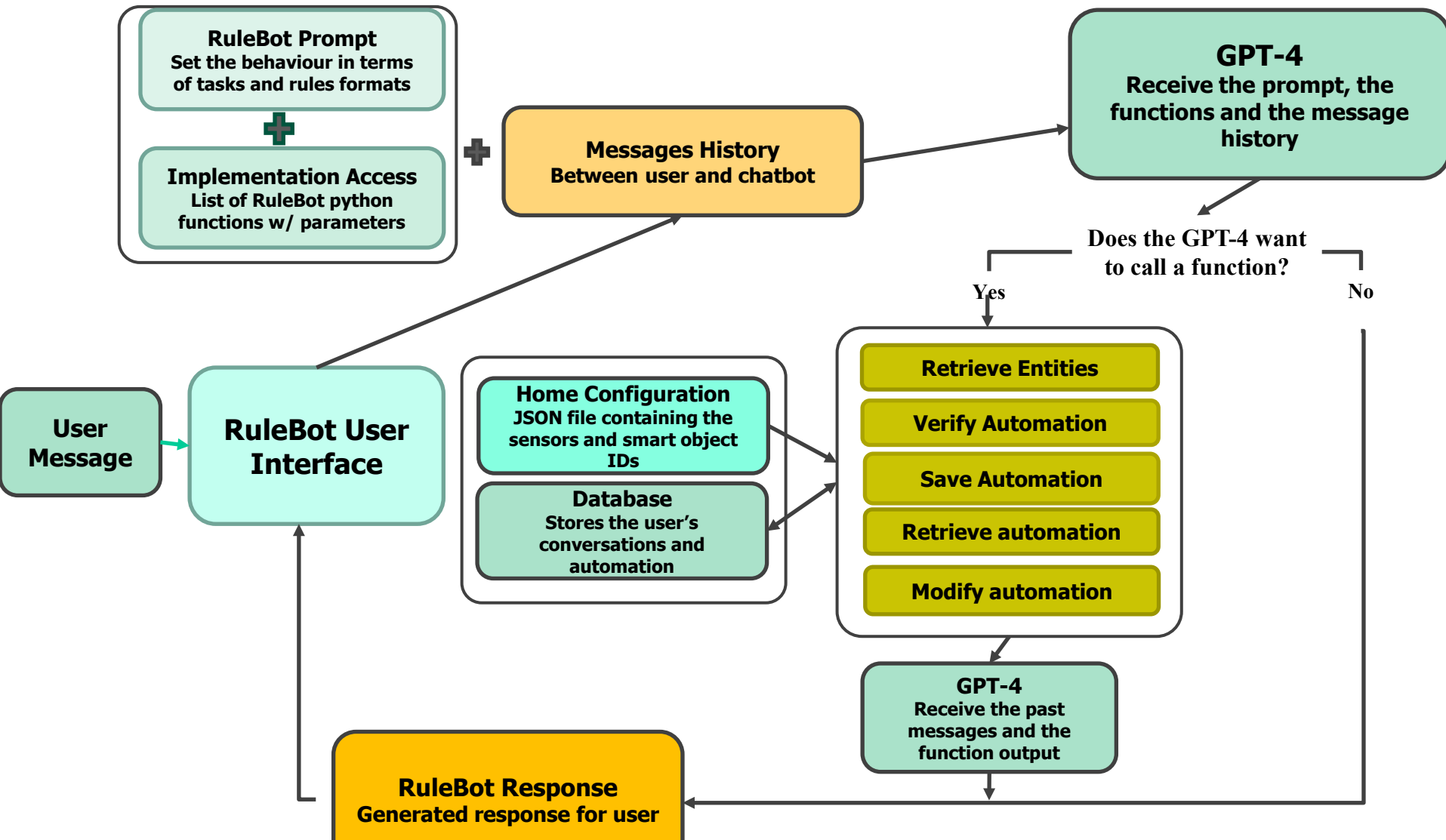
Inserisci qua il tuo input...

- The prompt includes:
 - an initial part where the RuleBot++'s identity and a high-level description of its functionalities are defined
 - a set of generic rules that the chatbot must apply during conversations
 - the necessary steps and rules to correctly manage the conversation

RuleBot++:

Creating automations with ChatGPT support

S Gallo, F Paterno, A Malizia, A Conversational Agent for Creating Automations Exploiting Large Language Models, Personal and Ubiquitous Computing 2024



RuleBot++:

Creating automations with ChatGPT support

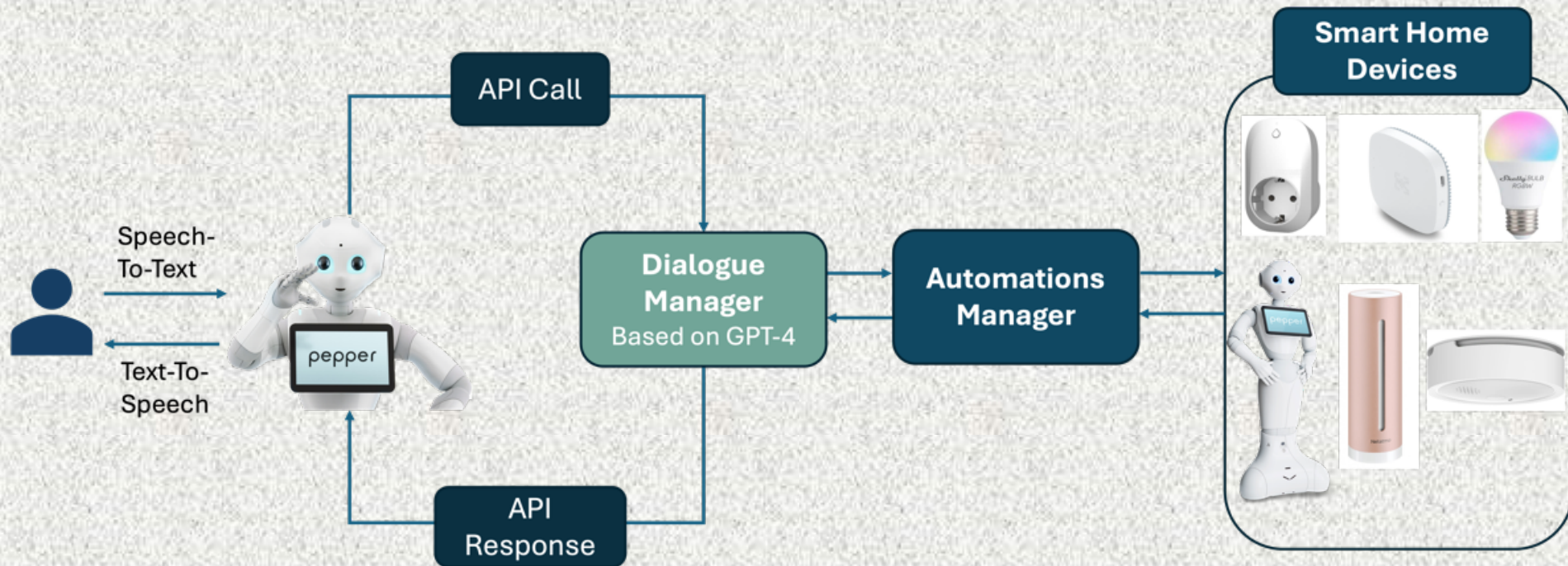
- User test with 16 participants with varied background who had to create automations for 4 scenarios with various complexity using both RuleBot++ and Home Assistant
- For complex rules, RuleBot++ consistently took less time than Home Assistant
- The overall number of errors was similar
- Regarding RuleBot++, we observed errors made by the user, errors from lexical ambiguities leading to misunderstandings between the User and RuleBot++, and errors due to the hallucinations of the model (which occurred when the chatbot had to generate the YAML specifications).
- Example hallucinations: the use of a wrong value in the configuration of triggers or actions (e.g., "on" instead of "off" about the state of a sensor); or configuring one sensor instead of another (e.g. the "bed presence" sensor was selected instead of the "room presence")

What about humanoid robots ?

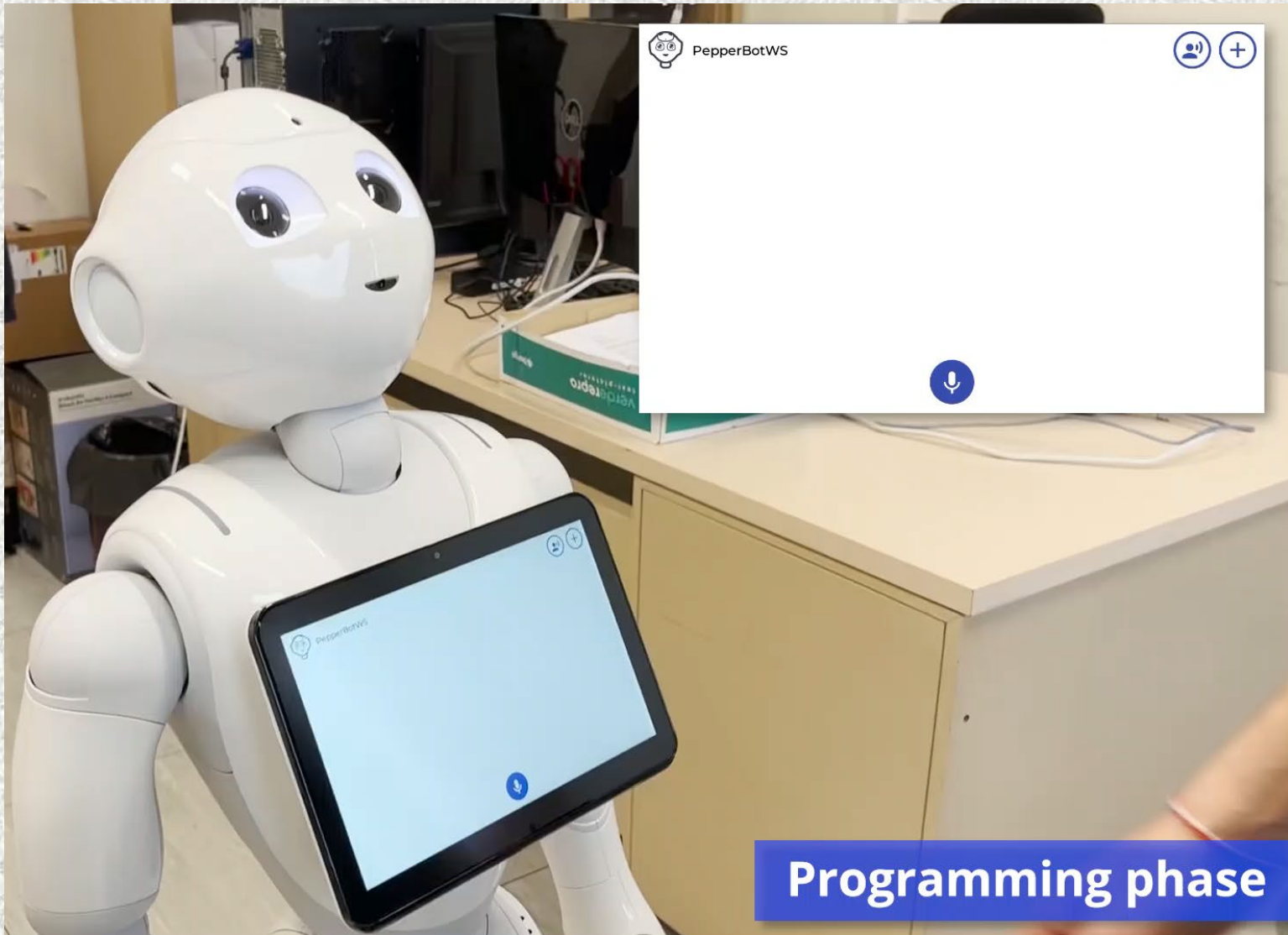
- Robots are increasingly used in many contexts
- Industrial robots and social humanoid robots
- Humanoid robots are an integration of sensors and actuators in a human-like shape
- Such robots interact with us by voice, gestures and all the other modes typical of human communication, and can also exhibit personalities
- A recent report estimates that a \$6 billion market (or more) in people-sized-and-shaped robots is achievable in the next 10 to 15 years



The Approach can be Extended to Robots !



The Approach can be Extended to Robots !



Programming phase

Another approach: Mobile augmented reality support for automation control !

- Possibility of direct interaction with the object of interest
- Avoid using special devices that many do not have and can be cumbersome
- Possibility of monitoring nearby automations while moving, also at different levels of granularity (object, room)
- Ability to select a real object directly and know the automations that involve it
- Ability to create new automations
- Ability to modify existing automations

First proposed solution

R Ariano, M Manca, F Paternò, C Santoro, Behaviour & Information Technology, 1-17, 2022

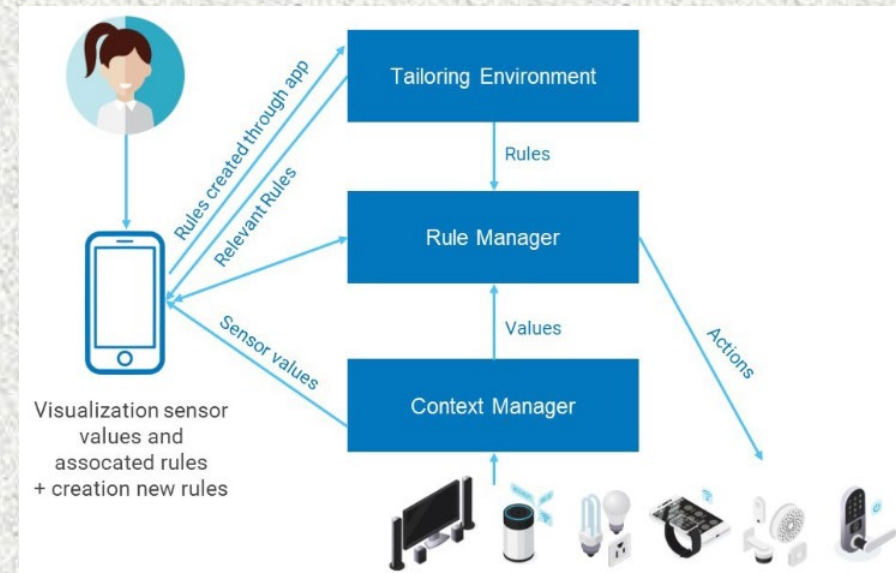
Android application (using Vuforia for object recognition) that:

dynamically receive information

- regarding the room where they currently are (user position obtained through Estimote Bluetooth beacons),
- regarding a specific object that is identified through the camera of the mobile device

augments the reality

- showing on top of the image of the target object various information about it and the surrounding environment,
- allows users to enter new automations involving that object on the fly

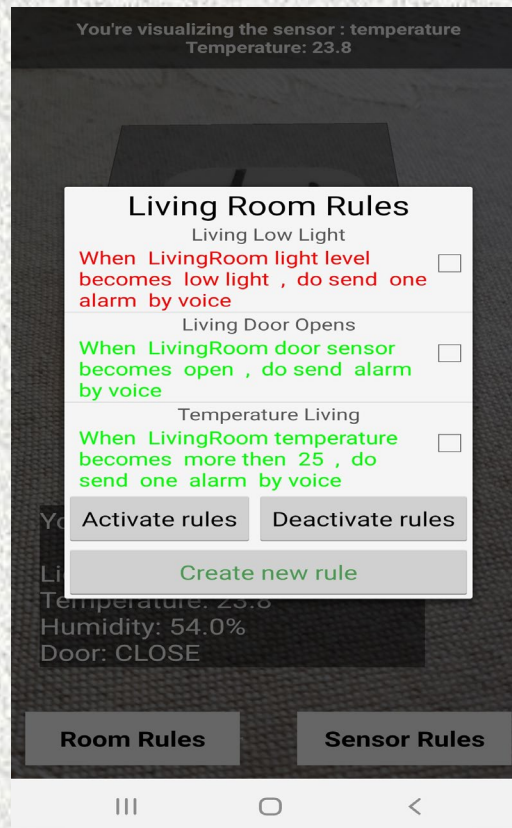


SAC platform architecture

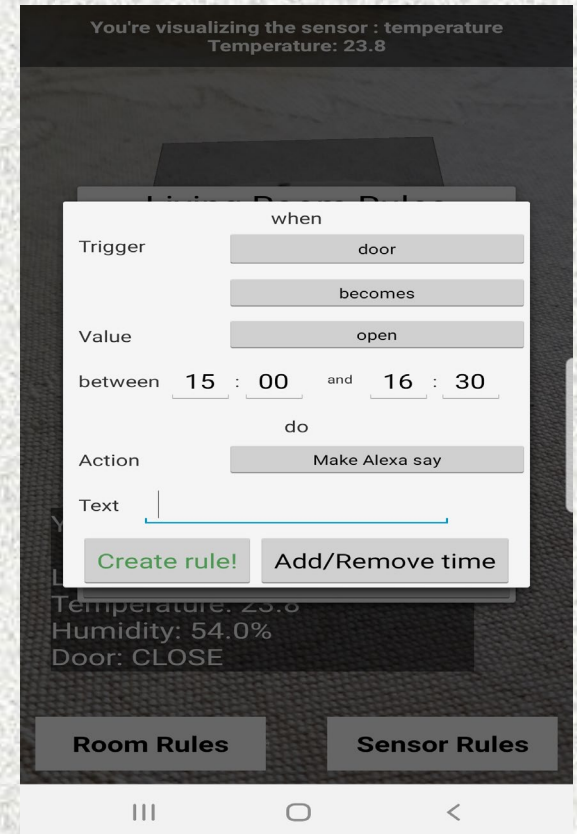
First prototype for mobile support



Information on current room



Rules created for current room



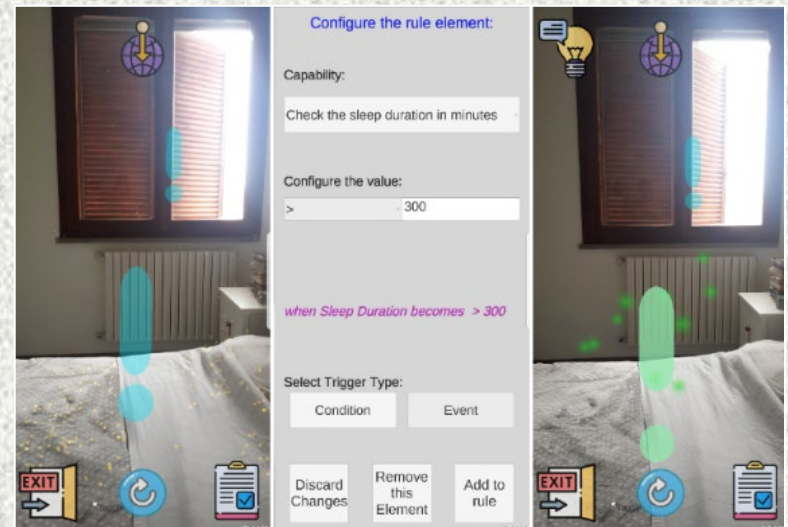
Creation of new rules

Solution with different way to identify objects

A. Mattioli and F. Paternò. 2023. A Mobile Augmented Reality App for Creating, Controlling, Recommending Automations in Smart Homes. In *Proceedings of the ACM on Human-Computer Interaction*, Vol. 7, MHCI, Article 195 (September 2023)

Android application implemented using Unity and the ARFoundation library.

- No need to go near an object and wait for recognition before interacting with it (objects position stored at the first use)
- Users can move about and select the object to use or services
- Allow the selection of services not directly linked to objects (globe icon)
- Different graphical elements are used to visualise some aspects of the automation composition process and provide feedback on the user's actions
- Textual descriptions of the created automations can be placed over the objects they refer to



(left) element to select (centre) rule editing (right) post-editing feedback

Recommendations in MAR automations

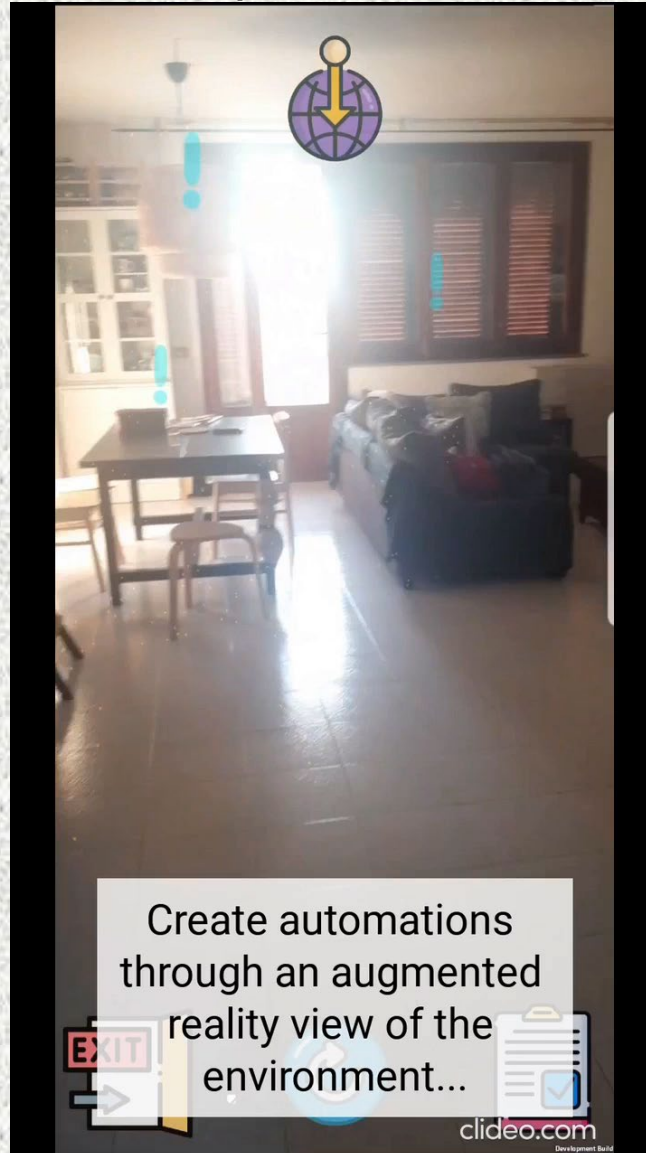
- Beginners can benefit from being guided / Advanced users can discover new possibilities on their own
- Automation creation is a process comprised of multiple steps, which can benefit from recommendations based on existing automations
- Previous studies indicated that users prefer to receive recommendations as rule elements instead of complete rules

Specific characteristics of the MAR setting for RS:

- the creation of rules does not necessarily occur in a sequential manner
- scarcity of space on the mobile screen, and users prefer to examine only a short list of recommendations
- first prototype for completing the automation was based on Doc2Vec (it considered similarity in the rules based on their textual description)

Example Prototype

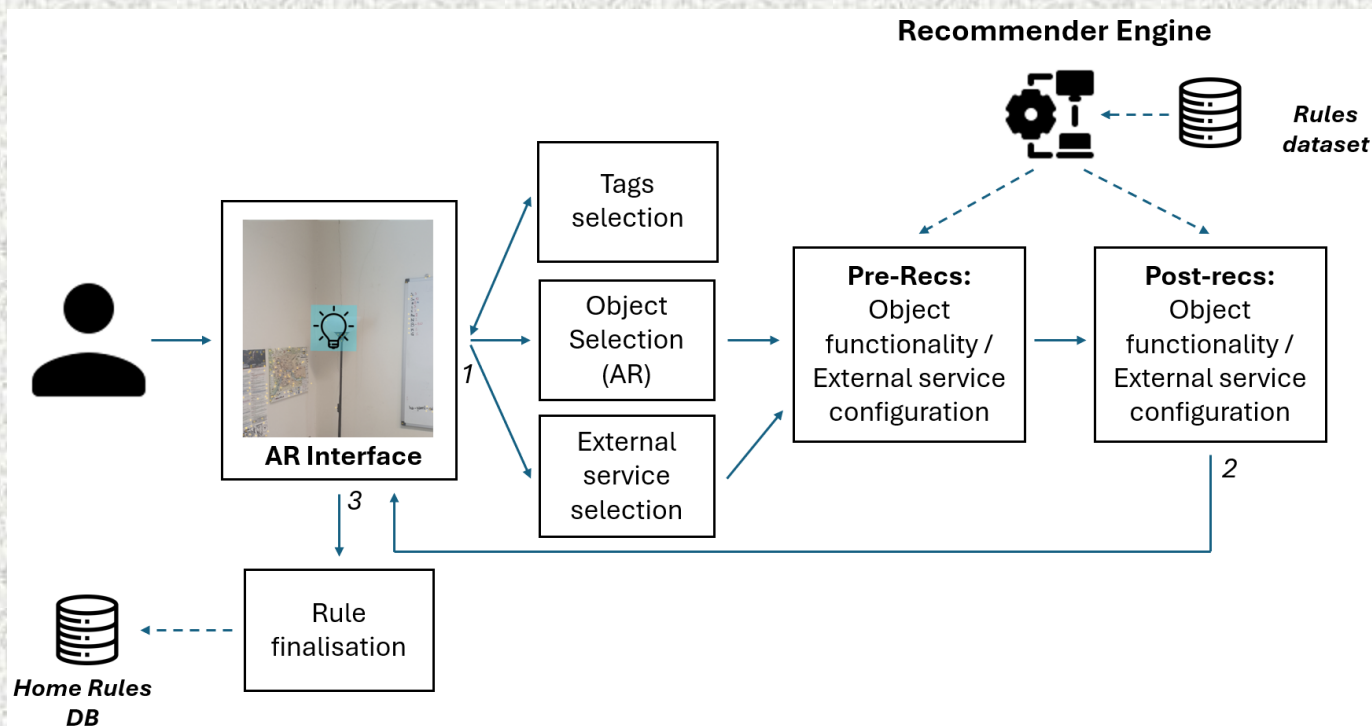
A. Mattioli and F. Paternò. 2023. A Mobile Augmented Reality App for Creating, Controlling, Recommending Automations in Smart Homes. In *Proceedings of the ACM on Human-Computer Interaction*, Vol. 7, MCHI, Article 195 (September 2023)



New Solution with Improved Recommendations

A. Mattioli and F. Paternò. 2024, Personalised Recommendations for Daily Automations in a Mobile Augmented Reality Application

- The RS should provide suggestions even before starting the initial configuration
- It should be possible to consider high-level features representing main user goals/interests
- The recommendations should be personalised with some collaborative filtering technique
- The RS should consider the rule element type (Events, Conditions, Actions)



Personalised Recommendations

A. Mattioli and F. Paternò. 2024, Personalised Recommendations for Daily Automations in a Mobile Augmented Reality Application

This automation is for...

Select a goal:
Generic

Select a typical situation:
ColdSeason

Select a typical user:
Generic

Back OK

Toggle



Living Room Hue Lamp

ACTION is selected

Event Condition Action

Select an example:
turn to BLUE the living room light
turn to BLUE the living room light
turn on all lights in the living room
turn off all lights in the living room
set the living room lamp colour to orange.

BLUE

Discard changes Add to rule

Toggle

Continue this automation with...

EVENT is selected

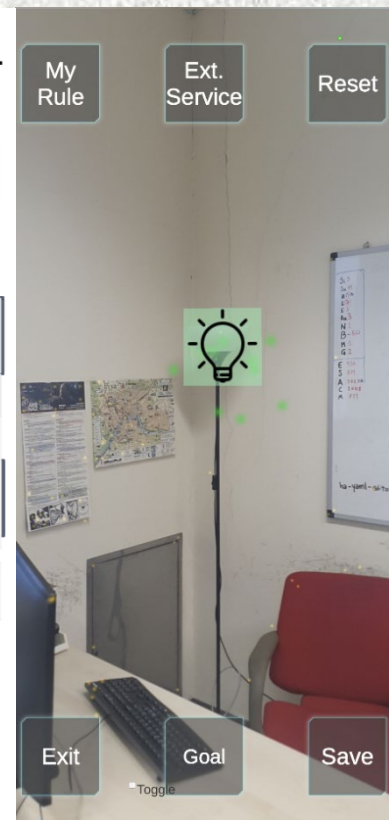
Event Condition Action

Select an example:
When outside temperature is less than 10 degrees,
When outside temperature is less than 10 degrees,
When outside temperature becomes 0 degrees,
When it's 18:00,
When it is raining outside and

less than 10

Go to AR Add to rule

Toggle



- A user study indicated that the RS significantly improves the user interaction with the MAR system from the perspectives of self-reported metrics, time to complete the tasks, and errors during the tasks.
- Notably, introducing the RS significantly decreased the errors in distinguishing between events and conditions, which is a crucial issue in tailoring environments.

Conclusions

- The explosion of the Internet of Things, robotics, and AI is increasingly leading to the presence of **automations in diverse and dynamic daily contexts**
- The people, applications, and connected objects around us can generate **myriad possible events**, and each user may have specific requirements about how to react to them
- Automations should be **transparent** to end users so that they can actually **control** and benefit from them
- Current solutions are limited in terms of support for better **understanding temporal aspects, dependencies and conflicts, privacy and security issues** in automations
- Various innovative interaction technologies (**chatbot, mobile augmented reality, humanoid robot**) can be useful for users **to control and modify their smart spaces**
- With the goal to obtain **humanations** !

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Some references

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