University of Maribor

Faculty of Organizational Sciences

Application of CPS&IoT systems to assist people with disabilities

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Wheelchair

- Cloud speech recognition applied in control of the wheelchairs for disabled persons
- Tight integration with Internet and its users, which continuously feed the database / possible to provide corrections
- Price, accuracy
- Drawbacks, such as latency
- Word error rate (WER – CER)
- Technical difficulty to use cloud Application Programming Interface (API)
- More new cloud speech recognition services available
- Develop efficient algorithms, which will combine speech recognition results

Specification

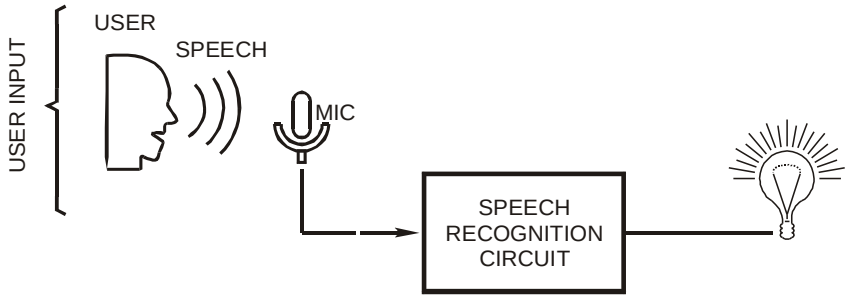
- Prototyping
- Control the movement of the wheelchair with speech
- The principle of cloud harvesting should be applied
- In addition to speech, control should be possible via web-based GUI
- Remote monitoring and control.
- Real-time video streaming from the wheelchair platform
- Biomedical signals
- Provide uniform GUI with interactive graphics of main parameters.

Cyber-physical Systems & Internet of Things

- A cyber-physical system (CPS) is a mechanism controlled or monitored by computer-based algorithms, **tightly integrated with internet and its users**
- Internet of Things (IoT) is a subset of CPS where „physical“ is omitted i.e. monitoring or providing an information (still in formulation)
- Today, informatics should not only measure but also listen, watch, interact with users, move, handle, grab etc.

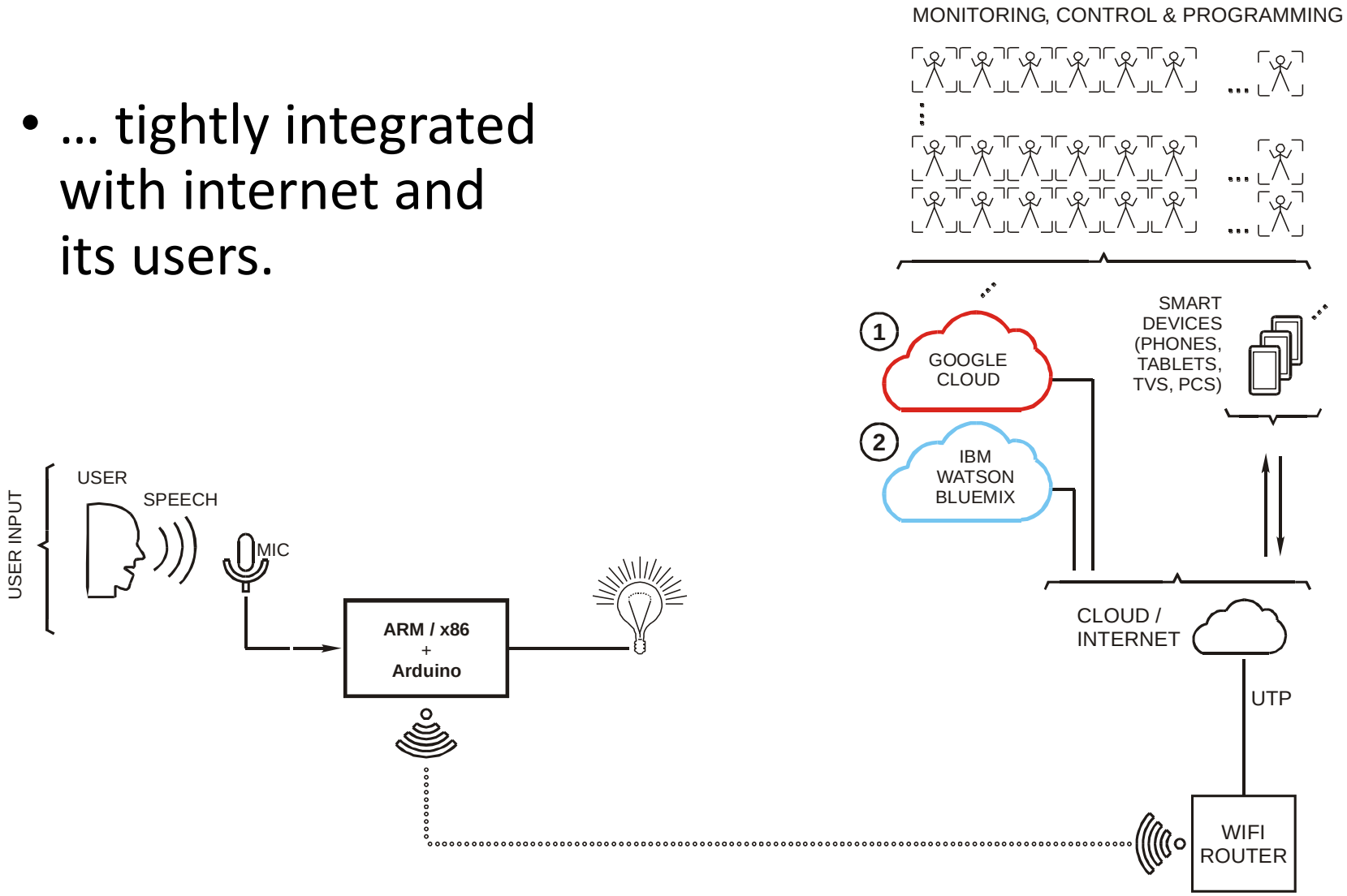
Example of speech controlled device

- Application of speech recognition circuit
- Embeded logic
- Hard to adapt
- Self sufficient device



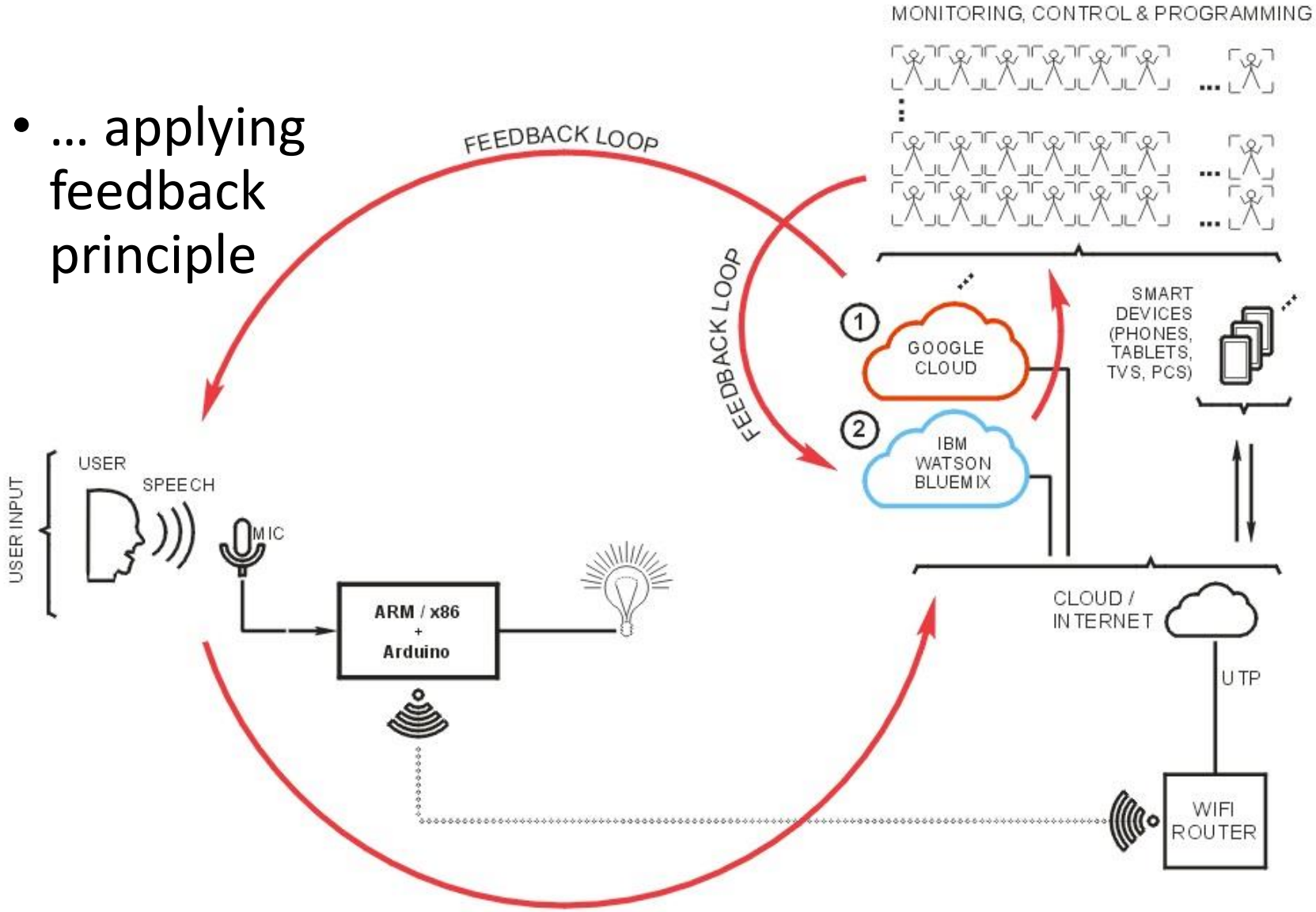
Example of speech controlled device (ver. 2)

- … tightly integrated with internet and its users.

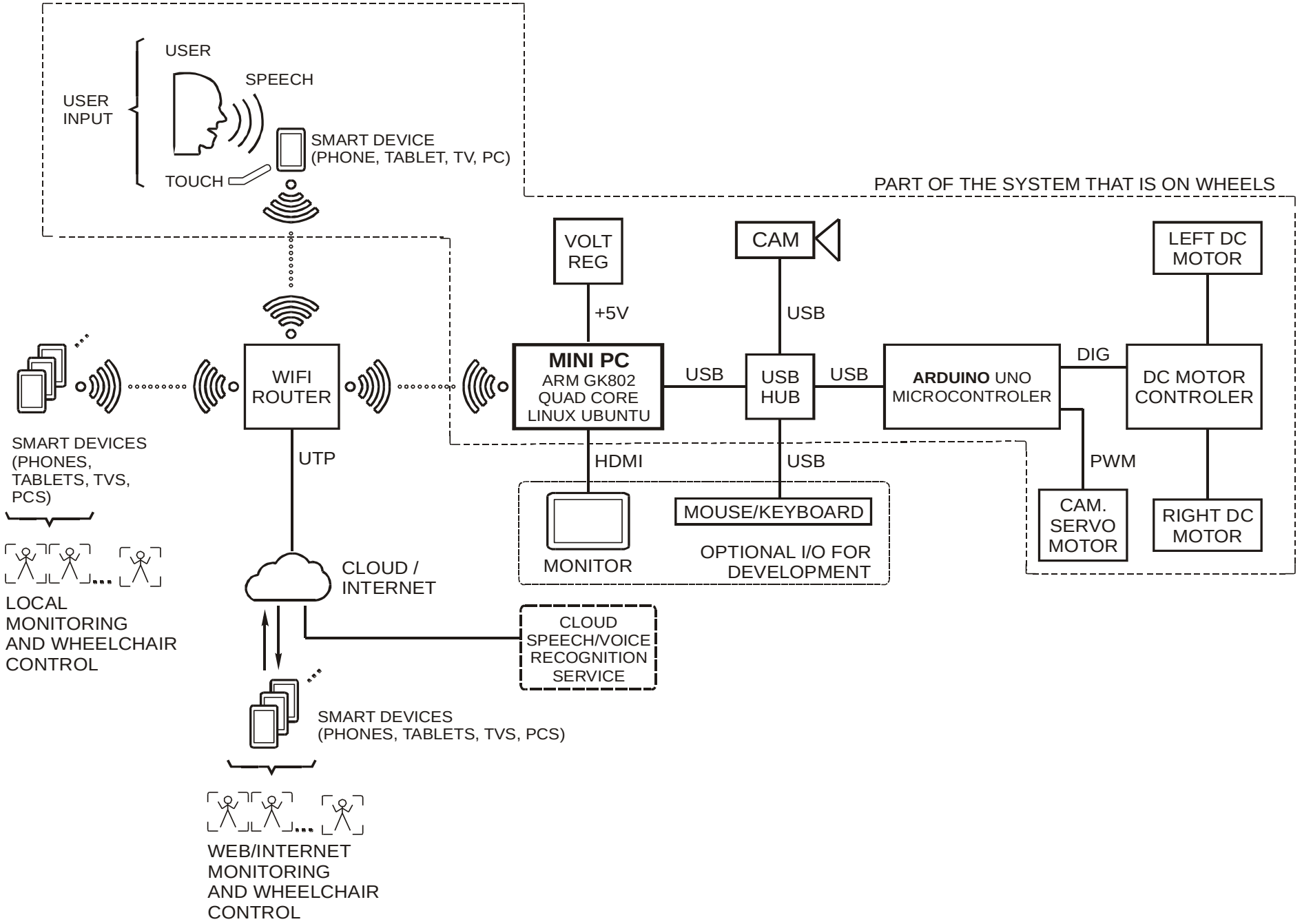


Example of speech controlled device (ver. 3)

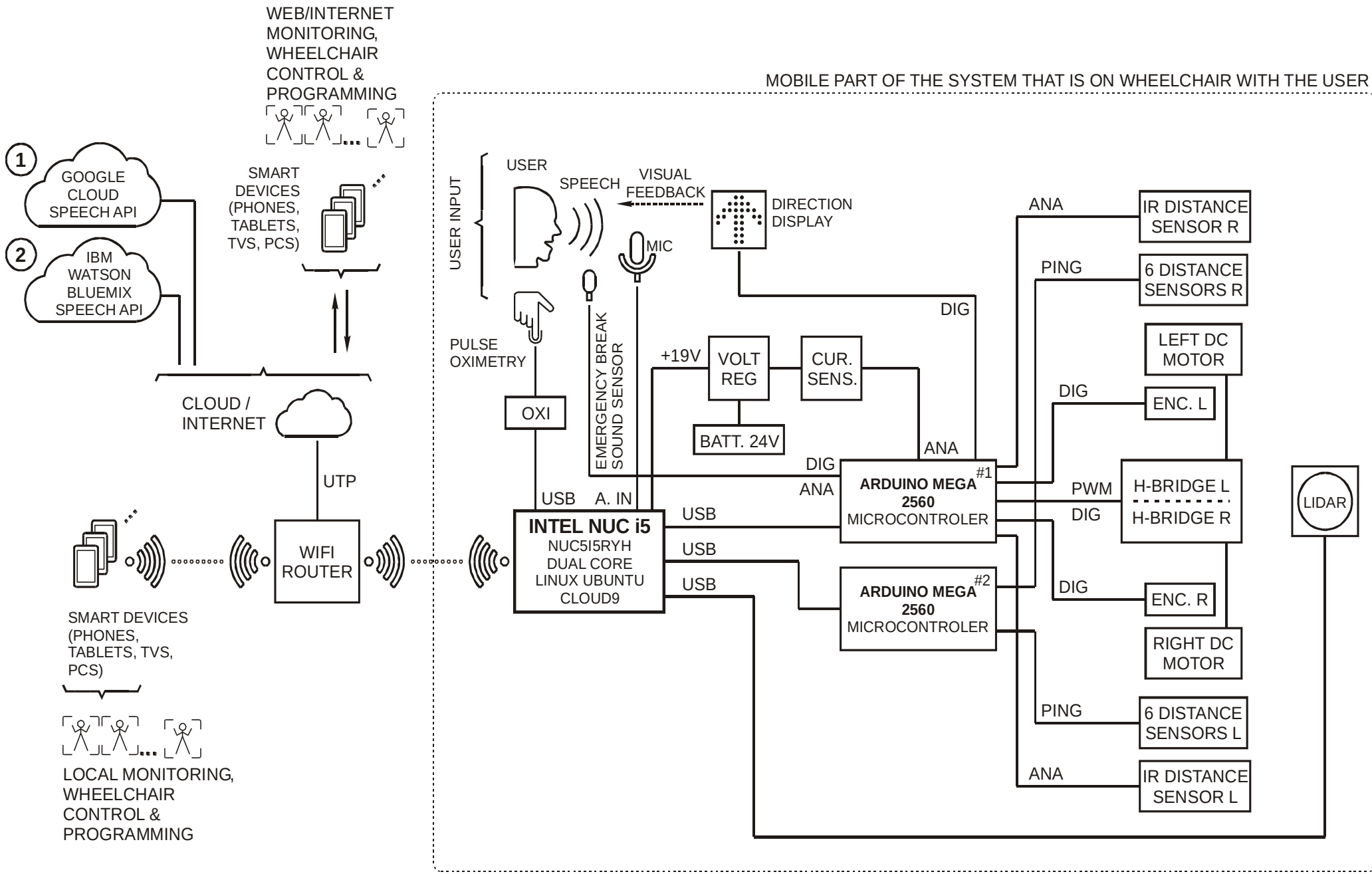
- … applying feedback principle



Wheelchair System Architecture 1st

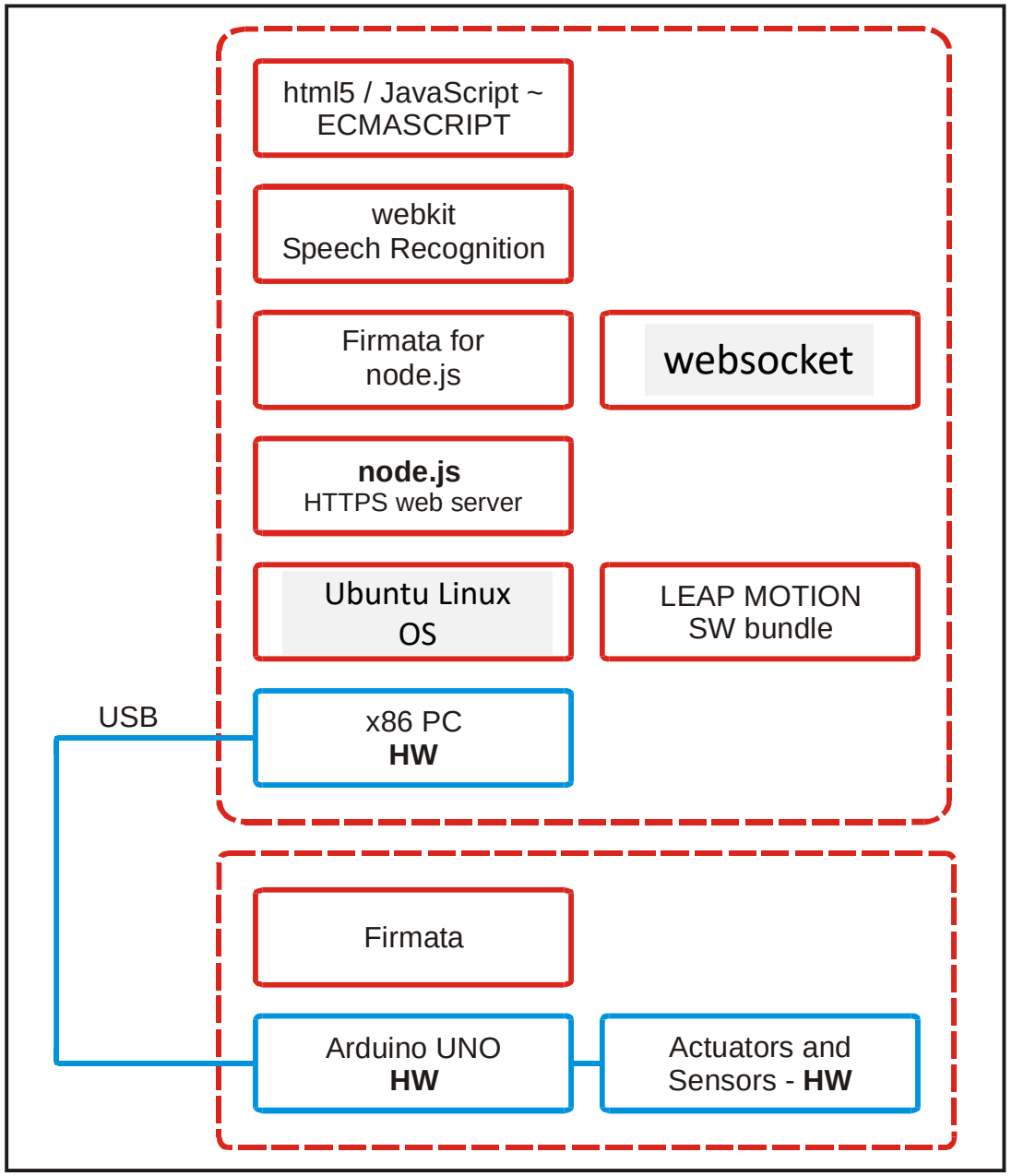


Wheelchair System Architecture 2nd



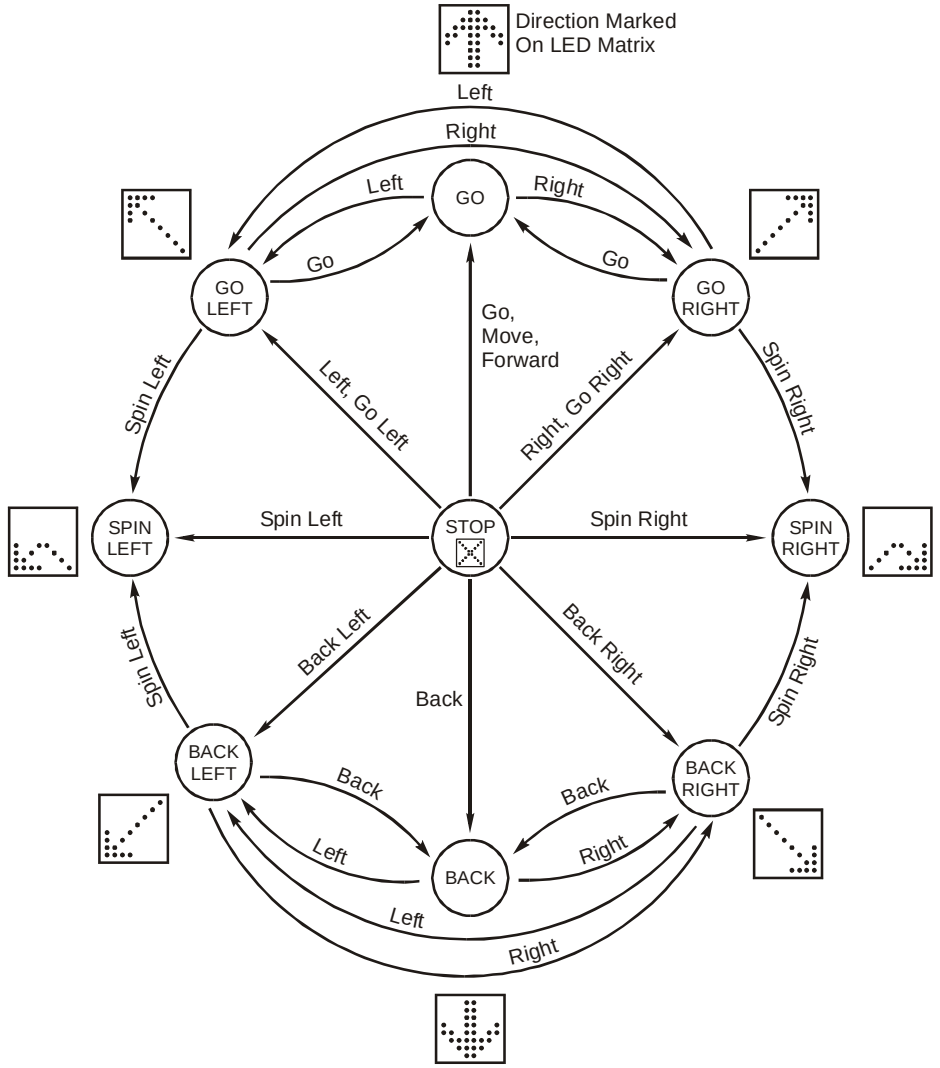
Software Stack

- node.js
- JavaScript / ECMAScript
- Firmata / Serial
- Ubuntu Linux
- Cloud Speech API
- Google & IBM Watson
- LEAP Motion SW Bundle



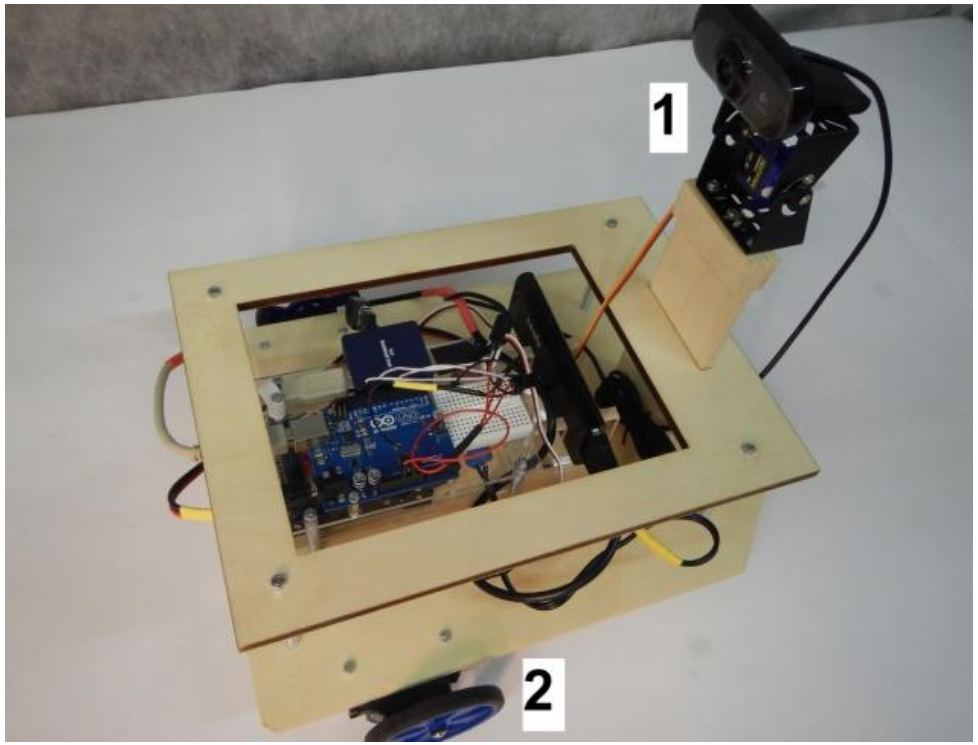
Transition Between States - Speech

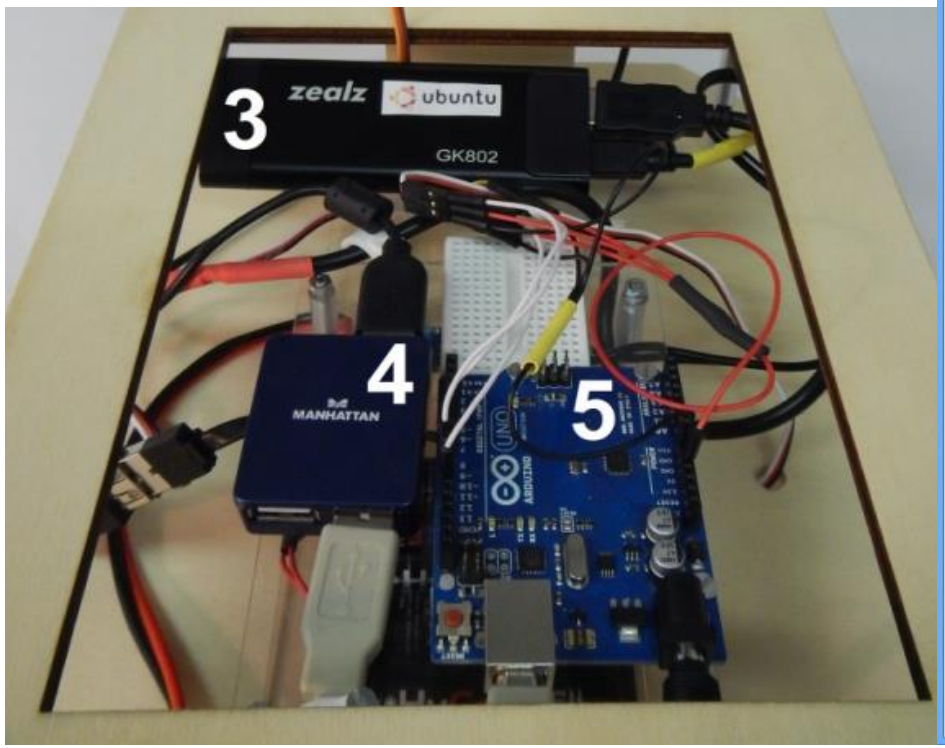
- Different interpretations depending on the sequence of issued commands

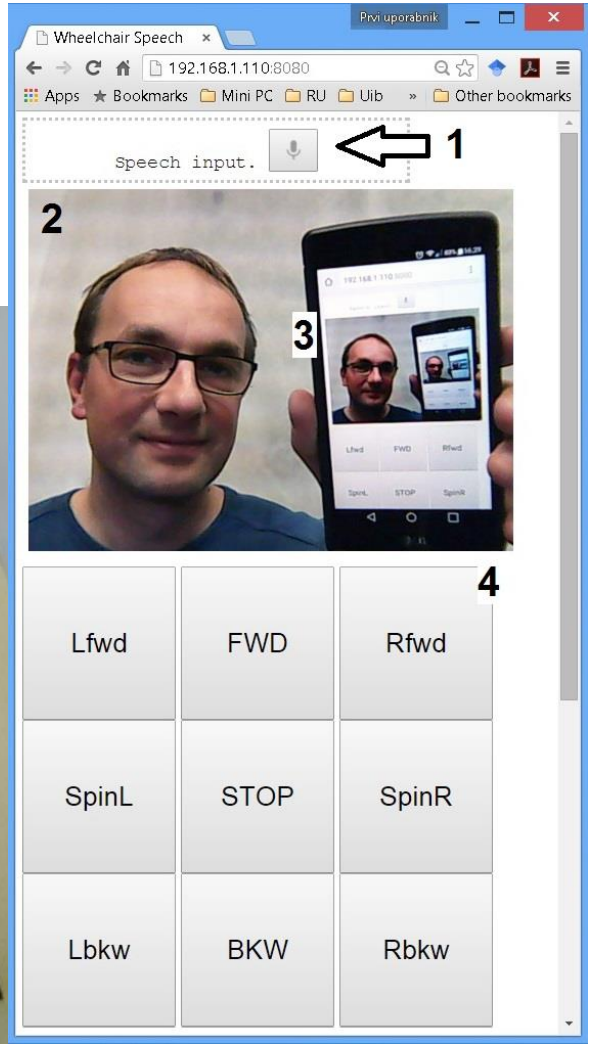


Prototype realization 0

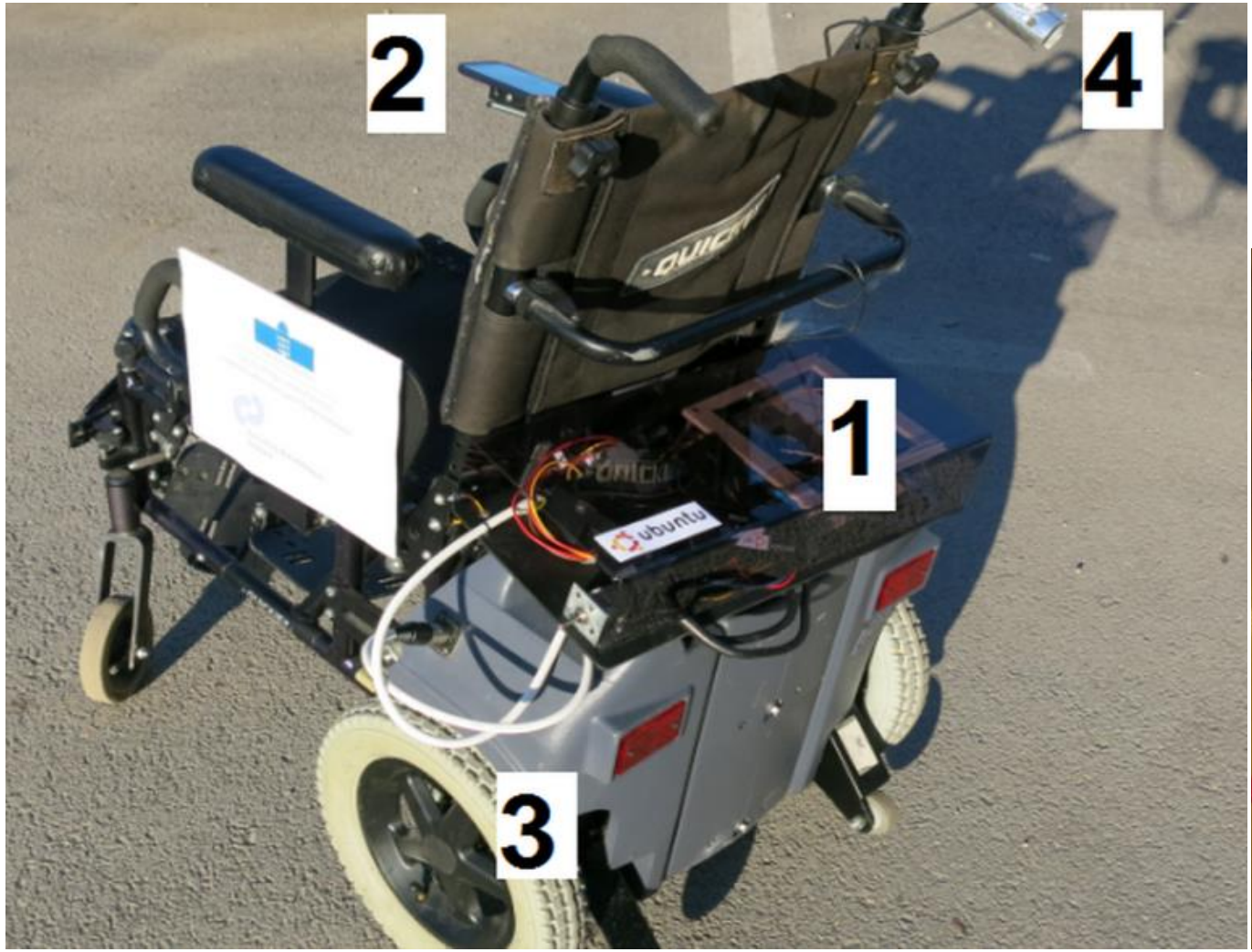
- ARM based solution GK802 quad core
- Speech controlled prototype: https://youtu.be/Y4El7lBTxQA



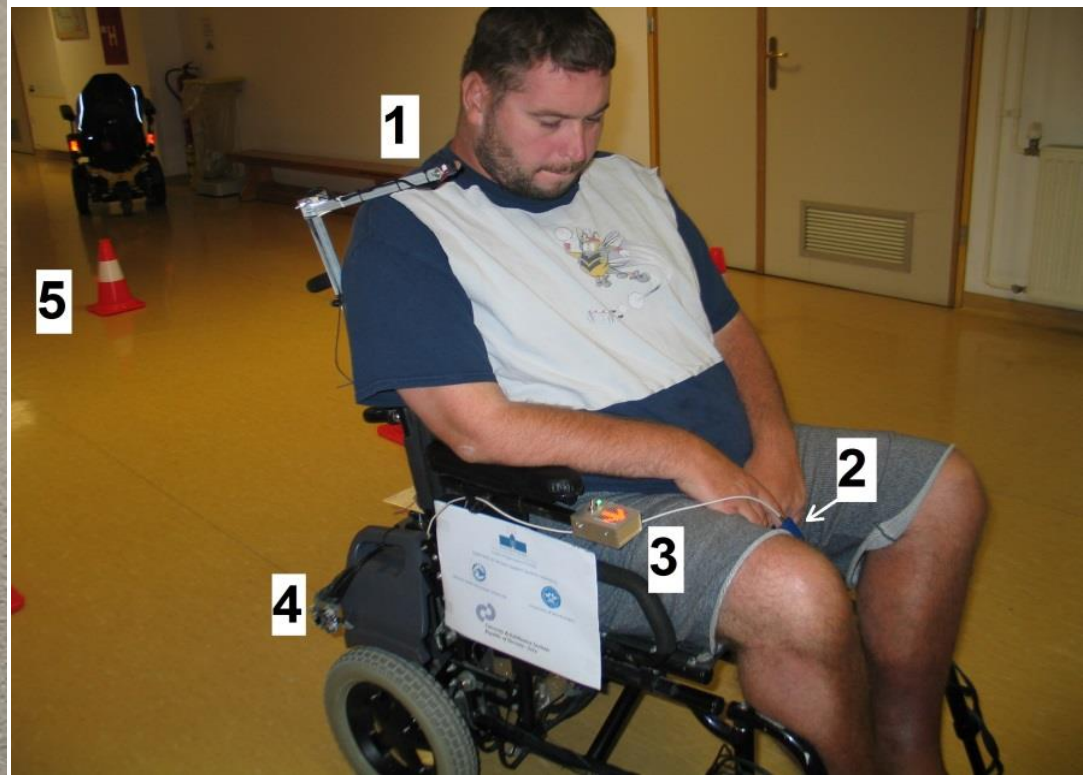




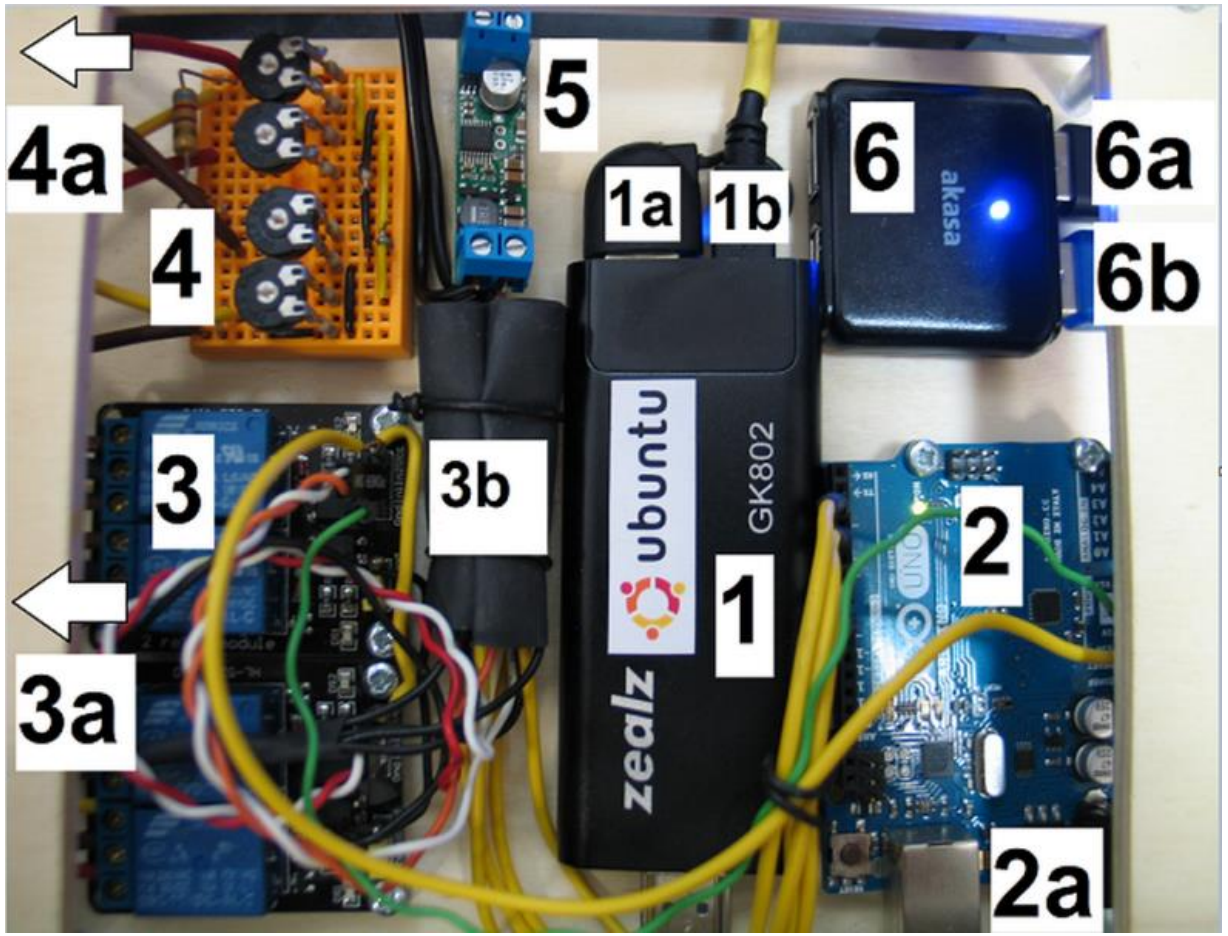
Full Scalled Prototype and Clinical Testing



https://youtu.be/FMjffyMWcKM?t=728



Comparison


4a
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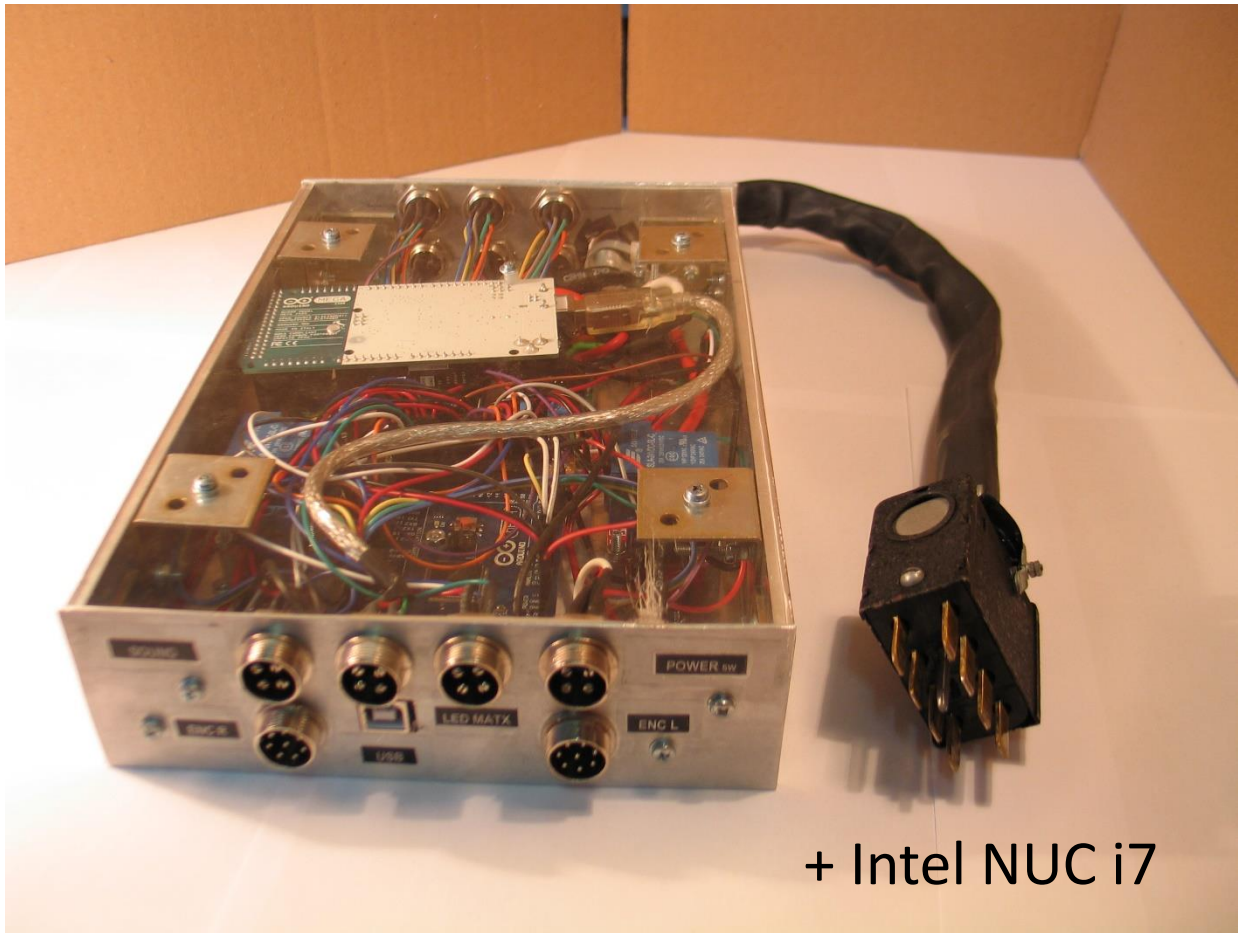
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LED MATX
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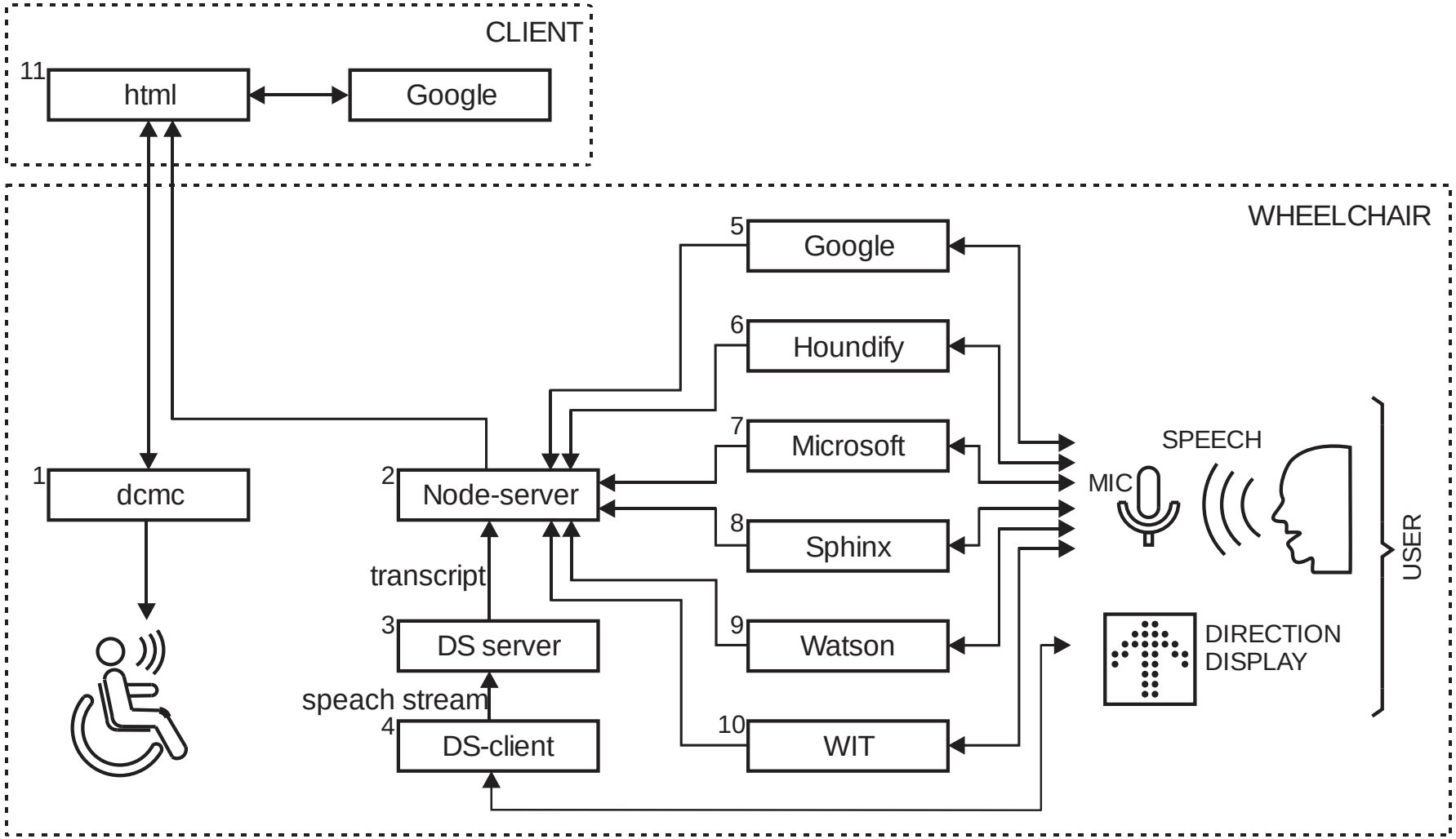
+ Intel NUC i7

Client and server side of a hybrid cloud/edge speech recognition ensemble system



Conditions

- In order for the procedure to be sucesfull it should hold:

$$f_2 = (a \wedge \neg b) \vee (\neg a \wedge b)$$

- For three paralel systems:

$$f_3 = (a \wedge \neg b \wedge \neg c) \vee (\neg a \wedge b \wedge \neg c) \vee (\neg a \wedge \neg b \wedge c)$$

- With CER when multiple clouds are harvested (+ latency etc.):

$$CER_m = \prod_{i=1}^{n} CER_i$$

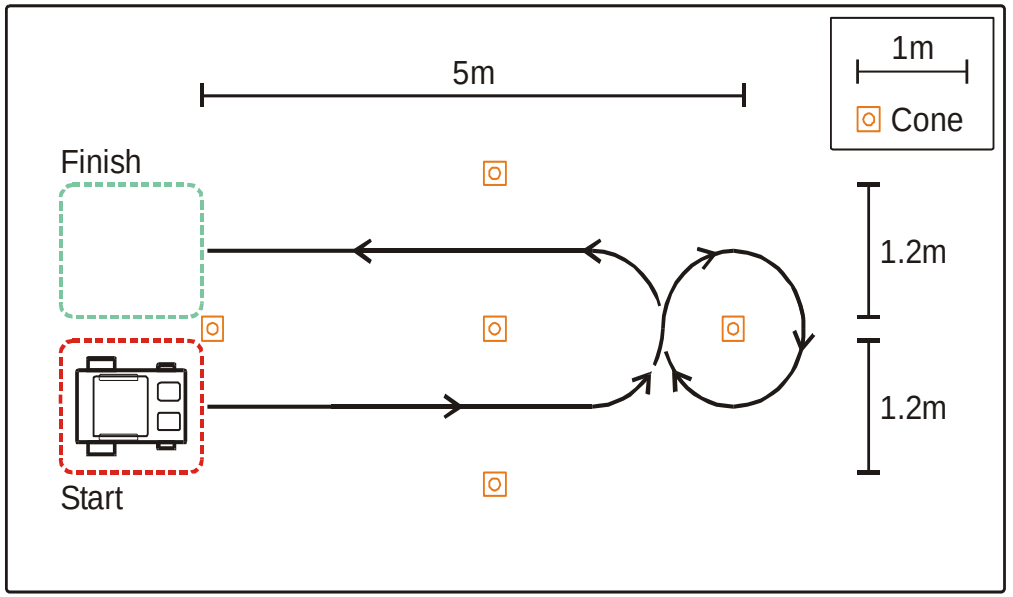
Speech-to-command cloud harvesting algorithm

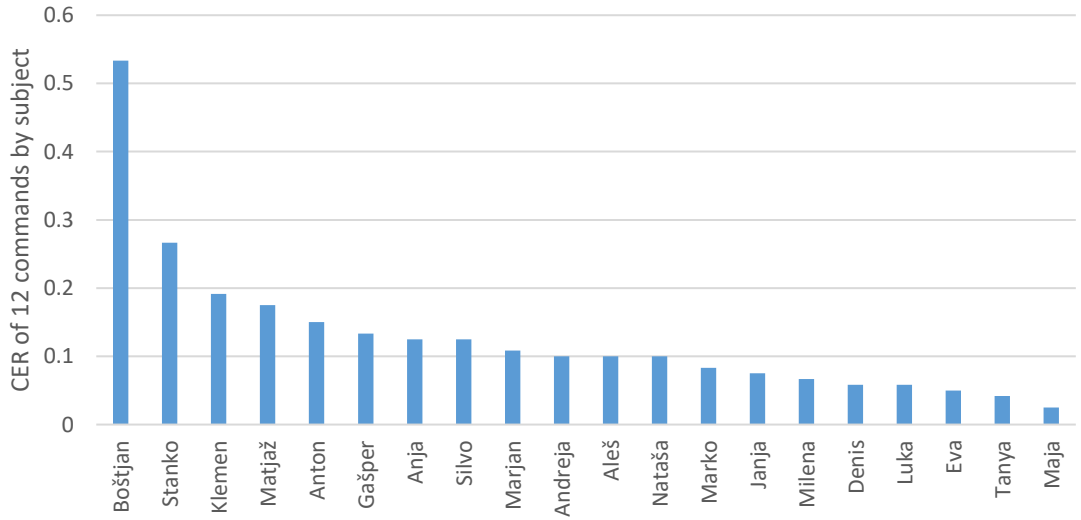
A1:	get user speech input
A2:	seed speech to the speech-recognition cloud field APIs
A3:	harvest set of interim transcripts and timestamps from cloud field
A4:	if $C_w > C_t$ add interim transcript to the $Cloud_i$ command subset
A5:	create unique union set of words for particular command from $Cloud_i$ command subset
A6:	check for pairwise disjoint condition for all unique union sets: $A_i \cap A_j \equiv \emptyset \ ; \ i \neq j$
A7:	if condition not met erase word pair
A8:	order checked unique union set by interim transcript timestamp
A9:	execute command with lowest timestamp

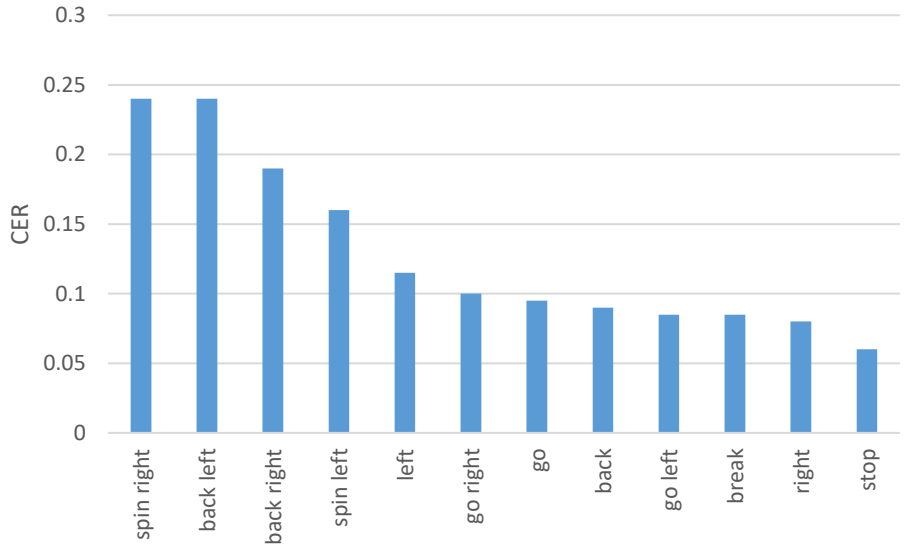
CER Measurement

- Testing 20 subjects
- Using poligon setup

$$CER = \frac{C_f}{\mathrm{No}}$$

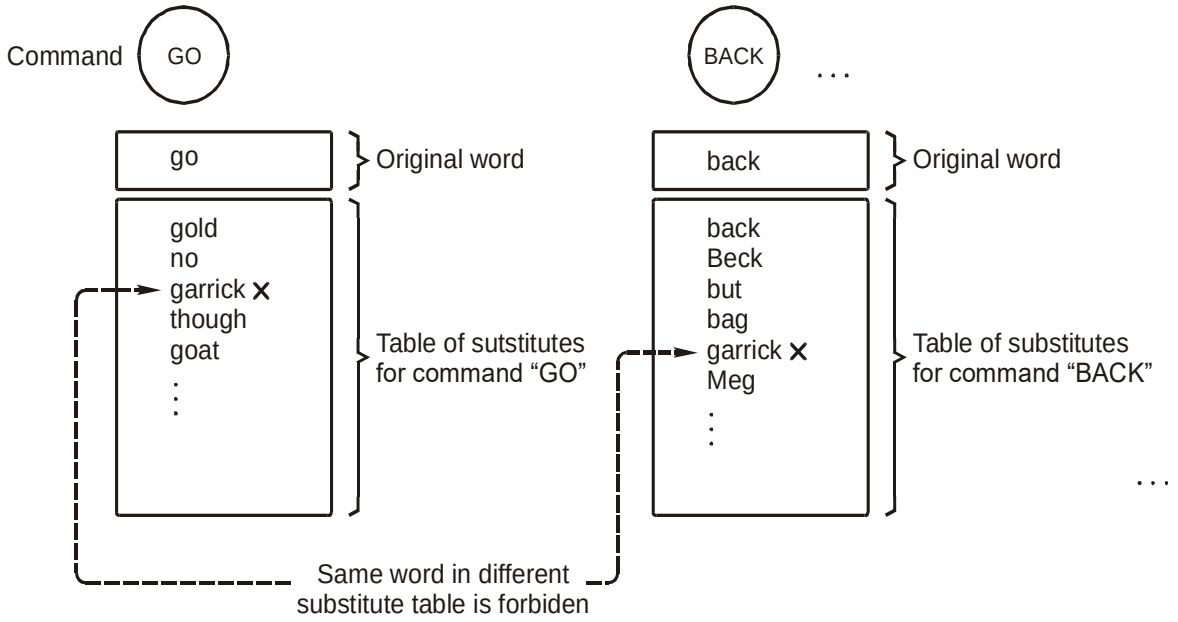






Algorithms

- Improve CER with table of substitutions
- Harvesting the clouds with corrections
- Application and automatic generation of substitution tables

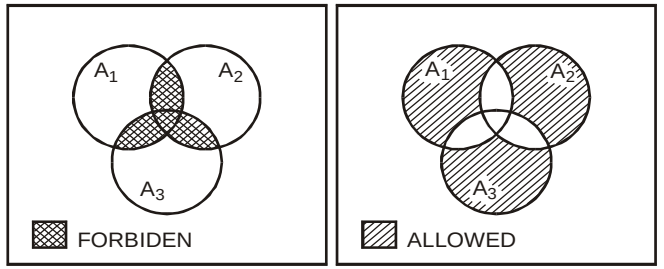


N substitution tables:

$A_1, A_2, A_3, \ldots, A_n,$

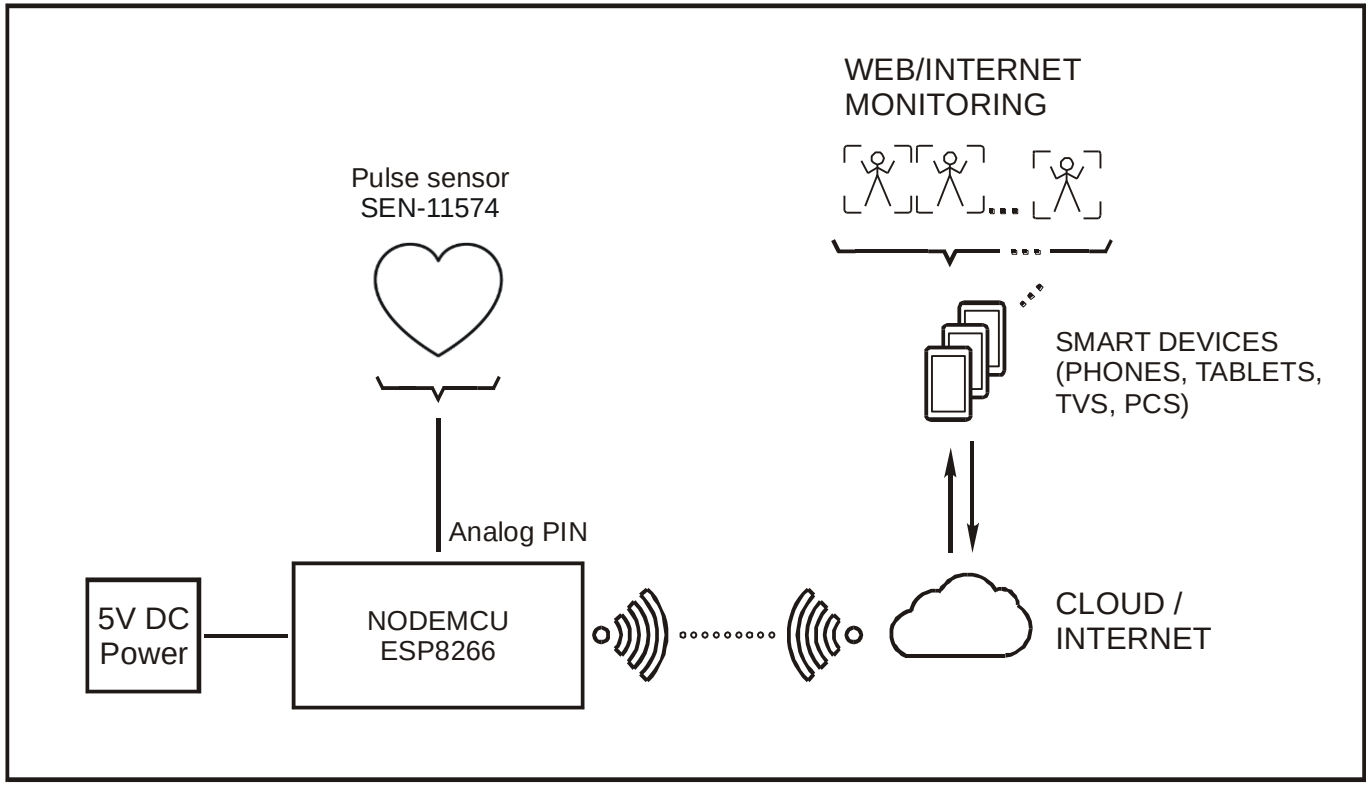
Pairwise disjoint

$A_i \bigcap A_j \equiv \emptyset \ ; \ i \neq j$



Streaming pulse data from Wheelchair

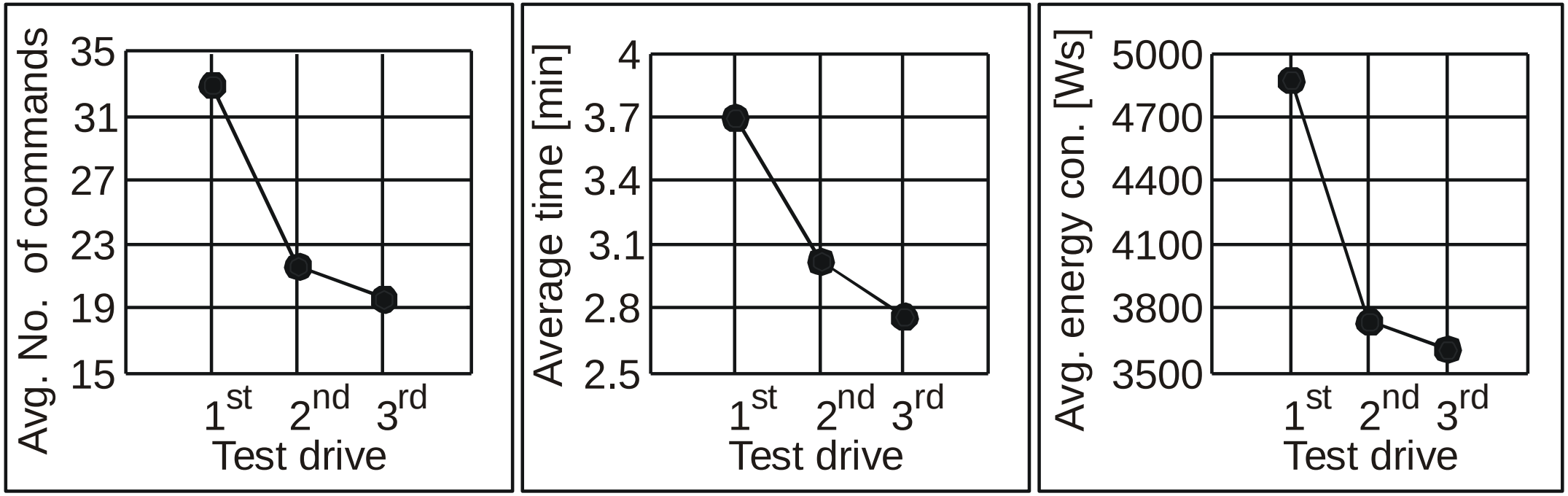
- NODEMCU ESP8266 module
- Less components and
- Directly connected to the Wi-Fi
- Sensor data processing is performed on the ESP8266
- Transmitted over Wi-Fi WebSocket to the cloud
- Additional data processing on the client side with JavaScript / ECMA Script



Average Energy Consumption

Run	N	AVG [#c.]	SD	N	AVG [min]	SD	N	AVG [W·s]	SD
1st	14	33.0	14.12	13	3.70	0.93	14	4875.79	1577.27
2nd	14	21.7	9.16	13	3.03	0.79	14	3742.50	1999.96
3rd	14	19.6	8.40	13	2.77	0.74	14	3606.64	1627.24

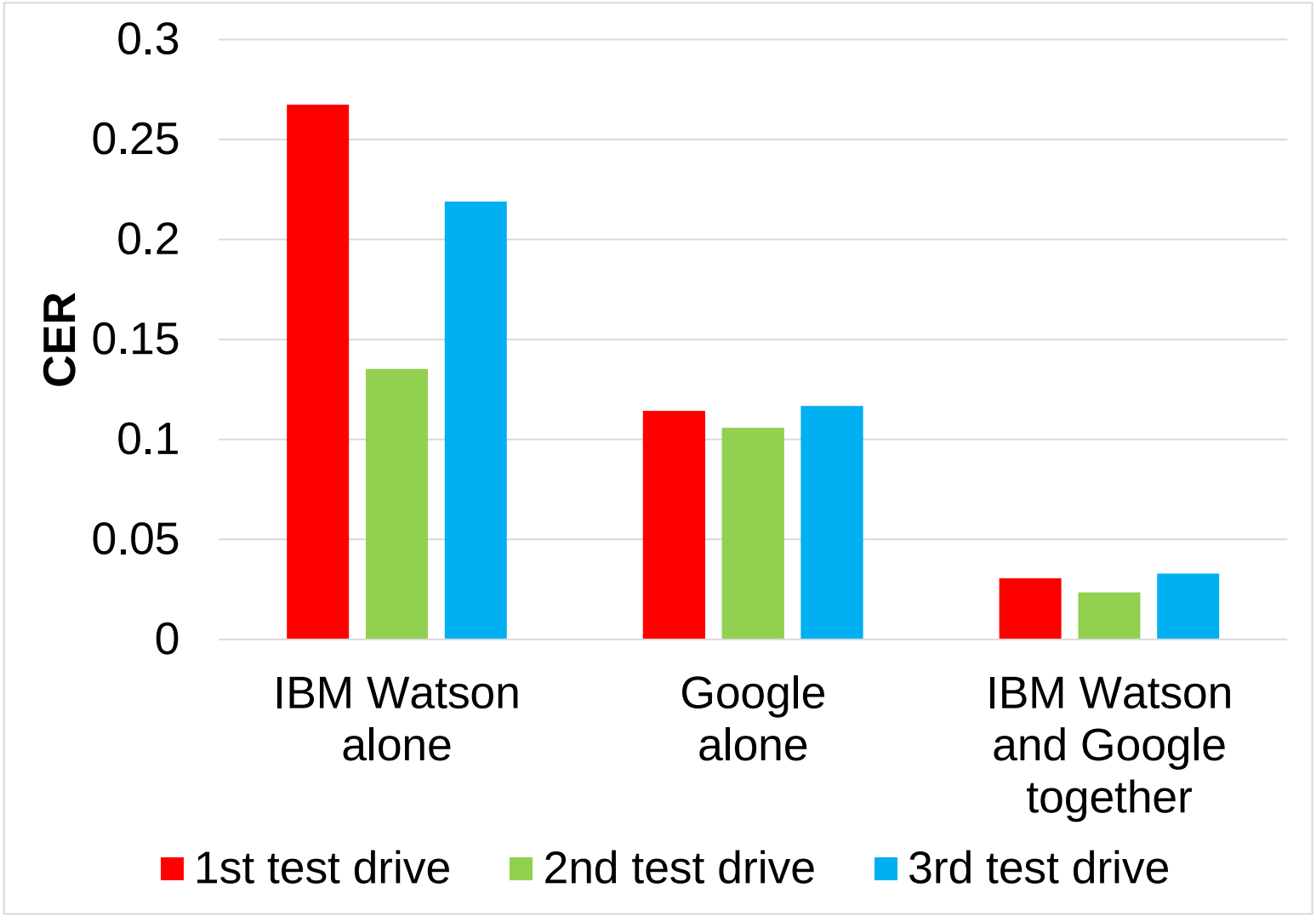
Learning effect



Harvesting Google & IBM Watson

Run	No. of issued comm.	N	CER of Google API alone (CERg)	CER of IBM Watson API alone (CERw)	CER of Google & IBM Watson combined (CERgw)	Google CER improvement	Watson CER improvement
1st	490	20	0.11	0.27	0.03	8%	24%
2nd	340	20	0.11	0.14	0.02	8%	11%
3rd	274	20	0.12	0.22	0.03	8%	19%

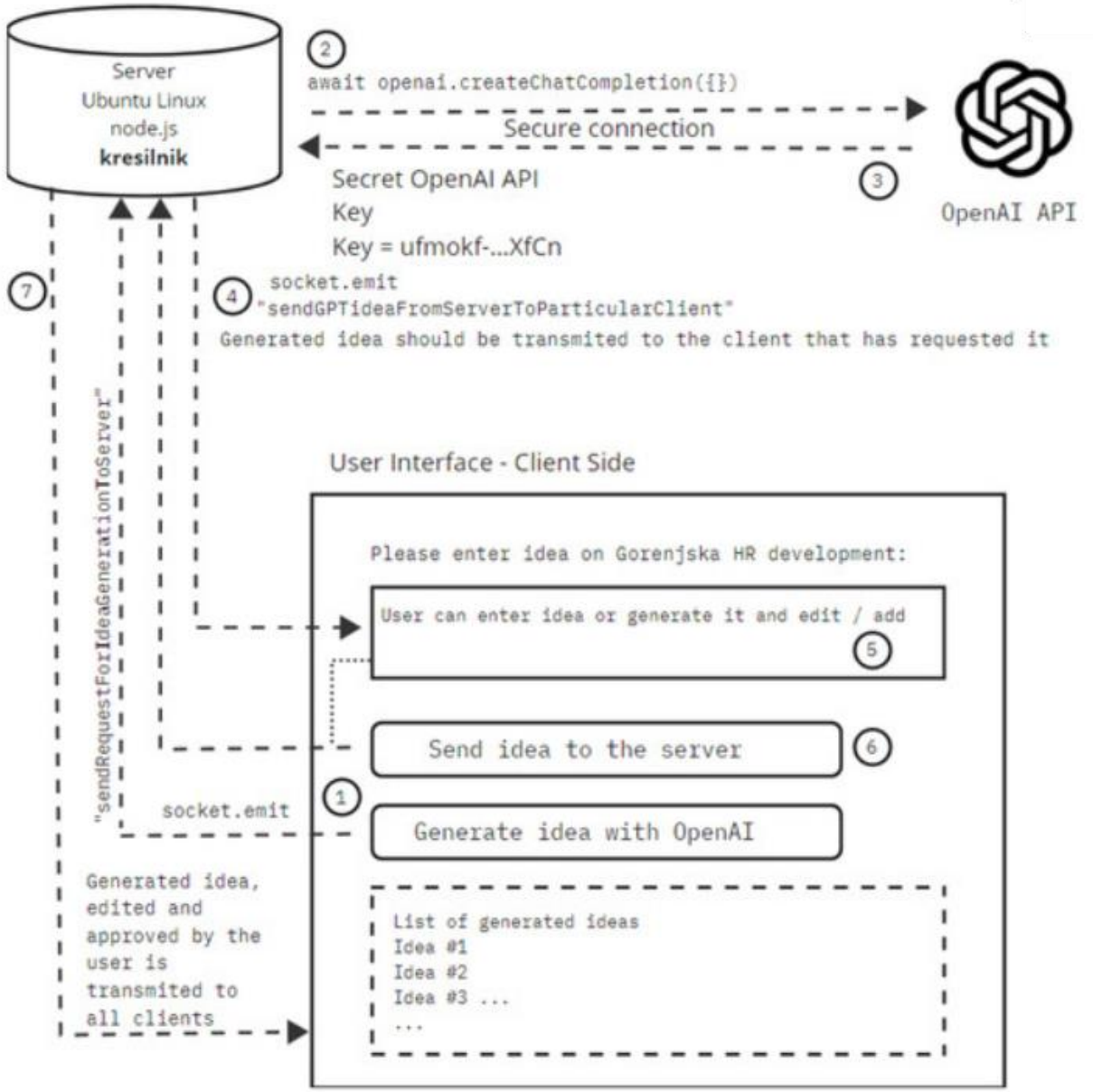
Improvement



AI & CPS&IoT

- Application of artificial brain – new possibilities that should be explored
- Example of the interaction with OpenAI LLM API at the process of generating innovative ideas
- json as the main data structure
- Fast development

doi: https://doi.org/10.3390/make5040065



Discussion I

- New technologies enable us to develop complex cyber-physical systems based on cloud information systems and edge computing - prototyping
- An important characteristic of cyber-physical systems is that they are tightly integrated with the internet and its users.
- The new paradigm of complex cyber-physical systems development.
- Backed up by edge computing
- From a technical point of view, it is beneficial that several independent cloud service providers exist
- Successfully tested by different users in a clinical environment
- Significant improvements in the CER that correspond to the proposed theoretical model
- JavaScript/ECMA Script & node.js

Conclusion (II.)

- Currently technology „in demand“, large interest
- Affordability of the technology, also regarding previous knowledge
- Practical application possible in several areas
- Possibility of innovative solutions
- Incorporation in the standard curriculum when addressing control systems, models, state space

Conclusion (III.)

- node.js, JavaScript, C++
- firmata, serial
- Exploration of the Cloud(s), development of algorithms
- Linux
- ESP8266
- ESP32
- Possibility to develop from prototype to full application
- Succesfull development of several prototypes
- Changing learning and technical system design paradigm

Acknowledgement

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