Social Assistive Robots in Elder Care: Pre-Adoption Analysis and Living Lab

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Distinguished Lecture

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Content

1.   IEEE Mission statement

"IEEE's core purpose is to foster technological innovation and excellence for the benefit of humanity."
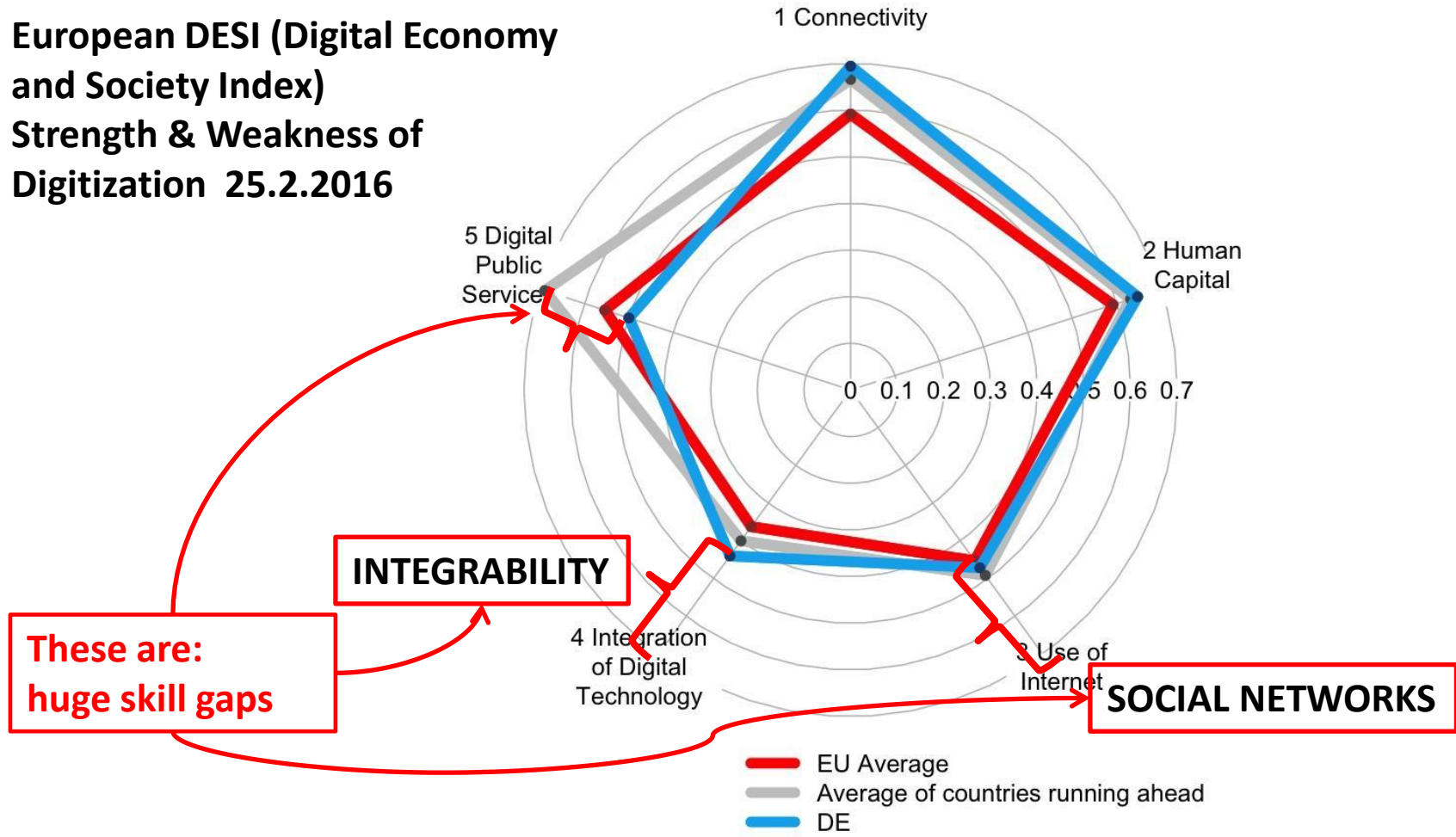
IEEE Vision statement

"IEEE will be essential to the global technical community and to technical professionals everywhere, and be universally recognized for the contributions of technology and of technical professionals in improving global conditions."

2. Technological Dynamics of Service Markets in the Light of Digitization

Digitization causes

- Fundamental, disruptive change in providing services,
- partially substituting human workers by
    - software,
    - autonomous mobile robots, sensors and actuators, smart machines
    - IIoT and IoT solutions,
- by using AI supported algorithms
    - contextual communication
    - knowledge acquisition
- comprehensively affecting service technology and
- labor markets

European DESI (Digital Economy and Society Index)
Strength & Weakness of Digitization 25.2.2016

1 Connectivity

2 Human Capital

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7

5 Digital Public Service

INTEGRABILITY

These are: huge skill gaps

4 Integration of Digital Technology

3 Use of Internet

SOCIAL NETWORKS

EU Average
Average of countries running ahead
DE

http://www.crn.de/software-services/artikel-109465-2.html

PICMET '18

Examples for service robots

<table>
<tr>
<td>

- **Service robots** for safety & security; intrinsically safe and explosion proof

- *Risk reduction for humans*

- See [14],[15], [21]

Credit: taurob robotics

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- **Service robot** Elderly Care Market and General Service Market

- *Work load relief for caregiver*
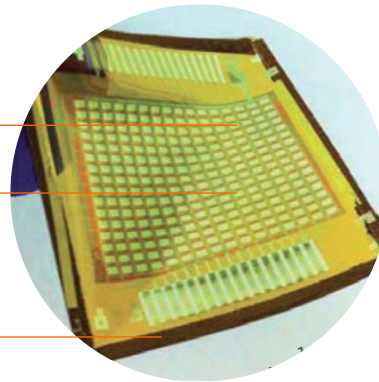
See [8]

Credit: mojin robotics

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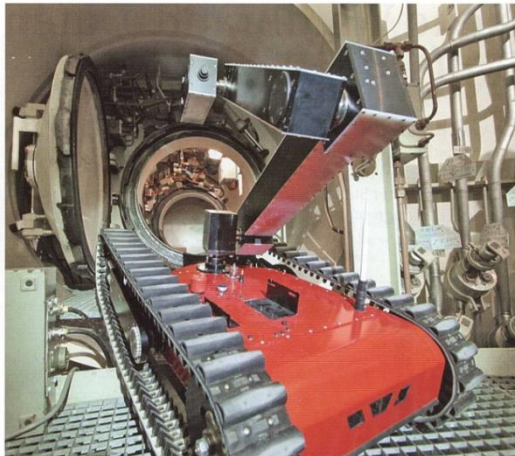
Functional material, real time systems, smart care

AI for X-ray picture interpretation based on 2D fractal geometry as software as a service

- Artificial Skin and diabetes treatment [16]

- Image Biopsy for early detection of osteoarthritis see [17]

ARTIFICIAL SKIN

sticky patch
(4 cm x 2 cm x 0,3 mm)

MONITORING

sensors to detect temperature and motion; RAM for data storage

TREATMENT

Micro-heaters and drugs

c) Advanced OA

3D image of bone

Late-stage OA

Loss of aggrecan Fibrillation

Articular cartilage

Calcified cartilage

Tidemarks

Subchondral bone plate thickness

Trabecular bone

Cross-section
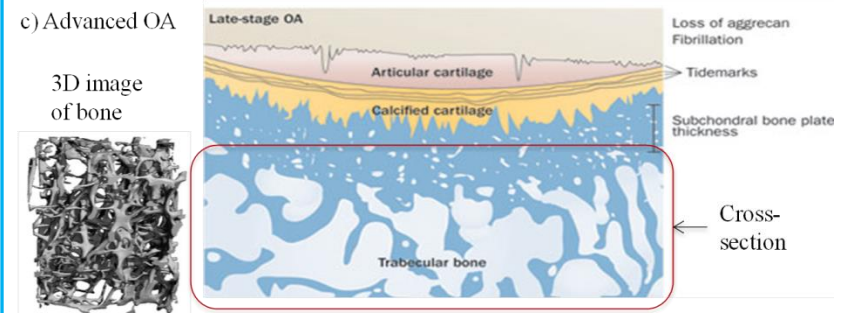
- **Wearable electronics**
- **Li-wearable battery**

Real time performance improvement, integrating stress measurement and systematic data evaluation, through smart wearable devices in Beach Volleyball [11]
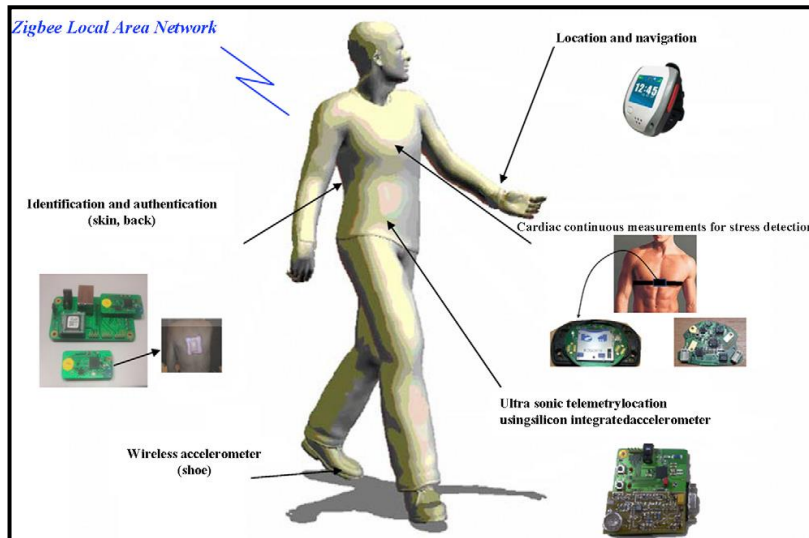
See: [12]

- **IoT (Internet of Things)**

The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
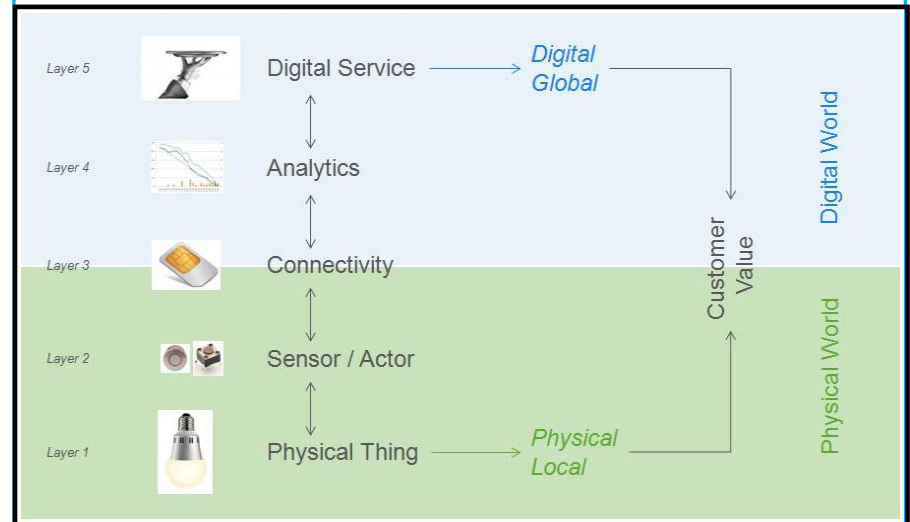
See [13] Business Models for IoT
See [20]

Operational approach combining AI and Human-Machine Integration in industry can be seen in examples see [7]
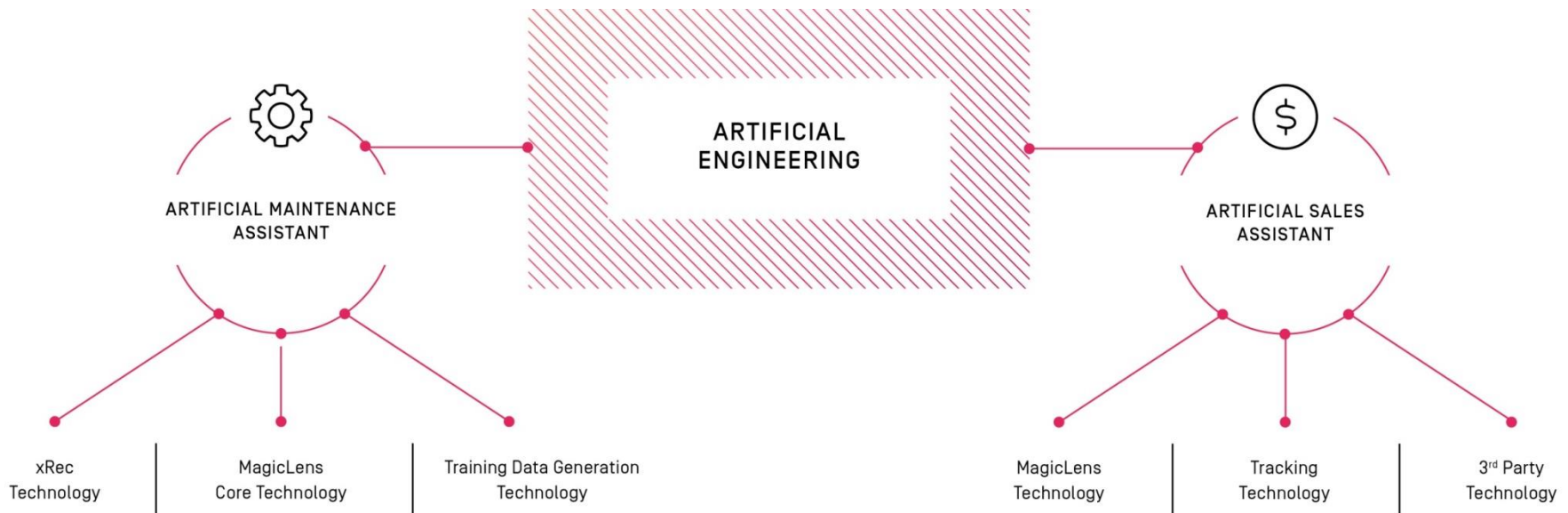https://www.humai.tech/

Artificial Engineering is an appropriate approach for SAR integration in AAL and Elderly care by IIoT

3. Growing Gap between supply and demand of elder care assistive services

- All economically high developed countries are facing a heavy shortage of qualified elder care labor capacity and increasing caring demand of elder people (longer life expectancy, ...)

- Digitization affects everyday life in all stages of human life age

- Robotization, Ambient Assisted Living (AAL) and AI-controlled user interfaces enable a high degree of

- **HU**man_**MA**chine_Integration (e.g. HUMAI ...) AND **HU**man_**MA**chine_Communication (e.g. https://www.humai.tech/)

TRL of AAL Robots [1, pp 22]

"An AAL robot is a robot that
1. assists the target group of older users including users with disabilities.
2. supports the target group during daily life or work.
3. improves or maintains the independent living of the target group." [1, p.37]

Robots in database
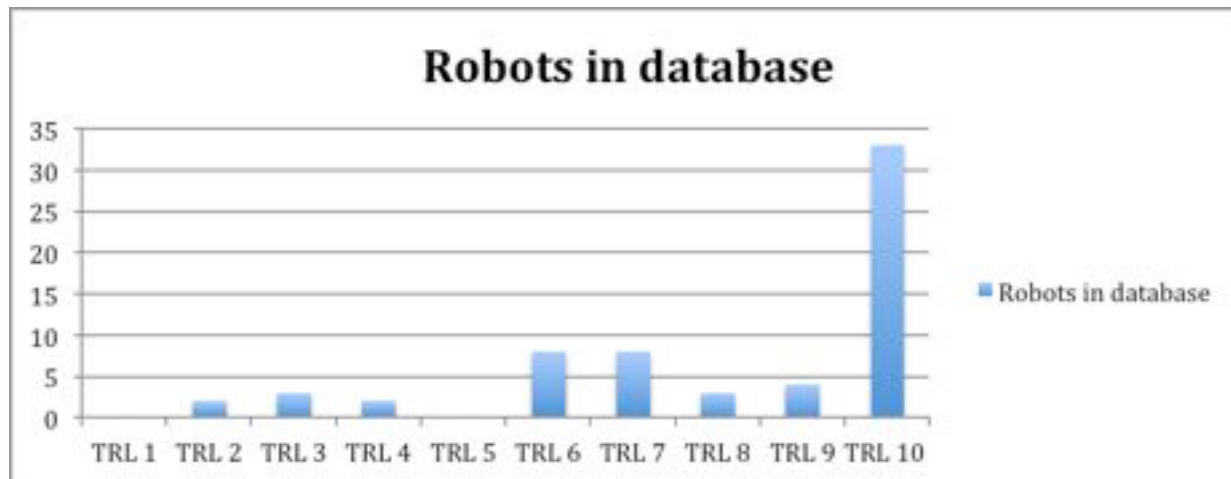
SAR Social Assistive Robot are AAL robots integrated in social service processes

Gap between supply and demand of elder care assistive services (1)

Elder-care: the care of elderly people who are unable to look after themselves.

To that end, researchers are asking questions like:[3]

• Do robots need to understand and convey emotion to be accepted?

• How can robots provide social support?

• Is it best when machines simulate eye contact with us?

• Does it help if they can converse?

AND:

• How are mutual **ethical challenges managed** between SAR, residents and caregiver staff?

Gap between supply and demand of elder care assistive services (2)

The US Census Bureau estimated that **15 percent** of Americans – nearly one in six of us – were aged 65 or older in 2016, up from **12 percent** in 2000. Demographers anticipate that by **2060** almost **one in four** will be in that age group. That means there will be some **48 million** more elderly people in the U.S. than there are now. [3]

HOW TO MANAGE THE INCREASING GAP OF ELDER CARE ASSISTIVE SERVICES?

Gap between supply and demand of elder care assistive services (3)

Cory-Ann Smarr and colleagues at the Georgia Institute of Technology showed groups of adults age 65 to 93 a video of a robot's capabilities: [18]

"Participants indicated a **willingness for robotic assistance** with chores such as housekeeping and laundry, with **reminders to take medication** and other health-related tasks, and with **enrichment activities such as learning** new information or skills or participating in hobbies. These **older adults** preferred human **assistance in personal tasks, including eating, dressing, bathing, and grooming**, and with **social tasks such as phoning family or friends**."

"The older adults we interviewed were very enthusiastic and optimistic about robots in their everyday lives. Although they were positive, **they were still discriminating with their preferences for robot assistanc**e. Their discrimination **highlights the need** for us to continue our **research to understand how robots can support older adults with living independently.**"

4. Social Assistive Robots

We distinguish between: [1]

- Personal **service** robots (ISO-Standard 8373)
  https://www.iso.org/obp/ui/#iso:std:iso:8373:ed-2:v1:en

- Personal **caring** robots (ISO-Standard 13482)
  https://www.iso.org/obp/ui/#iso:std:iso:13482:ed-1:v1:en

- Sub-group: social assistive robots:

  – mobile servants,

  – physical assistants,

  – person carriers, training, monitoring,

  – rehabilitation (see for example rehabilitation after shoulder surgical intervention: http://www.ferrobotics.at/en/products/medical-technology/ccpm.html
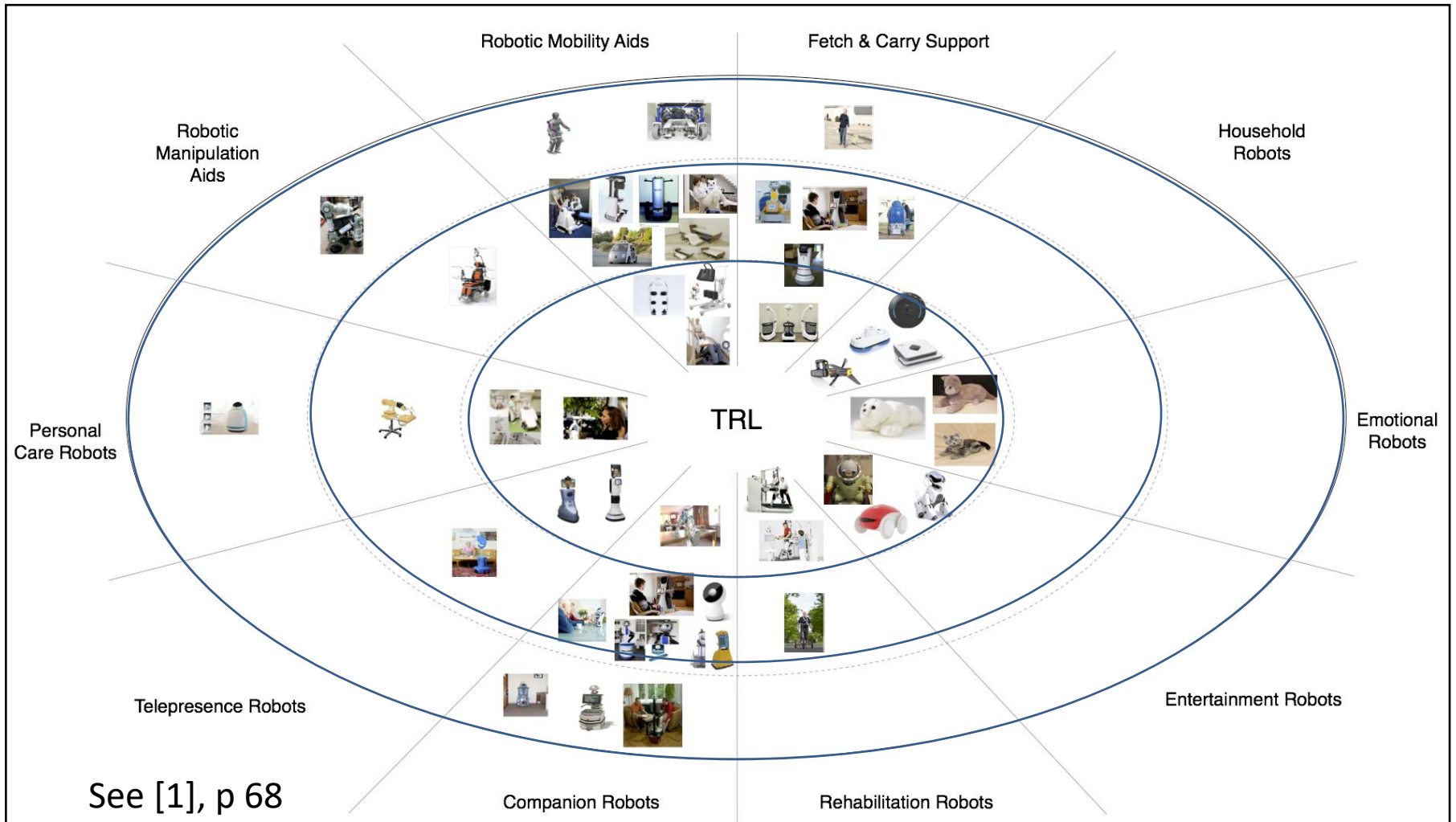
See [1], p 68

Required system abilities for elder care /assistive robots: [1] pp.59
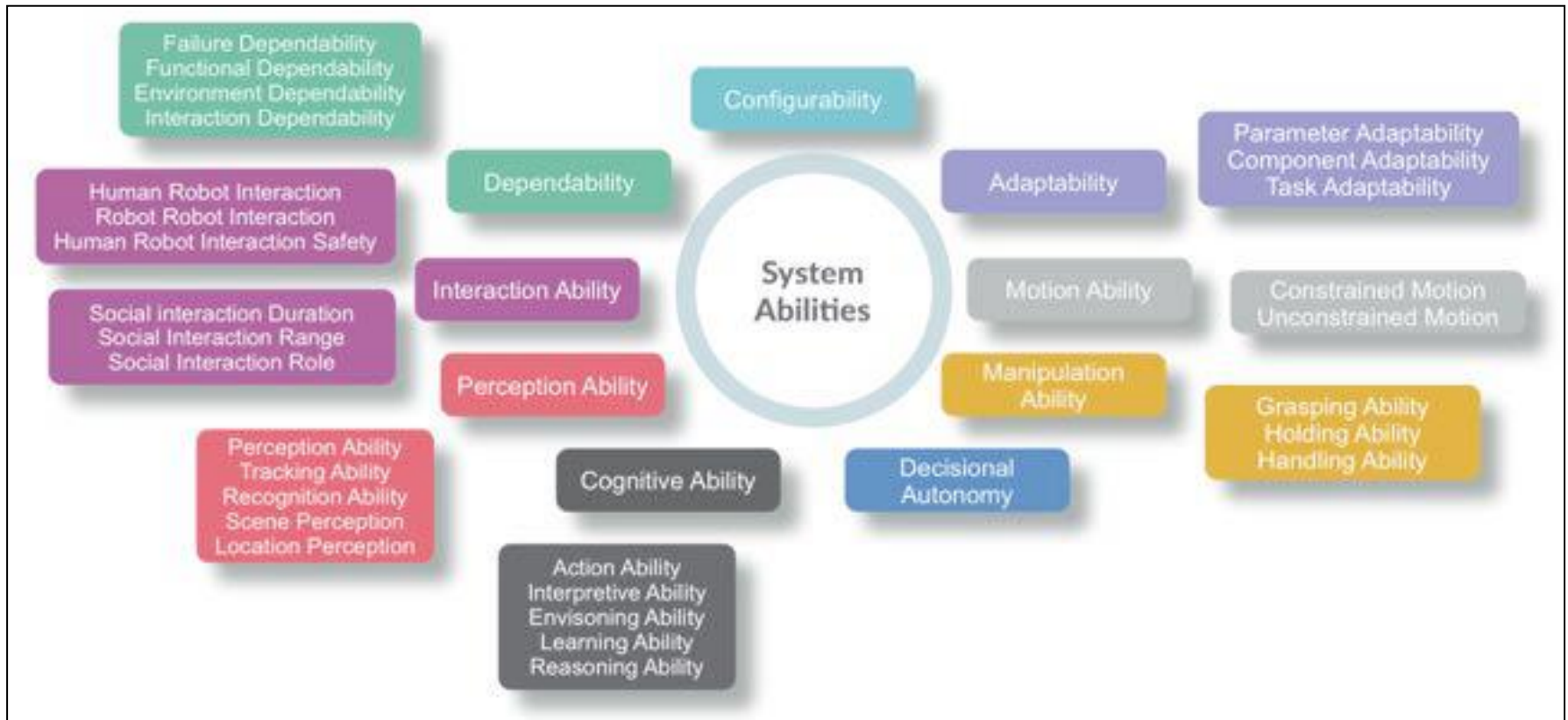
Elder Users' requirements of SAR:

- **Configurability:** High multitude of different needs, robot configurable by informal caring staff without technical knowledge background
- *Adaptabilit*y: *Phase 1*: predefined tasks. *Phase 2*: higher challenges due to changing environment and changing residents capabilities in short time
- **Motion ability**: collision avoidance, collaborative motion patterns with elder, soft and gentle movements combined with emotional gestures are only a few of the wide variety, how robots' task are defined to cope with elders' mobility impairments
- **Manipulation ability** based on high level perception of objects is still research. Grasping objects laying flat on the ground (e.g. book, knitting needle) is still a difficult task
- **Decisional autonomy** is **very limited**: currently available AAL robots can hardly perceive contextual patterns and recognize and grasp objects and decide autonomously.
- **Cognitive ability** requires AI supported algorithm of contextual understanding. Still a huge research task. HRI needs to understand and communicate with elder users , robot acting as intelligent smart social agent.

- **Perception ability** is a key challenge for SAR in private homes. Retirement houses offer a lower stochastic variety of objects due to higher degree of standardization of object surfaces and light reflection attributes. Nevertheless non-optimal lightning environment might reduce sensor ability to detect objects. (see also: experience with autonomous driving systems and obstacle perception under hard real time conditions and difficult lightning environment backlight, shadows)

- **Interaction ability** is also a key requirement of social interaction skills for human-robot integration. Our current research project relies on a **predefined catalogue** of social tasks with predefined users: *Phase 1*: caregiver and their assistants;

- *Phase 2*: **higher variety of additional primary and secondary users.** The **UCCCC*** approach serves to generate user specific semantic instances during a long term assimilation phase in the living lab context. Based on residents private, bibliographic data, subject to privacy protection.

- **Dependability:** Based on the probabilistic task environment of human robot interaction.
  - **Combination of probabilistic reasoning and heuristic path planning** for robots internal logistic tasks is required.
  - **Predefined catalogue of tasks** serves also as a complexity reduction used for reducing failure probability

* UCCCC [1]) User Centric Contextual Communication Corridor

5. SAR Content of R&D Activity for market entry

5.1. Pre Adoption study: pre-adoption analysis of elder people: executed between April to October 2017 reported at PICMET 2018 [7]

5.2. R&D Project: to implement a LIVING LAB for elder people dependently living and cared in retirement house : R&D project work in progress

Social Assistive Robot SAR

Definition: Social Assistive Robotics (SAR) support users not only through physical but also through social interaction (Feil-Seifer et al. 2005)

FEATURES
- **Height: 158 cm**
- **Weight: 142 kg**
- **Max Speed: 1,1 m/s**
- **Interface: 7" Touch Screen**
- **Degrees of Freedom: 29**

Service Robot Care-O-bot® 4

FUNCTIONS
- **Assisting**: Reminder and Fetch and Carry
- **Monitoring**: check of physical conditions and safety and calling help in case of danger
- **Entertaining**: Social communication through voice, dialogue, gesture, facial expression and by using a variety of media tools

Credit: mojin robotics

Sample

Respondents	131*
Age	65-100
Nationality	Austrian (98%)
Education	Heterogeneous
Physical Issues	50,4%
PC Usage	No users 63%
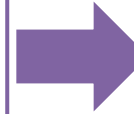
Data collected on field in 11 Austrian Senior Homes (9 KWP*, 2 Elderly Care Homes Kreuzschwestern).

To this purpose the survey was handed-in during a study session (1.15 h info session + filling survey)
* Viennese Care Homes

The sample size was determined considering data dimension big enough to give (statistically) significant results for the type of analysis carried out (see appendix: 2. The model). The accuracy and the richness of the results can be improved in further researches. [8]

The Pre-Market Phase: Final Users' Perception

requirements	Pro arguments	Contra arguments
Isolation	Social Facilitator	Human Substitution
Autonomy	Control over the environment	Security and Autonomy clash
Privacy	A Robot is preferred for intimate tasks	Data collection and safety issue
Safety	Monitoring Function	Accountability Issue and clash with autonomy
Dignity	Suspension of beliefs Decrease dependence Higher social acceptability	Deception Objectification Infantilism

Residents' Opinion Dynamics

The simulation has been run in 1000 time-steps on a 50x50 lattice. The software used is the **LSD**, **L**aboratory for **S**imulation **D**evelopment, based on C++. **LSD** is an online source for developing discrete-time simulations and specifically designed for economically oriented simulations

As a result it is clear that the NWOM* prevails by blocking the percolation of innovation and creating a strong rejection in the social system. The green dots represent agents adopting the innovation, while red rejecting. Only 32,8% of total cells are at state "1" at the final simulation step.
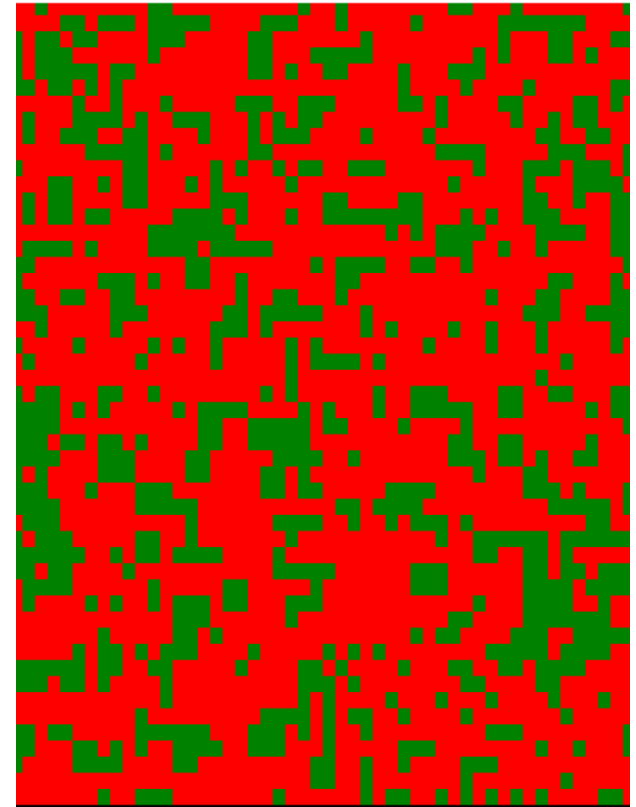
*NWOM Negative Word of Mouth

Suggestions to improve SAR acceptance

	Problem	**Social Implication:**	**Individual Implication:**
Enthu-siast	Targeting them in the first entry phase, Satisfying their needs	Involving experts in robot deployment, offering **assistance** and **group sessions**	Promoting and Explaining the assisting function by underlying robot **security**, **safety** and **autonomy**

	Problem	**Social Implication:**	**Individual Implication:**
Skep-tical	**Lack of TRUST** and they don't perceive the robot conform to their needs (low PA)	Working together with caregiver for dealing with the robot. Simulating confrontation with enthusiasts cluster	Promoting monitoring function through transparent information about data storage, processing and protection

Content of R&D Activity for market entry

5.1.Pre Adoption study: pre-adoption analysis of elder people: executed between April to October 2017

reported at PICMET 2018 [7]

5.2.R&D Project: to implement a LIVING LAB for elder people dependently living and cared in retirement house : R&D project work in progress

Living Lab [9]

„A Living Lab is a **real-life test and experimentation environment** where users and producers **co-create innovations**.

- Living Labs have been characterized by the European Commission as **Public-Private-People Partnerships PPPP** for **user-driven open innovation**.

A Living Lab employs four main activities:[9]

- **Co-Creation**: co-design by users and producers
- **Exploration**: discovering emerging usages, behavior and market opportunities
- **Experimentation**: implementing live scenarios within communities of users (employees, carers and residents of retirement homes)
- **Evaluation**: assessment of concepts, products and services according to socio-ergonomic, socio-cognitive and socio-economic criteria.

I consider Living Lab being in complementary relation to Triple Bottom Line systems: Social, Environmental and Economic Rationality

SOCIAL ASSISTIVE ROBOTS FOR ELDERLY CARE

PICMET '18

AI / Natural Language interface **UCCCC [1])**

Communication

Structure

Proximity

Existing & future solutions

Human

Animal

Machine: Social Assistive Robot

Living Lab

Resident

ROBOT + Smart AAL Environment / IIoT

in **near to body (BAN*)**

in **arms' length**

accommodation

Living environment

IIoT

wearables

mimetic fibres

1) UCCCC User Centric Contextual Communication Corridor

***BAN Body Area Network**

Description of Elderly Retirement Home:

- About 80 guests, 2/3 female,

- between 70 and 100
  years old, >50% walking impairments

- 90% single rooms, 10 % double rooms for elderly married couples.

- Personalized food and dietary scheme

    < 15% need eating support (mobility disabled)

    <15 % mentally disabled (dementia)

- Operated by Kreuzschwestern (catholic organization and professional operator of hospitals and elder retirement homes in Europe) http://www.kreuzschwestern.eu/

R&D Project Phases:

(1) Phase 1: dependent Elder Care **internal logistics**:

   a.   on schedule,

   b.   on demand

   c.   on emergency

(2) Phase 2: internal logistics combined **with intended Elder-Robot interaction / communication**

   a.   Food and drink logistics on schedule and on demand

   b.   Individual daily schedule supported and interacting with SAR

   c.   Personalized communication using contextual corridors for situational communication within the social experiment using Living Lab architecture (= RESEARCH AND DEVELOPMENT R&D) , fuzzy semantics and gestures. [10]

Phase 1: non intended contact with Elderly = „assimilation phase"

1A: internal standard logistics done by Care-o-Bot 4:

Laundry Cycle: collect used laundry and bring fresh laundry

(1) Flat laundry 1/week
(2) Personal laundry 1/ week
(3) Emergency laundry on demand (standard but on demand)

Cleaning Textile Cycle: collect used and bring fresh microfiber pieces, comply with contamination rules!: 3 categories .(1/day)

Waste cycle: collect full trash bags and bring empty bags

80 Homes, 3 dining rooms, 3 to 5 TV and entertainment rooms different waste types in different baskets

Phase 1: **non intended contact with Elderly = „assimilation phase"**

1B: on demand logistics done by Care-o-Bot 4:

(1) Infusion cart transport: round trip

(2) Medicine cart transport: round trip

(3) Wound treatment and wound dressing: cart round trip

(4) Laptop cart round trip (Cardiogram, EEG, blood , pressure, etc.)

Two pcs. of Care-o-Bot 4 working together, (two floors), well defined division of labor.

Phase 1: **non intended contact with Elderly = „assimilation phase"**

1C: Observation tour by Care-o-Bot 4 :

During night 3 to 4 times for each floor :

Different scenarios will be trained with SAR:

- Identifying obstacles which may cause a fall, (object recognition)
- elder people sitting on ground, (residents recognition, supported by RFID **if ethically acceptable**)
- lost orientation, (residents recognition, supported by RFID **if ethically acceptable**)
- wheelchairs, …

These incidences always require message handling to the floor manager sending pictures, audio-files and names of identified persons or objects.

Phase 2 **with intended contact between Elderly Residents and SAR**

- In phase 2 we plan to have closer and intended direct contact between residents and SAR

- Standard transports of meals (breakfast, lunch, dinner and on demand) to dining room or to the resident's living room

- Communication with residents

Phase 2 with intended contact between Elderly Residents and SAR (1)

Type of communication:

Care o Bot 4 is able to identify individual residents.

Using **bibliographic data** (Name, Age, family status, travel experience, former profession, education level, etc.)

Plus: actual data (time schedule of current week, last week, next week)

Plus: individual peculiarities

Plus: shortcomings in speaking (brain stroke), moving, seeing, hearing , smelling

We define an individual communication profile with different layers based on personal data, personal strength and weaknesses, daily and weekly events, problems (e.g. diagnosis, pains, joyful events,…)

Phase 2 with intended contact between Elderly Residents and SAR (2)

Type of communication:

The communication profile requires a personal, contextual, timely and pragmatic basis for a residents-centered dialogue.

This is still research, partially executable in narrow semantic fields. A bi-directional communication SAR ⇔ resident can be achieved.
The living lab approach allows us to test natural language interface with poly-contextural logic, gesture communication [10]

Idea: we define the concept of **U**ser **C**entric **C**ontextual **C**ommunication **C**orridor.

Corridor means that due to fuzzy semantics the dialogue must be trained along contact time with the individual user using neural network technology. We will have many **C**ontextual **C**ommunication **C**orridors (CCC) per resident, as training base for neural networks.

Challenges to SAR in Elderly Care Context:

- Sensor requirements to cope with residents' shortcomings:

- Speak and listen

- Reduced quality of pronouncing due to stroke and partial paralysis
  - Reduced quality of verbal articulation
  - reduced ability to hear, to distinguish words,… (robots speaking speed might be sometimes (in the morning) too high)
  - Too high environmental noise level, reduced discrimination

- See

- Fuzzy Touching (eg Parkinson disease)

- GESTIC COMMUNICATION [10]

6. TRL & MRL for Social Assistive Robots [2]

Key Questions:

- Is the elder care market ready for the SAR technology?
- Is the SAR technology ready for the market?
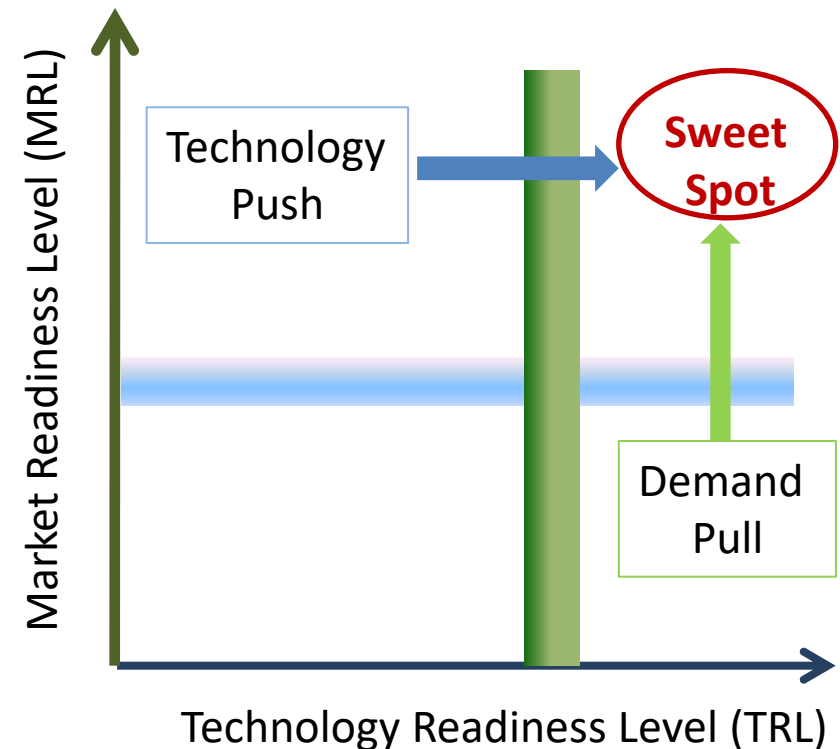
$\Rightarrow$ How to synchronize time and content of technology development and market development?

Technology Readiness Level (TRL)
PHASE 1
PHASE 2

| IPR RL **9   9** |
| Integration RL **7   5** |

Technology RL
7 to 9
5 - 7

| Manufacturing RL **8   6** |
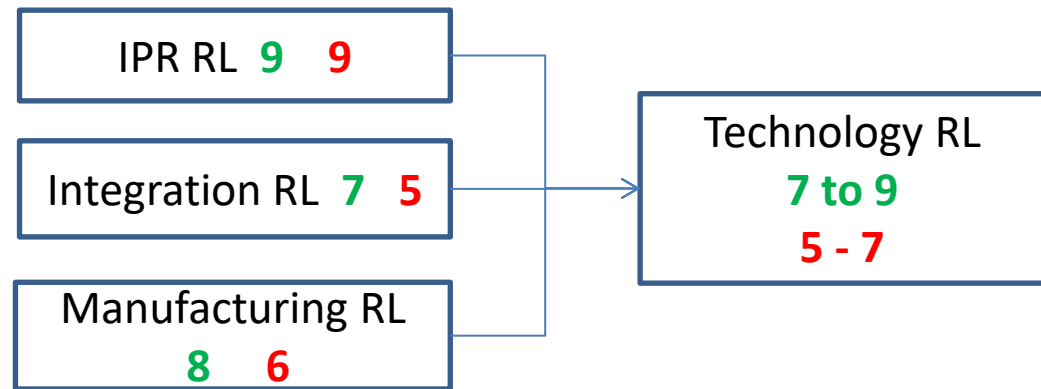
Consists of three components

- Intellectual property readiness
  - Has IP been protected?
  - Does the firm have the right to operate without restrictions?
- Integration readiness
  - Can technologies be integrated?
- Manufacturing readiness
  - Can product be manufactured?

Market Readiness Level (MRL)

PHASE 1

PHASE 2

Market RL
8 to 9
5 to 6

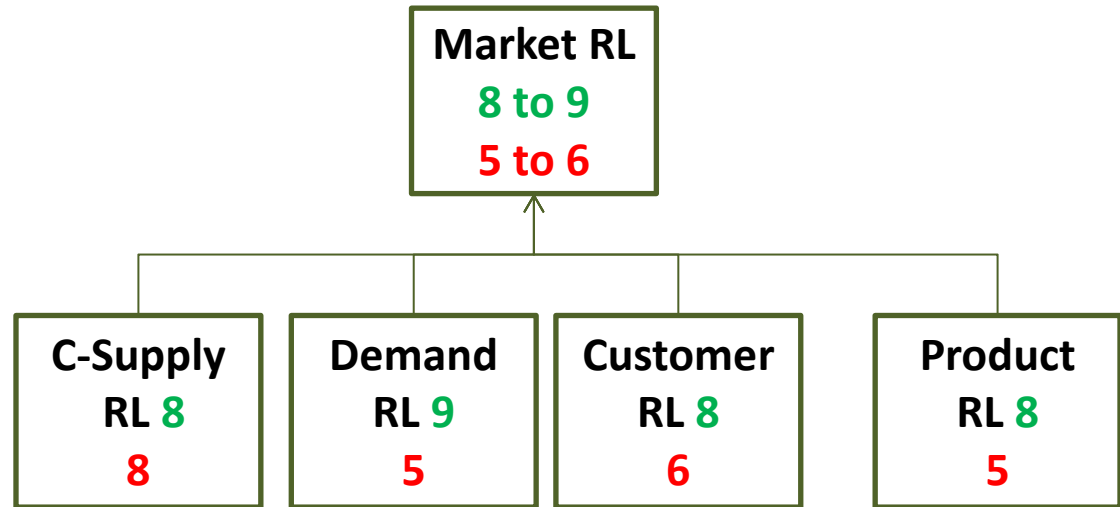| C-Supply RL 8	Demand RL 9	Customer RL 8	Product RL 8
8	5	6	5

- Consists of four components:
  - Competitive Supply readiness
    - To what degree are competitors' products available?
  - Demand readiness
    - What is the demand for the product?
  - Customer readiness
    - Is the customer ready to use and adopt the product?
  - Product readiness
    - Is the product ready for widespread use?
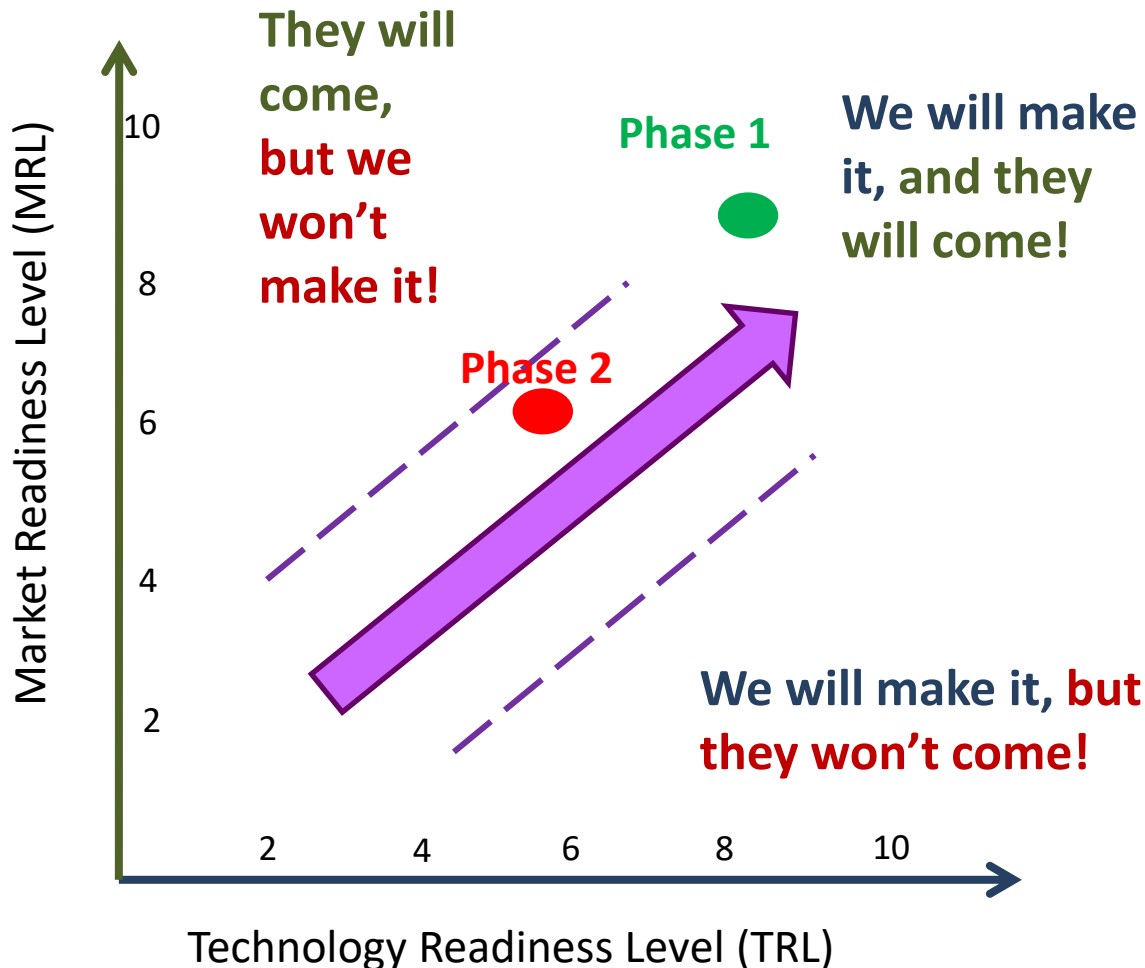
- Concurrent, step-by-step market and technology development places the right product into the right market window at the right time.

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**Marketability Criteria
MC 1 - 6**

**Technology Acceptance Criteria TAC
PU & PEoU**

(MC 1) Innovative?
(MC 2) Testable/correctable?
(MC 3) Controllable?
(MC 4) Compatible?
(MC 5) Implementable?
(MC 6) Assimilative?

Technology Acceptance

Perceived **U**sefulness

Perceived **E**ase **o**f **U**se

**Willingness
to Pay WtP**

+

–

Technology Rejection

- Cross-functionality is a proven economic success factor in high-tech innovation and implies communication between multiple knowledge disciplines
- Decision requires **multidisciplinary communication skills** [16]
- The buying / selling center is represented by a multidisciplinary buying / selling team in MDC (multidisciplinary communication)

7. Conclusions:

1. TRL estimated level for
    1. Phase 1: 7 to 9
    2. Phase 2: 5 to 7
2. MRL estimated level for
    1. Phase 1: 8 to 9
    2. Phase 2: 5 to 6

Open:

(1) smooth organizational integration via LIVING LAB project next 2,5 years

(2) UCCCC development is at the very beginning

(3) Personal remark: UCCCC is „extreme technology" approach

8. References

[1] S. Payr, F. Werner, K. Werner: „Potential of Robotics for Active Assisted Living" Vienna, June 2015 Grant no. 4719346,

[2] R. Hasenauer, C. Weber: "Managing Technology Push through Marketing Testbeds" Tutorial Session WB-05 , PICMET 2015, August 5)

[3] https://phys.org/news/2017-08-robots-bridge-elder-care-gap.html#jCp

[4] ENOLL: https://www.openlivinglabs.eu, European Commission 2009

[5] ISO-Standard 8373) https://www.iso.org/obp/ui/#iso:std:iso:8373:ed-2:v1:en

[6] ISO-Standard 13482) https://www.iso.org/obp/ui/#iso:std:iso:13482:ed-1:v1:en

[7] https://www.humai.tech/

[8] Belviso Carlotta, Hasenauer Rainer , Ulrike Bechtold : Socially Assistive Robots Diffusion in Elderly Care - A pre-adoption study through Agent-Based Modeling, PICMET 2018, 20. August 2018, Honolulu

[9] ENOLL https://www.openlivinglabs.eu , European Commission 2009

[10] R. Hasenauer: „Management von Nichtwissen – Eine Chance zur positiven Zukunftsentwicklung? At WU-IFU Seminar 16.Jan 2014

References

[11]: Blanca Schroll Casares, 2017:"Real time performance improvement, integrating stress measurement and systematic data evaluation, through smart wearable devices in Beach Volleyball" Vienna 2017

[12] Marie Chan et al. : „Smart wearable systems: Current status and future challenges" in: Artificial Intelligence in Medicine 56 (2012) 137–156 https://de.scribd.com/document/225525235/1-s2-0-S0933365712001182-main

[13] Bosch IoT Lab: Business Models and the Internet of Things, White Paper August 2014 www.iot-lab.ch

[14] http://taurob.com/de/

[15] http://epub.wu.ac.at/id/eprint/4414

[16] Rainer Hasenauer, Miriam Falcone: "The pre-adoption process of a new technology: a percolation study of artificial skin for medical diabetes treatment." PICMET 2016 pp 3155-3174

[17] R. Ljuhar, C. Schön, D. Ljuhar: Bone Assessment Redefined: i3A Technologies in: Hasenauer/Schildorfer http://epub.wu.ac.at/id/eprint/4414 , pp152

[18] Cory-Ann Smarr: "Older Adults' Preferences for and Acceptance of Robot Assistance for Everyday Living Tasks" at Human Factors and Ergonomics Society HFES 56th annual meeting, Boston September 12, 2012

[19] Cynthia Matuszek:"How robots could bridge the elder-care gap" August 28, 2017 The Conversation

[20] Stan Schneider: The Rise of the Robot Overlords – Clarifying the Industrial IoT 2018

[21] https://www.indsci.com/Intrinsic-Safety/

9. APPENDIX & Contact Details

Contact Details:

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Wirtschaftsuniversität Wien

https://www.wu.ac.at/mm/team/hasenauer/

http://www.hitechcentrum.eu/

http://www.hitec.at

http://www.inits.at

http://epub.wu.ac.at/4414/

Stages of Market Readiness

Level   **_Market Readiness_**

1   Unsatisfied needs have been identified

2   Identification of the potential business opportunities

3   System analysis and general environment analyzed

4   Market research

5   Target defined

6   Industry analysis

7   Competitors analysis and positioning

8   Value proposition defined

9   Product/service defined

10   Business model defined coherently*

- *Measurement of readiness level is done by checking if the criteria used to describe the level are fulfilled.*

  *Added by KIC InnoEnergy

Technology Push/Market Entry Projects

(2013-2014)

ID	Innovation	Entry	Industry
A	Gesture controlled mmi	2014	scanner
B	Technical simulation	2014	software
C	Atmospheric nitrogen deposition collector	2014	sensor
D	Aerosol jet-printing	2014	3d printing
E	Selective Laser Melting	2014	3d printing
F	Sensors for mobile robots	2014	sensor
G	Health CCPM	2013	robotics
H	Safety Robot	2013	robotics
I	Atmospheric plasma for wood surface energy	2013	material science
J	Phase change material	2013	building construction
K	Flame retardant rubber	2013	material science
L	Magic lens augmented reality	2013	software
M	Bone diagnostics	2013	medical diagnosis

Technology Push/Market Entry Projects
(2011-2012)

ID	Innovation		Entry	Industry
N	Continuous Non-Invasive Blood-Pressure Measurement	2012	medical diagnosis	
O	'Watch dog' for semiconductor		2012	software
P	Containment		2012	building construction
R	Lab on chip diagnostics		2012	software
S	Vibrational acoustic analysis	2012	medical diagnosis	
T	Smart bottling plant		2011	machine construction
U	Bright red systems	2011	scanner	
V	mmi pressure and temperature sensors	2011	sensor	
W	Bionic surface		2011	material science
X	Cellular materials	2011	material science	
Y	V-REDOX	2011	energy storage	
Z	Diamond-like carbon		2011	material science

Market Readiness	Level	1	2	3	4	5	6	7	8	9
Building the adapted answer to the expressed need in the market	9						L;		H;	
Identification of the Experts possessing the competencies	8					Q;U;	B;		J;K;	Y;
Definition of the necessary and sufficient competencies and resources	7									
Translation of the expected functionalities into needed capabilities to build the response	6					O;	M;T;	P;		
Identification of system capabilities	5				Z;	A;				
Quantification of expected functionalities	4		W;		F;V;	R;	N;	E;		
Identification of the expected functionalities for new product/service	3			S;	X;	C;	G;	D;		
Identification of specific need	2		I;							
Occurrence of feeling "something is missing"	1									
Level→ Technology Readiness		1 Fundamental research	2 Applied Research	3 Research to prove feasilibility	4 Laboratory Demonstration	5 Technology Development	6 whole system Field demon-stration	7 Industrial Prototype	8 Product Industrial-isation	9 Market / Sales Certification

Technology Risk

Market Risk

Hasenauer, et al., Managing Technology Push