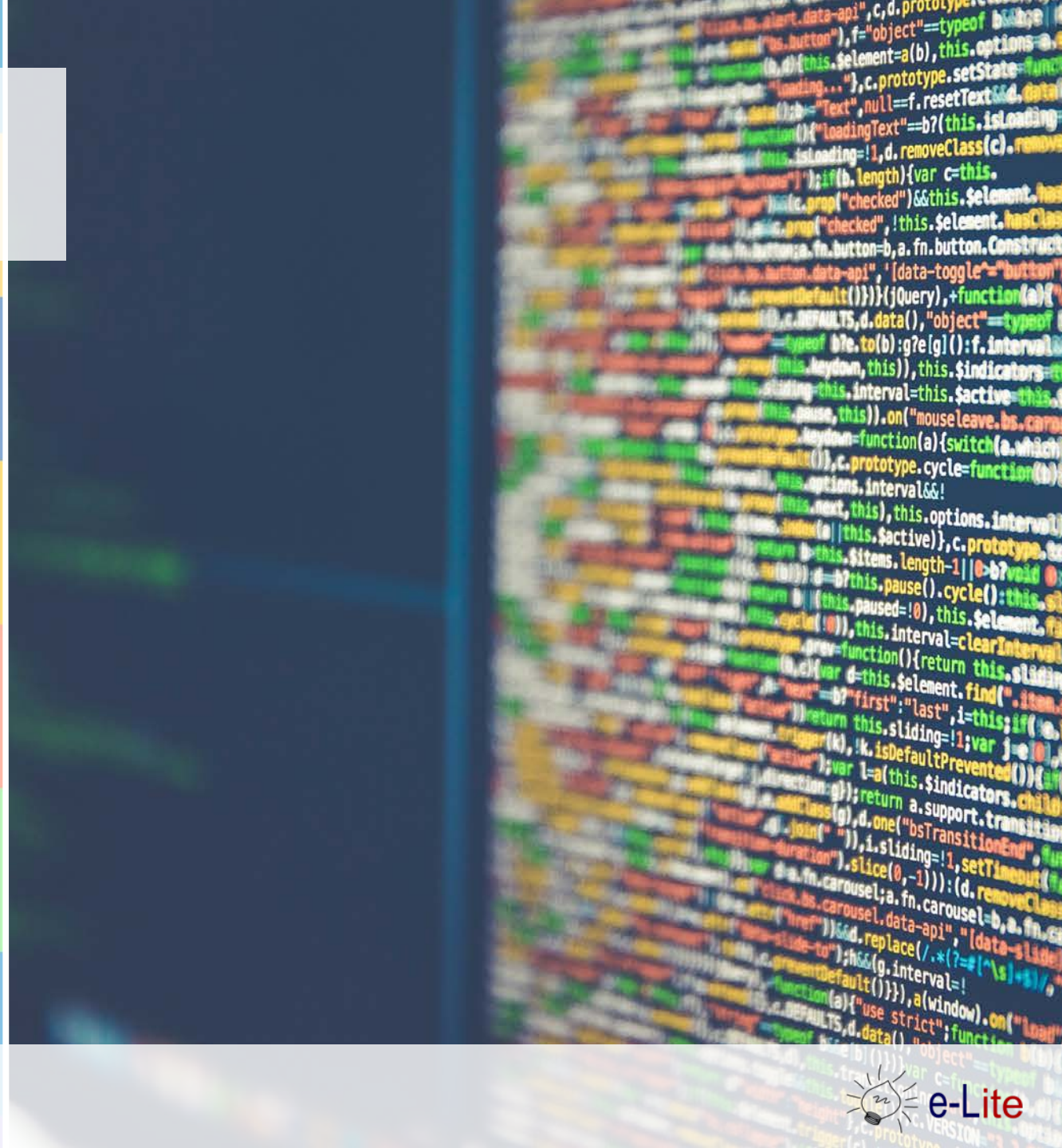
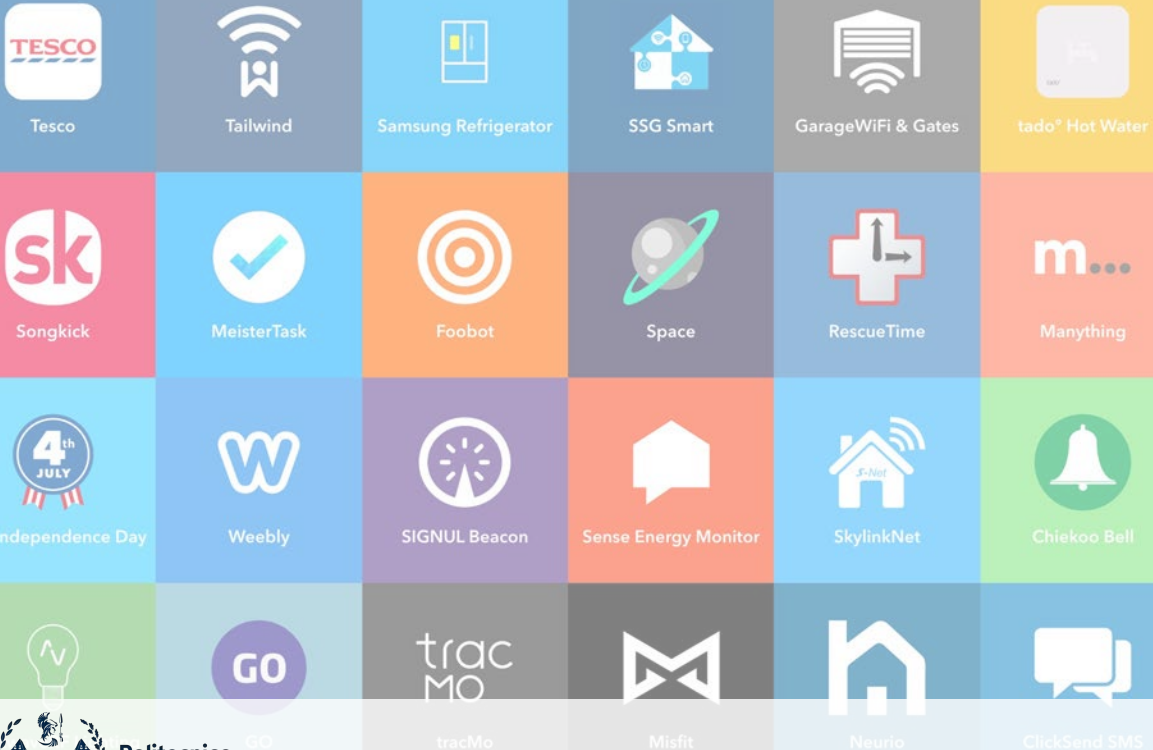


# DEVELOPMENT + IoT = ?

UNIVERSITÀ DEGLI STUDI DI SALERNO – MAY 3, 2023

Luigi De Russis  
@luigidr





Associate Professor

Politecnico di Torino, Italy

Background: Computer Engineer

@luigidr (on social media)

♥ sci-fi, coffee, travel, nature, running

Motto: *"Be kind"*



1

2

3

4



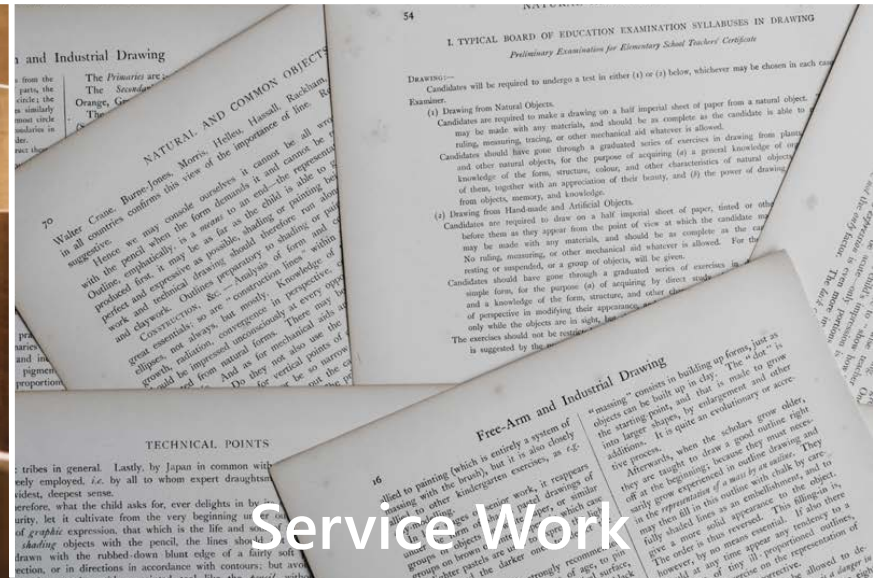
Research



Industry/Projects



Teaching



Service Work



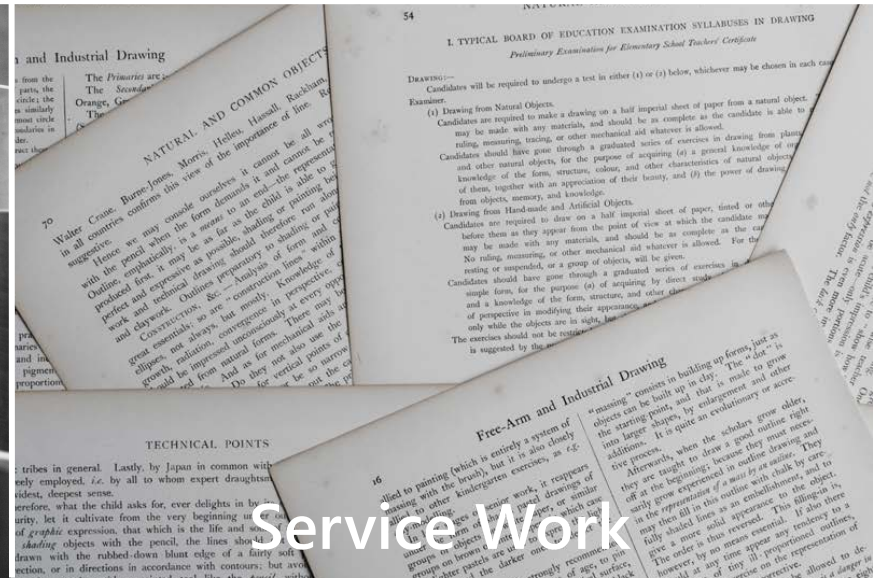
Research



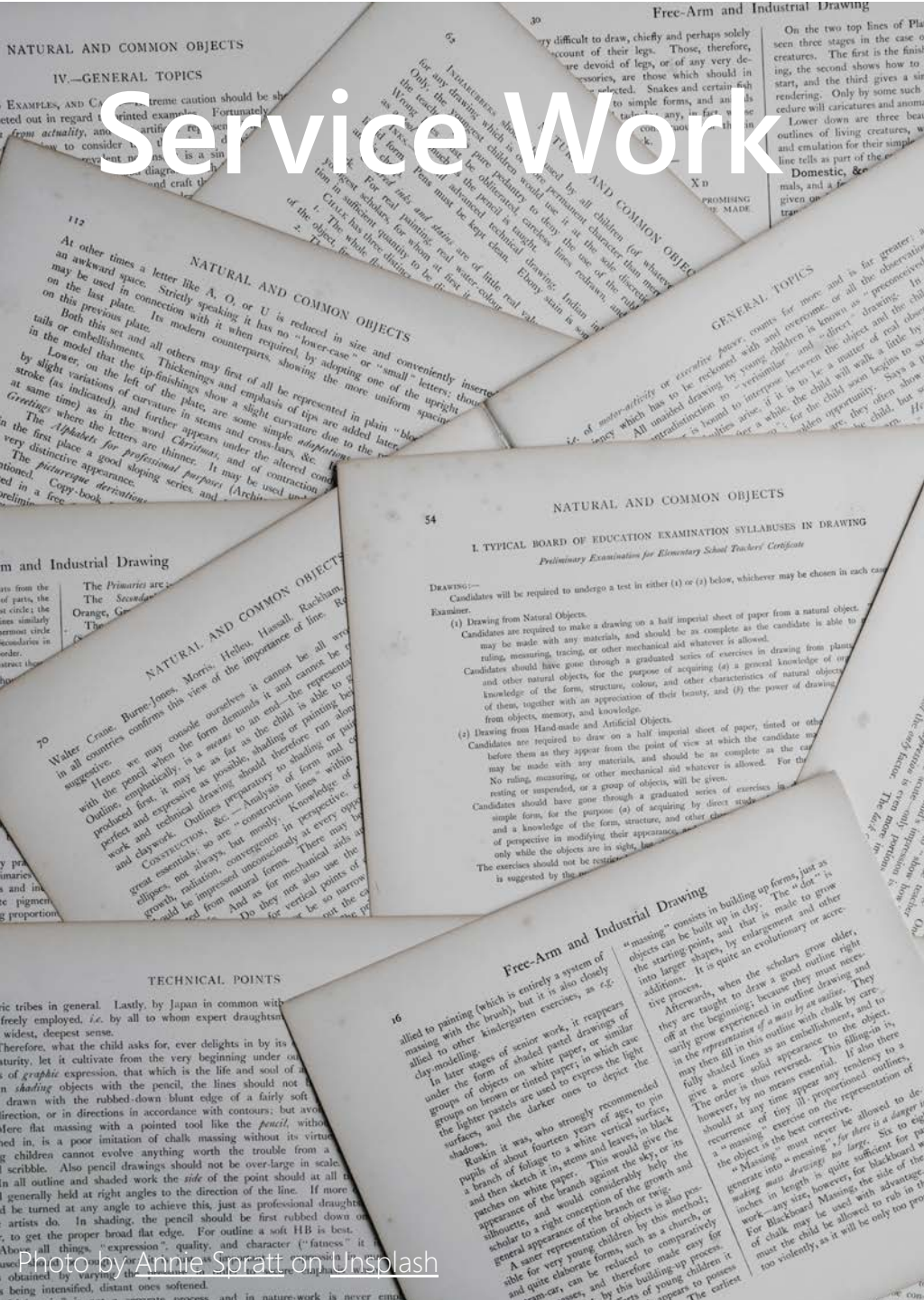
Industry/Projects



Teaching



Service Work



To **give back** to the community!

Also, a *good way* to meet people and network

Not “just” reviewing papers

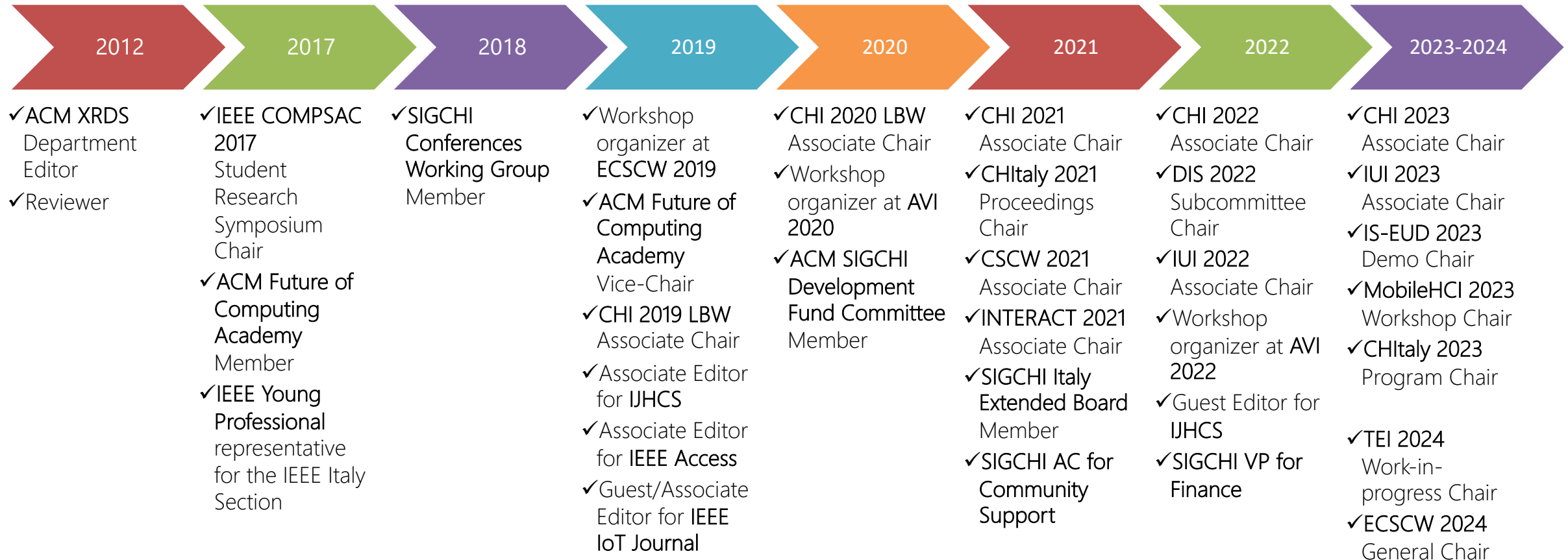
Scientific organizations’ committees

Conferences’ committees

Workshops/Special issues organization

**Example:** SIGCHI has open calls for various committees at <https://sigchi.submittable.com>

# My (Service) Story So Far...





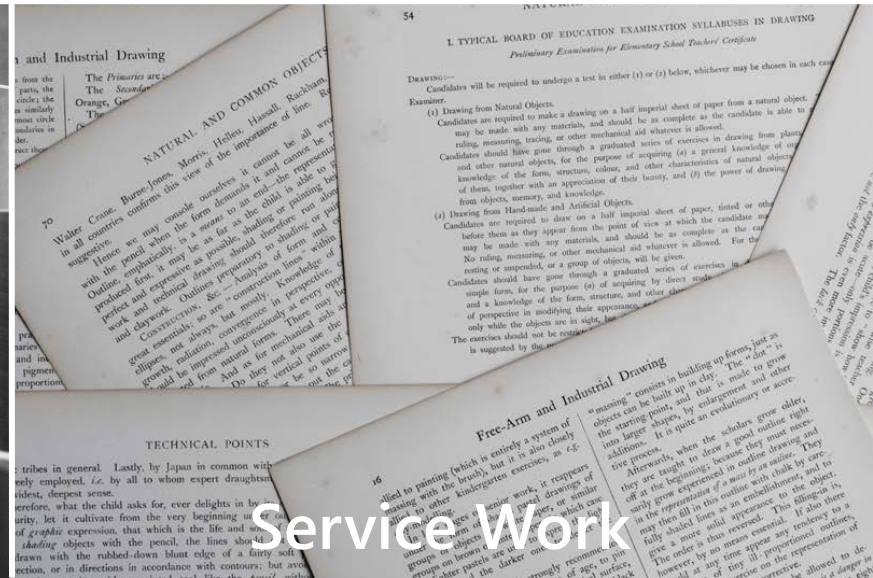
Research



Industry/Projects



Teaching



Service Work



# Research



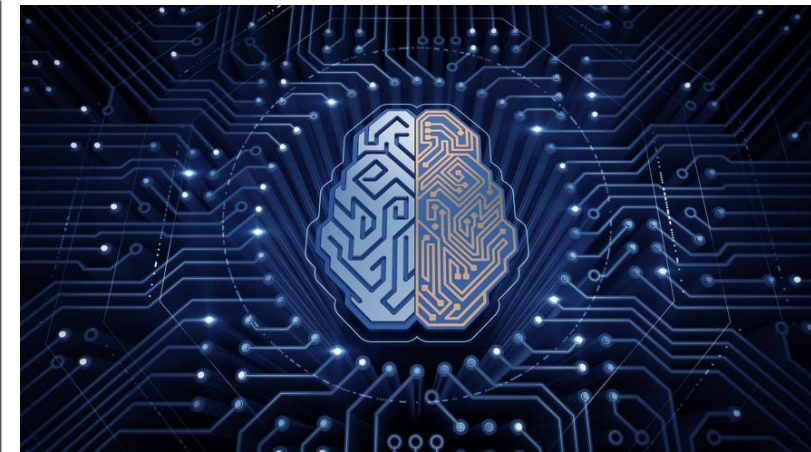
“*How can people make their experiences with computers more personal(ized)?*”



# Digital Wellbeing



# Internet of Things

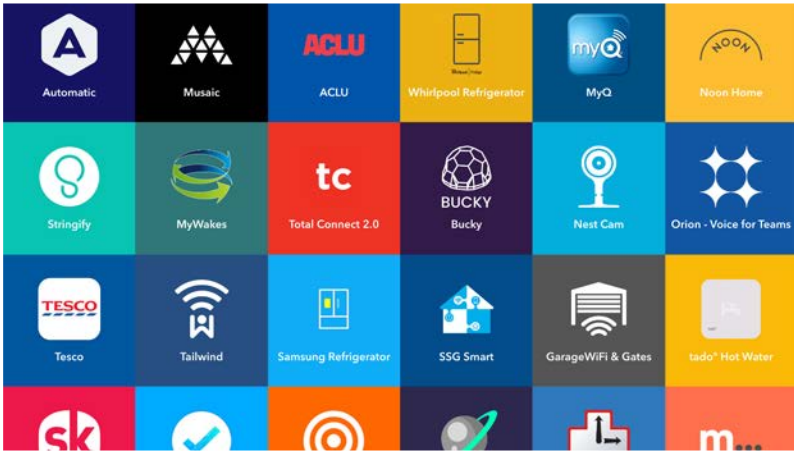


# Human-centered AI

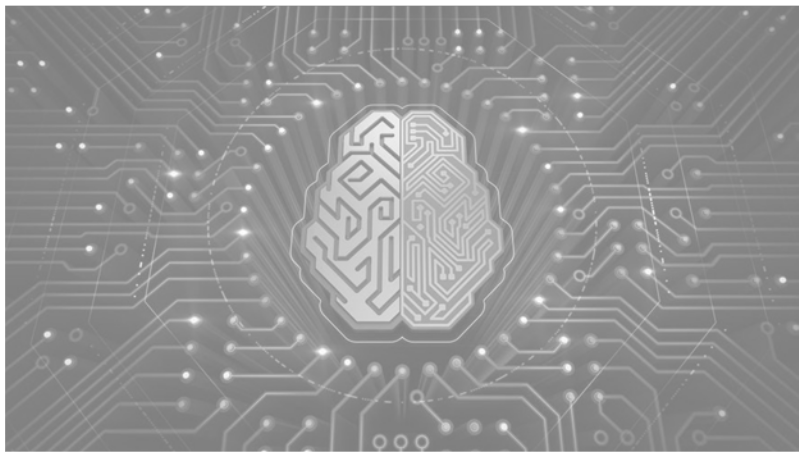




# Digital Wellbeing

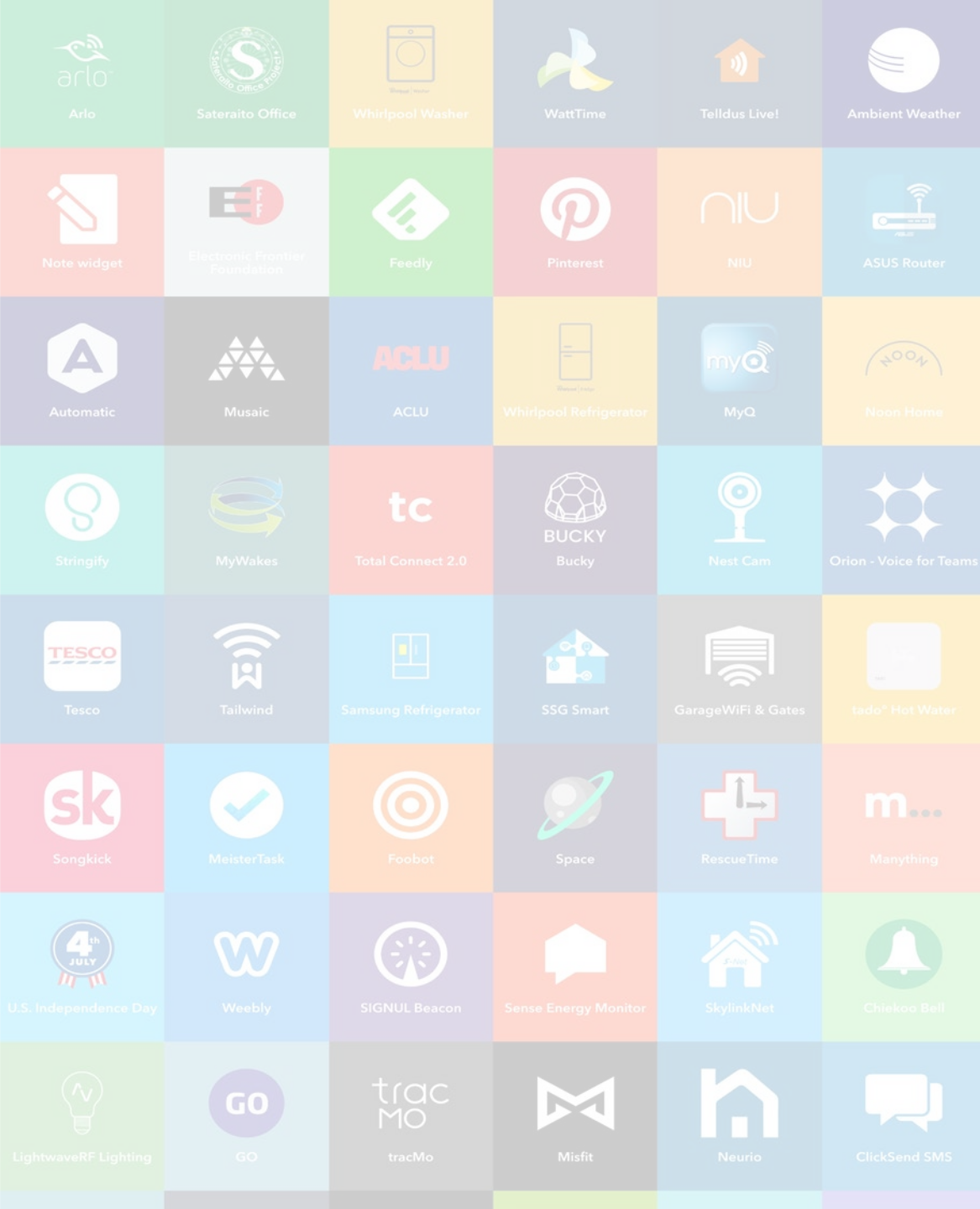


# Internet of Things



# Human-centered AI





“

*What is the*  
**Internet of Things**

?

”

# Internet of Things



The **Internet of Things (IoT)** refers to the ever-growing network of physical objects that feature an IP address for internet connectivity, and the communication that occurs between these objects and other Internet-enabled devices and systems.

Table 1. Internet of Things (IoT) Installed Base by Category

| Category             | 2011           | 2012           | 2013           | 2014            |
|----------------------|----------------|----------------|----------------|-----------------|
| Automotive           | 40.0           | 100.0          | 312.0          | 5,011.0         |
| Consumer             | 1,041.1        | 2,041.2        | 3,014.9        | 10,011.0        |
| Industrial Equipment | 10.0           | 176.4          | 600.0          | 1,070.0         |
| Medical Equipment    | 400.0          | 476.3          | 1,000.0        | 1,000.0         |
| <b>Grand Total</b>   | <b>1,491.1</b> | <b>3,793.9</b> | <b>8,926.9</b> | <b>17,092.0</b> |

Source: Strategy Analytics (November 2014)

What Is Internet of Things (IoT)? Webopedia Definition  
[www.webopedia.com/TERM/I/internet\\_of\\_things.html](http://www.webopedia.com/TERM/I/internet_of_things.html)

About this result • Feedback



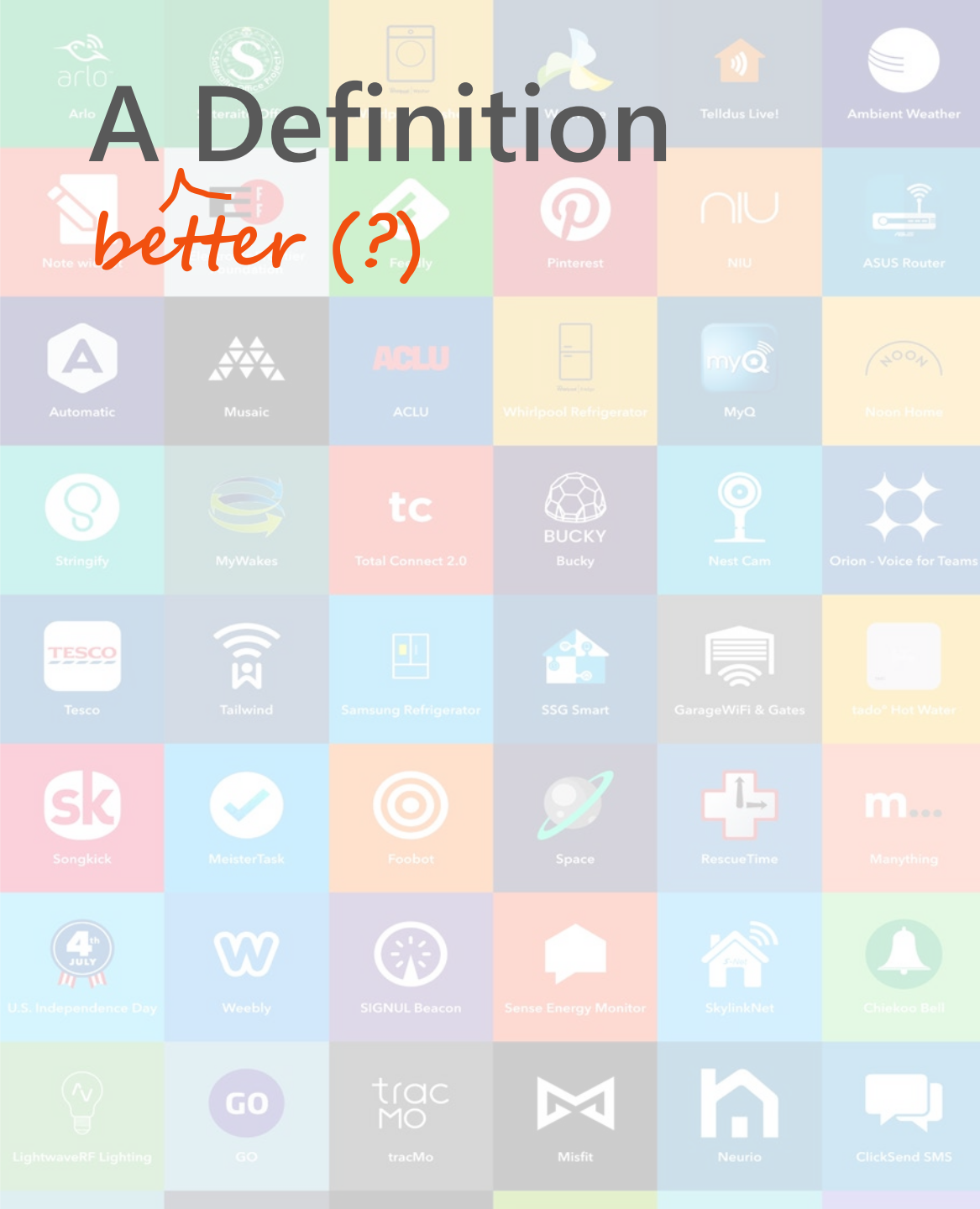
Define the Internet of Things in two sentences



The Internet of Things (IoT) is a network of physical devices and objects embedded with sensors, software, and connectivity to enable them to collect and exchange data. These devices communicate with each other and with other systems to perform tasks and make decisions, creating a more connected and efficient world.

# A Definition

*better (?)*



“A complex network of physical and virtual entities, involving **developers and end users.**”

# Developers + IoT

How **complex** are the software development tasks needed to build an IoT system?

Which are the software development tasks that are perceived as the most **challenging** to complete?

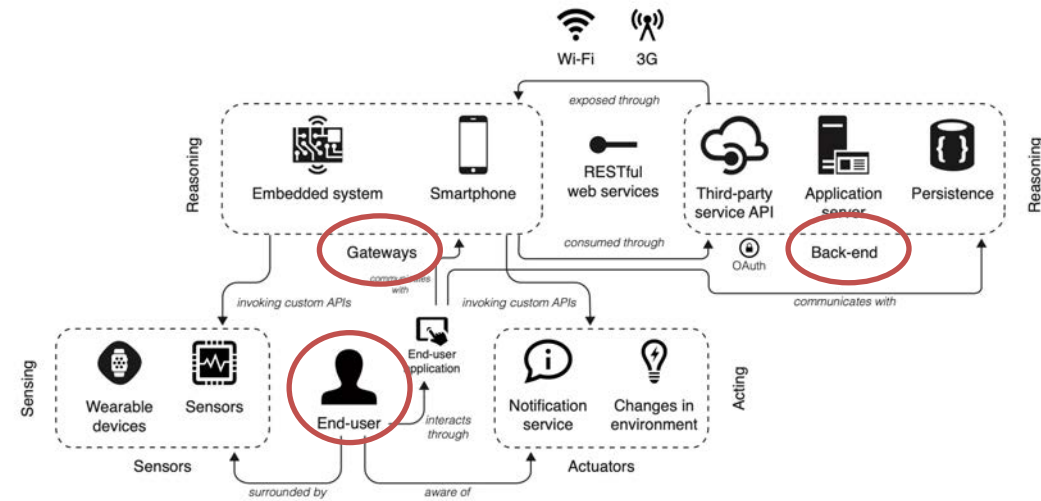
Why are these tasks **perceived** as the most challenging?

# Understanding Developers' Challenges

Pilot study:

- 7 students
- completed at least one IoT course at university level  
(**novice IoT developers**)

Survey with 40 **novice IoT developers**



| Rank  | Section A: End-user  | Difficulty |   |   |   |   | Time spent |   |   |   |   |
|---|--|------------|---|---|---|---|------------|---|---|---|---|
| <b>Develop a native end-user mobile application</b> |  |            |   |   |   |   |            |   |   |   |   |
|   | Become familiar with the mobile application platform-specific programming language | 1          | 2 | 3 | 4 | 5 | 1          | 2 | 3 | 4 | 5 |
|   | Configure the development environment  | 1          | 2 | 3 | 4 | 5 | 1          | 2 | 3 | 4 | 5 |
|   | Develop the models' classes  | 1          | 2 | 3 | 4 | 5 | 1          | 2 | 3 | 4 | 5 |
|   | Develop the controllers' classes   | 1          | 2 | 3 | 4 | 5 | 1          | 2 | 3 | 4 | 5 |
|   | Develop the user interface (views)   | 1          | 2 | 3 | 4 | 5 | 1          | 2 | 3 | 4 | 5 |
|   | Connect the push notification module with the platform notification service        | 1          | 2 | 3 | 4 | 5 | 1          | 2 | 3 | 4 | 5 |
|   | Handle the notifications received in the end-user's smartphone                     | 1          | 2 | 3 | 4 | 5 | 1          | 2 | 3 | 4 | 5 |



# Main Challenges\*

**Heterogeneous environments** – IoT developers need to program with/learn multiple languages and platforms

**Docs + code** – Lack of well-structured documentation, especially linked to suitable code

# IoT Notebook

Extension for **Jupyter**

Built on the literature

**Code cells** can be:

- Executed together with others
- Marked as prerequisite

The screenshot shows a JupyterLab browser window at localhost:8888/lab/workspaces/auto-M. The notebook 'sound-level-sensor.ipynb' is open, displaying the following content:

## Implementing the sound level sensor in Arduino

In the next cell, we will be importing the libraries we have just installed, and we will define a set of constant values that we will be using across the code.

The **BROKER\_IP** corresponds to the URL where our MQTT broker is located, the **DEV\_NAME** is the identifier that we will assign to the device from which MQTT messages are being sent, and **MQTT\_USER** and **MQTT\_PW** are optional values in case the broker had some authentication. Since our broker doesn't have any authentication mechanism, we won't modify these values.

Notice that in this cell, we have selected the checkbox '**Is prerequisite**' below the cell. By doing so, we are saying that it is mandatory to execute this cell to make the Arduino implementation work.

```
[ ]: #include <MQTT.h>
#include <WiFiNINA.h>

#define BROKER_IP      "test.mosquitto.org"
#define DEV_NAME       "MV_MKR1010_mqttdevice"
#define MQTT_USER      "mqtt_user"
#define MQTT_PW        "mqtt_password"
```

Install library  Is prerequisite  Execute together with the previous cell

The status bar at the bottom shows '0 \$ 6 Arduino | I... Saving comple... Mode: Comm... Ln 1, Co... sound-level-sensor.ip...'

JupyterLab

localhost:8888/lab/workspaces/auto-M

File Edit View Run Kernel Tabs Settings Help

sound-level-sensor.ipynb

## Installing the required libraries

In this implementation we will be using two Arduino libraries: [MQTT](#) and [WiFinINA](#).

As their name suggests, the MQTT library will manage the communications using that protocol, and WiFinINA will enable us to use the WiFi capabilities of the board. Feel free to explore the documentation of these libraries by clicking on the links.

In order to execute the following cell, please connect your Arduino and click on the **'Board'** button on the top left part of this document.

Would you please execute the cell below by clicking the **'RUN'** button to install the MQTT Arduino library?

```
[27]: arduino-cli lib install MQTT
```

Install library  Is prerequisite  Execute together with the previous cell

**RUN**

Command 'arduino-cli lib install MQTT' return with error (code 1): b'MQTT@2.4.7 already downloaded\nError: MQTT@2.4.7 is already installed\nError installing library: MQTT@2.4.7\n'

Once executed, the outcome from the cell might indicate that the library has been successfully installed or that it was already installed.

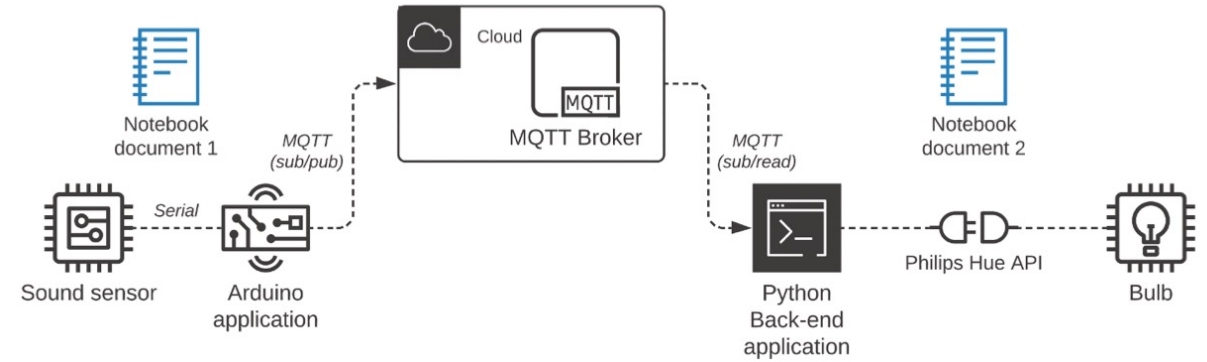
6 Arduino | I... Saving comple... Mode: Comm... Ln 1, Co... sound-level-sensor.ip...

## Notebook doc can:

- Be **grouped** together according to their architectural elements
- Identify and connect to **devices**
- Support multiple **programming languages**

**Configuration cells**, to install dependencies

# Key Findings



Exploratory **user study**

13 **novice** IoT developers

Appreciated for **prototyping** IoT applications

Features were **easy** to understand and **useful**

**Missing:** graphical representation of the components' interactions

# What's Next?

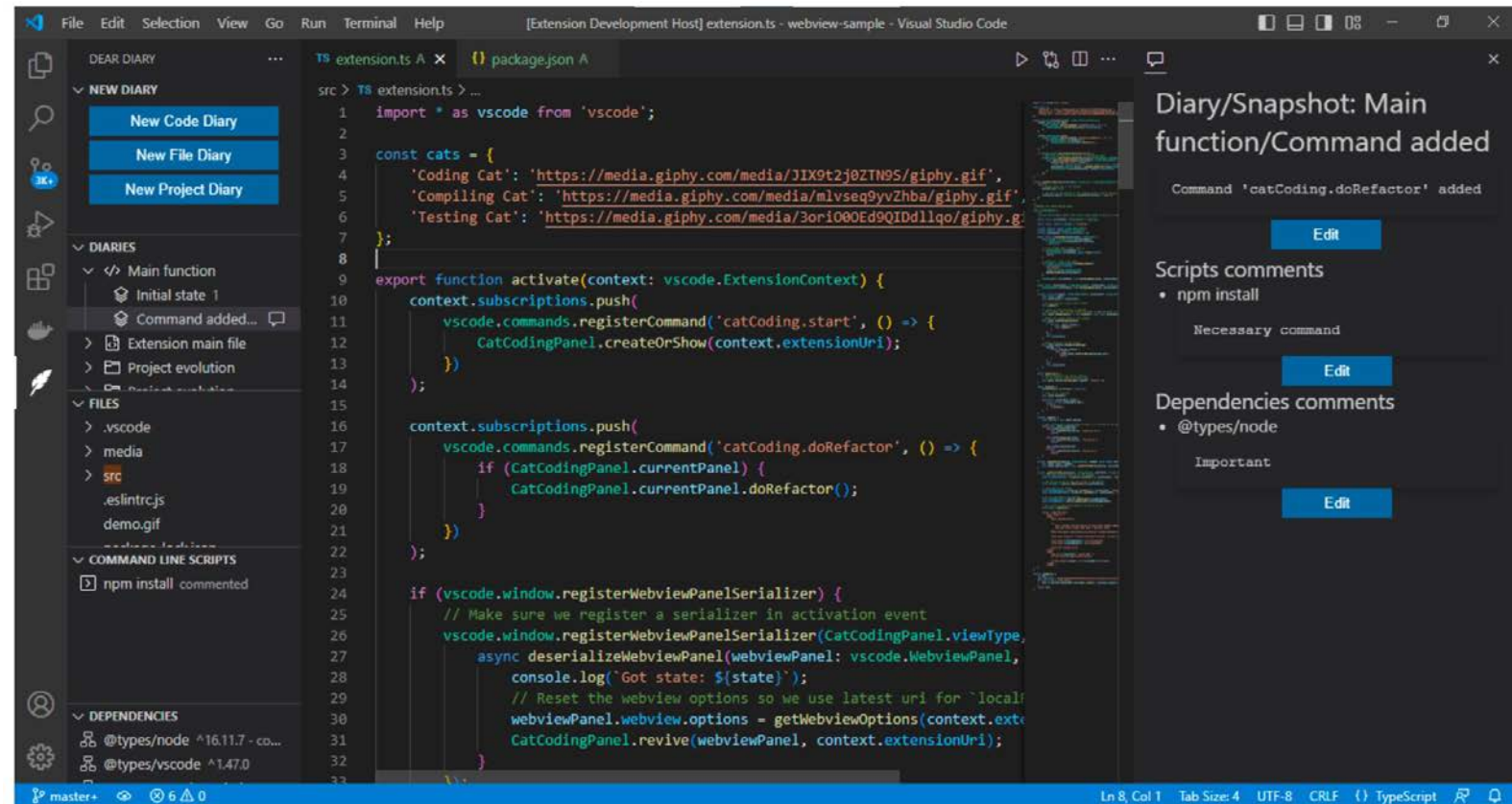
## Developers

What about building on the **diary** metaphor so that they can collect

- Background information
- Rationale for the solution
- Used environments and libraries about (complex) code projects?

**Dear Diary:** documenting novices' development processes

Visual Studio Code extension to support the creation of "diaries" of development



The Zapier logo features a stylized orange asterisk icon above the word "zapier" in a lowercase, rounded, orange sans-serif font. The background of the entire image is a blurred photograph of a laptop on a desk with a notebook and a pen in the foreground.

zapier

End users can program the IoT through **trigger-action rules**

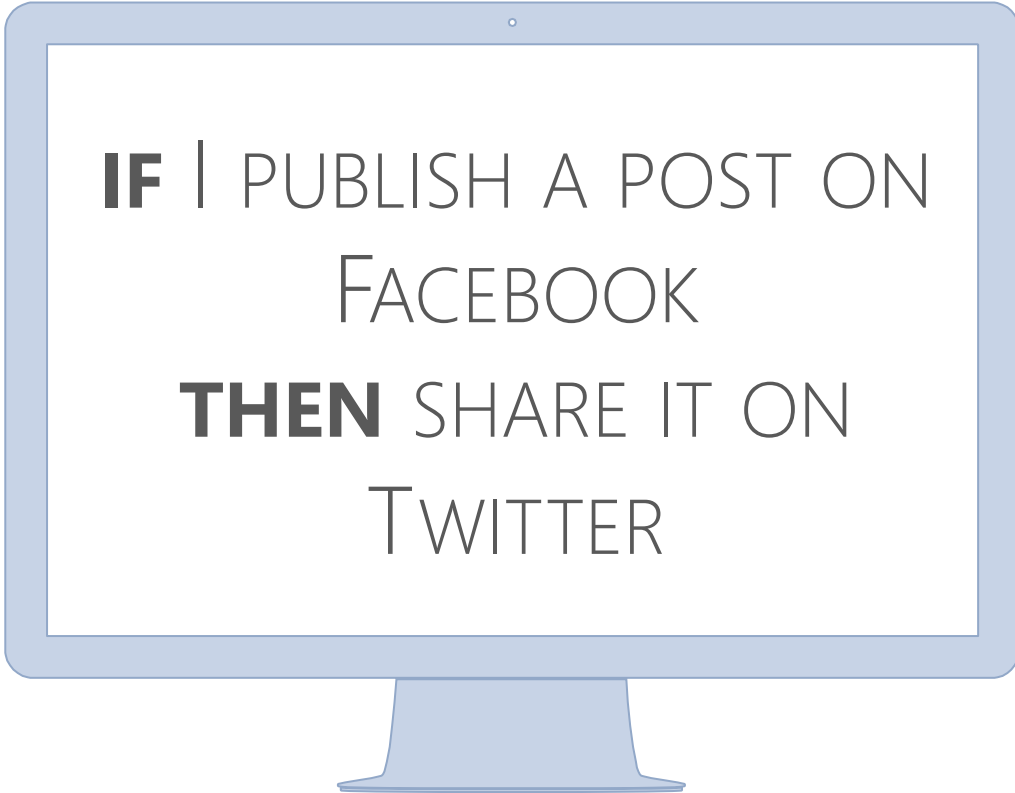
**IFTTT**



Microsoft Flow



**IF** THE SURVEILLANCE  
CAMERA RECOGNIZE ME  
**THEN** TURN ON THE  
SMART THERMOSTAT



**IF** I PUBLISH A POST ON  
FACEBOOK  
**THEN** SHARE IT ON  
TWITTER

if  **this** then **that**




# Main Challenges



**Abstraction** – end users create lot of rules, and they need to know lots of details

**Support** – end users need ways to discover new rules, and debug misbehaving rules

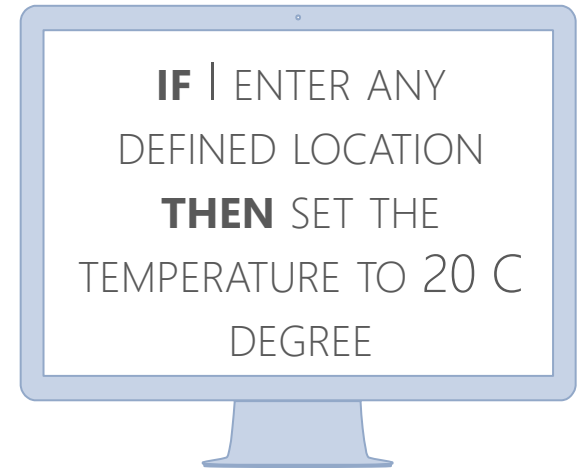
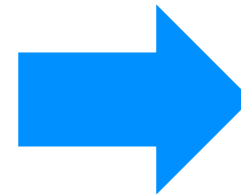
# Abstraction



John is always hot, especially in summer. He loves air conditioning, and he would like to set a low temperature wherever it is possible.

At home, John has an intelligent Nest thermostat, that he controls through his Android smartphone.

John goes to work by his BMW smart car. There, all the offices are equipped with a Samsung air conditioner.

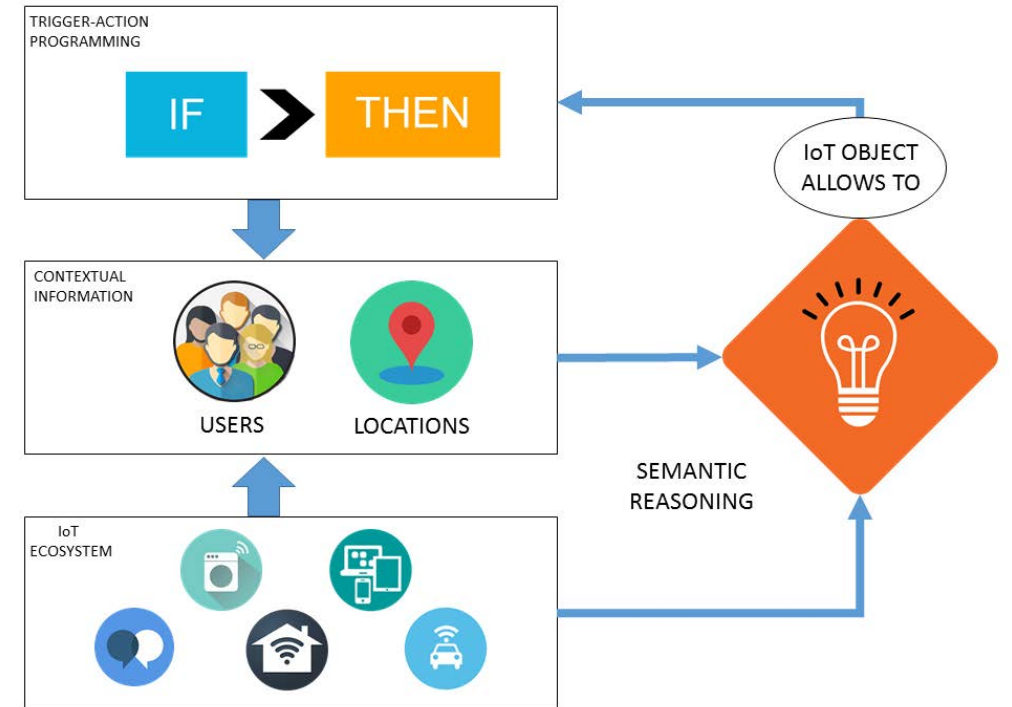


# EUPont

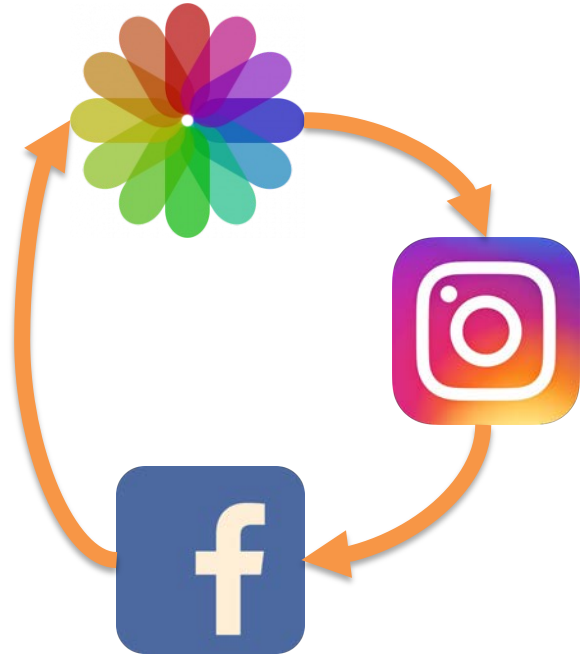
End User Programming **ontology**

## Goals

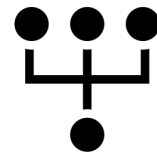
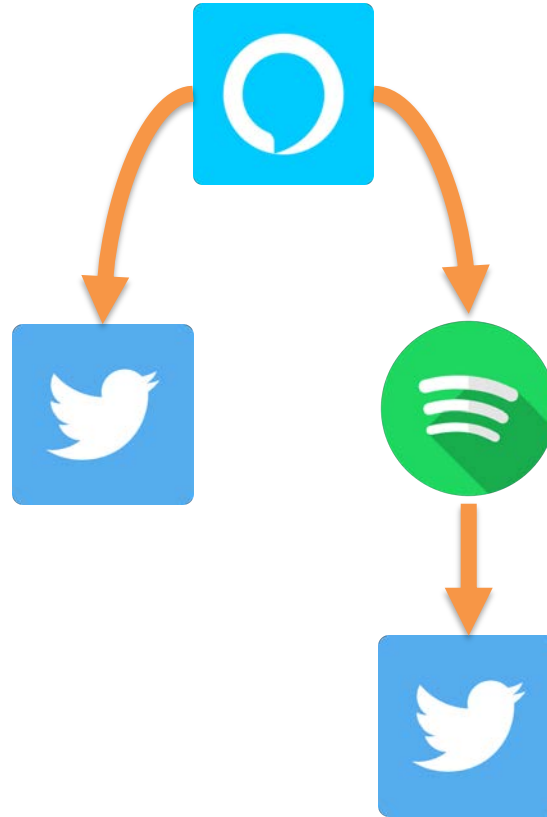
- Higher level of abstraction
- Programming by functionality
- Context dependent rules



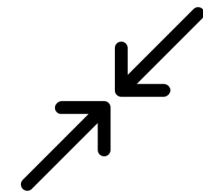
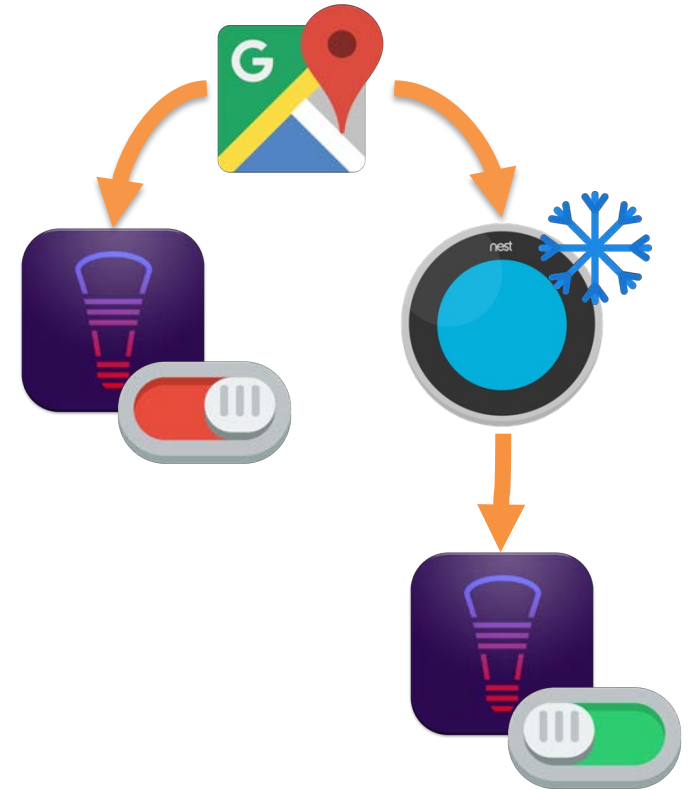
# Problems To "Debug"



Infinite Loops

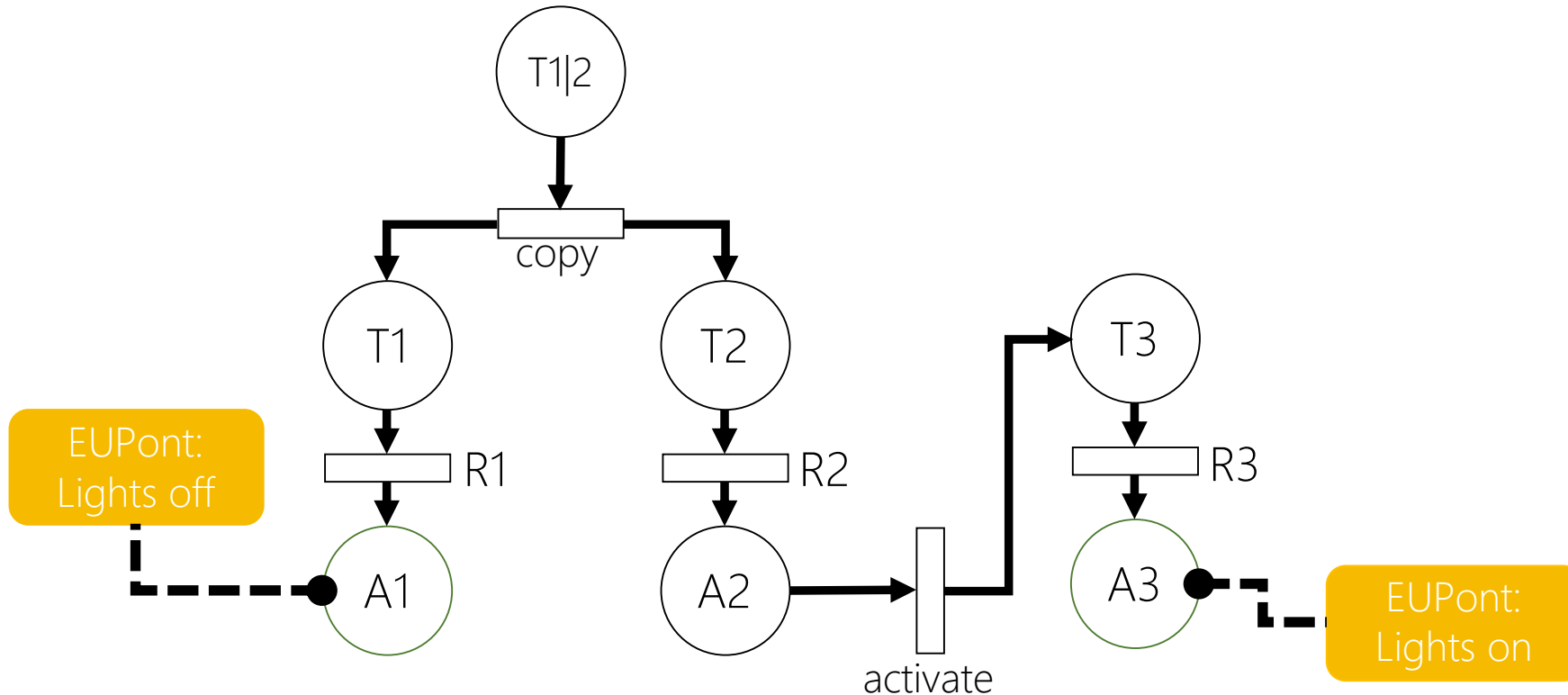


Redundancies



Inconsistencies

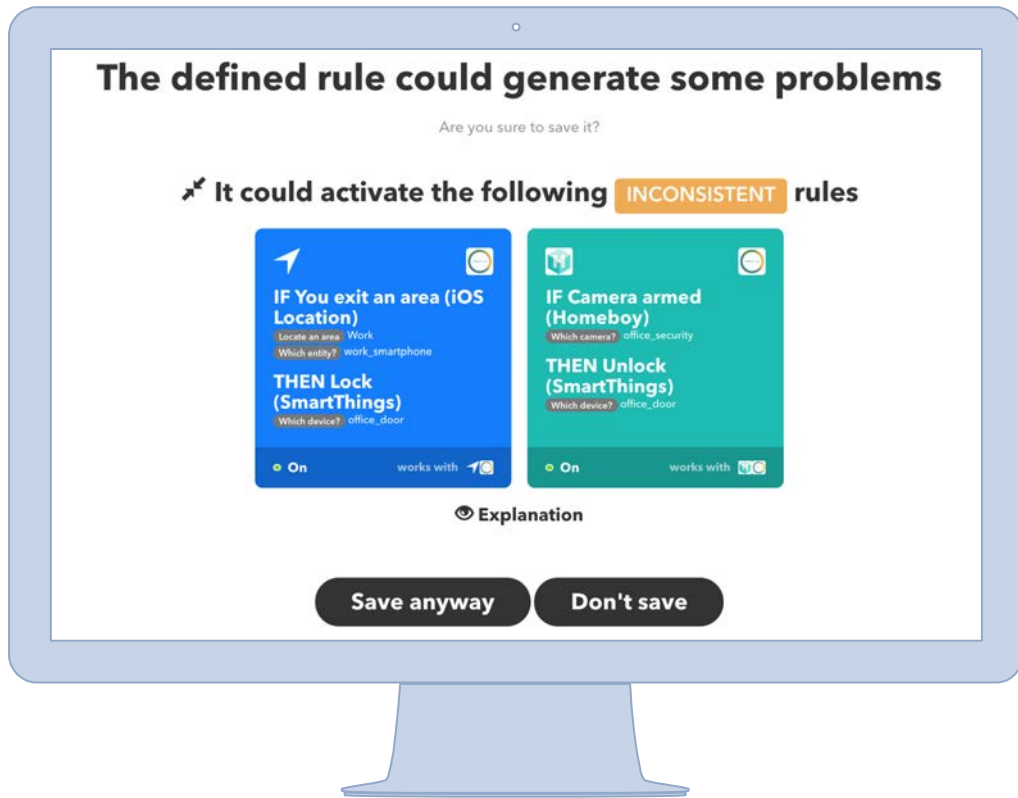
# EUDebug



**IF** I exit home (T1)  
**THEN** turn off the kitchen Philips Hue lamp (A1)

**IF** I exit home (T2)  
**THEN** set the Nest to Away mode (A2)

**IF** the Nest is set to Away Mode (T3)  
**THEN** turn on the kitchen Philips Hue lamp (A3)



STRATEGY 1:  
**Identifying**  
rule conflicts

STRATEGY 2:  
**Simulating**  
rule conflicts



# Key Findings

Exploratory **user study**

15 **end users**, 12 **trigger-action rules** (2 inconsistencies, 2 redundancies, 1 loop)

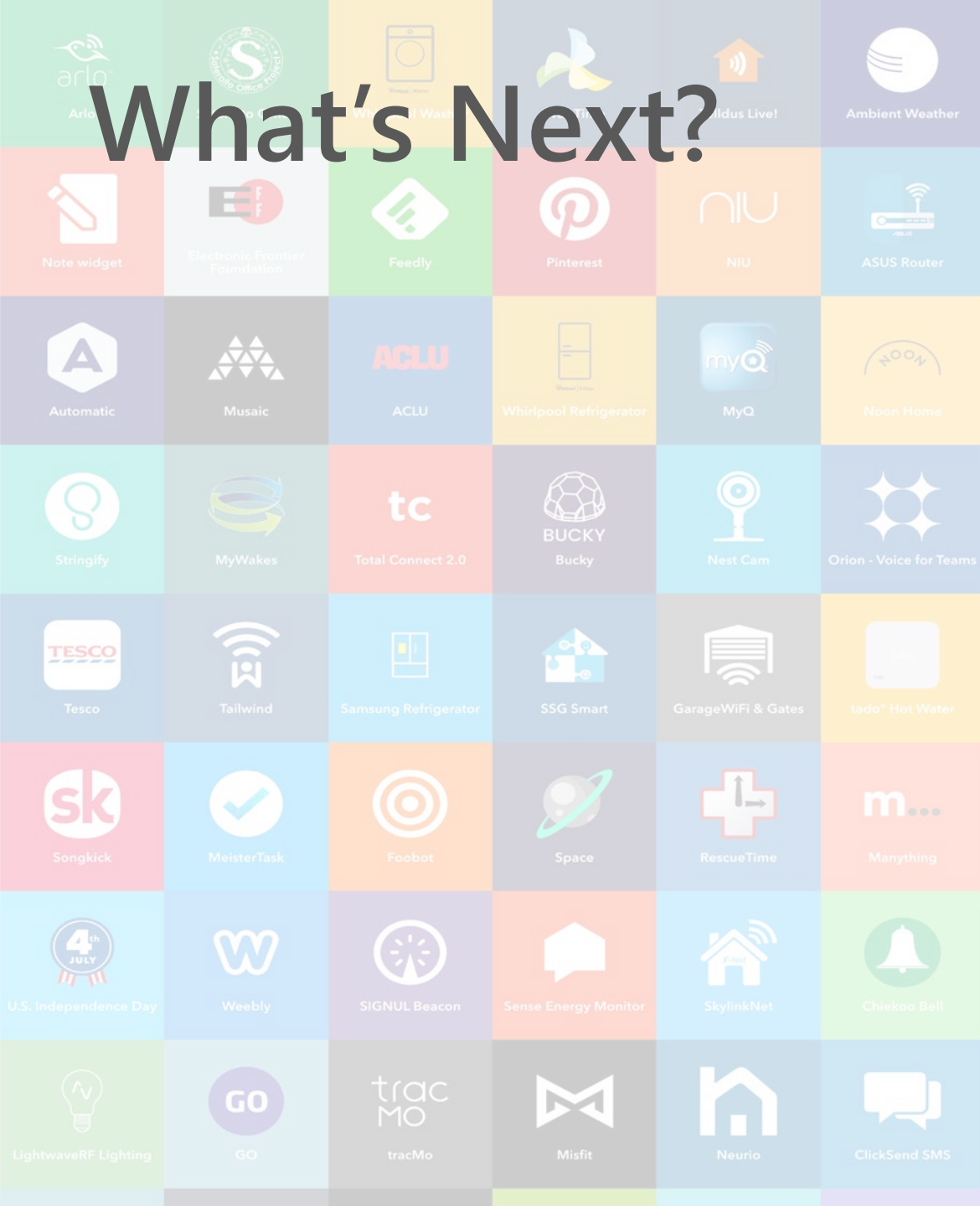
Different **perceptions**:

- Inconsistencies and loops are perceived as **dangerous**
- Redundancies can be even **acceptable**

Loops are **harder** to understand and identify

**Step-by-step simulation** helped understanding problems

# What's Next?



## End users

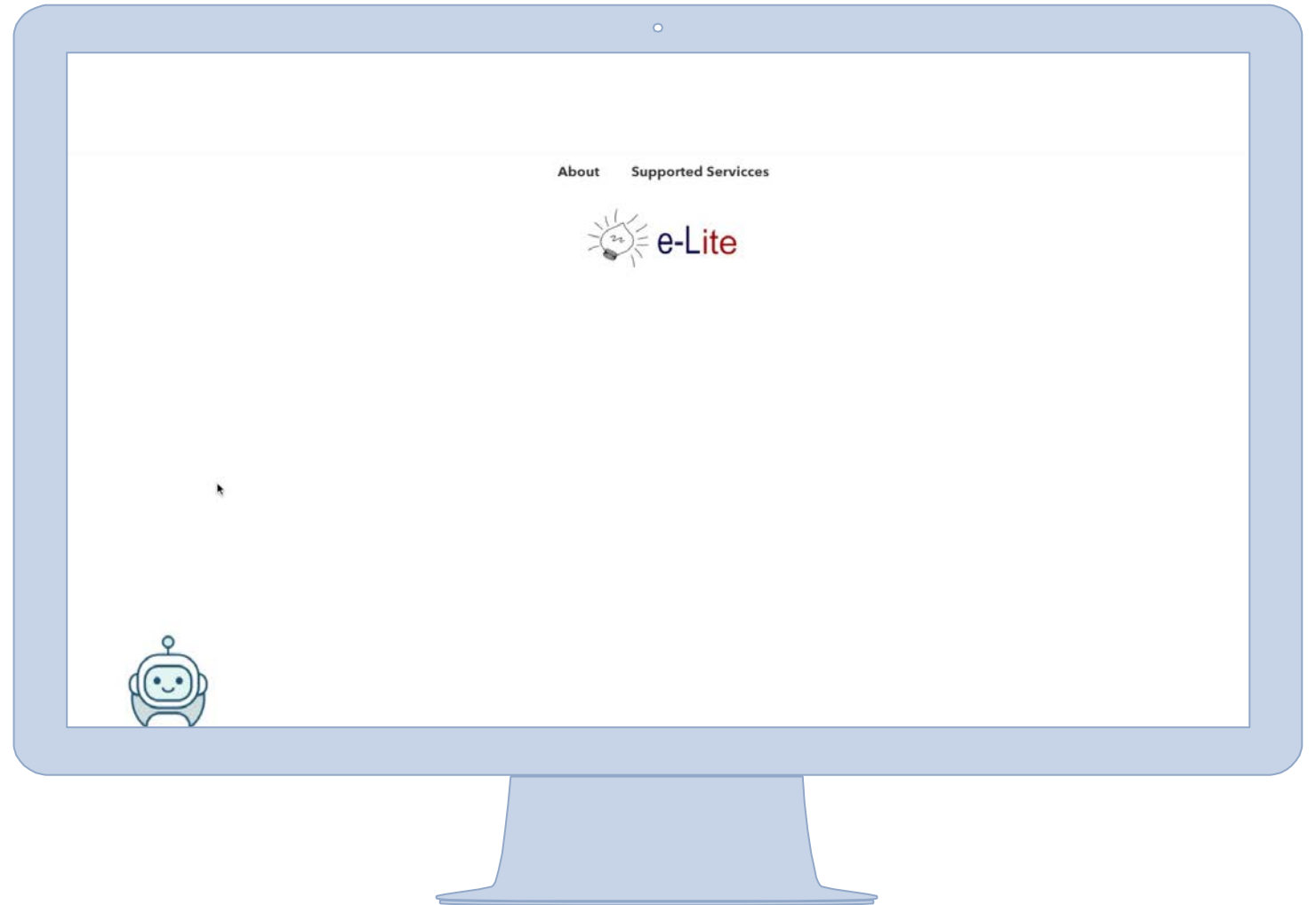
Can we leverage **conversational agents** to

- Compose
- Explain and debug rules?



HeyTAP<sup>2</sup>: a  
**conversational** and  
semantic search and  
recommendation platform

**Map** abstract users' needs  
(intentions) into  
executable IF-THEN rules



# THANK YOU!

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