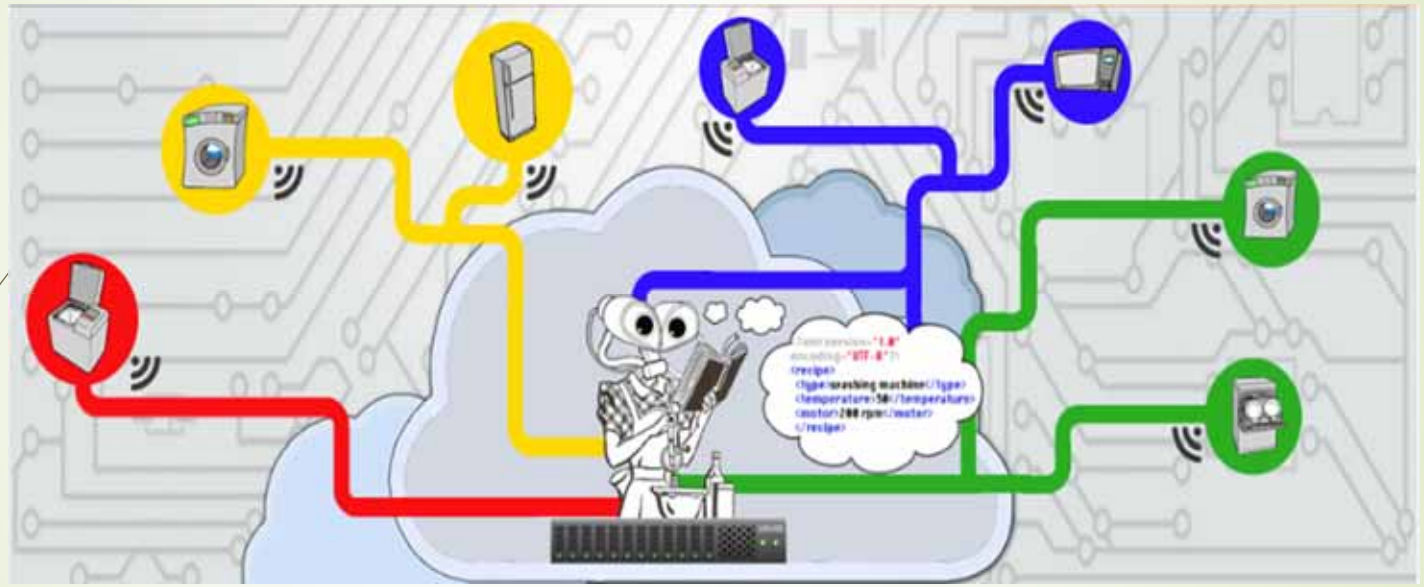
The SandS Ecosystem

B. Apolloni and team

Torino 14/4/2015

The general paradigm:
social household appliances



You ask a task for your appliance

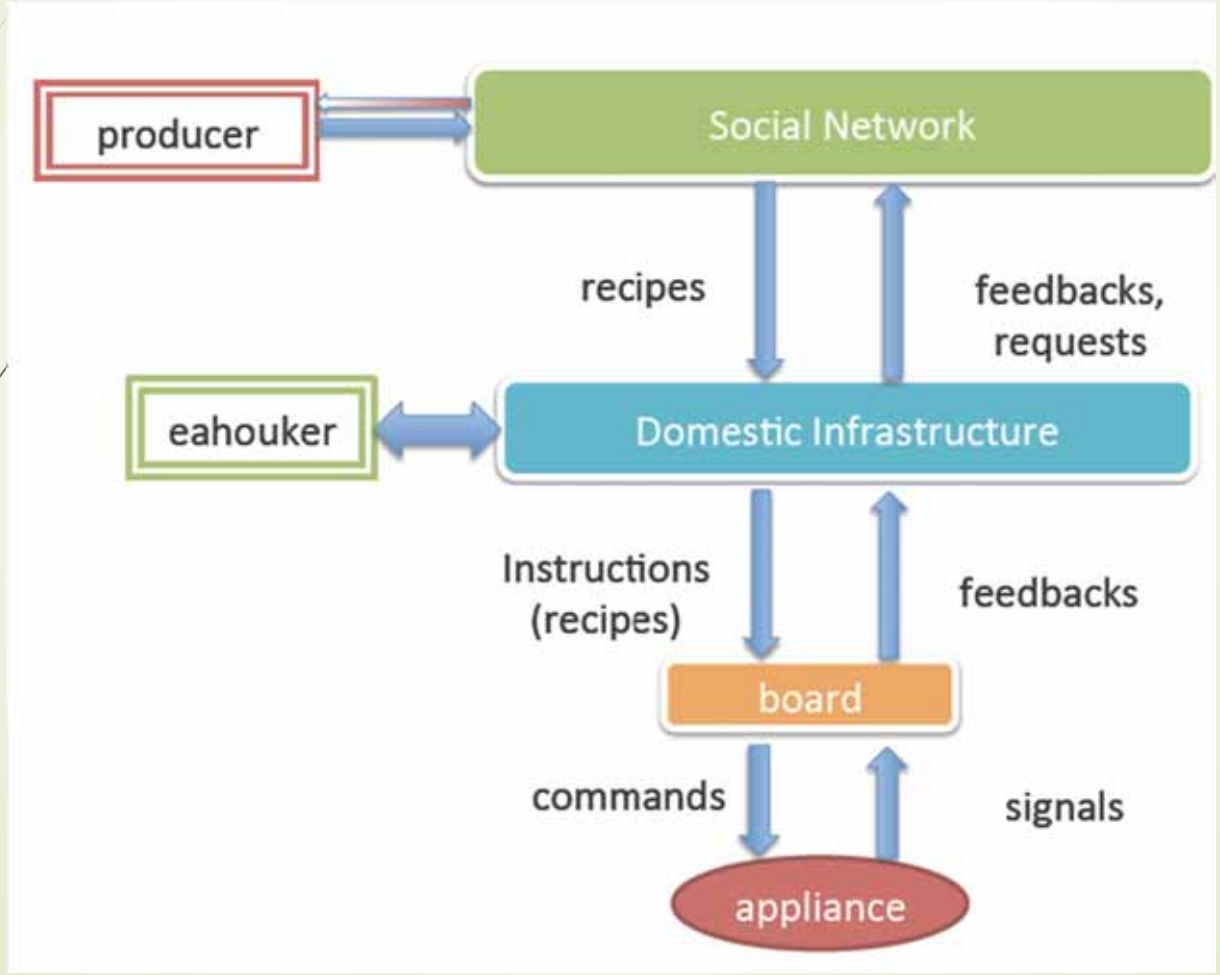
The network executes it through proper recipes

A true instance of Internet of Things

The four pillars

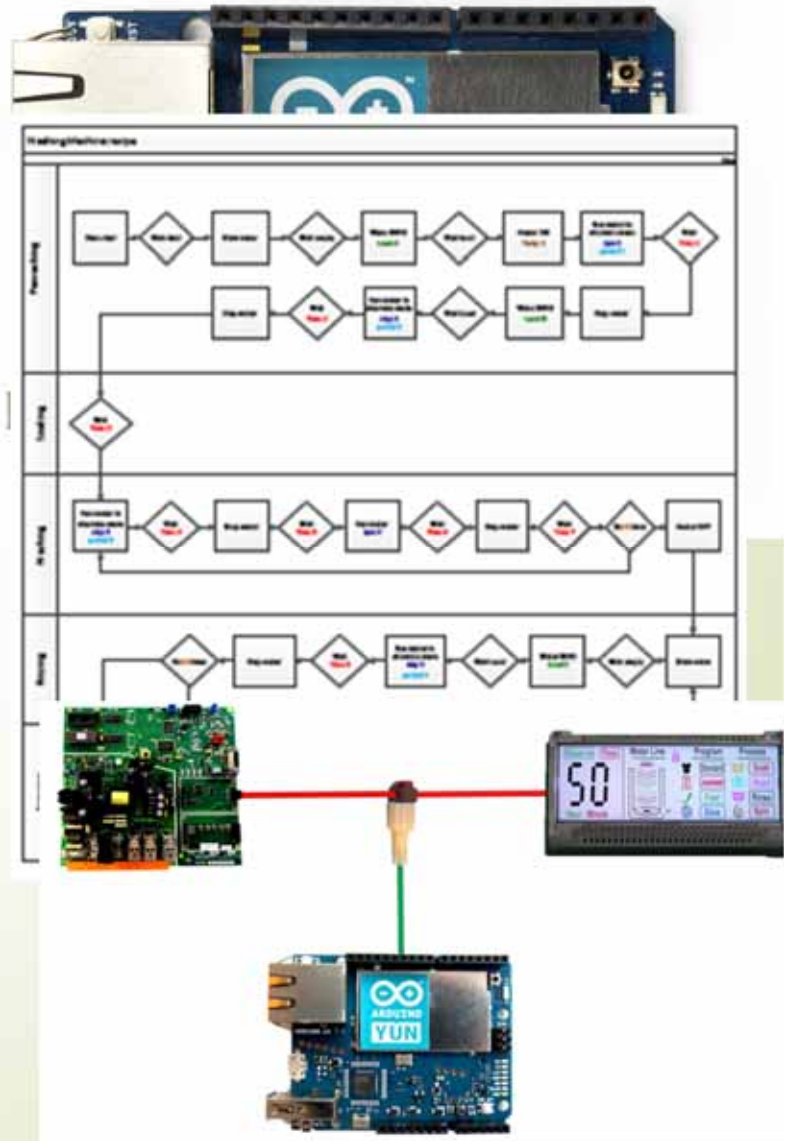
- Hardware once, software ever improving
- If I don't know, I ask the network acting on my name
- Open Social Network of Facts
- Networked intelligence

Lo schema logico dibase



hardware

- Board di basso costo +
- Automa a stati finiti +
- Normali interfacce digitali



TLC

- Architettura scalab
- MQTT broker
- Tecnologia node.js
- Normale router wifi elettrodomestici

Social things

Now we can

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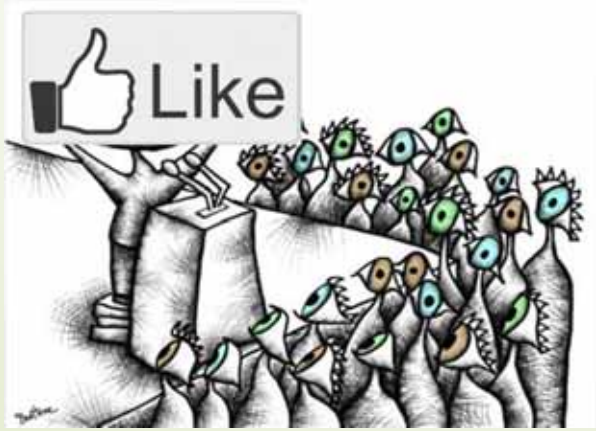
Pisa 10/12/2014

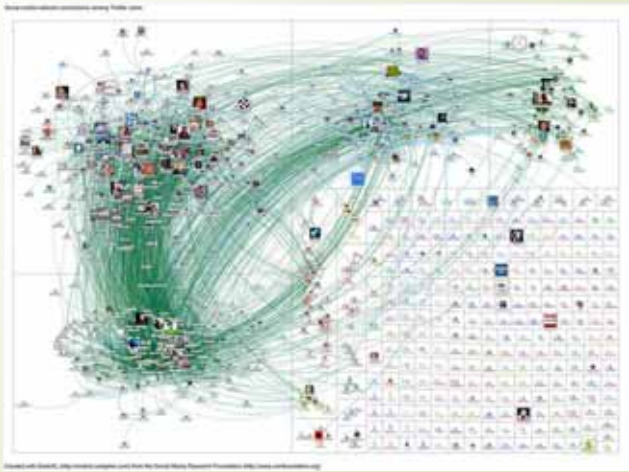
Why now?

- Because Internet of Things connects things almost everywhere to constitute a network
- Because we trust on Social Network
- Because we are used to dialoguing with Internet
- Because things become more and more complex
- Because we expect optimal performances by things in a continuous updating process

What they aren't

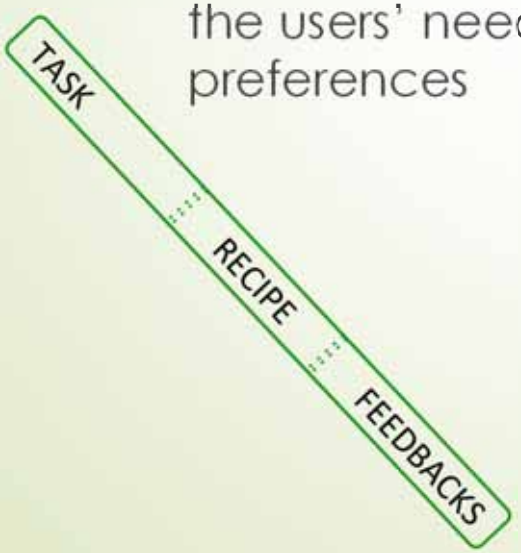
- Things shared by people (the socialism of things)
- Things connected to Internet to form an autonomous social network (SIoT)
- Things governed by owners community's consensus (the I-like tyranny)

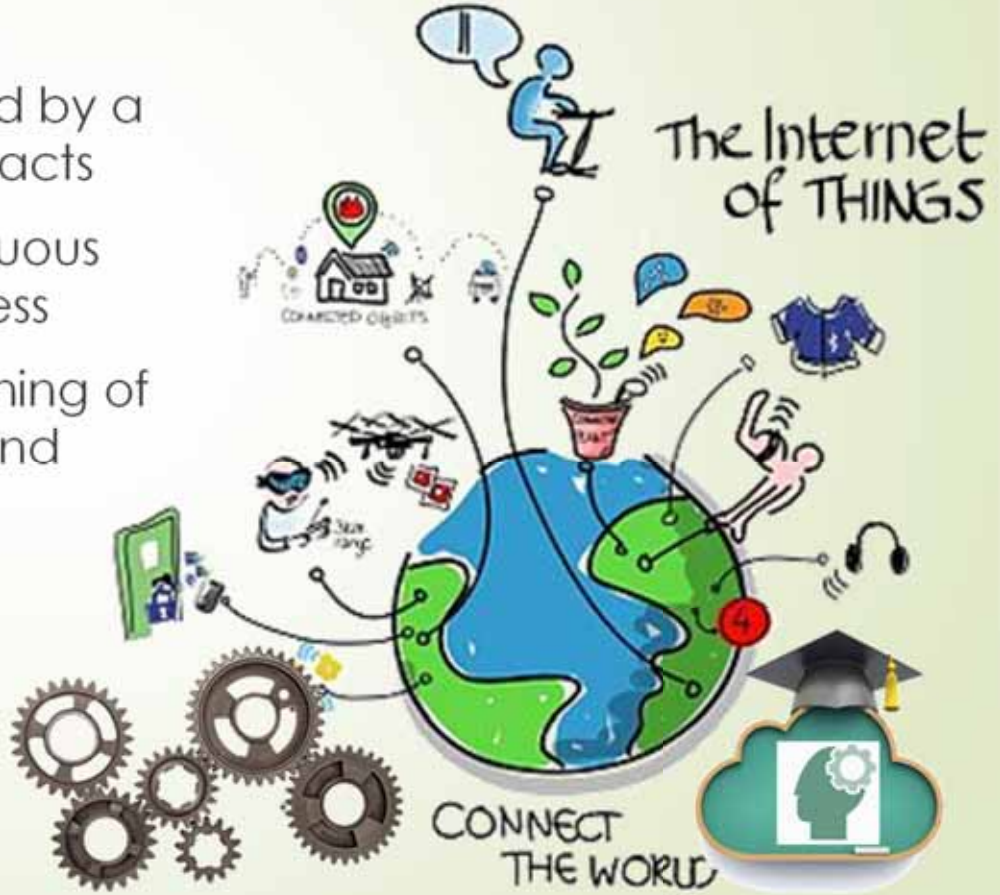




What they are

- Things
  - directly conducted by a social network of facts
  - thanks to a continuous optimization process
  - based on the learning of the users' needs and preferences





Optimization engine

User Preference learning

Lead philosophy

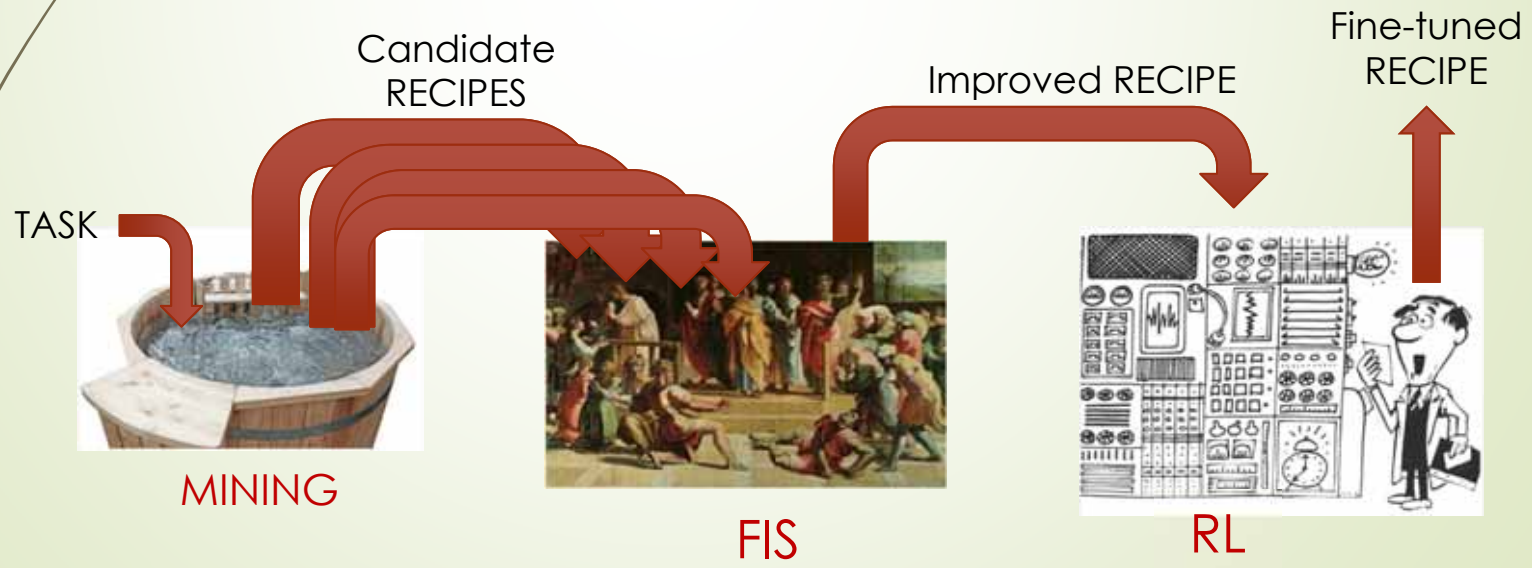
- I don't know how optimally operate my appliances, hence I ask the network
- The network learns to optimally satisfy the user request on the basis of the informative triplet

  <task|recipe|evaluation>

- The social feature of the network stands in the members' contribution in terms of profiles (of them and their appliances) and log of the above triplets

The overall procedure in three steps

- Mining
- Fuzzy System Inference
- Reinforcement learning



The scientific challenge

- Consider Horn clauses suc
  - **If** less crusty **and** soggy **th**
  - **If** very crusty **and** crisp **the**
- Involving:
  - Crisp variables: rising time
  - Fuzzy variables: crustiness
    - With fuzzy quantifiers: les

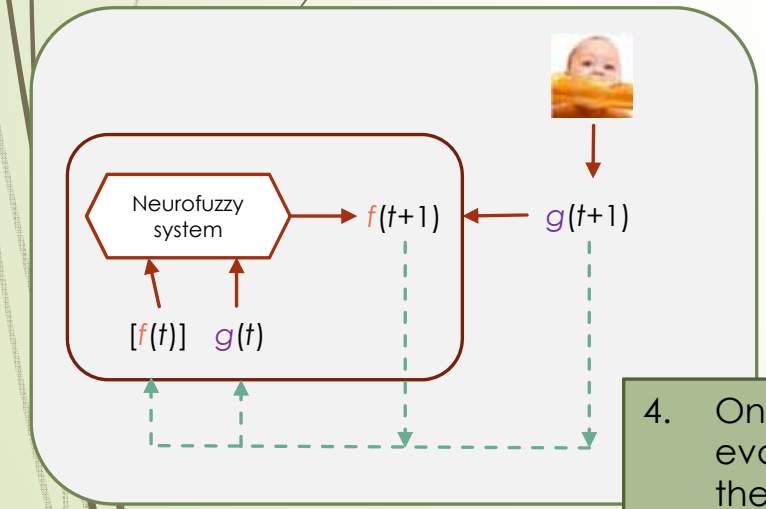
1. On-line learning

1. Prepare a new bread

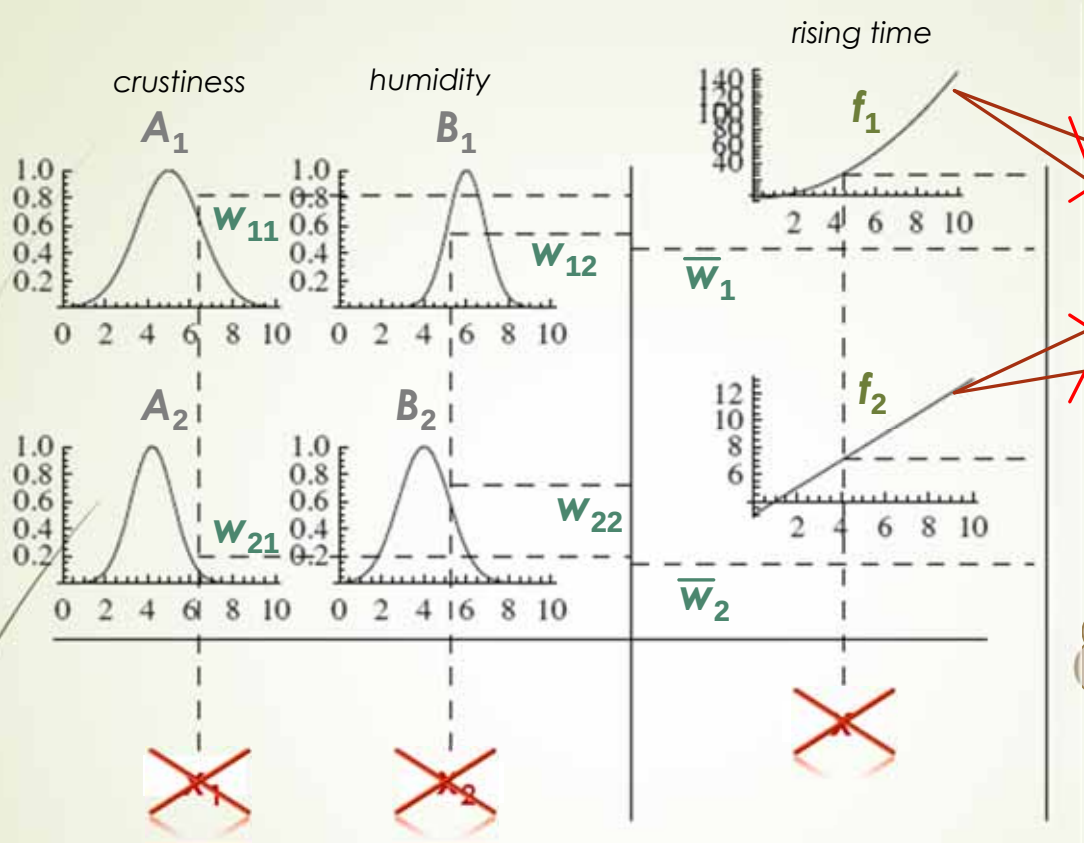
2. Taste it

3. Evaluate the bread

4. On the basis of the evaluation, adjust the bread machine parameters through the neurofuzzy system



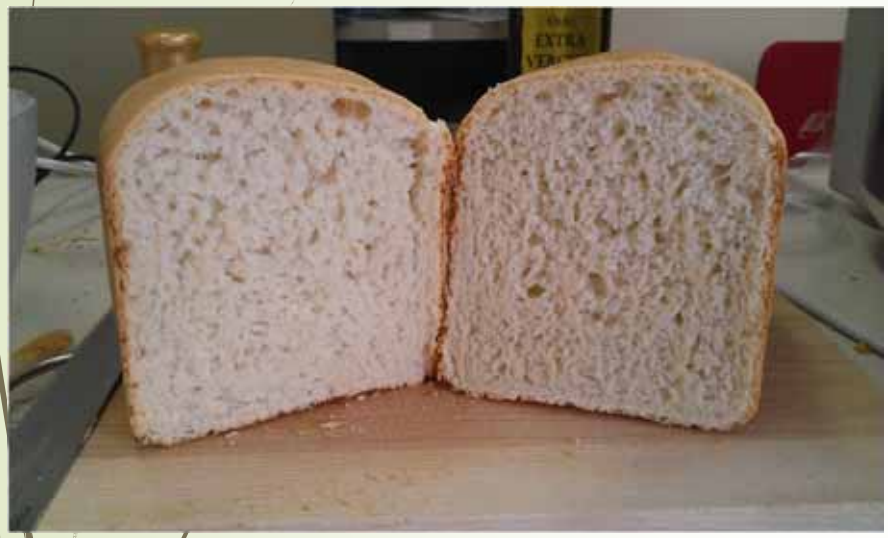
With the further complication



Rather we must infer from the evaluation **g** induced by **f**

LEARNING FROM NOWHERE

Bread is ready!



FIRST LEAVENING		SECOND LEAVENING		PRE COOKING		COOKING		BROWNING		EVALUATION			
Time	Temperature	Time	Temperature	Time	Temperature	Time	Temperature	Time	Temperature	Fragrance	Softness	Baking	Crust
1821	33	2788	35	575	59	3885	118	101	126	+3	+1	+1	+1
1792	33	2813	35	569	59	3872	118	100	126	0	+2	+2	+2
1820	33	2787	35	570	59	3885	118	97	126	0	+1	+1	+1
1766	33	2754	34	560	59	3889	117	93	124	0	+2	+2	+2

Starting from facts: Cartif and Milano mockups

Twin mockups

- Cartif for demonstration
- Milano for prototyping
- Both for experimentig

- ✓ All planned appliances in site
- ✓ All appliances connected to DI
- ✓ Experiment campaign started
- ✓ Functional tests in progress

The kitchen is open, let's operate

Who's the beneficiary?

- USERS
  - – full exploitation of the appliance facilities,
  - – product lifetime extension,
  - – energy use optimization,
  - – greater user convenience,
  - – provision of value-added services,
  - – low cost appliance enhancement
- PRODUCERS
  - – run-time monitoring of the entire appliance fleet
  - – with statistical analysis of the inner and outer sensor
  - – data and their correlation with specific functions,
  - – failure analysis,
  - – remote refresh of the microcontroller software,
  - – collection of user feedbacks,
  - – remote assistance,
  - – loyalty building.

Green goals

- Lavastoviglie e lavatrice sono devices che consumano moolta acqua e moolta energia
- Le regole della casa permettono di adattafre le esigenze idriuche e energetiche degli elettrodomestici alle esoigenze del circondario
- Si può impostare un giusto trade tra tempo, pultio e quantità/tipoi di dewtersivo

Thank you for your attention

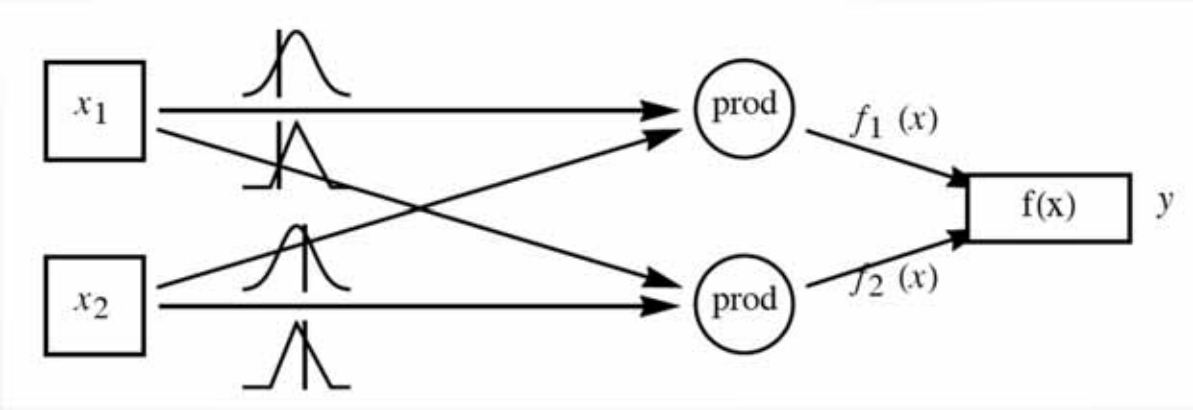
Say bye bye Bruno

Fuzzy Inference System

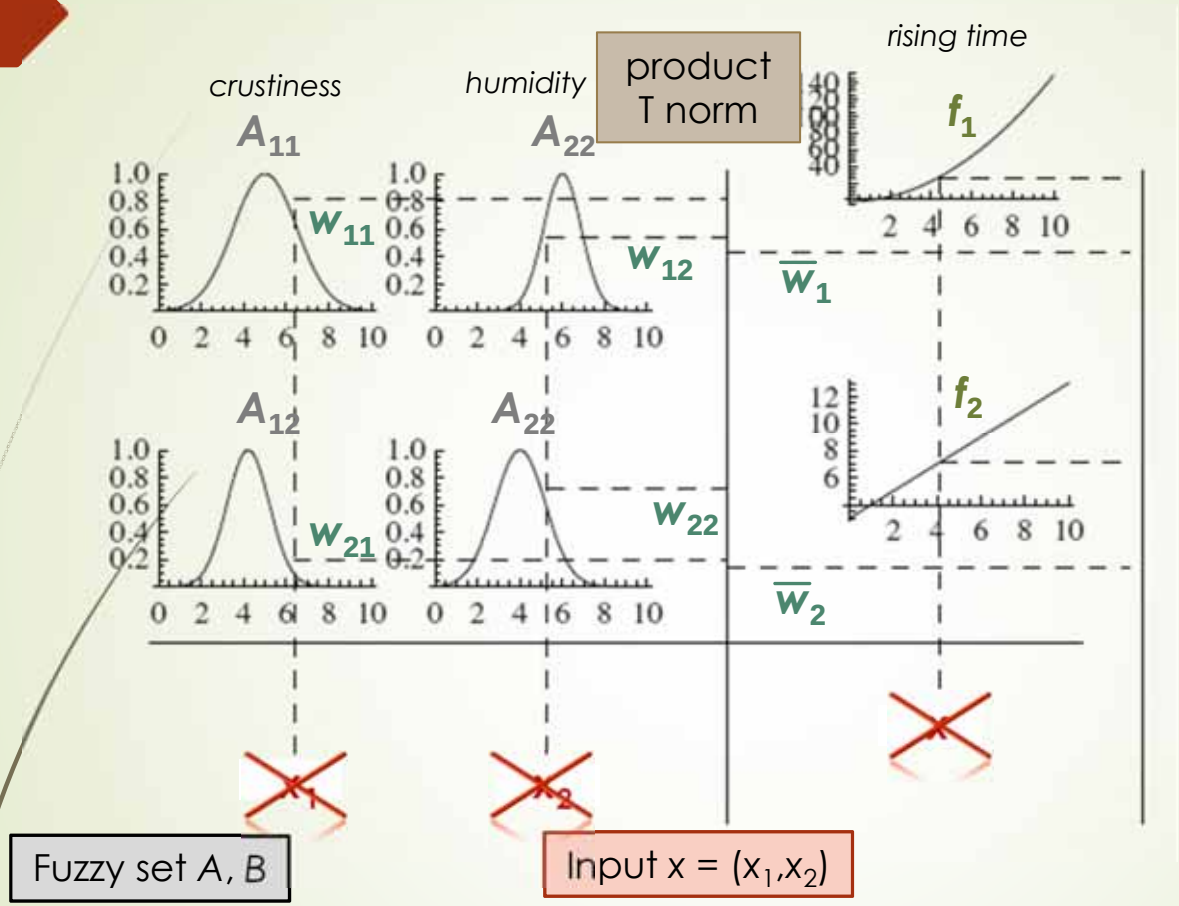
- The generic fuzzy rule system

$$
\begin{aligned}
&\textbf{if } x_1 \text{ is } \mathrm{A}_{11} \text{ and } x_2 \text{ is } \mathrm{A}_{12} \text{ and } \ldots \text{ and } x_n \text{ is } \mathrm{A}_{1n} \textbf{ then } y \text{ is } \mathrm{B}_1,\\
&\textbf{if } x_1 \text{ is } \mathrm{A}_{21} \text{ and } x_2 \text{ is } \mathrm{A}_{22} \text{ and } \ldots \text{ and } x_n \text{ is } \mathrm{A}_{2n} \textbf{ then } y \text{ is } \mathrm{B}_2,\\
&\qquad\vdots \qquad\qquad\vdots \qquad\qquad\vdots\\
&\textbf{if } x_1 \text{ is } \mathrm{A}_{k1} \text{ and } x_2 \text{ is } \mathrm{A}_{k2} \text{ and } \ldots \text{ and } x_n \text{ is } \mathrm{A}_{kn} \textbf{ then } y \text{ is } \mathrm{B}_k,
\end{aligned}
$$

- The Sugeno variant



With the further complication



rising time

$$f = \overline{w}_1 f_1(\mathbf{x},a) + \overline{w}_2 f_2(\mathbf{x},a)$$

Fuzzy set *A*, *B*

Input $x = (x_1, x_2)$

Output *f*

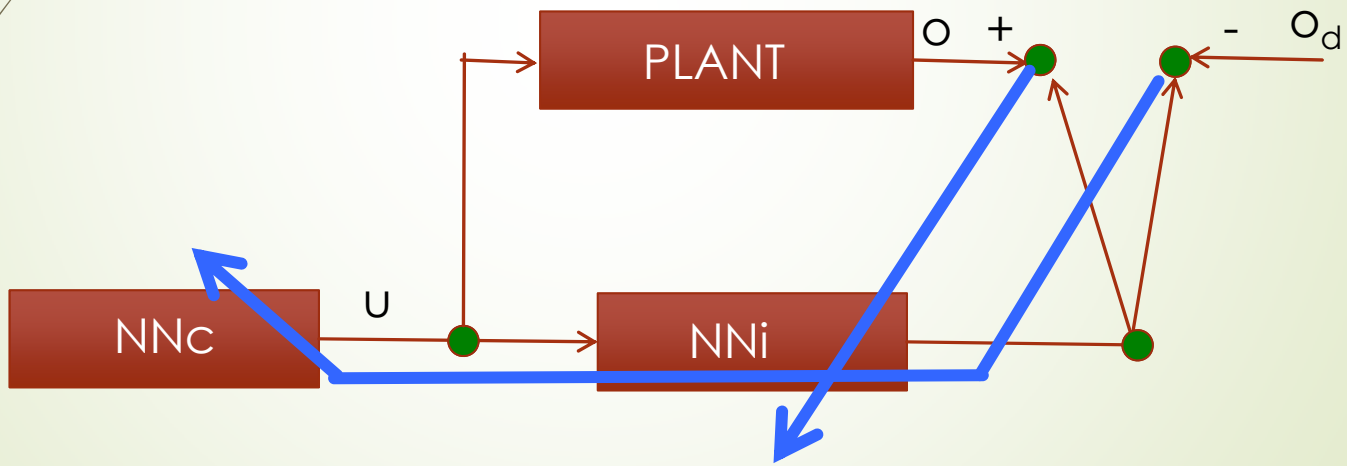
Weight w_{ij}
Normalized weight $\overline{w}_{ij}$

Sugeno functions f_i

Hence we must infer x as well

1. A mixture of identification and control

Let's recall distal learning by Rumelart and Jordan



Learn to compute the *u*

once you have learnt the PLANT *model* for whatever *u*

A peculiar cognitive problem

- Recipes are sequences of parameter/value pairs.
- Tasks and evaluations are sets of both crisp and fuzzy variables.

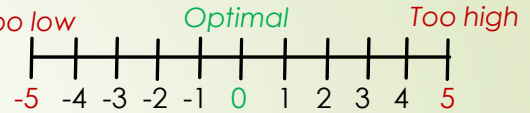
but

- Fuzzy quantifiers do not refer to a specific metric space

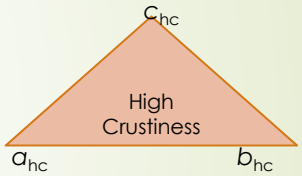
LEARNING FROM NOWHERE

Computational issues
Active variables

- **Output *f***: rising time → positive continuous
- **Evaluation *g***: judgement → likert scale



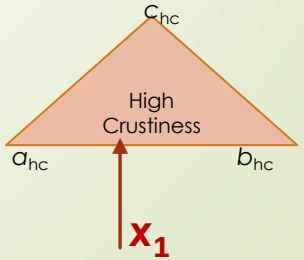
- **Parameters *θ***:
  - of a membership function
    - Vertex of triangular mf
    - Mean and std of asymmetric Gaussian mf
    - …

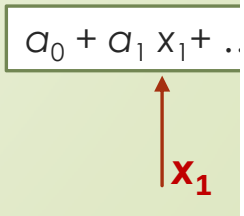


  - of the Sugeno function
    - usually linear in the function

$$f_1(x,a) = a_0 + a_1 x_1 + a_2 \log(x_2)$$

  - the input position within the membership function as well
    - to identify input coordinates





- **Error *E***: e.g. g^2

2. Computational issues

Simply a richer derivative chain

$$\partial E/\partial g \; \partial g/\partial f \; \partial f/\partial \theta$$

Identification phase

- $E = (y - f)^2$
- $\frac{\partial E}{\partial f} = 2(y - f)$
- $\frac{\partial f}{\partial \theta} =$ canonical learning update rule

Control phase

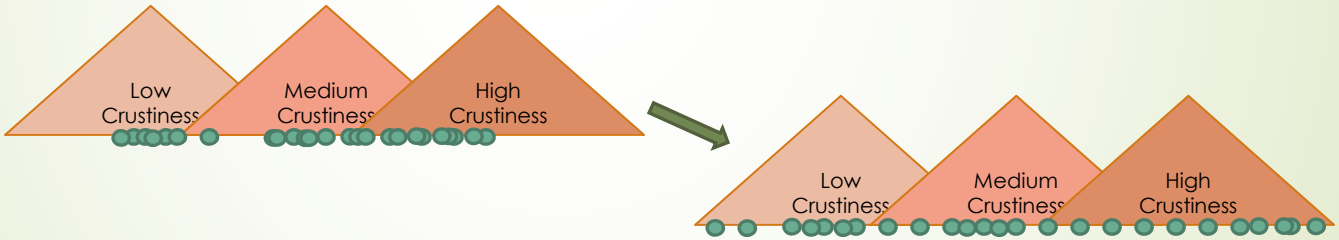
- $E = g^2$
- $\frac{\partial E}{\partial g} = g$
- $\partial g \,/\, \partial f$
  - analitic way: $\left(\frac{\partial f(t+1)}{\partial g(t+1)}\right)^{-1}$
  - numeric way: $\approx \frac{g(t+1) - g(t)}{f(t+1) - f(f)}$
- $\frac{\partial f}{\partial \theta} =$ canonical learning update rule

Legend

- **Output *f***: rising time
- **Evaluation *g***: judgement
- **Parameters *θ***
- **Error *E***: e.g. g^2 //$(y-f)^2$

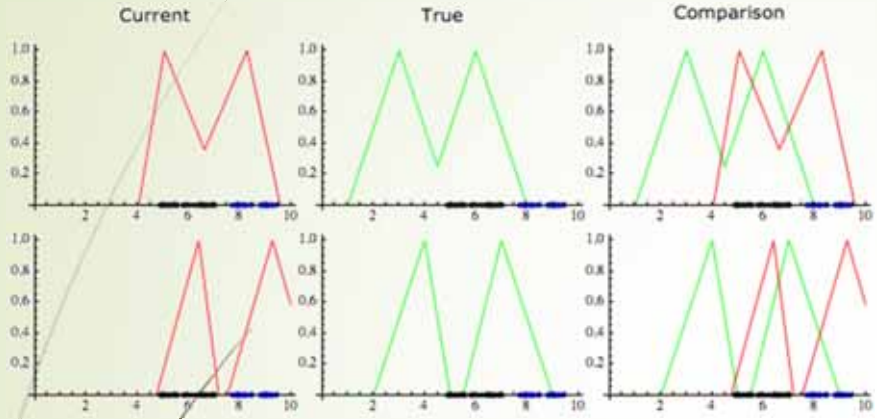
Two kinds of retropropagated signals

1. Task-related signals
   a. User judgment
      - **On-line**
   b. Target appliance parameter
      - off-line mode
2. Empirical evidence-related signals

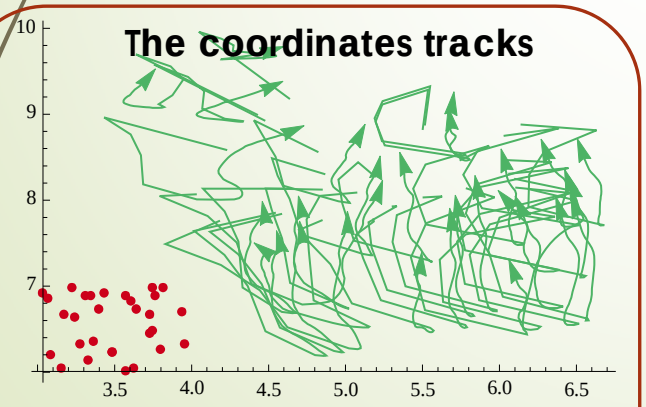


The doble life of g_is: **fuzzy sets as for antecedents,**
Likert metrics as for consequent

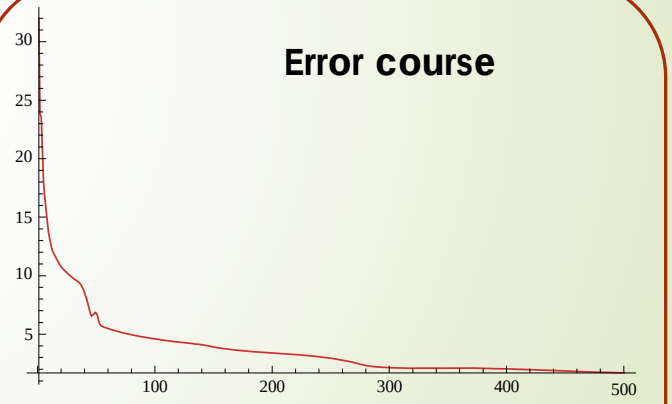
Early numerical results: case study



True mf (green triangles) vs. inferred mf (green triangles)

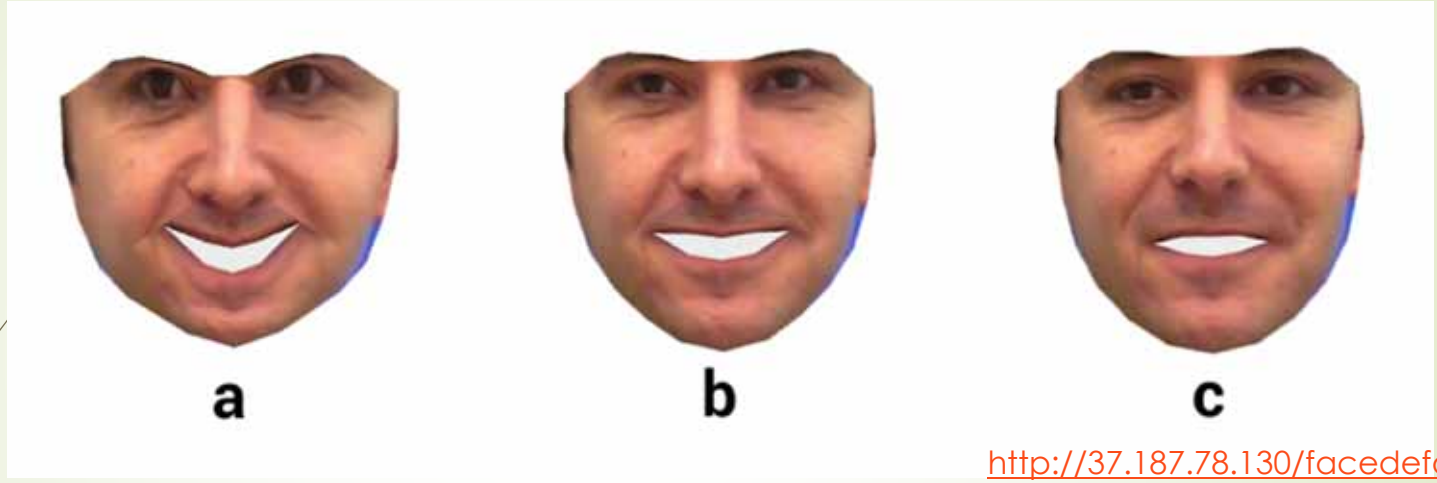


Input trajectory (green arrow) and true input (red ponts)



Error computed on arbitrary target with non-linear Sugeno functions

Early experiments
a close case



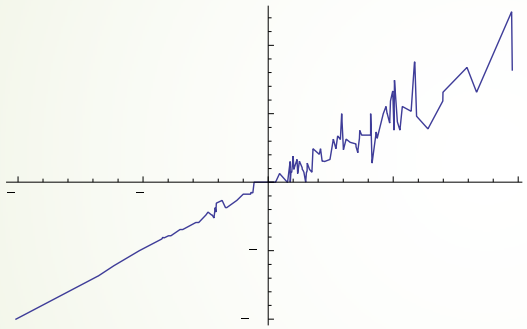
http://37.187.78.130/facedeform/

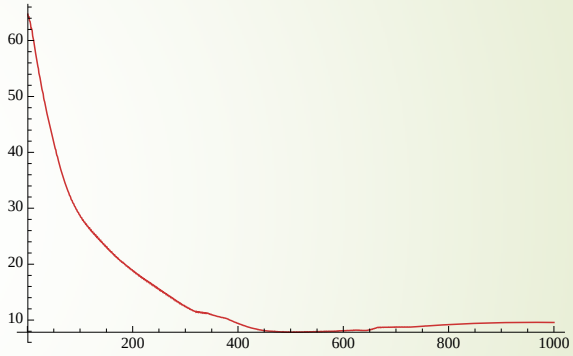
- Main fe
  - 10 p
  - 4 e
  - No
    par

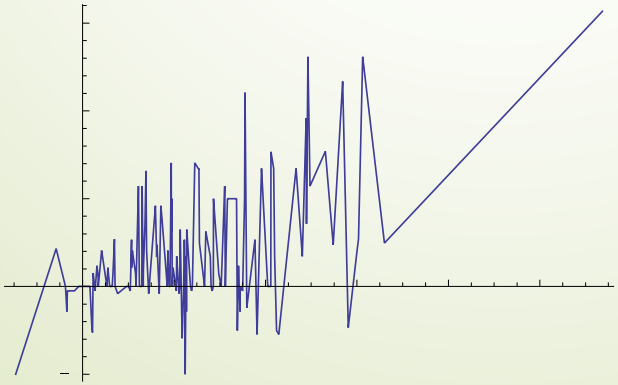
between

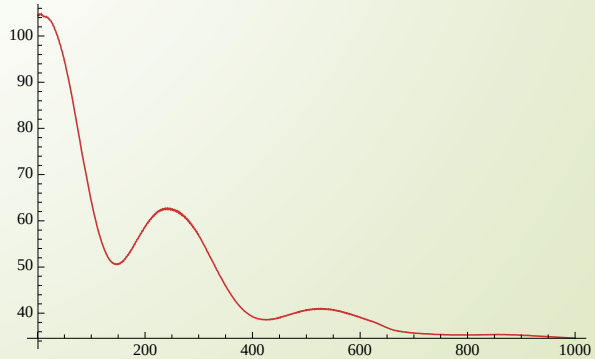
The identification phase

Relating the four judgements to two parameters



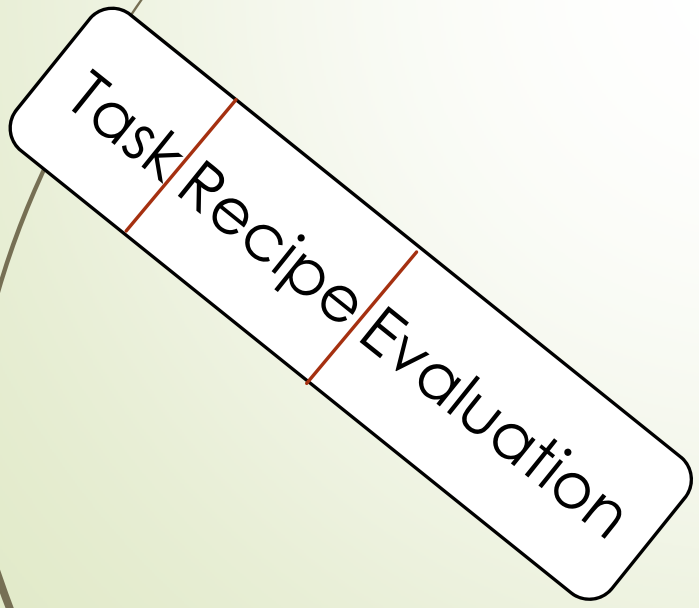






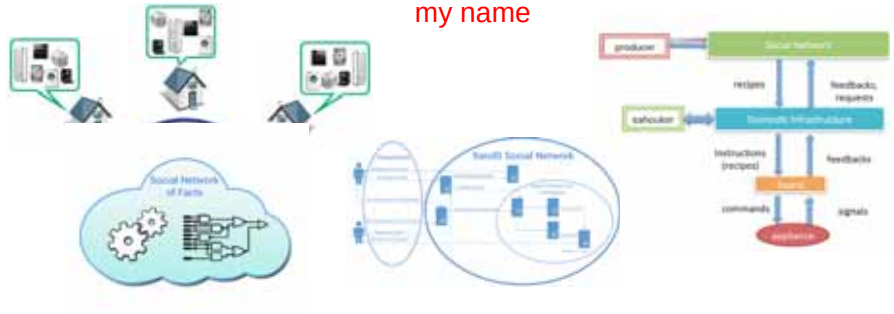
Training and generalization problems

- No training from judgements if no on-line learning
- No on-line learning if the training largorithm is not efficient.

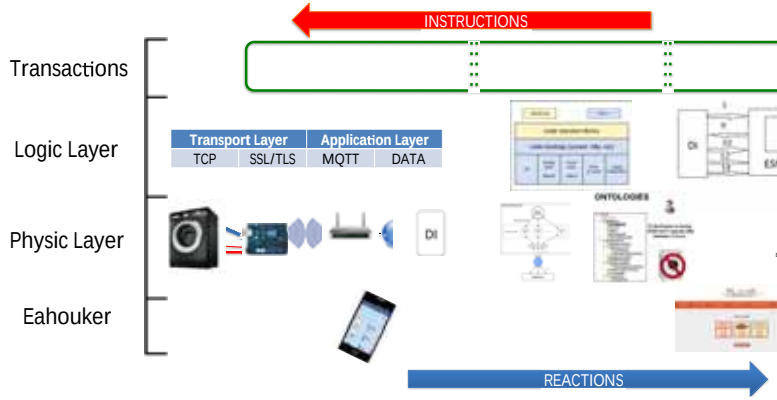


SandS
Social & Smart

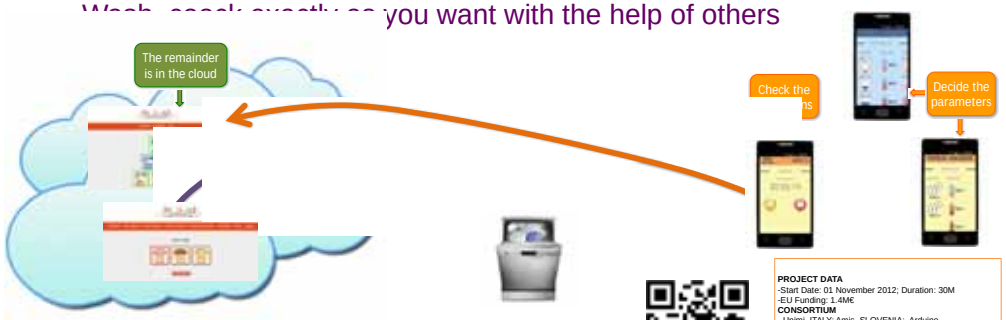
A social network of facts that physically manages all appliances parameters on my name



A four layers approach to implement an overall ecosystem



Wash, cook exactly as you want with the help of others



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Future Internet Research and Experimentation – FIRE
SandS – Social & Smart
http://www.sands-project.eu

PROJECT DATA
-Start Date: 01 November 2012; Duration: 30M
-EU Funding: 1.4M€
CONSORTIUM
- Unimi, ITALY; Amis, SLOVENIA; Arduino, SWITZERLAND; Ntua, GREECE; Cartif, SPAIN; Gorenje, SLOVENIA; Libelium, SPAIN; Upv, SPAIN;
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