INBOTS
Inclusive Robotics for a better Society

INBOTS WHITE PAPER

ON

INTERACTIVE ROBOTICS MARKET ANALYSES & SUPPORT FOR SMEs

(Business models & exploitation strategies)

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 780073

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1. Executive Summary

This White Paper aims at providing an overview of the market in Interactive Robotics highlighting in the same document non-technical issues such as business models, IPR aspects and experiences of real entrepreneurs.

Interactive Robotics field is an emerging field where robots are conceived to perform intended tasks in close proximity with humans, cooperating with them both physically and cognitively. Within the INBOTS consortium, several companies work in different fields of the interactive robotics like exoskeletons, humanoids, prosthetics, collaborative robots, etc..; for the first release of the white paper, WP1 partners together with the Project Coordinator agreed to mainly focus on two fields of the interactive robotics: Humanoid service robots, (HUM) and Wearable Robots (WRs). In particular, for WRs are intended robots that are physically connected to human body and that exchange mechanical power to the wearers like exoskeletons and robotic prostheses. For Humanoid Service Robots are intended legged or wheeled robots that are designed primarily to interact with people in various settings (such as retailing, hospitality, education, health care, entertainment, etc...), built to mimic human motion and interaction in various ways, both with people and with the environment. Another important aspect is that the document addresses Humanoid Service Robots and Wearable Robots in three specific domains: manufacturing, healthcare and consumer.

This document is intended as a handbook for SMEs operating in the HUM and WRs fields, able to provide an overview of the market, a collection of experiences of entrepreneurs (i.e. founders of companies or long-time members) in terms of milestones, barriers and challenges and, last but not least, a summary of the main business models as well as IPR aspects related to interactive robotics. Some activities of the document have been carried out in close collaboration with the "COST ACTION 16116 - Wearable Robots for Augmentation, Assistance or Substitution of Human Motor Functions" extend the visibility of this work to the whole robotics community and to collect feedbacks for the interviews.

The Final White Paper will extend the analysis to other fields of the interactive robotics, trying to maintain the same approach able to provide both numerical information and experiences of real entrepreneurs where their insight and know-how were able to change small spin-off in successful companies. In addition, results shown in the Intermediate White Paper, will be furtherly refined and updated.

Main outcomes of the HUM and WRs fields are that these two fields are very attractive both in terms of companies founded in the last 5 years and in terms of potential market. Indeed, one of the main aspects that emerges by the interviews carried out with founders of companies is that the market seems to be enough mature to accept humanoid or WRs products, if you propose a clever way to solve a real problem for the customers. However, some negative issues still remain like the lack of clear normative framework and the selection of the right business model to guarantee self-sustainability as well as some residual psychological barriers in accepting new technologies.

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2. Introduction

As outlined in the executive summary, the primary objectives of the white paper are to promote entrepreneurship in the field of interactive robotics and to provide non-technical support to small and medium enterprises - or SMEs.

To meet this goal and foster new robotic enterprises in a scalable fashion, we decided to generate a white paper:

- to synthesize the experience and insight of real entrepreneurs, to highlight the main obstacles they've faced and the strategies they've employed to succeed in the interactive robotics market
- to provide an overview of the market in the Humanoid Service Robots, (HUM) and Wearable Robotics (WRs) fields in terms of number of companies, companies classification, country, patents and projects
- to identify the main business models that a SME could adopt to find its self-sustainability
- to describe the main Intellectual Property Right (IPR) aspects for protecting the IP of the company (which is in most of the cases the real added value of the company)

It is worth noting that in this first version of the white paper, WRs are intended robots that are physically connected to human body and that exchange mechanical power to the wearers like exoskeletons and robotic prostheses.

In order to provide to the readers a map of the document, the main five sections are briefly described hereafter:

Section 3 focuses on interviews carried out with entrepreneurs of companies, highlighting the structure of the interview followed, the main different approaches to the company problems and a summary reporting analogies and barriers found.

Section 4 provides an overview of the market, outlining the companies that currently work in the two considered fields, namely HUM and WRs. Numerical data found on companies' websites or database searches are also reported to give an idea of the market.

Section 5 describes the database research that has been carried out to get an overview of the robotic companies working in the two selected fields, namely HUM and WRs. In particular, in this section will be highlighted the main database characteristics as well as different visualizations.

Section 6 is related to IPR aspects adopted in the robotics field; indeed, to get an overview of the IPRs landscape an exploratory survey was conducted. Results are shown within this section, outlining different strategies and solutions to manage intellectual properties.

Section 7 outlines business models that can be adopted by SMEs, showing pros and cons of different approaches. In addition, some examples of spin-off companies are presented.

Section 8 concludes the document with key information elaborated in the document.

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3. Real entrepreneurs' experiences

This section aims at reporting stories about challenges and barriers that companies in the field of Humanoid Service Robots or Wearable Robots faced/have overcome/were not able to handle.

Naturally, collecting and distilling all this information is a non-trivial endeavour. Fortunately, the INBOTS project provides the resources and collaborative infrastructure to pave the way to a complete picture of the interactive robotics landscape, thanks to its broad and diverse consortium of SMEs and large companies working in this specific field. Together, these companies hold a wealth of experience and perspective about the main challenges and barriers that often discourage new robotics entrepreneurs, and how to overcome them.

So far, we have identified three main classes of business barriers:

- First, there are Economic barriers, including the accurate identification of the real needs of the target market, access to funding, and various legal services such as those related to intellectual property;
- Second, there are personnel challenges, of gaining access to experienced collaborators, and of assembling a talented team with a suitable spectrum of multi-disciplinary expertise;
- Finally, there a number of psychological barriers to overcome among end-users, including educating the target market about the capabilities and benefits of interactive robotic technologies.

To provide a preview of what we intend to produce, we've assembled the following personal accounts of commercialization experiences and barriers from real entrepreneurs.

The approach for collecting these stories is to perform interviews with founders/longtime members of the staff. Some interviews have been made in collaboration with the COST Action project (CA16116 - Wearable Robots for Augmentation, Assistance or Substitution of Human Motor Functions, https://wearablerobots.eu/).

The interview consists of 8 questions, trying to describe challenges and barriers that the entrepreneurs faced with:

- Who you are? Please describe briefly yourself.
- Which was your role in the company at the beginning and what is your role now?
- What was your vision of your company at the beginning and how this vision changed during the years?
- Would you define three milestones in the growing of the company?
- Which kind of barriers did you find? Please define the most critical ones.
- What was/is the role of the academia in the creation and growing of the company?
- Which is the most critical element for the growing of a company in our sector?
- Which is the biggest opportunity for a company in our sector?

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Entrepreneurs that we interviewed are coming from both WRs and Humanoids fields and they are listed below:

- Francesco Ferro (CEO of PAL Robotics, https://pal-robotics.com/en/home/)
- Nicola Vitiello (Founder of IUVO and technology advisor, www.iuvo.company)
- Jody Saglia (CTO of Movendo, https://www.movendo.technology/en/)
- Hugh Gills (VP of Touch Bionics, http://touchbionics.com/)
- Jaime Duarte (Co-founder, CEO of Myoswiss, https://myo.swiss/)

1. Interviews

a. Knowing Francesco Ferro (F.F) and PAL Robotics

[Interviewer] Who you are? Please describe briefly yourself.

[F.F.] I'm the CEO and owner of PAL robotics. I'm a telecommunication engineer coming from Polytechnic of Torino Italy and I'm in PAL robotics from scratch and I'm the co-founder of the company.

[Interviewer] Which was your role in the company at the beginning and what is your role now?

[F.F.] I started in PAL robotics doing computer vision. Our first commitment was to make a robot that was able to play chess. We accomplished this activity in only 14 months, making the first humanoid bipedal robots in Europe. Since that, I started doing Image Processing, then navigation, embedded system, software manager and then I jumped to the management layer and to the CEO (to substitute my colleague that left the company in 2010).

[Interviewer] What was your vision of your company at the beginning and how this vision changed during the years?

[F.F.] At the beginning, like employee of PAL robotics, I was wondering to make my best in order to make robots working as best as possible. I was the expert in robotic vision, but I always helped all my colleagues for all the software in the company. At the beginning, our idea was to make research, so we were a kind of research lab dedicated to research and development. Then during the years, we opened our commercial market and so we started producing more and more platforms for our researchers all around the world. Therefore, the vision from the beginning to up to now is completely different: now we have a very clear market strategy based on product development as well as project development.

[Interviewer] Would you define three milestones in the growing of the company?

[F.F.] The first one was when we made the change between only pure R&D company to a real commercial company: we started opening our mind to be closer to the market. This is a very big milestone and, for sure, all the companies around the world have to improve this milestone. But I think that we reached a quite good compromise. Then, the second one is about the team: one of the biggest things that we did in our company is to work with all our colleagues at the same level. I don't want to make comparison with democracy or whatever but, what we tried to do in order to make our environment as best as we can, is to have shared decisions. We tried to listen everybody in the company to take the best decision because everybody has a very

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clear role and responsibility in the company. Then for sure, the third milestone probably is something that will happen in the near future to confirm and consolidate our leadership as global humanoid robotics provider.

[Interviewer] Which kind of barriers did you find? Please define the most critical ones.

[F.F.] I will tell you a short funny story: at the beginning, we were two Italian engineers with crazy ideas funded from UE to make the first bipedal humanoid robot in Barcelona and, I can guarantee, we were not able to speak neither a word of Spanish. So, the first big barrier for us, was to find the right place to work: indeed, we spent the first three months to find the place and to design robot in the bar of Barcelona. Can you imagine? This is a very funny story: in America usually, entrepreneurs started their business in the garage, in Barcelona we made it in a bar. For sure, it was more "social". This funny story is to highlight the main barrier that we found: the cultural barrier. Indeed, we found this barrier also designing robots because it's not the same, aesthetically speaking, a robot that should work in UE or in Spain or in US. Another big barrier for sure is the heterogeneous safety regulations among different countries: we have not the same rules. In addition, speaking about industry, different target applications have different rules: for example, service robotic applications are completely different from home/medical applications. Finally, here in Europe, we didn't find yet the right organization that can help us to make the right tests to have the proper certification for collaborative robots.

[Interviewer] What was/is the role of the academia in the creation and growing of the company?

[F.F.] At the beginning, we didn't start like a spin-off of university. So, we started with a private agreement with the company, but during the years, we noticed that academia is very important for basic research and we really need research that tries to find innovative solutions. For this reason, PAL robotics is involved in competitions to push the limit of robotics, finding ideas, finding new solutions to deal with easy daily tasks like standing during manipulation or walking on rough terrain.

[Interviewer] Which is the most critical element for the growing of a company in our sector?

[F.F.] I think there's a common denominator in all the companies, which is the most important value ever, that is the team. Finding the right person with proper technical and soft skills. Indeed, we completely believe that everybody can work alone but if we work together and we create a strong team, also a few people could change the world. And for me, team is the best element ever.

[Interviewer] Which is the biggest opportunity for a company in our sector?

[F.F.] In service robotics, the biggest opportunity is to survive. No, I'm joking, the actual biggest opportunity is that we are at the beginning of the service robotics era and this market is huge but unfortunately being at the dawn of this new era, the market it is not still mature. So, what we have to do in the meantime, is to do research and make more development to simplify as much as possible our robots, introducing easier human-robot interface and reducing the cost.

I think that in the service robotics market we will have space for everybody, therefore we have not to be scared. Another thing that I said in all my presentations is that service robotics is not something that only one company, even PAL robotics, can do alone. In the last years, we have

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seen a lot of example of big institutions or big companies that were just falling down or shut down the doors because funding is missing or people leaving or whatever because they tried to do everything on their own. Synergy is the key point. In conclusion, have a clear idea and clear final objective is fundamental. And for us, the goal is to have a bipedal humanoid robot that could help all the persons in everyday tasks.

b. Knowing Nicola Vitiello (N.V) and IUVO

[Interviewer] Who you are? Please describe briefly yourself.

[N.V.] Hello, I'm Nicola Vitiello and I'm an associate professor at the Bio Robotics Institute of Scuola Superiore Sant'Anna and I'm also one of the co-founders and advisor of IUVO that is a spinoff company of Scuola Sant'Anna. I'm a scientist in the field of wearable robotics for about 12 years and I really like do exoskeletons.

[Interviewer] Which was your role in the company at the beginning and what is your role now?

[N.V.] When we started the initiative, we were six colleagues, then we became fourteen. And then, after the joint venture between Össur and Comau that invested in the company, I became an advisor. And I'm right now an advisor so I am quite interested in the business development of the company.

[Interviewer] What was your vision of your company at the beginning and how this vision changed during the years?

[N.V.] The vision at the beginning I would say is still the vision that I have of the company now. So, when we raised the company we wanted to be at the cutting edge of the research and development in the field of wearable robotics, acting like a kind of discovery engine for the field. And it is still exactly like that. Of course, we are trying to do our best for the first successful story. And of course, there is still a long way to do but we believe that we are on the right track in the right direction. So, my vision, our vision, is still there.

[Interviewer] Would you define three milestones in the growing of the company?

[N.V.] I feel that the first milestone is about the moment in which we started the collaboration with Comau in 2015. Basically, we were able somehow to get Comau trusting in our capability of being innovators. And the second milestone is necessarily in 2017, when the company entered into the FCA group and received the investment from Comau and Össur because from that point in time we weren't anymore a startup. We were a real company that had to grow. I don't like the idea to be a startup forever. The third milestone is on June 2018, when Comau presented the MATE technology at the Automatica fair in Germany, because it was the first product that has been somehow developed by IUVO and brought on the market. For sake of clarity: I would say the first milestone is when we started convincing people in relying on us. Then when we received the investment and now when the first product is on the market.

[Interviewer] Which kind of barriers did you find? Please define the most critical ones.

[N.V.] I think that the main barrier for wearable robotics is about the fact that we are going to develop a hardware with the human in the loop. So, the first barrier that I see in my view, it's still there: the challenge is the development of a reliable and really usable technology. The

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second barrier, from my point of view, is about the business model: finding the right business strategy that can give to any start-up company in the field of wearable robotics the possibility to have a sustainable business. I mean, many companies failed in the first years because they have a shortage of money and they have difficulties in developing the company structure. Therefore, when we started the company, we wanted to avoid these risks. And that's the reason why, from the very beginning, we tried to convince two large corporates to support our initiative. And that's the way we tried to work around this barrier. So, just to briefly recap: while the first technological barrier is still there (and our engineers and myself tried to everyday improve our robots), the second barrier (i.e. a sustainable business model) is something that IUVO tried to work around to have successful products in the wearable robotics market.

[Interviewer] What was/is the role of the academia in the creation and growing of the company?

[N.V.] I think that for our company, Scuola Sant'Anna plays a crucial role. The fact that I am also a professor is really the demonstration of a very important value chain. Indeed, it's the university that is taking care of educating future engineers that would join in our company. And it's the company that has the goal of taking the technology developed within the university and bring the technology to the market. Of course, we have two large industries that are backing the initiative and they have the sales force to bring the products to a success but, as you see, this is a value chain and the starting point is in the university. Without the university, I would say, that IUVO wouldn't exist and, if it will be successful, most of the merit will be in the university and in the nice ecosystem that Scuola Sant'Anna represents.

[Interviewer] Which is the most critical element for the growing of a company in our sector?

[N.V.] The most critical element is the humans: the human resources. I always say that the only reason why we can accept the challenges of developing new exoskeletons is because we have the best team that you may have. Wearable robotics is something that is relatively new: it's not like aerospace or automotive engineering. I mean, there's not a school where you can learn how to do exoskeletons but I'm sure that it will happen in the future due to the increasing interest. Therefore, when you have a talented person that after one or two or three years is educated and enters into the field you have a kind of super value. It's something that has an incredible impact and I would say it's our treasury: our fundamental element are the people that are in IUVO. And I'm sure that the only way to grow up is to have a team that progressively and in a sustainable manner will increase the number of talented engineers.

[Interviewer] Which is the biggest opportunity for a company in our sector?

[N.V.] I think that the opportunity in our sector comes from the fact that many decision makers around the world are underestimating the sustainability of our welfare: the opportunity comes from the real need. So that's very interesting and important. Wearable robotics is not a speculative market. Wearable robotics is a real market because it's a market that relies on the real needs of people. So that's the biggest opportunity.

c. Knowing Jody Saglia (J.S) and Movendo Technology

[Interviewer] Who you are? Please describe briefly yourself.

[J.S.] Hello my name is Jody Saglia. I'm 36 years old and I am a mechatronics engineer. I studied at Polytechnic of Turin and I spent some periods in Finland and in London where I did

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some years of research. Then, I did a PhD in robotics and I did R&D of robotic technologies for assistive applications and, in particular, for physiotherapy and rehabilitation. It has been a long journey. So, the current product the company is selling now was actually my master thesis.

[Interviewer] Which was your role in the company at the beginning and what is your role now?

[J.S.] I was in the initiative from the very beginning as a developer and I am one of the co-founders of the company and now I'm the CTO and innovation manager for the company.

[Interviewer] What was your vision of your company at the beginning and how this vision changed during the years?

[J.S.] Initially we thought of creating a company that would design, develop and sell exclusively medical devices for rehabilitation based on robotics technology. Now, we're changing our mind and we are understanding that the real value is in providing a service which can really change the market of rehabilitation and physiotherapy. So, it's not just a matter of selling devices; it is a matter of providing the best tools that can manage the whole process of rehabilitation to change the way the physiotherapy is delivered.

[Interviewer] Would you define three milestones in the growing of the company?

[J.S.] First of all, it was developing technology that works and that can actually be applied to the field that you're targeting. So, the first milestone was to develop a product which could be really used in real clinical settings. The second milestone was to set up a team of people that could actually be the basis of the company creation and find someone to support us in terms of financial investment (i.e. providing the funding to start the company). Finally, the last milestone we had last year was the real product launch on the market: presenting a commercial product in a clinical setting which could be used in an everyday life of a clinic was amazing. So, this was actually one of the last and maybe even the most important one.

[Interviewer] Which kind of barriers did you find? Please define the most critical ones.

[J.S.] When you target product development, you had to forget about technology and so on. Unfortunately, usually researchers tend to focus more on the technical aspects of a solution, while somehow neglecting or forgetting or at least not thinking very clearly about the real problem they're trying to solve. So, the first barrier is that you need to change your mindset, you need to focus on what is the problem that your customer has to solve and then use the technology leverage to solve it. And this is, culturally speaking, in academic environment or in research environment, the first barrier that you certainly find. Therefore, you need to find right people and team up with people who are really focusing on the end user and not just on the technology development. The second one, that we are actually facing now, is that when you do something very innovative, people tend to resist to the change. And, these cultural barriers in every market, are due to the fact that people always tend to stay conservative and try not to change the way they do things every day. Actually, this is the biggest barrier for us. Indeed, now we have a product which is very innovative, which brings a new way of doing things, and people try to avoid the change.

[Interviewer] What was/is the role of the academia in the creation and growing of the company?

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[J.S.] It is very important. First of all, because that's where we come from. And that's where we were able to access the top technologies in our field, in robotics and in the bio mechanical engineering. And it was very important for the product development at the beginning. And for sure it will be more and more important in the future because, as a small company as we are now, we are not able to do everything on your own. We need to partner up with universities, research institutes or R&D companies to support our development in a sustainable manner.

[Interviewer] Which is the most critical element for the growing of a company in our sector?

[J.S.] It's finding the right market niche because there are a lot of initiatives, there are a lot of technologies. Technologies for assistive applications are nowadays becoming more and more mature but you need to find, and again I'm not saying anything new now, but you need to find a killer application. So, the technology itself, as I said, it's a tool but it's not the solution. You need to find how to solve a problem. And this is true for every market. And even more, for the healthcare sector because you are dealing with people. And you have a lot of constraints around, you have a lot of regulations, you have a lot of competitors. So, you need to find the right solution to the real problem. Then you need to work on it, to prove it, to partner up with the top clinicians, top institutions, top hospitals and then drive your development from there.

[Interviewer] Which is the biggest opportunity for a company in our sector?

[J.S.] There is a number of opportunities out there. I would say that the biggest is the fact that our population, and I'm not saying anything new, is aging. The average age in general is increasing a lot of people will have issues related to their basic abilities to move, to walk and to do everything as they did when they were younger.

So, people want to live healthier and better for longer. And to do that, they need support from the technology side. They need support from new approaches in healthcare services: more sustainable and reliable approaches. Approaches that will rely on measurements and quantitative evaluation of your health and your status, and not on the capabilities of the operators to really see and understand how you feel or what you need from a healthcare viewpoint. So, developing technologies for this kind of market, it's going to be a big thing in the next years.

d. Knowing Hugh Gills (H.G) and TouchBionics

[Interviewer] Who you are? Please describe briefly yourself.

[H.G] My name is Hugh Gill. I'm currently working for Touch Bionics. I've been in ten different companies in my career and I've been with Touch Bionics coming up for 12 years. My background was a degree in mechanical engineering, and I created my own company. So, I'm like an entrepreneur as well as a businessperson plus engineer.

[Interviewer] Which was your role in the company at the beginning and what is your role now?

[H.G] So, I started as the Director of Technology and Operations in Touch Bionics on July 2007. I was the fourth person to join and it was a virtual company because we had no location. On 2012 my title changed to CTO, chief technology officer, and in 2016 when Ossur acquired us, I became the vice president of R&D upper limb prosthetics and also the manager of TouchBionics.

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[Interviewer] What was your vision of your company at the beginning and how this vision changed during the years?

[H.G] The original vision was to bring on the market disruptive technologies with a multi-articulated hand and partial hand products. The vision changed as we moved to enable the product to be faster, stronger and smarter. The "smart" feature was added by introducing gyro gesture controls: it's motion movement would allow the hand to go in two different grips. Also coming up with new technologies like wireless communication for beacons and wireless communication to setup the system with a smartphone app.

Through time, we expanded our range from the original vision, adding different sizes to cover the patient population. We also acquired a company in New York to realize coverings for our products. And we started to expand our collaboration with clinics and our vision changed getting feedbacks from clinicians and patients. Finally, also our interpretation of the company changed: we changed our strategy from distribution without a real sales channel to direct sales approach.

[Interviewer] Would you define three milestones in the growing of the company?

[H.G] So, one milestone was on 2007 when we launched the product and the next milestone after that was on 2009 with a partial hand prosthesis with patients who have lost one up to five digits. And at that time, it was a major milestone because no one was in the market to support any partial hand patients. The second milestone was the release of a new hand prosthesis with a rotating pivot thumb, which occurred in 2013. At the moment, Be-bionics was one of the competitors that came in the market in 2010 and they still did not have a rotating pivot thumb (like human hand) which is very useful when you want to automatize grips. And then, the last milestone occurred on April 2016 when Ossur acquired Touch Bionics; so that was a big milestone that we were trying to reach for many years. And we did it in 2016.

[Interviewer] Which kind of barriers did you find? Please define the most critical ones.

[H.G] So, Touch Bionics was the first company to spin out of the NHS (National Health System within the UK) and we actually spun out of the NHS many years before the NHS would support the segment of prostheses and patients. Therefore, most of our effort in the early stages was focused towards US and Europe because of the commercial barriers. Commercial barriers are really challenging to overcome. The next critical barrier was the self-sustainability of the company: at the beginning we were growing at over 20 percent per year and to maintain this growth level you must continuously reinvest the capital into the company. So, for at least 10-12 years, we required support of business angels; without support of business angels you have to continuously show how the business is moving forward and why you continually need reinvestment into the business. So, at the end, it was thanks to the support of business angels, that allowed us to keep growing, that we reached a level where we were self-sustainable. Another barrier that we dealt with was the L-code in America, that is a reimbursement code for prosthetics products, and it took quite a bit of time to get one of these codes assigned: we applied to get L-code in 2007 and the L-code became effective in 2012. So, once we got the L-code, the reimbursement was allowed in all states of America. Prior to that acceptance, you had to use miscellaneous codes because your product didn't have L-code. This was a big barrier for us, and it took a long time to get over: five years to get our L-code assigned.

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[Interviewer] What was/is the role of the academia in the creation and growing of the company?

[H.G] So, academia hasn't played a major part in Touch Bionics. I have had academia supporting the company, but it has not been involved in critical activities. I've also hired over the time two PhD and they worked independently in two different teams: unfortunately, they didn't survive one year because they didn't like the piece of business and they didn't like uncertainty. In academia they may have a three- or five-year horizon and you are not used to having schedules and milestones in the same way as we have. Academia is quite different from business.

[Interviewer] Which is the most critical element for the growing of a company in our sector?

[H.G] I would see a couple things that were critical. The big one for us was regulatory standards that took a significant amount of resources and for which, start-up companies, may not truly understand. So that was a critical element to allow us to be successful and then eventually for the acquisition as well. And I would say that another critical element of the company was maintaining the overhead and the staff as we start as we were ramping through the classical hockey stick curve. And that was always challenging to keep up pace of the resources. Indeed, it was difficult also to build up capital inventory when you're growing at the same rate level

[Interviewer] Which is the biggest opportunity for a company in our sector?

[H.G] I have personally been looking at robotics and I created a product called rubber hand. I started as an entrepreneur to put nose into the market and it has been successful, but I sort of pulled back from it as we focused more in prosthetics. So, I think there is opportunity there. I would say the biggest opportunity in robotics and prosthetics is assistive devices especially for the aging as well. So, I think it's going to require a lot more engineering and product offerings for people who are now living to 80 to 100 years of age. And I see that they require assistive devices. And then there's also assisted devices in general which has been beginning to explore the more over the past three to five years. So, I think there's a real opportunity in those areas, the opportunity is basically stroke victims that they need rehabilitation There's also opportunities in prosthetics itself, including upper limb and lower limb prostheses even if those are quite small markets.

e. Knowing Jaime Duarte (J.D) and MyoSwiss

[Interviewer] Who you are? Please describe briefly yourself.

[J.D] My name is Jaime Duarte. I am the CEO and one of the co-founders of MyoSwiss. I am a mechanical engineer. I'm graduated in Florida in the United States and I did my master's in mechanical engineering at the University of California in Irvine. Since my graduate program, I've been working in the field of rehabilitative robotics; so looking to use robots to understand how humans and animals move with the ultimate goal to be able to use this knowledge to help in the rehabilitation process of people with movement problems or to develop technology that assist people to have some kind of movement problems.

[Interviewer] Which was your role in the company at the beginning and what is your role now?

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[J.D] The company was founded in the middle of 2017 and it was originally founded by me and by Kai Schimdt. He had started a project as part of his PhD work in the sensory motor systems lab at the ETH Zurich in 2015 and towards the end of the year I joined the lab. The following year we started talking also to investors both towards the commercialization of the technologies and creating a company that could take the technology from the lab into the market. My role now continues to be the CEO of the company. So, me and Kai continue to lead the company. In these years, the company itself has grown in terms of employees and in terms of our applications but is still Kai and me who lead the company at the executive and management level.

[Interviewer] What was your vision of your company at the beginning and how this vision changed during the years?

[J.D] So we started with the vision of bringing technology that could be used by people in their daily lives. Technology like wearable robots that people can wear in daily life and can help people with mobility impairments to be more independent and to be engaged in daily life. And I would say it hasn't changed too much. We're still moving towards this goal.

So, the idea on what we are currently working is the development of our technology. I think it has been faster than we expected in some areas and slower in some other areas, but we are quite happy with the developments that we've made in the company to bring the technology from the lab into the market.

[Interviewer] Would you define three milestones in the growing of the company?

[J.D] So, the very first milestone was the negotiation with the technology transfer office of ETH Zurich of the agreement about the licensing of the technology developed within the lab. The second milestone was the creation and the growing of the company. In particular, in terms of growth of the company, I think what we've seen is initially a more technology-oriented growth to create a team of people for the technical development of the company. And the following milestone, I would say is now more towards the business development. Indeed, now the focus is to bring in the company people with more expertise on the business development side in order to create a team that will actually go out and sell our technology, i.e. a sales team.

[Interviewer] Which kind of barriers did you find? Please define the most critical ones.

[J.D] I would say at the beginning we thought that one of the big barriers was moving out from research and technical oriented mentalities. Indeed, both of us (i.e. me and Kai) we had been working in academic environments where the focus was mainly on the research side but, when you create a company, the goals changed quite a bit. Now the goal is to make technology that is not only interesting but also (i) commercially viable and (ii) accessible to the people that need it and that can become part of the market for those who need it. In conclusion, I think one of the big challenges is adapting the mentality of going as engineers as researchers more into business minded people.

[Interviewer] What was/is the role of the academia in the creation and growing of the company?

[J.D] I would say it was mostly on the creation side and on the early development of the technologies. Indeed, the role of academia is quite important there: projects that are may be

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riskier and that are at the forefront of technology. That kind of projects normally tend to happen in academia.

Then there is a very important aspect of the business development where is how do you make that technology now available to the mass market: there, academia is maybe not as important and then it's more developing this business side of the company.

[Interviewer] Which is the most critical element for the growing of a company in our sector?

[J.D] So I think the most critical is bringing on the market new technology that hasn't existed before. And getting the general population to understand what the technology is doing and how it's designed to help them and to get people aware about these new approaches to the mobility.

[Interviewer] Which is the biggest opportunity for a company in our sector?

[J.D] For us, the biggest opportunity is the market need that has not been met by the appropriate technology. So, we target the population that has some mobility impairments but still have some movement abilities like elderly or people that are still moving but with injuries. And if you look at the market today, there isn't much available for this group of patients: a lot of them end up being on wheelchairs or they end up using walkers or rollators, instead of using their bodies in a more natural way.

2. Summary of interviews

During this first period of the INBOTS project, the idea of gathering experiences and know-how about the initial period of companies paved the way to a structure of interview and to a list of long-time members/founders of different WRs and Humanoids companies. In particular, our main goal in these interviews was to highlight which kind of barriers and opportunities an emerging field like interactive robotics can offer.

Collecting this kind of information is something that is not easily accessible, but for new entrepreneurs, that would like to create their business in the interactive robotics field, is something that could provide a sort of handbook to identify at a very early stage potentialities and barriers.

The list of companies contacted was created by the internal know-how of the writers and the data coming from an extensive analysis through database search (e.g. CrunchBase, CORDIS, etc..).

Different companies met different difficulties, but some common aspects can be highlighted in terms of opportunities and milestones:

- All founders identify the TEAM has one of the main pillars to have a successful story
- Access to talented people with know-how in interactive robotics is very challenging
- Ageing of the population creates opportunities for interactive robotics applications like humanoids, WRs, rehabilitative robots, etc.
- Role of the academia as a fertilization tool for new technologies (e.g. start-up companies, European projects, etc.)

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Focusing on the negative aspects (i.e. the barriers and the critical elements), different interesting points have been identified which are not only of the company side or of the customer/product side, but they are also of the entrepreneurs' side.

- **Business model**: the main barrier for the creation of a new company, especially in the innovative field, is finding the proper business model to guarantee self-sustainability. Different business models can be adopted according to the type of product or service that you want to provide (e.g. business angels, shareholders, etc..) and having a clear knowledge about pro and cons of different models is fundamental (for more detail, see Section 4 about business models). In addition to this, it is important to have a clear vision of the commercial part of the company and the added values of the company compared to competitors.
- **Mindset of the entrepreneur**: in some cases, innovative companies are former spin-off of universities and founders are usually people that come from the academic world. To have successful companies, one of the most important things is to have a mindset where the focus has to be the customer's satisfaction. Indeed, it is important that the goal of the entrepreneur for the product is to really solve the customers' problem and not the technological challenge behind the problem.
- **Psychological barriers**: being interactive robotics a new branch of the traditional robotics, there are a lot of psychological barriers for the potential customers in the adoption of new technologies. In particular, for technologies that are in close proximity with humans and that interacts physically and cognitively with different environments and different situations, customers could be scared about commercial products. In addition, there is a sort of mental inertia in adopting new technologies to solve problems: people tend to maintain the same mental scheme to reduce the cognitive effort of a new solution.
- **Standardization/certification**: also, in this case, being interactive robotics a new branch of the traditional robotics, there is a lack of standardization and certification aspects. Policy makers don't provide clear information about the requirements and about standards. Another aspect related to standard/certification is the high cost in terms of economic resources as well as time resources to get certification of the products.

4. Overview of the Wearable Robots and Humanoid Service Robots companies

Finding economic data of the companies is not an easy task, especially as open sources data and for micro or SMEs. Specific and expensive report are usually adopted by the companies to carry out extensive market analysis. In this section, a new approach based on the data available on open-access websites is proposed.

Indeed, the method proposed here is to adopt an indirect approach for evaluating the economic size of the market in terms of main companies, for both fields (Wearable Robots and Humanoid Service Robots), based on the following list of variables:

- foundation date of the company;
- number of employees;
- number of products;
- number of national/European projects involving the company;
- number of patents/patent applications; etc.

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This list could be extended during the desk research of these information due to their availabilities. In addition, describing the size of the market through the above terms could provide to entrepreneurships a macroscopic picture of the main trend and strategies of the companies operating in these fields.

Research Introduction

As mentioned above, the different variables were used as indicators for the research. By using keywords like robotics, healthcare, humanoids, assistive robotics, exoskeletons, prostheses, wearable robots, etc., a first overview of companies developing HUM and WRs was preserved. Nevertheless, this draft needed to be filtered by their products' relevance, activeness, capabilities and company size as not all of them were viable for measuring a realistic global market size.

Once this comprehensive list of companies producing HUMs and WRs was created more information about founding date, number of employees, products, involvement in European projects and patents was gathered by online research, which has been done on the following platforms:

- Domicile and founding date: Usually this information is provided in the company's homepage and if not, it can easily be found on platforms like LinkedIn[1] or Owler[2].
- Number of employees and revenue: Owler.com crowdsources competitive insights and contributes companies' profile, revenue, number of employees etc. Searching for the selected companies on this platform gave us the possibility to gather needed data.
- Number of patents: We could seek information about patents at patents.google.com and espacenet.com by using the keywords robot and the company name.

In conclusion, we got numerous companies with appealing information relevant for market research, which we are presenting in the excel sheet reported in the annex of the white paper. The results of this analysis will be demonstrated in following paragraphs.

1. Humanoid Service Robots

Results

During the first data research, a preliminary conclusion has been achieved already during the early stage by observing the results. Altogether there has been found 29 companies worldwide which were considered as important to create a decent market analysis and to show the developments during the past 20 years. The results will be separated in the following paragraph in four different sections:

1. Company size
2. Company growth
3. Patents
4. Geographical distribution.

[1] https://es.linkedin.com/
[2] https://www.owler.com/

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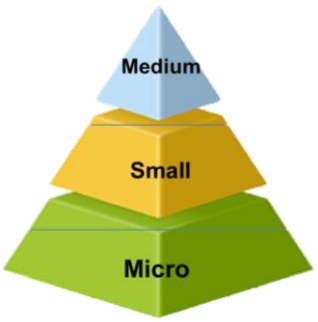
a. Company size

First of all, the results of the research present that almost all of the analysed companies (measured by staff headcount) are small and medium-sized enterprises (SMEs), which states the fact that SMEs represent 99% of all businesses in the European Union. To get closer to this topic, it is apparent that these companies play a big role in the vitalization and development of national economies as they are not only creating job opportunities and promoting stability, but also are enhancing the development of regional economies, competition and cooperation and adding high value added products. These key factors primary lead to a high-level production of creativity and innovation that fuels economic progresses and secondly raises the level of skills with their flexible and innovative nature by using inter-enterprise cooperation.

Overall, defining SME got more and more important for the access to finance and EU support programmes targeted specifically to these enterprises. The main factors determining whether an enterprise is an SME or large company, are staff headcount and either turnover or balance sheet total. These number are regulated by the EU and demonstrated in the **TABLE IRMASS 1**below:

TABLE IRMASS 1 COMPANY SIZE CRITERIA

Company category	Staff headcount	Turnover or Balance sheet total	
Medium-sized	< 250	≤ € 50 m	≤ € 43 m
Small	< 50	≤ € 10 m	≤ € 10 m
Micro	< 10	≤ € 2 m	≤ € 2 m



Contemplating the companies analysed for this market analysis, it is distinctly and visibly that only 5 out of 27 businesses are large enterprises and all the others are SME's or research labs which could be due to the cause that the global market is still growing. In the paragraph below about company growth and market forecast you can find more information about the expected expansions.

b. Company growth

Large private enterprises like NASA and Boston Dynamics already were founded even before the 21st century, but according to their company size and product variety/working sector it is not possible to integrate them in the evaluations for the market size which is why there will be a conclusion in the next period for finding a way how to break down results correctly.

The graphics below is showing a trend of the firms developing service robotics we used for this market analysis over the past 16 years. Already in 2003 more and more companies, research labs and start-ups started establishing service robotics for research purposes. There was a period where no further enterprises have been developed during the years 2006 and 2010 which could be due to research purposes on already existing platforms. From the year 2010 a

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steady growth in the development of new companies is keenly visible and especially showing a trend for the upcoming years. According to a statistic of the International Federation of Robotics, the market growth is expecting an increase of 21% for service robotics for domestic/household tasks and 12% for entertainment purposes. They are emphasizing that especially the market for robots for elderly and handicap assistance is estimated to grow substantially within the next 20 years and that 34,400 units will be sold in the period of 2019-2021.

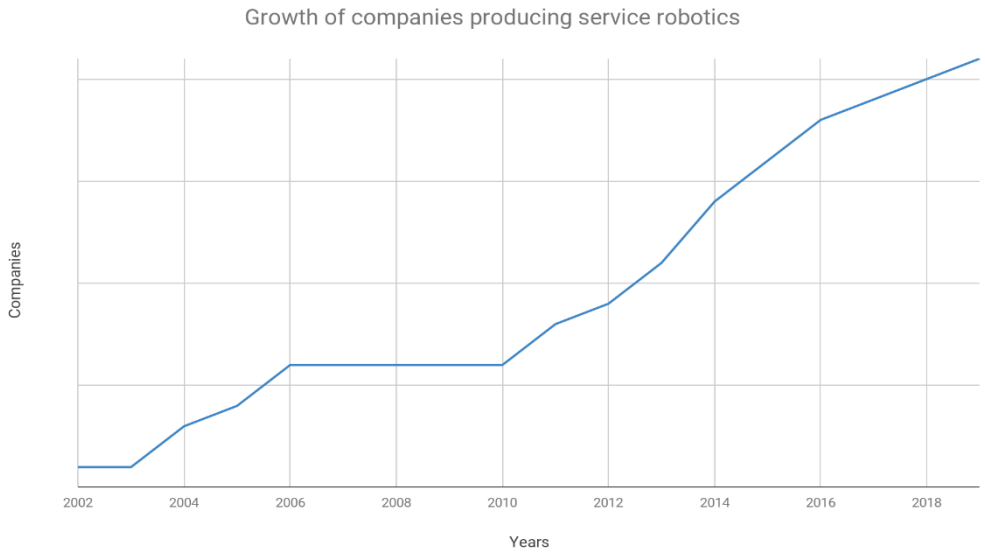

FIGURE IRMASS 1 TREND OF THE COMPANIES DEVELOPING HUMANOID SERVICE ROBOTS

c. Patents

Another important indicator to mention in the results is the n° of patents belonging to a company as the desk research has unfolded, that only 7 out of 27 companies are having registered patents. Protecting robotics solutions by patent has been a big issue since a long period because of both, already existing products and financial means for SME's. During the creation of the analysis it exposed, that almost exclusively large enterprises are having patents on their innovations which proves the perception of the immense cost factor. For small and medium sized enterprises coming out of a start-up, research group or entrepreneurs, it is difficult to apply patents for their products as those exceptional high costs are basically not covered 100% by their budget. Complementary, large enterprises developing inventions are already having sufficient capital what provides them the benefit of being able to settle a patent without any problem. Furthermore, a big issue with gathering them is the fact of already existing products. As humanoid service robotics are very hard to differentiate from each other, might it be software or hardware, it is very sophisticated for innovative products to be patented. In order to give a first perspective on how to overcome this tremendous problem, there will be done further investigations and analyses in the next period.

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d. Geographical Distribution

FIGURE IRMASS 2 GEOGRAPHICAL DISTRIBUTION OF THE SERVICE ROBOTICS COMPANIES

The market for Humanoid Service Robots is experiencing an advanced rate of growth over the past couple of years. More and more companies are launching state-of-the-art robotics to enhance people's quality of life and to improve their daily routine. According to the excel sheet and the research that has been done, there are thirteen companies located in Europe, eight in America, whereas six are based in Asia. As mentioned in the paragraph company growth, it is important to point out that most of those companies located out of Europe are large enterprises like NASA or Kawada which cannot be integrated in the analysis reasonably for showing a decent market share.

2. Wearable Robots

Results

As for the HUM part, some preliminary conclusions have been achieved during the early stage of the desk research by observing the results. Globally, in the final table have been found 41 companies worldwide which were considered as important to create a decent market analysis and to show the developments during the past 20 years. Also, in this case, the results will be separated in the following paragraph in four different sections:

1. Company size and growth ratio
2. Application domain
3. Patents
4. Geographical distribution.

a. Company size

As for service robotics, the results of the research confirm that almost all of the analysed companies (measured by staff headcount) are small and medium-sized enterprises (SMEs), which states the fact that SMEs represent 99% of all businesses in the European union.

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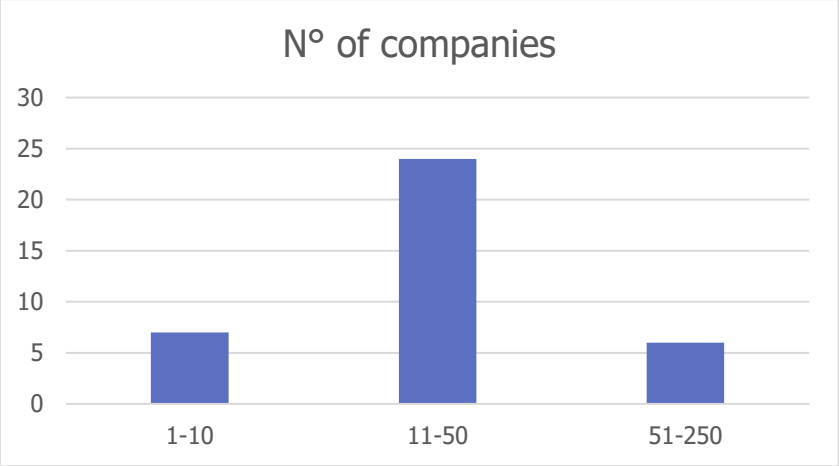

FIGURE IRMASS 3 COMPANY SIZE FOR WEARABLE ROBOTICS COMPANIES IN TERMS OF EMPLOYEES. X-AXIS REPRESENTS THE SIZE OF THE COMPANY.

In addition, being the Wearable Robotics a relatively recent branch of the robotics, it is reasonable that the market is not yet structured with big players, but with a lot of SMEs. In particular, here for the classification it has been adopted the standards described by the European union (and described in the previous paragraph).

In addition, being classified as SME introduces more important advantages for the access to finance and to the EU support programs (targeted specifically to these enterprises).

As shown in the barplot above, the companies found for this market analysis, it is distinctly and visibly that only 14% are medium sized companies and most of them, nearly 58% are small enterprises. It is worth noting that there are also micro enterprises (staff headcount < 10 employees) as 17% that means that the market is still growing.

b. Application domains

One of the objectives of the white paper is to analyse the market for Wearable robotics in three different fields: healthcare, manufacturing and consumer.

In the barplot shown below, there are reported the n° of companies operating in one of the specific domains, in two of them or in all domains.

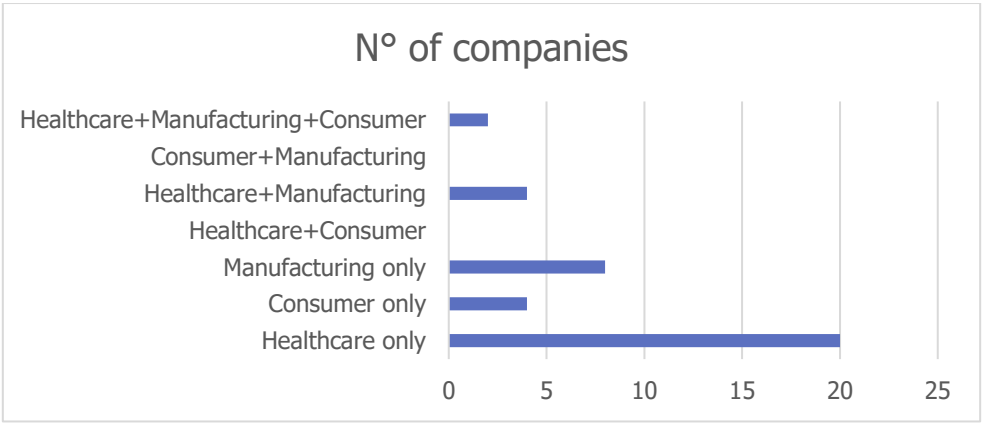

FIGURE IRMASS 4 APPLICATION DOMAINS FOR WRS COMPANIES. X-AXIS REPRESENTS THE N° OF COMPANIES

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It is interesting to note that most of them operates only in healthcare domain where the perception of the life improvement due to the adoption of wearable robotics, like exoskeletons or robotic prostheses, is more evident than other application domains. In addition, due to high costs of these new technologies, the healthcare field is the field where expensive products are more easily accepted.

It is worth noting also the relatively high number of companies working in the "manufacturing field only" where the adoption of new technologies in the framework of industry 4.0 (the fourth industrial revolution) is creating new market opportunities.

Less than 5 companies operate in multiple domains like "healthcare+manufacturing" and "healthcare+manufacturing+consumer", since the direct costs in operating in three fields are quite high due to the different requirements and different certification standards.

c. Patents

Another indicator important to mention in the results is the patents belonging to different companies. Despite the desk research has been performed only on google patent and not in the Patent office websites (like European Patent Office, EPO or the world Patent Office, WPO), results show that only 12 out of 41 companies (nearly 29%) are not having registered patents.
For wearable robotics, protecting robotics solutions by patent provides an added value for the companies, especially for micro or small enterprises where innovative solutions to a specific technical problem can lead to an added value with respect to the other competitors. However, advantages and drawbacks of patenting strategies have to be taken into account especially for micro and small companies; some aspects related to the Intellectual Property Rights management will be deeply analysed in the last section of the white paper.

d. Geographical Distribution

The geographical distribution of the companies operating in the wearable robotics field is shown in the graphics below. The distribution of the companies highlights that Europe has over the 50% of the companies worldwide and America and Asia cover together the rest of the 50%.

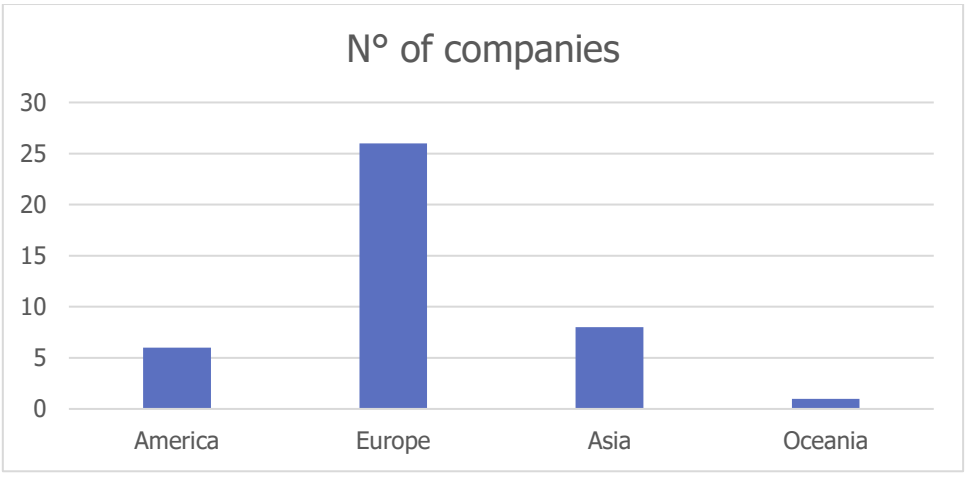

FIGURE IRMASS 5 GEOGRAPHICAL DISTRIBUTION OF THE WRS COMPANIES WORLDWIDE

As mentioned in the paragraph company growth, it is important to point out that most of those companies located out of Europe are medium or large enterprises like Cyberdyne or EKSO Bionics which confirm that in America and Asia, the trend of the companies is to have a few bigger companies with respect to a lot of small enterprises.

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5. Innovative database tools supporting SMEs

1. Database Overview:

The following paragraph is going to give an overview over a generic set of databases that can be used for the examination of the service robotic market and funding landscape. There are many more databases available online which cannot be discussed in this format. The databases have undergone practical testing to a certain extent. The databases that have been used for identifying research projects in the area of service robotics were the database of the National Science Foundation (NSF), the Federal RePORTER database (FEDREP), the CORDIS database and Förderkatalog (FÖKAT). To identify companies which are active in the field of robotics the crunchbase database has been used. All the databases are accessible over the web with a browser-based graphical frontend. However, it is strongly advised to use local copies or imports of these databases to be in full control over the analyses.

The FEDREP database (260 000 projects in total) and the NSF database (70 000 projects in total) both cover US national projects including rich data like a project description (4000 characters) and information on the grant received by each institution active in the project. FEDREP is to some extent a meta-database covering projects by different national bodies on US federal level including, at least partially, NSF. Nevertheless, the information available for each project is somewhat more comprehensive in the NSF database. This is why NSF is included in the following discussion. Both of the databases are relevant in the context of (service-) robotics. For FEDREP around 2000 projects or 0.8 % of the projects with a connection to robotics have been identified. For NSF the number of projects is slightly higher, 2700, making up for 3.9 % taking into account that the database consists only of a portion of the size of FEDREP. The relevance of NSF is thus much higher for research related to robotics.

The CORDIS database is the database for European research programmes conducted by the European Commission. It covers 40 000 projects in total stemming from the research and innovation agendas under FP7 and Horizon 2020. The information on each project is comparable to the projects in the NSF database with a slightly shorter project description ranging around 2000 characters. This difference might sound trivial at first glance. But if sophisticated queries with word-vectors in contrast to basic key-word searches are conducted the number of characters to characterize the content of a project is essential. The more text for each project is available, the more precise the results tend to be. Around 1000 projects in the CORDIS database have been identified to be relevant for the field of (service-) robotics which results in 2.5 % of the whole database. With this amount the CORDIS database ranges in between NSF and FEDREP.

FÖKAT database covers German national research projects on a federal level. The database covers around 200 000 projects. This number seems fairly high since research projects that are carried out by more than one institution collaboratively are regarded as separate projects (one for each institution) in the database. Around 1200 projects have been identified to be relevant for the field of robotics, a share of 0.6 %. Unfortunately, FÖKAT does not offer project descriptions. Thus, the number of characters against which search queries can be run is limited to the titles of the projects which are often less than 100 characters. This is relatively

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unproblematic for keywords searches. But with word vector searches which compare the vector of the search string and the vector of the project description a low number of characters can cause a domination of one certain keyword. A high number of characters tends to even out these outliers.

If queries are run against multiple databases, the language of project descriptions has to be taken into consideration as well. Whereas FEDREP, NSF and CORDIS provide English project descriptions FÖKAT is kept entirely in German. Comparing word vectors in different languages is generally challenging especially with very domain-specific vocabulary from research projects. There are generally two ways to deal with this. The first way is to translate the descriptions in the database from German into English. This is a lot of initial work that has to be automatized. Once it is done search queries can be run. The second way to deal with different languages is to have the search-vector in both languages and conduct the searches simultaneously. The initial effort is lower, but the translation has to be redone for each query.

TABLE IRMASS 2 DIFFERENT RESEARCH FUNDING DATABASES AND THEIR RELEVANCE FOR ROBOTICS.

	FEDREP	NSF	CORDIS	FÖKAT
Number of research projects	260.000	70.000	40.000	200.000
Number of robotics projects	2.000	2.700	1.000	1.200
Share of robotics projects	0,8 %	3,9 %	2,5 %	0,6 %
Number of characters in project description	4.000	4.000	2.000	100
Language	English	English	English	German

There are multiple databases to identify companies which are active in the field of robotics. However, this discussion focusses on the crunchbase database. It is a highly dynamic database that is updated on a regular basis and lists over 730 000 companies. Crunchbase offers extensive data for each company ranging from geographical locations, employee count to a short description of the activities of the company. The last criterion has been used to identify whether the company is potentially relevant for the field of robotics. Unfortunately, the quality of the data varies from company to company. This is particularly relevant for the geolocations. However, the short description for each company is surprisingly complete and thus qualifies for a database search. What makes the data from crunchbase particularly valuable for market analyses is the tracking of acquisitions, meaning that one company is acquired by another. Visualisations of acquisitions offer valuable insights into market dynamics and an approach to accomplish this is described in the following sections of this discussion. The number of companies that are relevant in the field of robotics ranges around 2200. To have a qualitative look at each company the number of 2200 companies that are roughly associated with robotics had to be reduced severely by specifying search terms. This has been accomplished and the number could be reduced to 200 which is a number of companies that qualifies for the examination by an actual human being. The information for each company serves for a qualitative market analysis in a further step.

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2. Visualisation methods

At the end of an extensive and costly gathering and cleansing process we dream of a visually attractive and an understandable result or even product. The pitfalls and obstacles that hinder us from reaching this goal are discussed in this paragraph.

Once the data is imported, prepared, pre-processed and cleansed begins the fun part of the whole process: visualising the results. There is generally a vast amount of different options for visualisations. The choice for one or the other option depends on many variables like the obvious of what is actually intended to be expressed or the different levels of programming skills that different visualisations require.

In this place two examples of visualisations are presented that require only moderate skills for their production but are more appealing than simple bar charts. Both of the examples are based on datasets that have been acquired in the process described beforehand.

As part of a thorough market analysis, the market dynamics of a specific branch, during a specific period or at a specific location might be of interest. With a little bit of pre-processing of crunchbase data "flows" of the ownership of companies can be visualised. This is relatively easy to accomplish since crunchbase offers curated metadata with information on when one company acquires another. This can be visualised as "flows" in a Sankey diagram. A Sankey diagram is a graphical representation of quantity flows which is typically used for material flow analysis. However, it can be adapted for the display of company acquisitions. Fig. 1 presents an example of a Sankey diagram that has been used for a market analysis in the field of robotics. It covers all the acquisitions that have been performed within 2016 and 2017 in the field of robotics as listed in the crunchbase database. The diagram is to be read from left to right. The centre of the diagram shows the acquisitions on a company to company level. The outer nodes left and right of the centre represent nation-states in which the companies are listed. The nodes on the left and right outside borders of the diagram represent continents. The width of the connecting arrows is 1 for each acquisition. This results in the height of the nodes representing how many companies have been shifted from one nation-state or continent to the other. The result shows that companies North America and Asia have been more successful in acquiring companies than Europe.

Unfortunately, the price of the acquisition is in most of the cases classified and thus not integrated into crunchbase. It is thus only possible to judge the success of each company, nation-state or continent by the number of acquisitions and not by their volume. The diagram has been produced with the D3-framework which requires basic programming-knowledge in JavaScript. The pre-processing of the data has been conducted with a script comprising 100 lines of SQL-code.

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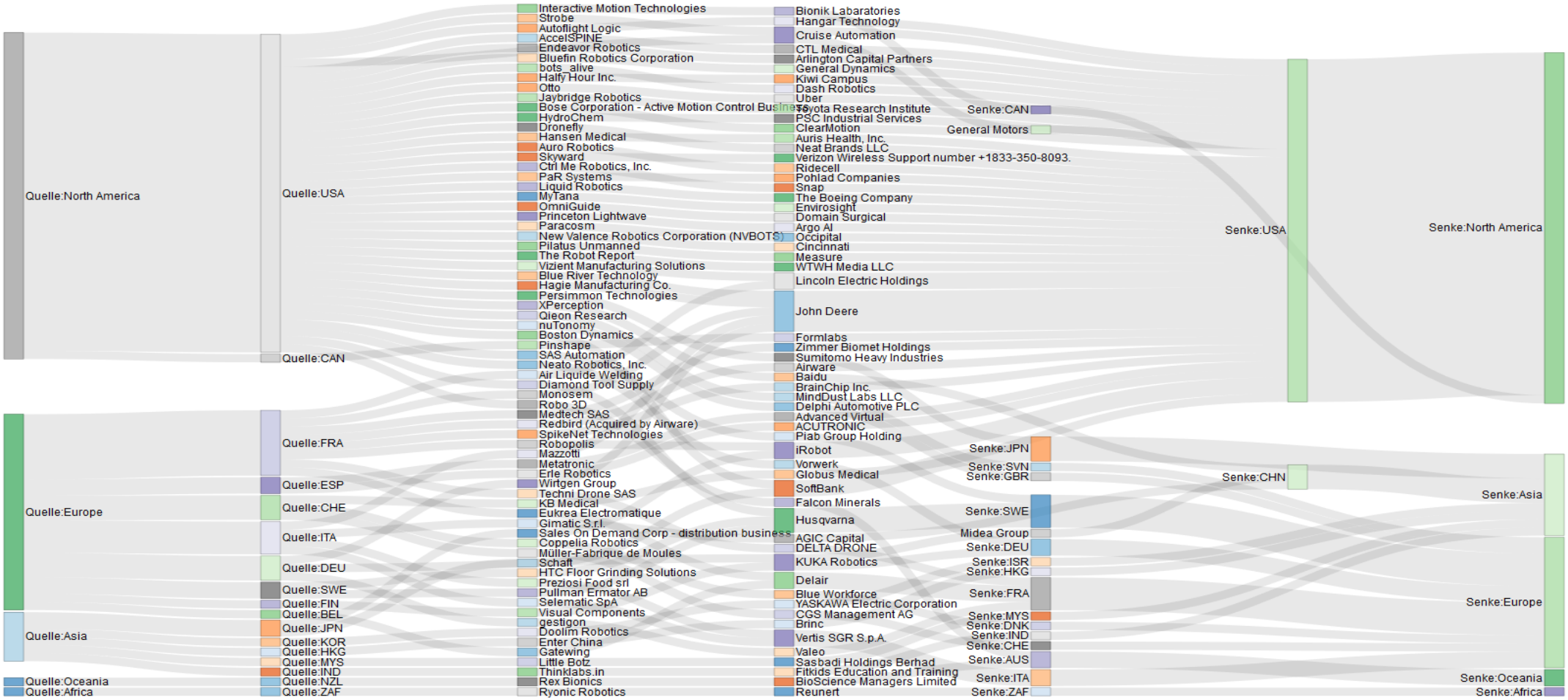

FIGURE IRMASS 6 A SANKEY-DIAGRAM SHOWING THE ACQUISITIONS THAT HAVE BEEN CONDUCTED BY COMPANIES IN THE FIELD OF ROBOTICS BETWEEN 2016 AND 2017.

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The second example presented in this discussion bases on data from the CORDIS database which covers around 40 000 research projects. A question that might be relevant for SME and start-ups is in which way funding for innovation project can be obtained. A part of an approach to answer this question could be to obtain an overview of the institutions that are particularly successful in the acquisition of research funding. This could be done with simple bar-charts representing the number of research projects that an institution is involved in or the funding received. However, this discussion presents an alternative approach trying to visualise the research landscape in the field of robotics in a network where connections between cooperating institutions become visible. With an analysis like that SME would be enabled to find an entry-point or potential sources for information in the research landscape and be more successful in future acquisitions of grants. Fig. 2 presents a network visualisation, based on 2318 nodes (institutions) and 46140 edges (cooperation). Only the institutions are displayed that have the highest involvement in research projects. Whenever institutions cooperate in a funded research project, a connection between them is drawn. The stroke thickness of an edge represents the number of projects between the connected institutions. The different colours of the nodes distinguish different communities in the network which were calculated with a community-detection-algorithm. The figure shows that the network of the institutions that are most active in research funding is dominated by Fraunhofer Gesellschaft. The visualisations have been accomplished with Gephi which is available for free. The pre-processing of the data required for the use in Gephi took around 40 lines of SQL-code. The visualisation in Gephi is pleasantly simple since it features a graphical frontend that does not require any programming skills.

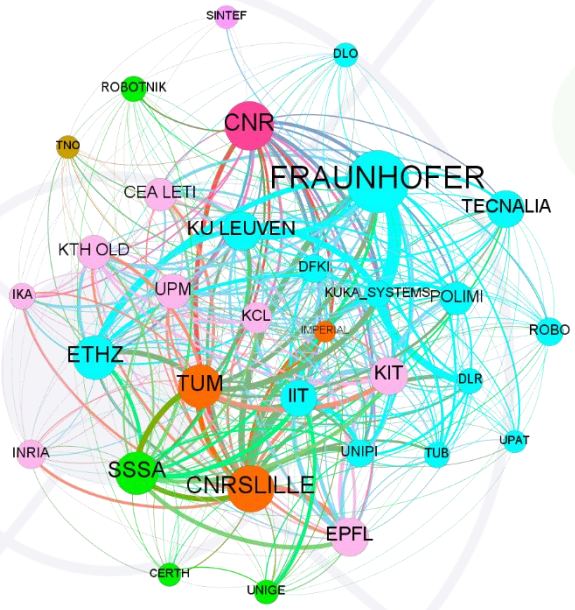

FIGURE IRMASS 7 A NETWORK VISUALISATION OF THE FUNDING LANDSCAPE BASED ON 2318 NODES (INSTITUTIONS) AND 46140 EDGES (COOPERATION) PROVIDED BY THE CORDIS DATABASE. HERE, ONLY THE MOST ACTIVE INSTITUTIONS ARE DISPLAYED

3. Combination of two databases and social network analysis

The following section describes an approach of how to identify potential stakeholders, opponents or allies among companies that are active in the field of service robotics. It uses the method of social network analysis and combines data from two databases.

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The data to identify the companies by their descriptions stems from the crunchbase database. With over 700 000 companies listed crunchbase provides a relatively long full text description about the companies' activities, products, services etc. This data has been used to perform a keyword search. Two specific fields in the field of service robotics where of interest: humanoids and wearable robotics. Thus, two different datasets are generated: one containing the companies that match the humanoids keyword-search and one that contains the matching wearable's companies. Keywords for the humanoid search are keywords like "service robotics, humanoid, collaborative robots, anthropology, robot, orthotics". The wearable keywords are "exoskeleton, prosthetics, limb …". These keywords are combined with AND, OR and IF statements to optimise the search results. With this keyword search the most relevant companies can be identified due to the long full text description that is provided by crunchbase.

The crunchbase data offers only very little information about how these companies are linked with each other. In this case the links of the companies that are collaborating in research projects are studied with the help of the Cordis database. In this manner companies that are linked particularly well with academia and other companies can be identified. To do this the lists with relevant companies from the crunchbase database are matched with the organisations from the Cordis database. For each match, meaning the company is present in the crunchbase-results and in Cordis, the associated research projects are identified. Based on these research projects a network is constructed with all involved stakeholders, academia and companies, and especially the humanoids/wearable's companies.

The figure below shows the full research network from Cordis with all the organisations collaborating (grey) with the matching robotics companies (red). Node size is according to betweenness centrality (i.e. a measure of centrality in a graph based on shortest paths). Edges between two nodes are drawn if the organisations are in one identical research project. Distinct clusters represent research projects. It is quite obvious that many of the matching companies are only present in one cluster and thus in one research project. These companies tend to be poorly linked. Fewer companies tend to act more like brokers between clusters and are better linked. Especially companies that are present in two or more research projects have a lot of first-hand access to the innovative results from the projects with which they might be able to improve their products and services.

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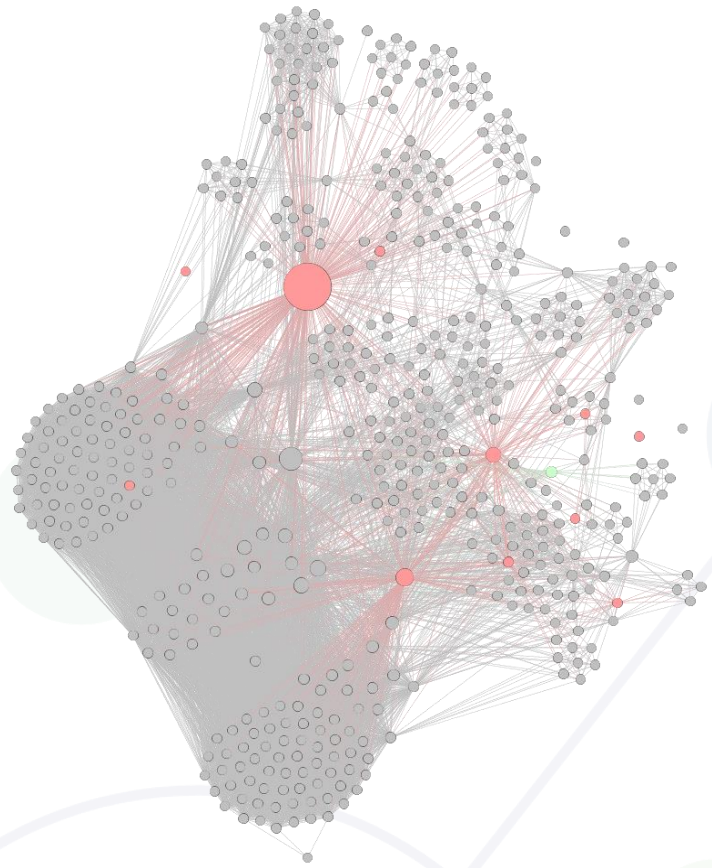

FIGURE IRMASS 8 FULL RESEARCH NETWORK FROM CORDIS WITH ALL THE ORGANISATIONS COLLABORATING (GREY) WITH THE MATCHING COMPANIES (RED). HOCOMA AG HIGHLIGHTED (GREEN). NODE SIZE ACCORDING TO BETWEENNESS CENTRALITY. EDGES DRAWN IF THE LINKED ORGANISATIONS ARE IN ONE IDENTICAL RESEARCH PROJECT

Table IRMASS 3 presents the top ranging robotic companies according to their degree. The degree is a measure for how many in- and outgoing edges a node possesses.

TABLE IRMASS 3 ROBOTIC COMPANIES FROM THE NETWORK AND THEIR DEGREE

Name	Degree
ROBOTNIK AUTOMATION SLL - PATERNA, ES	276
SOFTBANK ROBOTICS EUROPE - PARIS, FR	170
MARSI BIONICS SL - RIVAS VACIAMADRID, ES	108
PAL ROBOTICS SL - BARCELONA, ES	105
IUVO SRL - PONTEDERA, IT	41
HOCOMA AG - VOLKETSWIL, CH	22
BIOSERVO TECHNOLOGIES AB - KISTA, SE	19
WANDERCRAFT - ORSAY, FR	9
ANYBOTICS AG - ZURICH, CH	7
GOGOA MOBILITY ROBOTS S.L. - URREXTU, ES	3
FOLLOW INSPIRATION SA - FUNDAO, PT	0
HY5PRO AS - RAUFOSS, NO	0

Figure IRMASS 3 presents the top ranging robotic companies according to their degree. The degree is a measure for how many in- and outgoing edges a node possesses. Taking into

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account the initial question of how well connected the organisations are the degree shows a company's direct and non-bureaucratic access to potential partners via research projects. The degree does not take into account whether these potential partners stem from the same or different project. A high degree could be the result of the involvement in one big research project with many partners or the involvement in different smaller research projects.

To dig deeper in this differentiation another measure is calculated for each company, see Table IRMASS 4 the betweenness centrality. The betweenness centrality is a measure of how often a node lies on the shortest path between two nodes. So, for the case examined here the betweenness centrality represents a measure for the information that is able to flow from company to company. Once a company has a high betweenness centrality, information from all over the network, academia and organisations, is very probable to be noticed by the company. This information, e. g. about recent developments, innovations etc., could then be used to the benefit of the company.

For example, HOCOMA AG, highlighted green in Figure IRMASS 8 possesses a degree of 22 in the network and thus ranges only on position six of Table IRMASS 3 However, the company possesses a betweenness centrality that is unexpectedly high, see Table IRMASS 4 Figure IRMASS 8reveals that HOCOMA AG acts as a hub for different smaller projects. It can thus be concluded from a network point of view that for a company to benefit the most from its cordis-activities to be involved in projects with a wide range of partners and not necessarily huge consortia. It should also be taken notice of the fact that the calculation of one betweenness centrality involves every single node in the network. The betweenness centrality is thus quite dependent on how well the other nodes are linked as well. The maximum potential betweenness centrality is 1. The highest degree in the network is 276 in the case of ROBOTNIK AUTOMATION SLL and the maximum betweenness centrality is 0.267849 also in the case of ROBOTNIK AUTOMATION SLL.

TABLE IRMASS 4 ROBOTIC COMPANIES FROM THE NETWORK AND THEIR BETWEENNESS CENTRALITY, NORMALIZED TO [0,1].

Name	Betweenness Centrality
ROBOTNIK AUTOMATION SLL - PATERNA, ES	0.121672
SOFTBANK ROBOTICS EUROPE - PARIS, FR	0.025006
PAL ROBOTICS SL - BARCELONA, ES	0.015913
J.W. OSTENDORF GMBH & CO. KG - COESFELD, DE	0.007419
FERROAMP ELEKTRONIK AB - SPANGA, SE	0.003645
HOCOMA AG - VOLKETSWIL, CH	0.003425
PORTENDO AB - STOCKHOLM, SE	0.000952
IUVO SRL - PONTEDERA, IT	0.000936
BIOSERVO TECHNOLOGIES AB - KISTA, SE	0.0004
MARSI BIONICS SL - RIVAS VACIAMADRID, ES	0.000002

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6. Intellectual Property Rights in Interactive Robotics

Intellectual property (IP) rights are valuable assets for any business. They keep the business away from competitors, they can be sold or licensed (providing revenues) or be used as security for loans, the company can offer something new to customers and they are an essential part of the marketing or branding strategies.

Ignoring or undervaluing the potential of IP can lead to risky situations, for example, opening the possibility of competitors of taking advantage of technical innovations, business, ideas, reputation in the market, etc.

Business can be protected by many ways, which, for the case of robotics and interactive robotics in particular, is of main importance given the nature of the several technologies and aspects integrating an IR (algorithms, software, hardware, middleware, designs, brands, robot names…).

1. Tools to support IPR for SMEs

IP protection is important in all R&D intensive industries, and the field of robotics is no exception. Robotics firms often require years of intensive (and expensive) research before being in a position to sell their products and reach commercial success. The lengthy and costly process of delivering profitable products highlights the role of IP rights, which are viewed as necessary to recoup up-front investments and to fend off competitors seeking to capitalize on the R&D investments of their rivals.

Types of IP:

- **Intellectual property** (author rights or copyright).
- **Industrial property** (distinctive signs, forms creation, invention). Rights over brands, commercial names, reports, industrial design, patents, model of utility, industrial secret.
- **Specific protection of software** (EU vs USA). Computer programs and computer assisted inventions.

How to protect:

- Previous knowledge as a starting point.
- Confidentiality agreements with third parties to ensure a secure interchange of information.
- Property, co-property and exploitation agreements for the generated knowledge.
- Record of property rights: patents, patenting process, strategies for patenting (national, European, PCT).
- Technology Awareness: search for patents, publications, etc to know the start of the art, who is working on what, follow the competition, patent infraction…

The strength of the IP /IPR depends on:

- Nature of invention (fundamental / incremental).
- Overall strength of rights: strong / weak).
- Possibility of ties or conflicts (Freedom to use) (none / much prior act).

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- Is the invention covered by a range or rights or just one? (strong collection of IPR / single IPR).
- Potential to strengthen IP through partnering (strong / weak).
- Potential to strengthen IP through further development (strong / weak).
- How easy to monitor and deal infringers (easy / difficult).

FIGURE IRMASS 9 AGENTS INVOLVED IN THE IPR APPLICATION

IP is **a valuable asset** which can be traded, bought, sold, leased, used in Joint Ventures.

Patents

R&D within the robotics industry often takes place several years before resulting in a viable commercial opportunity, with patents being the main legal instrument to recoup investments. **Patents protect innovations and give their owners a right** to prevent others from exploiting the patented technology. Both large and small companies can rely on patents to attract investors as well as protect their investments in technology. For example, smaller and more specialized firms often use patents to protect their IP assets defensively against larger players.[3]

The patent route can be particularly **valuable for companies whose robots, or their elements, can be easily reverse-engineered** (as is also known, reverse-engineering is the process whereby a product can be deconstructed to disclose its elements and the way it is manufactured). Indeed, in situations where reverse-engineering is simple, filing for a patent may be favoured over the alternative tactic - trying to protect the process of manufacturing and/or the relevant product by keeping them secret - with that patent being enforceable against any third party that exploits the invention without the patentee's consent. Symmetrically, relying on trade secrets to protect robotic inventions can work well where (i) robots are produced

[3] C. Andrew Keisner et al., "Breakthrough Technologies – Robotics and IP", Economics and Statistics Division, WIPO (2016), http://www.wipo.int/wipo_magazine/en/2016/06/article_0002.html

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and used in a controlled environment, (ii) reverse-engineering is not easy to carry out and, (iii) those working with the products are committed to secrecy.[4] Also, **trade secret protection may potentially last much longer than that offered by patents (20 years from the filing date),** as industrial secrets that meet the relevant requirements are protected for as long as they remain confidential (potentially for an indefinite period). Thus, the decision to apply for a patent may be influenced by the complexity of the company's products and whether the company's competitors are likely to get their hands on such products and subsequently reverse engineer them. For example, are the robots likely to reach millions of private homes or will they merely be deployed behind closed factory doors? These are factors that need to be considered when it comes to protecting robotics innovation through IP[5].

Trade secrets

As mentioned, robotics firms may rely on trade secrets and the legal protection given to such information, to protect their investments in technology. A reason why trade secret protection could be preferable is that such protection is **offered without the need to adhere to certain prescribed formalities,** such as filing an application with an office. Robotics companies can therefore avoid certain costs and complexities associated with patent filing and prosecution. Secondly, trade secrets (rather obviously) **do not require disclosure**, as the patent system does. A patent is granted in return for the disclosure of technical information so that the public at large, including patentees' competitors, will be able to exploit the invention after the 20-years term of protection expires. Therefore, as mentioned above, for robotics inventions that are more difficult to reverse-engineer, the trade secrets option may prove a superior alternative as the protection could potentially last indefinitely.[6] Indeed, patenting robots does not always produce benefits. It has been noted, for instance, that in the 1980s several companies in this field obtained numerous patents that ended up expiring before the owners could commercialise the protected products.[7]

Also, **trade secrets can protect subject matter that patents may not,[8] for example innovation related to software and computer code**. This option would be particularly beneficial also in light of the fact that protecting software inventions via patents has proven to be a contentious (and complicated) at national and international levels.

Copyright

Certain elements of robotic devices, especially software codes, could be protected by copyright (copyright is indeed the **main legal tool to protect software**). This is an important option also in light of the fact that – as we have just seen - availability of patents for computer programs has proven contentious. Software code is indeed crucial in this field, with robots being unable to function without them – robots deprived of software would basically be unable to

[4] Michael R., et al., "Patents or Trade Secrets: The Choice Is Yours", Robotics Business Review (2014) https://www.finnegan.com/images/content/8/6/v3/866/IntellectualPropertyConsiderationsfortheRoboticsIndustry-revised.pdf
[5] E. Bonadio et al., "Intellectual Property Aspects of Robotics", European Journal of Risk Regulation (2018)
[6] Michael R., et al., "Patents or Trade Secrets: The Choice Is Yours", Robotics Business Review (2014) https://www.finnegan.com/images/content/8/6/v3/866/IntellectualPropertyConsiderationsfortheRoboticsIndustry-revised.pdf
[7] C. Andrew Keisner et al., "Breakthrough Technologies – Robotics and IP", Economics and Statistics Division, WIPO (2016) http://www.wipo.int/wipo_magazine/en/2016/06/article_0002.html
[8] Ibid.

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perform their intended tasks. Typical tasks performed by robot include pathfinding, control, locating and sharing data.

Firms in this field may also rely on 'technological protection measures' to restrict access to, and prevent copying of, a robot's copyright-protected code. More precisely, what these companies may be interested in is to attempt to make it difficult for third parties, both competitors and users, to get their hands-on relevant software code, by inserting electronic barriers to prevent access. Copyright laws allow this construction of barriers. This is a type of protection that may be useful against users or competitors that want to access commercially valuable software code.

Trademark

How can trademark rights add value to robotics companies and their products? In general, registering trademarks is crucial **to protect products' goodwill and reputation**, especially in business-to-consumer industries. Notably robotics – especially interactive robotics - is increasingly becoming an industry where **products are sold directly to millions of end-users**. The commercial success of products such as nanny-robots, pet-robots, caretaker-robots and medical-robots also depends on a reliable brand which consumers know, trust, appreciate and remember. For this reason, robotics companies with a strong brand name and solid reputation are indeed investing on and registering trademarks (see for instance iRobot,[9] ABB,[10] Kawasaki[11] and Roomba[12] brands).

Designs

As said, today's robots are becoming much more consumer facing, and thus robots' **physical appearance and their 'look and feel' play a central role in influencing consumers' choice**.[13] Robot designs that meet certain requirements, for example novelty and individual character in the European Union, can be registered.

Some robotics companies in Europe have indeed taken advantage of this chance and obtained EU design registrations protecting the ornamental features of products such as vacuum cleaners,[14] robotic lawnmowers[15] and transportation robots.[16] Also, designs rights may soon be regularly sought by companies active in the field of wearable robots, i.e. devices that are used to enhance people's motion and physical abilities. Despite having functional elements, these

[9] *European Union Intellectual Property Office. https://euipo.europa.eu/eSearch/#details/trademarks/W01353068.*
[10] *European Union Intellectual Property Office. webpage https://euipo.europa.eu/eSearch/#details/trademarks/002628964.*
[11] *European Union Intellectual Property Office. https://euipo.europa.eu/eSearch/#details/trademarks/000814681.*
[12] *European Union Intellectual Property Office. https://euipo.europa.eu/eSearch/#details/trademarks/002995108.*
[13] *Meenakshy Chakravorty et a., "Design-Patent Protection for Modern Robotics Companies: What to Do When the Face of Your Robot Becomes the "Face" of Your Company", Robotics Business Review (2014)*
[14] *European Union Intellectual Property Office. https://euipo.europa.eu/eSearch/#details/designs/004680866-0025; https://euipo.europa.eu/eSearch/#details/designs/004680866-0026.*
[15] *European Union Intellectual Property Office. https://euipo.europa.eu/eSearch/#details/designs/002524462-0002.*
[16] *European Union Intellectual Property Office. https://euipo.europa.eu/eSearch/#details/designs/005418506-0001.*

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products may be devised in a way which makes them more appealing to final consumers – and design rights could exactly be the appropriate legal tool in the hands of such firms to protect the eye-catching elements of their products. In other words, these rights may help these companies to keep pace with the likely "fashionalisation" of the robotics industry.

Results of the survey on IPR

With the aim to gather information about the non-technical barriers that the robot manufacturers must face when developing interactive robots for real life applications, a survey was developed, and stakeholders were invited to participate.

The survey was structured in 7 sections: (1) impact of topics influencing the development of IR, (2) impact of topics influencing the marketing of IR, (3) impact of topics influencing the protection of intellectual property of IR, (4) interest of companies in the types of IP tools, (5) patent infringement, (6) success stories when developing/marketing/protecting IP, and (7) fail stories when developing/marketing/protecting IP.

The survey was distributed through various channels:

- websites (INBOTS and project partner websites),
- direct contacts with customers and partners of Tecnalia,
- conferences (INBOTS, ICNR, WeRob 2018),
- mailing lists (EU Robotics),
- newsletters (Hisparob), and
- other related research projects (RobotUnion, EUROBENCH).

As shown in Table IRMASS 5, main concern for SMEs when developing IR in the access to financial resources, access to business networks and potential investors, collaboration with research centres and integration of the product into existing markets, whereas the required infrastructure and location are of minor importance.

Dealing with the marketing of IR (Table IRMASS 6), SMEs state as the most important issue the demonstration of the added value, followed by the benchmarking of the product and commercialization of the robot. Again, the location and size of the SME are less important.

Table IRMASS 7 shows the main issues when protecting the intellectual property generated. Main concerns are the lack of knowledge, complexity, cost and lead times when managing IPR process, especially if there is collaboration with large companies. The funding seems to be a minor problem.

The most preferred type of IP protection among SMEs (Table IRMASS 8) is the European and national patent and trade secret. The protection of design and trademarks are also important, this could be explained by the fact that many IR are focused on the domestic and healthcare domains, where the appearance of the robot is important for the end user. Also, already known robot brands (coming from "traditional robotics") are moving to the interactive robotics markets. The relative moderate influence of the copyright tool is a surprising result, since it is the most common IP tool to protect the software (at EU level).

The last question in Table IRMASS 8 ("Freedom to operate") shows a coherent result with the answer in: companies give an important role to this point, so there are few patent infringements.

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SMEs have declared the main reason for their success stories when developing/marketing/protecting their IR in Table IRMASS 10. Main issues are good economic results and access to new markets and clients. When they have faced a fail result (Table IRMASS 11) the main causes are lack of economic resources for the marketing/sales stage and bad economic results.

TABLE IRMASS 5 RESULTS OF QUESTION Q1

Q.1 Please state the impact of the following topics for SMEs when developing Interactive robots

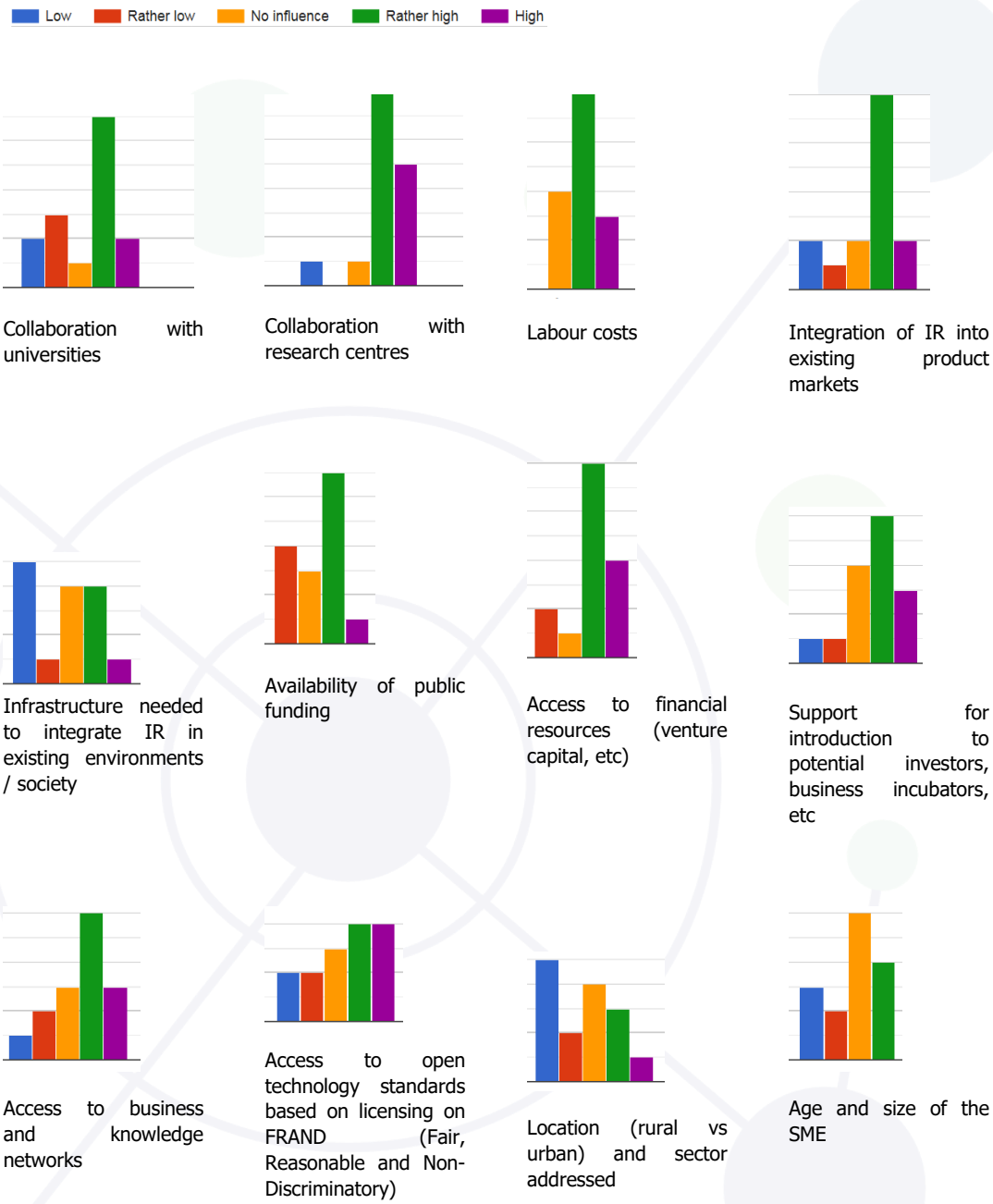

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TABLE IRMASS 6 RESULTS OF QUESTION Q2

Q.2 Please state the impact of the following topics for SMEs when marketing Interactive robots

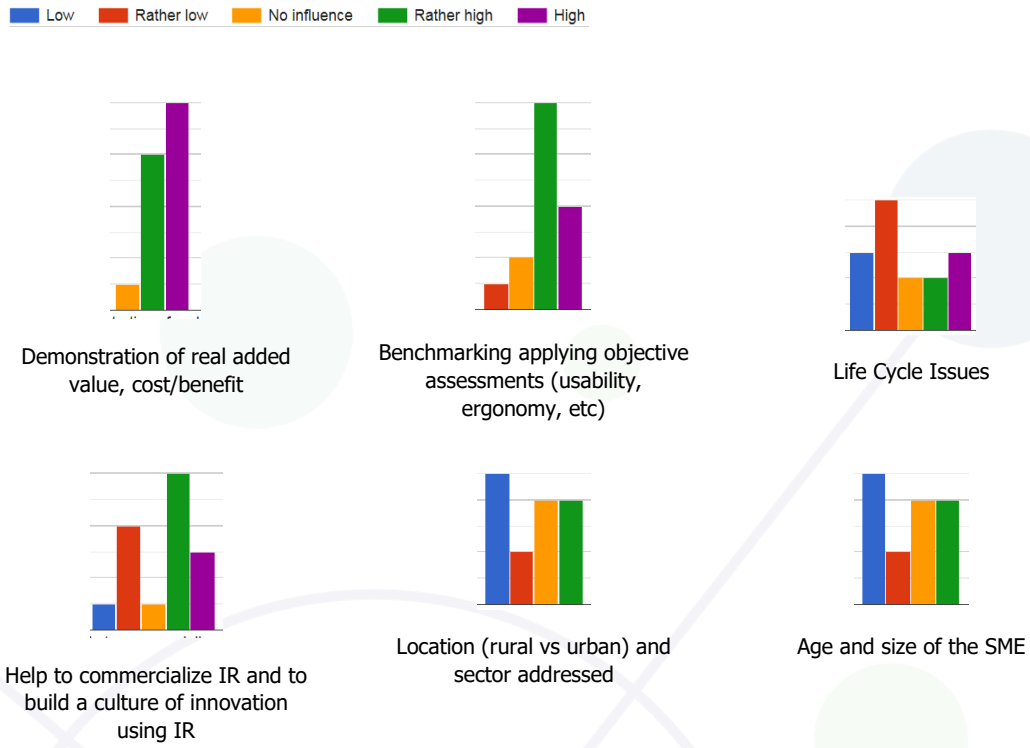
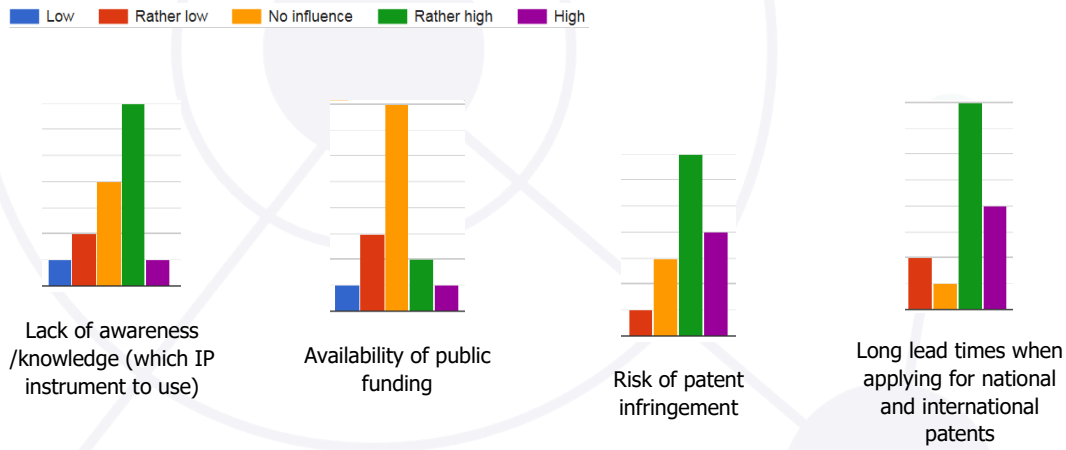


TABLE IRMASS 7 RESULTS OF QUESTION Q3

Q.3 Please state the impact of the following topics for SMEs when protecting Intellectual Property (IP) in Interactive robots



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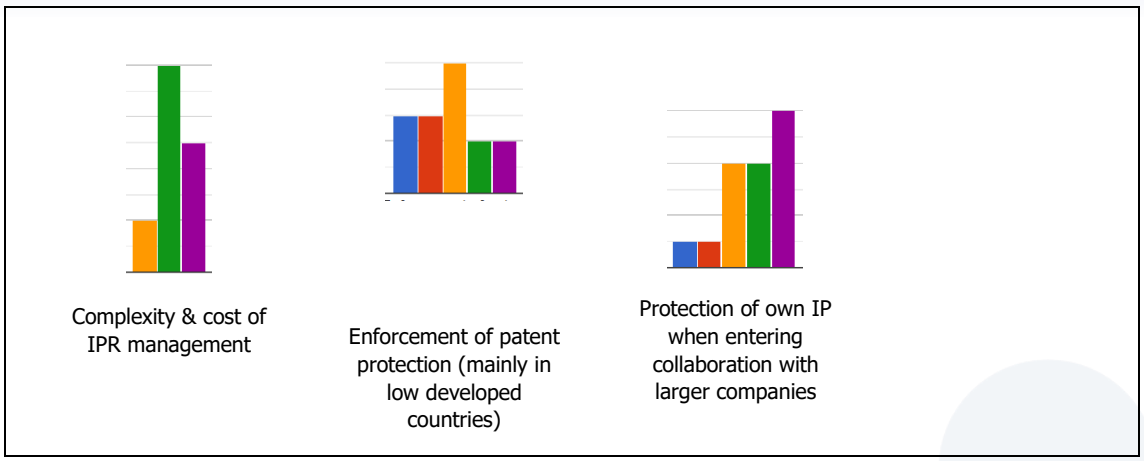

TABLE IRMASS 8 RESULTS OF QUESTION Q4

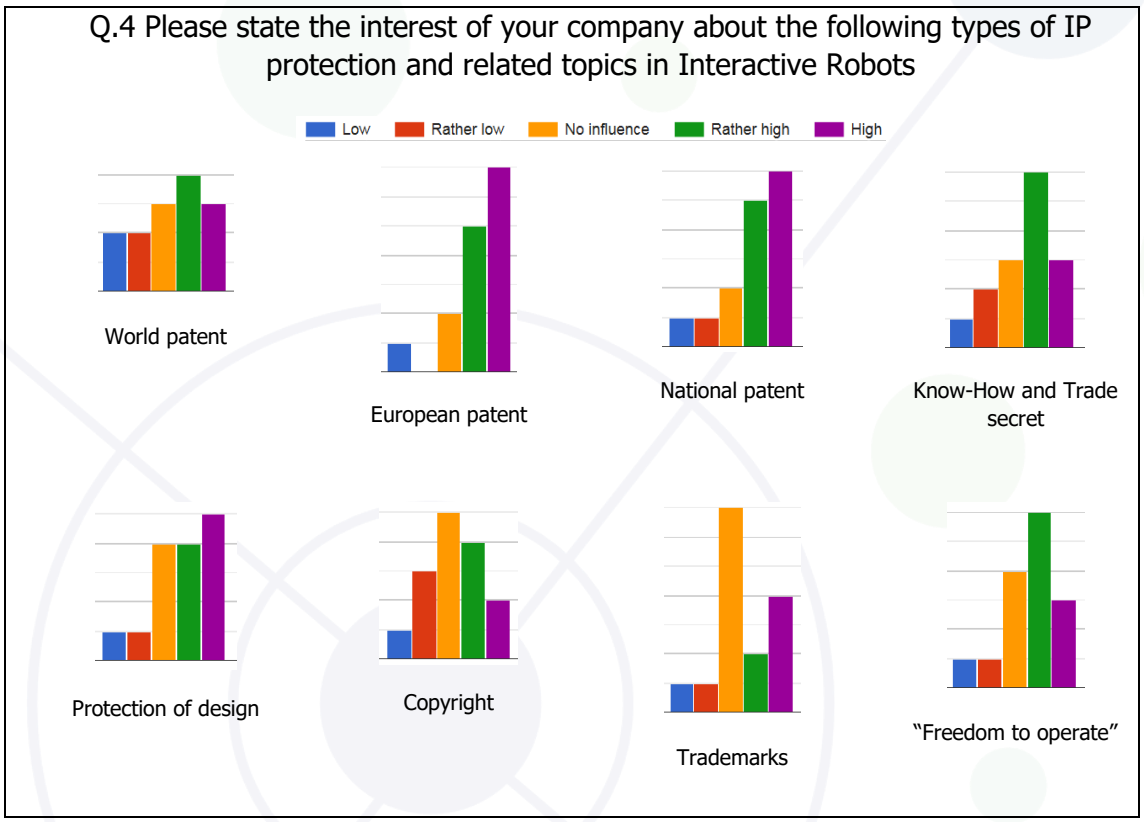

TABLE IRMASS 9 RESULTS OF QUESTION Q5

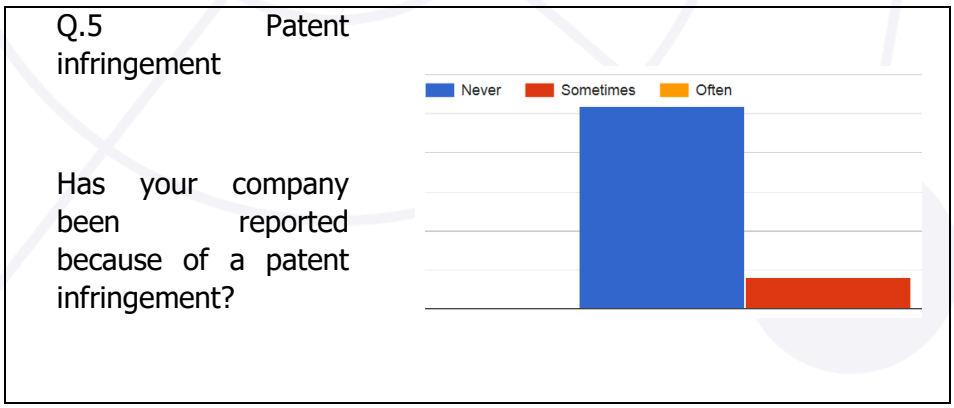

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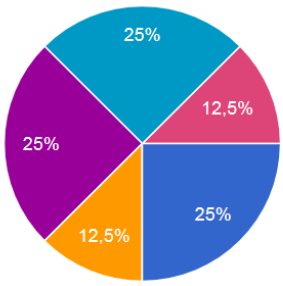
TABLE IRMASS 10 RESULTS OF QUESTION Q6

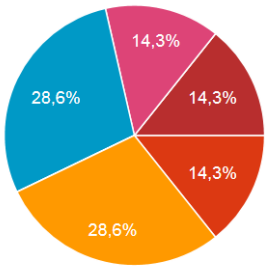
Q.6 Have you ever had a success story when developing/ marketing / protecting IP with Interactive Robotics? If yes, why?



- Good economic revenues by robot sales
- Good economic revenues by IP (royalties, patents sales)
- Good technical result
- The image of the company improved
- Access to more/new clients
- Access to new projects
- Difficulty to define clear business cases

TABLE IRMASS 11 RESULTS OF QUESTION Q7

Q.7 Have you ever had a fail story when developing/ marketing / protecting IP with Interactive Robotics? If yes, why?



- Bad economic result
- Bad technical results
- Lack of economic resources for the development
- Lack of human resources for the development
- Lack of human resources for the marketing/sales
- Technical problems
- Lack of demand in the market
- Lack of legal coverage for protecting IP
- Changing requirements from potential clients

2. Tips to identify technological assets

In the following section conclusions from research projects that have just been finished are presented with respect to strategies on how to identify technological assets. The institutions involved in the projects need to put their results into exploitation strategies. These sections present information on how technological assets are handled in German national research projects in the context of service robotics.

There are multiple approaches on how technological assets are handled by the institutions involved in the research projects. They range from rather simple steps to sophisticated strategies and are going to be discussed in the following paragraphs.

One approach is the **economic exploitation through further development of the company's own product range**, e. g. new adaptive behaviours for the products offered by the company or new products that are completely self-contained. This also includes the certification processes.

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Specific examples are the development of **further applications**, associated markets and other sectors, e. g. in the design of human-robot assembly stations in the industrial sector, through experience in the use of safe and real-time interaction forms and corresponding interfaces or new products in the field of support systems for people with physical disabilities. A growing market segment for service robotics has been identified by the institutions in the coming years. In this context large **retail chains** in which business is already involved play a role. New or extended products and further applications could thus be transferred to the customers much quicker. Also, entering completely new market segment has been mentioned in the context of further applications.

Thus, requirements for **flexible production** and assembly in the electronics industry and new fields of **cooperation** and research in the field of the development of multimodal interaction approaches for intuitive use by humans are an asset as well. Hence the possibilities to offer multimodal interaction technologies in other economic areas that go beyond the scope of intuitive interaction in the specific sector have been mentioned.

Another way to deal with technological assets from research project is the general approach of **capacity building**, e. g. by a thorough documentation of the results and by integrating them into company processes.

Linking up with existing fields of activity in the field of industrial robotics, like finding new distribution partners was also part of many strategies.

A strategy that has often been applied by the companies is the **quantification of the market size by several measures**, e. g. the number of potential users per year or region, the planned sales/licensing price per system, the sale of a specified number of units over a certain period of time, an estimation of the total turnover, by making the sales price of the product flexible or by estimating the sale potential.

There are also a variety of different **market launch strategies**, e.g. launching the product in different regions shuffled over a certain period of time or the adaptation for market requirements, e g. a special focus on data security in Europe.

On the one hand the results of the research projects led to the **specialization** in a certain field, e. g. the development of components for a general robot platform to perform specific tasks. On the other hand, the results were used for a **broadening**, e. g. testing the developed system on as many platforms as possible to demonstrate the universality of the interaction strategies. This could then be used as a general basis for a social robot offering possibilities for using the robotic system in multi-robot applications in which the domain knowledge collected by the individual robots is made accessible to all other robots on a cloud basis. A broader use of the robotic system was also part of some dissemination strategies.

The different strategies and their combinations have proven more or less successful in the past years. Very often it is the case that success stories are published in big campaigns and are sometimes unavoidable considering the German market. This is for example the case for the robotic system "Franka Emika" https://www.franka.de/. Unfortunately, the success story of "Franka Emika" has only very little to offer to conclude tips or recommendations which could be used by other companies. It seems that the success of "Franka Emika" is more a complication of coincidences. As it is very often the case the worst-practice example are usually the ones from which we are able to learn the most. But usually there is very little information on why exactly one specific company or product has failed. The following paragraph tries to shed light on the strategies mentioned above which have been described in national German funding

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projects. We should keep in mind that very often the application of different strategies in a complex world is more than the sum of their parts. This means that even the analysis of every single step of an exploitation strategy cannot fully explain the success or failure of a company or product.

Early steps in the lifetime of a company, product or service are the analysis of the market that needs to be addressed and the quantification of its size. At this early step it has to be decided whether the activities to launch and develop a product are worth the effort. It is a very crucial moment since it could cause the investment of large sums or the discontinuation of the activities. A market analysis should be planned wisely and economical since the company has only limited resources. A market analysis that takes too long and takes up too much money raises the threshold at which the company can expect a return of investment. So, the market analysis should be as short and focused as possible

Cooperation is another important keyword for an exploitation strategy. The company should search for potential partners. It is always easier to team up with a potential opponent than to destroy each other's sales markets. Maybe the potential partners could combine their products or services in a symbiotic way. To find potential cooperation partners a lot of activities should be conducted e. g. the participation in conference, desktop research, database research or the usage of the personal professional network of the employees.

Once a product is ready for the market launch the work is not done. The exploitation strategy has to continue along the whole product cycle. Documentation is a very important keyword in order not to lose the capacities that have been built up. Especially with changing staff documentation is extremely important. There are a lot of good strategies for documentation that have their roots in software and hardware engineering e. g. Kan-Ban boards or git. It is very often useful to invest time into setting up these systems even though the initial work might seem high. These systems save up a lot of time in the later process.

The companies involved in German research projects have discussed the issue of specialization and broadening of their target points for their products in their final project reports. We can conclude here that neither of the two has proven better or worse. Specialization has usually been more successful if the market was tackled by opponents that have a larger production capacity. The companies could survive by finding their own niches. And often from these niches these companies still have an influence on the market. The broadening of the product range was successful whenever the demand (B2B and B2C) for specialized products was low. It was used by the companies to build up several new pillars, e. g. broadening from purely medical applications to applications in the care for the elderly or, and even bolder, into the consumer electronics industry.

7. Business models and exploitation strategies for SMEs

This section analyses how complementarity between **Robots and ICT (Information and Communication Technology)** and **organisational innovation** affects the **Open Innovation (OI)** strategy, contributing to the need to adapt new structures and operations of organisations by creating **Business Model Innovation (BMI),** which can in turn help create value in SMEs companies. That is, to identify how ICT (especially through the robots) are decisive for developing Absorptive Capacity in its two dimensions, internal and external, and

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therefore for the success of the Open Innovation strategies through the creation/adaptation of Business Model Innovation that creates company value.

The study covers how companies can use ICT to develop their Open Innovation strategies, by paying attention to how company capacities can impact the success of this form of innovation. Three sets of internal factors are analysed in relation to their impact on Open Innovation: **ICT, organisational innovation and employee skills**.

Open Innovation[17] and Business Innovation Models[18] are some of the developments that have aroused the greatest interest in the field of Business Administration in the last decade. The Open Innovation approach considers that companies must intensify their search and use of external knowledge to obtain a higher level of success in the development of products and changes in the business models that make them more efficient[19,20,21,22,23,24,25]. From a theoretical standpoint, the need to find a resource such as knowledge outside the organisation is based on fairly deeply rooted theories in Management literature. For example, from an evolutionary economics perspective, Cyert and March (1963)[26] suggested that organisations should look for knowledge beyond their borders in order to reinforce their ability to develop new products. Development of Absorptive Capacity is necessary for the success of an Open Innovation strategy[27]. The Open Innovation approach may also be framed as a specific case within the

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resource dependence model[28]; Absorptive Capacity[29]; open distributed innovation[30]; dynamic resources and capabilities[31,32,33].

However, and although literature has abundantly researched access to external knowledge for decades[34], there is a current need to drive research that provides greater understanding of Open Innovation. This need emerges from the rise of novel Open Innovation practices such as Robots[35,36,37,38], the use of social media[39], electronic marketplaces of knowledge and ideas or the use of new ICT tools to manage the stock and flow of knowledge in the organisation, in short, thousands of data (Big Data) that must be acquired and absorbed, to then transform and use them to facilitate the flow of external, but also internal knowledge, to be able to generate skills (dynamic and adaptive) for companies to innovate and create value [40,41,42,43,44,45,46].

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Automation itself is not bad. In fact, countries with a higher density of robots per worker are countries whose jobs have a lower risk of being replaced by automation. Hawksworth et al., (2018)[47] in their report, "Will robots really steal our jobs? An international analysis of the potential long-term impact of automation", shows a negative correlation between the potential jobs at high risk of automation, adjusted to account for industry composition, against the density of industrial robots in the country. This suggests that workforces in more technologically advanced countries such as Japan, South Korea and Singapore that are increasingly working alongside robots have already adjusted to automation to some degree and so may be at lower future risk. Instead they may be well placed to reap the benefits of automation in terms of higher productivity and real wages.

The theoretical framework of the **Skill Biased Technological Change** (SBTC), is based on the idea of the existence of strong complementarity between new technologies and skilled workers[48], both at an industry level[49] and a corporate one[50]. In both cases there is evidence of a direct and positive relationship between ICT and employee skills, even Doms et al., (1997)[51] proved at corporate level and in various industries, that the use of the latest technologies entails recruiting and hiring more skilled professional profiles, once again arguing said bias towards the very intrinsic needs of technology itself. Even though human capital does not appear in company financial statements, it is generally accepted that the value of a company could be determined by the value of the human resources comprising it, and this is particularly true in the case of services companies[52].

Changing needs in the various skilled profiles as a result of implementing ICT, are based on the reduction of communication, supervision and organisational costs[53,54] furthermore, these ICT entail a change in the organisational structure that means flattening company hierarchies and a significant reduction of repetitive tasks, allowing more complex decision-making for problems

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never faced before [55,54]. Assuming all of the above is true, companies with a heavy use of ICT will look for employees with generic skills capable of performing multiple tasks[52,55,56].

We have found literature that focuses on the use of skilled labour to foster organisational change in the context of a rapid absorption of ICT[57]. In a study on companies, Bresnahan, Brynjolfsson and Hitt (2002)[55] concluded that an increase in the demand of skilled workers associated to the dissemination of ICT could be attributed more to the organisational change induced by ICT than to the technology itself. This study highlights the -importance of having a workforce with generic skills that supplement new technologies[57]. We understand there are rewards for skilled workers through organisational change, when transformations are required inside the company to obtain improvements in productivity. It follows therefore, that ICT have an impact on company productivity, leveraging pre-existing and complementary resources [58,59,60]. Frey and Osborne (2017)[61] analyse the average median wage of occupations by their probability of computerisation, and they do the same for skill level (measured by the fraction of workers having obtained a bachelor's degree, or higher educational attainment) within each occupation. They reveal that both, wages and educational attainment exhibit a strong negative relationship with the probability of computerisation. Their model predicts that computerisation will mainly substitute for low-skill and low wage jobs in the near future. By contrast, high-skill and high-wage occupations are the least susceptible to computer capital.

Open Innovation (OI) is a paradigm that studies how organisations expand their innovation efforts beyond their own limits by using incoming and outgoing knowledge flows to improve innovation success[62]. Chesbrough (2003)[62] originally identified two separate processes: A) Use of external innovation internally, and B) external marketing of internal innovation, but companies may also collaborate combining these incoming and outgoing flows jointly [63]. This

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idea was later qualified by Chesbrough and Bogers (2014)[64] defining OI as a distributed innovation process based on knowledge flows directed with a purpose through the organisation boundaries, using financial and non-financial mechanisms in line with the company's business model.

Companies that decide to use third-party resources in their own business models face a series of related challenges both in Absorptive Capacity and in their own organisational inertia. Absorptive Capacity is a concept developed in literature that analyses the sharing of knowledge among companies [65], referring to the capacity to recognise the value of new information, absorb it and apply it to business purposes. Therefore, Absorptive Capacity has a potential value in incoming Open Innovation activities. In particular, Absorptive Capacity is considered a key element for company survival, as it facilitates integration of external knowledge, which is crucial for innovation[65].

Popa et al., (2017)[66] provided empirical evidence on the relationship between organisational background and innovation climate in OI, and SME performance. The results revealed that organisation factors such as human resources practices based on engagement had a positive impact on innovation climate and that innovation climate contributes both to incoming and outgoing flows of OI which in turn improve performance. This effect was moderated by environmental dynamism. In another similar study, Martinez-Conesa et al. (2017)[67] evidenced the importance of management capability, absorption, SME knowledge and how the latter is influenced by ICT and human resources practices based on engagement in an OI environment.

A company's **Absorptive Capacity** is, in turn, associated to three specific capacities: capacity to find resources (acquisition), capacity to integrate resources (absorption and transformation), and capacity to use resources. Expanding the area of application of this concept to the framework of our study of open business models, we can assert that the success of a company that decides to use third-party resources depends on their capacity to detect resources that may create value, their capacity to integrate these external resources with their internal ones, and their capacity to use and capture the value created by these external resources[68,69].

Absorptive Capacity may help understand the incoming flow in the Open Innovation process of a company, since both literature on OI and on Absorptive Capacity back how innovative

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companies can benefit from these external sources of technology [70]. Nowadays, we cannot ignore that external knowledge can be generated in alternative ways to patents, technologies, etc., and that this can be the result of the massive analysis of information[71]. Gassmann (2006)[72] had already indicated that research was neglecting to study the access to external knowledge through other tools.

Development of Absorptive Capacity is necessary for the success of an Open Innovation strategy [73]. One of the studies conducted along these lines is by the research group GIPTIC-UCM directed by Sandulli et al. (2012)[74] which noted that in the case of Spanish companies, Open Innovation is more common in large companies, in emerging, knowledge-intensive sectors with little concentration. Size is very important as in general it is considered that due to their lower absorptive capacity and availability of resources, they will have greater difficulties to obtain rents from Open Innovation strategies[75]. However, the results of previous work by the research group[76,77] suggest that with the right tools (ICT) and strategy (alignment between IT-Organisational Innovation-HR Skills), SMEs can offset their lack of resources through Open Innovation strategies. This is where Robotic and Big Data can play a significant role in the generation of external knowledge as a source of Open Innovation for SMEs.

Although business models (BM) have been studied for decades now[78]. First with definitions associated to the operating activity carried out, taking into account IT [79]. It was in the 1990s when they started talking about key business processes and how they are interrelated [80]. Most definitions found in literature have many elements in common with the definition provided by Teece (2010)[81] who defined BM as the design or architecture for value creation, delivery and

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capture mechanisms in a company. Furthermore, as shown by Saebi, Lien and Foss (2016) [82], in spite of using different terminology, literature agrees upon the components that make up a BM: the company's value proposition and the market segments it will compete in; the value chain structure necessary for the value proposition, the mechanisms to capture value deployed by the company, and how these elements are jointly related in an architecture.

Foss and Saebi (2017)[83] proposed a BMI classification based on two variables: A) scope, according to the number of elements involved in the change, if the change is to the architecture or modular; and B) novelty, if the changes are new for the company or the industry.

Therefore, four types of BMI can be differentiated:

- Evolutionary, is new for the company, but it would require an adjustment in certain individual components as a result primarily of the passing of time.
- Adaptive, BMI implies changes in BMs in general which are new for the company, but not necessarily new in the industry[82]. This is the case when companies adapt the architecture of their BM in response to changes in the environment, in response to competition from a new BM in their industry[81]
- Complex can be defined as the process through which management makes changes to the company architecture to conduct a disruptive change in the market (that is, something new in the industry).
- In the case of Focused, the company innovates within an area of the BM, normally in a new market segment which has been ignored by its competitors. Conducting a modular but new change for the industry.

Bi et al. (2017)[84] in a recent study, confirmed a theoretical model, based on RBV, that relates e-business capacities and the business value of rapidly growing SMEs. Results show that internal skills (ICT resources, employee ICT skills and ICT strategic alignment) and external skills (market focus and partner relationships) have a significant and indirect impact on SME performance by developing dynamic e-business capacities while helping them adapt their business processes to the competition.

However, if a company is not capable of adapting and reshaping its resources to absorb this knowledge, it will not generate a competitive advantage, which is why companies should be sufficiently capable of generating dynamic capacities to respond to required changes [85,86,87,88]. Companies should be proactive in their response to changes in the environment by detecting even weak signs from customers and other stakeholders to predict consumer trends and even design new products and reach new markets[88]. For Opresnik and Taish (2015)[89] , the term

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"dynamic" refers to the ability to renew competencies in order to achieve coherence and alignment with a changing business environment. The term "capacities" stresses the key role played by strategic management in appropriate adaptation, integration of resources and reconfiguration of internal and external organisational skills, necessary resources and functional competencies required to respond to environment changes. If these changes affect the structure, content and/or governance of a company, new BMI is generated in response to new needs [90,91].

Five cases have been identified. The CASE 1 is a case of External Open Innovation practices (acquisition of robot, external collaboration with other companies and Big Data) have a positive impact on a company's value creation (improve productivity, cost reduction, ...), for the mere fact of incorporating a robot. The CASE 2 is a success case of a company that incorporates a robot and the workers are prepared and have fully accepted it. The robot is part of the strategy and not just a "machine". The practices of Internal Open Innovation (product and process innovation, organizational innovations: ICT capabilities, the skills of ICT workers, the use of networks at work and ICT alienation with the strategy) have a positive influence on the creation of value of the company

The next case, CASE 3**TABLE IRMASS 18**, is a success case that is mainly due to the workers ICT capabilities, the skills of ICT workers and ICT alienation with the strategy. Otherwise, the robot wouldn't have succeeded. Finally, two more cases, CASE 4 (industrial sector) and CASE 5 (service sector), are companies that has implemented a high degree of automation and had to redesign its business model (eliminating jobs to create others, customer relations, relations with suppliers, ...). Following this suggested classification, next table offers a guide to recommended business model for SMEs developing innovative IR.

TABLE IRMASS 12 QUICK GUIDE FOR RECOMMENDED BUSINESS MODEL

Type of SME	Type of product / innovation	Description	Recommended business model
All SME	External Open Innovation	Acquisition of robot, external collaboration with other companies and Big Data. Have a positive impact on a company's value creation (improve productivity, cost reduction, ...), for the mere fact of incorporating a robot	Evolutionary
SME that incorporates a robot and the workers are prepared and	Internal Open Innovation	The robot is part of the strategy and not just a "machine". The practices of Internal Open Innovation have a positive influence on	Evolutionary

[90] Foss, N.J. Saebi, T. "Fifteen Years of Research on Business Model Innovation", *Journal of Management* 43 (2017): 200

[91] Zott, C.; Amit, R. "Business Model Innovation: How to Create Value in a Digital World.", GfK MIR, 2017

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have fully accepted it.		the creation of value of the company	
SMEs with workers with high ICT capabilities and skills and the automation is aligned with the strategy	Workers and Robots are aligned with the strategy	SMEs use robots and ICT to change and replace processes. Workers perform highly skilled tasks. The SME already has previous experience in the use of robots, and it has been a success.	Adaptive
SMEs with very high degree of automation	High degree of automation and had to redesign its business model	The SME completely redesigns its business model. Allowing to obtain an important competitive advantage. Makes changes to the company architecture to conduct a disruptive change	Adaptive and complex

1. Fund raising and Business fora

One of the main outcomes of the survey (see previous section about the results of the survey on IPR) shows the importance of the access to funding, financial resources, potential investors and business networks. This section covers these issues, offering a general view of the types of private and public funding opportunities, business fora and how to deal with them.

Private fund raising

In order to attract potential investors to fund the innovative new companies developing IR, the entrepreneurs need to know **how to identify the opportunity** for their new business related to integrating / using IRs:

1. Customer-Problem-Solution

   The solution has to be validated in the market with real customer. The problem with IR is that sometimes the customer does not know the current advantages of integrating IR in his/her company.

2. Does the opportunity match the founders experience, skills and interests?

   The opportunity to start a business should enable the entrepreneur to use and leverage the skills and expertise he/she has acquired over time, based in personal experience. Sometimes this expertise comes from the world of traditional robotics (i.e. no interactive robots).

3. Can they recruit and lead the team needed to exploit the opportunity? (lack of available workforce experienced in interactive robots?)

   The new company needs to recruit and lead a balanced and complete team, not only form the technical point of view, but also a first-class management team.

4. Do the resource needs of the opportunity shorten the odds-on success?

   Apart from people, the new business also needs capital, facilities, equipment, materials, etc.

5. Is the timing of the opportunity, right?

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When looking for funds, the new company should understand fully the temporal dimensions of the opportunity. For example, the changing / growing driven by regulation, technology, market demands, etc.

6. Do they need to comply with legal requirements? (lack of standardization & legal framework for IR)

   It is fundamental to check the legal requirements of the new business. A legal assistance should be requested, but perhaps this is a difficult issue given that the standardization works and legal framework for IR is under development.

7. Does the opportunity constitute a scalable (and saleable) business?

   It is important to have a clear idea, from the beginning, on how big the business could become. It is not easy to achieve scale without proportionately adding to overhead. The size of the potential business depends not only on the type of IR to sell, but also on external factors. For example, when dealing with medical interactive robots, the success in the certification process opens a wide door to sell the robot to national health systems.

8. Does the opportunity offer good margin potential?

   It is difficult to state the gross margin, and its sustainability. The margin usually erodes as competition develops. When the intellectual property of a development expires, it is important to have a replacement or to have additional incomes related to the main IR equipment. An example is the Da Vinci surgical robot: despite the manufacturer is continually developing new IP, they have an important percentage of income due to the sales of consumables which are integrated in the system. The advantage of business dealing with IR is that they may integrate many different technologies (electronics, motors, control software, image & voice analysis, learning functionalities, etc.), so there is potential to grow and new developments in each of them.

9. Which one is the best channel to expand the business?

   The entrepreneur should find out which kind of suppliers actually have his/her potential customers. Many suppliers are multi-brand suppliers, so he/she can make an arrangement with them in order to distribute also the new IR.

10. Are they developing an opportunity or simply an idea?

    The value to be delivered to the customer is the key to be found. Uniqueness lies in the particular blend of experience, skills and other resources that can be brought to bear on the opportunity exploiting in a way that others cannot easily replicate. An example is the Aibo dog, a robotic pet for entertainment developed by Sony in 1998 when nobody talked about IR. The company took the opportunity of their technological background and sales network, together with a good marketing campaign, to sold thousands of robots.

11. How are they going to make money?

    The entrepreneur should design a specific business model for her/his business.

12. Who are their competitors and their competitive advantage? (difficulties in identifying competition since IR is a relatively new technology)

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The new company need to create a unique value proposition which differentiates from competitors. Barriers of entry are a good way to keep players out of the business. Here, standardization, legal framework and certification play an important role.

13. Which one is the Exit strategy?

    It is important to understand the players, who will be, in the future, willing to buy the new company to gain more market share, to avoid getting out of the market, etc. An example is the Danish company Universal Robots, founded in 2005 and with a business volume of 170 M$ in 2017 worldwide. The company was acquired by US company Teradyne (supplier of automatic test equipment) in 2015.

It is also important to **know why investors invest**; they must believe in the proposed business/idea:

- Trustworthiness of the entrepreneur (often they are spin-offs, start-ups)
- Expertise of the entrepreneur
- Enthusiasm of the entrepreneur
- Track record of the entrepreneur
- Perceived rewards for the investors (maybe it is difficult to differentiate from "traditional robotics"?)
- Sales potential of the market
- Growth potential of the market
- Expected rate of return (sometimes it is difficult to compute, especially when dealing with IR for social applications)
- Quality of product
- Overall competitive protection of the product
- Potential exit routes (liquidity)

Some things the entrepreneur should **know about potential investors**:

- What kinds of investments have they made in the past?
- What kinds of deals are they looking for currently?
- How do they make investment decisions? What kinds of deals do they like?
- Do they understand and have experience of the IR sector (or robotics sector in general)?
- How much detail are they looking for?
- What are they like? What is their style?

The entrepreneur must be ready to answer to **potential questions the investors ask**:

- Can the new company accomplish the tasks described in the business plan?
- How does the new company and IR product fit into the industry?
- What are the trends in the IR market?
- What are the drivers to success in the IR industry?
- What type of business experience does the management team have?
- How did you determine total sales of the industry and its growth rate?
- What industry changes most affect your company's profits? (regulation, standardization…)
- What makes your business different?
- Why will this business succeed?
- Why is this IR product useful? What will it do for the user?
- What is the expected life cycle of the IR product? What is the product liability? How does the regulatory environment affect the IR?

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The new trends in start-ups creation is that the firm must **share the value that it creates (*value of the firm*) with its customers and suppliers**. This strategy involves three basic rules:

1. To attract customers away from competitors, the company must provide sufficient customer value as compared to rival firms.
2. To attract key suppliers away from competitors, the company must offer sufficient supplier value.
3. To attract investment capital in competition with other market investment opportunities, the company must increase the value of the firm for its investors.[92]

When trying to put a new IR on the market, the **developer must have answer for these open questions:**

- Why will the business succeed when it must compete with larger companies? There are a lot of robotics companies which started manufacturing robots many years ago, and now they are moving to the IR sector.
- Does the product meet a specific need or perceived need of the customer? The customers hardly show a need to have an IR in their lives.
- Does the product have brand-name recognition?
- Are there repeat uses for the product? It is assumed that an IR is flexible enough to be used in several applications.
- Is the consumer the end user of the product? For example, for IR in domestic or industrial sector, probably yes, but when dealing with medical sector, probably not.
- Does this product have mass appeal or single large buyers? There is a big difference between IR for industry and IR for domestic use.
- Who is the competition and what advantages does the competition has over the new company?
- What advantages does the new company have over its competition? Price, performance, service, warranties?
- Are there any substitutes for your product?
- How does the new company expect the competition to react to the new business? The most common movement from competitors is to buy the company.
- How do advances in technology affect your product and business? An IR integrates and depends completely of several advanced technologies, so any change / discontinuity / lack of compatibility may affect the production of future versions of the IR.

The investment risks depend on the TRL of the product: high risk for early stage (TRL 1-3), low risk for market ready (TRL 7-9). Usually the **financing follows these three main stages:**

1. Financing early stage technologies to make ready for license or sale (pre-seed or seed funding).
2. Financing a start-up.
3. Financing a company for growth and exit by investors.

<u>Types of funding sources: Venture capital vs Business Angels</u>

[92] Daniel F Spulber, *Economics and Management of Competitive Strategy* (USA: Northwestern University, 2009) http://www.worldscibooks.com/business/7171.html

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Venture Capital: case of Tecnalia Ventures as a tool for private funding

Tecnalia Ventures[93] develops business opportunities for the valorization and commercialization of technology by connecting the main pillars of an entrepreneurial ecosystem: minds, management and money. When the results of a research project reach a certain TRL, they look for:

- **people with an entrepreneurial profile** / business vision capable of transferring the developed technology to the market, thus generating real business opportunities. These are profiles to which the value proposition of transforming a technological spin-off into a growing SME is attractive to them.
- **smart investors** that not only provide the necessary financial muscle to transform technologies into revenues but are also committed to supporting the development of the company.

They offer services such as: acceleration programs, entrepreneurs' club, technology transfer training programs, support for business diversification, set up of proof-of-concept funds, etc. The aim is to turn innovative technological assets into new profitable and sustainable businesses. They do all this by identifying technologically disruptive solutions, exposing them from early stages of development to investment criteria, focusing the efforts on the business opportunities with highest commercialization potential.

- **Entrepreneurs' club**: entrepreneurship ecosystem by connecting entrepreneurs that want to turn groundbreaking technology into business opportunities which have an impact on the market and on society. Tecnalia Ventures organizes specific events, offers training, connects ideas with entrepreneurs and promotes mentoring.
- **Omega Funds / Pre-acceleration program**: aimed for a business idea which:
  - is technologically innovative
  - is in the initial development stage
  - is aimed at industry
  - could solve the financial problems of companies

The entrepreneurs can take part in TECNALIA Challenges – an 8-week pre-acceleration program that will help the new business idea take shape and give access to OMEGA proof of concept fund. The program covers the following areas:

- Identifying technological risks
- Developing the business model and marketing
- Legal support
- Analysing patentability
- Access to the OMEGA proof of concept fund. This fund is linked to a timebank for Tecnalia's researchers. The result is that it helps innovative start-ups to cross the valley of death, increasing the value of their R&D, developing technological skills that set them apart and therefore mitigating the technological risk to which private investors are so averse. Once the business opportunities have taken root, the process of speeding up the incubation of these technology-based business opportunities begins by exposing them to investment criteria from an early stage and concentrating efforts on ventures that have the greatest marketing potential, thereby ensuring that they are ready for private investment.

[93] https://www.tecnaliaventures.com/?lang=en

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Tecnalia Ventures also contacts potential investors and gives them access to business opportunities that match their investor profile and help them identify the risks and potential of their investment in technology-based business projects. Through the ***Inspiring Business Forum***, a corporate investment forum, Tecnalia Ventures offers its members business opportunities that are at the marketing stage. The members of this forum (corporate ventures, investment funds, etc), also show their needs for investment and diversification. They have the first option to choose, valorise and take part in the projects of main interest for them, and to select several ways to participate.

Other related initiative is the **Innovation Forum**, a network created by the universities of Cambridge and Oxford which connects entrepreneurs and researchers with investors and business angels worldwide. The network already has more than 15 nodes in Europe, Asia, USA and among the partners there are big companies such as Johnson & Johnson Ventures, IBM, Roche and Astellas Pharma. The Innovation Forum will hold an event in October 2019 in Bilbao.

These tools help value the technological aspects of a business opportunity so that the potential investor can be sure before they invest. This involves checking all aspects related to technology, including valuation, protection, solidity, standards, integration, etc. Once the work has been carried out, the investor will be provided with a report outlining the conclusions and risks that have been identified.

Business Angels

Angel investing is **equity finance**. An angel investor is a high net worth individual who makes use of their personal disposable finance and makes their own decision about making the investment. The investor would normally take shares (an equity stake) in your business in return for providing equity finance (funds). The angels normally seek to not only provide the business with money to grow, but also **bring their experience and knowledge to help the company achieve success**. They can invest alone, or as part of a syndicate (a group of angels). [94]

Venture capital differs from angel investing because it invests in businesses through managed funds, coming from private or public money. The venture capitalist manager invests the money on behalf of the fund which has to be profitable and make a return for the fund's investors. Due to high costs of administration and the need to be very selective to ensure a return on the fund, VC funds are more risk averse and thus make fewer small investments in start and seed stage.

That is why business angels are becoming more and more significant in funding new ventures by supplying **smaller amounts of capital to companies that cannot be economically funded by the established venture capital market**. Business angels make their own decisions about investments they make and **generally engage directly in meeting the entrepreneurs, often seeing them pitch their business.** Angels also engage directly in the due diligence and investment process and are signatories on the legal investment documentation. This can be done either on their own or with a syndicate. Angel investors then follow their deal either actively taking a role on the board or actively supporting the business or may act passively as part of a group with a lead angel taking this role on their behalf.

Differences between Business angels and venture capital firms not only deals with the size of their investment, but also in their approach. Angel investing is often called "patient capital"

[94] https://www.ukbaa.org.uk/

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since angels are less concerned with rapid return and exit and are prepared to support the business through its path to growth and exit over a longer timescale.

Public funding

Public funding for Robotics in the EU.

The following section covers all the EU funding opportunities, in the field of robotics, found in the Research and Innovation Framework Programme (H2020, Horizon Europe).

Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020)[95] – in addition to the private investment that this money will attract. Horizon 2020 is the financial instrument implementing the 'Innovation Union', a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness.

By coupling research and innovation, Horizon 2020 is helping to achieve this with its emphasis on excellent science, industrial leadership and tackling societal challenges. The goal is to ensure Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation.

Seen as means to drive economic growth and create jobs, Horizon 2020 has the political backing of Europe's leaders and the Members of the European Parliament. Horizon 2020 is open to everyone, with a simple structure that reduces red tape and time so participants can focus on what is really important. This approach makes sure new projects get off the ground quickly and achieve results faster.

Forecasts are very positive after Horizon 2020, since the Commission has already published its proposal for 'Horizon Europe', an ambitious €100 billion research and innovation programme over the years 2021-2027, that will succeed Horizon 2020.

Guide to Robotics-related activities in H2020 - WP2018-2020

Funding opportunities under Horizon 2020 are set out in multiannual work programmes which cover the large majority of support available. The work programmes are prepared by the European Commission within the framework provided by the Horizon 2020 legislation and through a strategic programming process, integrating EU policy objectives in the priority setting.

Robotics can be found on many of the current H2020 programmes and calls. This guide is designed to help potential proposers find Robotics-related topics across the different parts of H2020 Work Programme 2018-2020.

Like in all work programmes, actions supported cover the **full innovation chain**, from basic research to market uptake:

[95] https://ec.europa.eu/programmes/horizon2020/en

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- Advanced research to uncover radically new technological possibilities and Robotics contributions to upstream research and innovation are addressed in the **"Excellent Science"** part of the work programme, respectively under **"Future and Emerging Technologies (FET)"** and **"European Research Infrastructures (eInfrastructures)";**
- Research and innovation activities on generic ICT and Robotic technologies either driven by industrial roadmaps or through a bottom-up approach are addressed in the **"Leadership in Enabling and Industrial Technologies (LEIT)"** part of the work programme;
- Multi- disciplinary application-driven research and innovation leveraging ICT and Robotics to tackle societal challenges are addressed in the different **"societal challenges"** part of the work programme.
- The implementation of the pilot of the **European Innovation Council (EIC)**[96] is also included, which brings together several innovation support schemes: the SME Instrument, the Fast Track to Innovation (FTI), FET Open, and Horizon Prizes. Each addresses the needs of a particular community in the innovation ecosystem and are SME-oriented.

Horizon 2020 calls can have different **types of action** (funding schemes). The type of action specifies: the scope of what is funded, the reimbursement rate and specific evaluation criteria to qualify for funding. The list below gives a short overview of the most relevant H2020 types of actions and their funding rates.

a) **RIAs (Research and Innovation):** Activities aiming to establish new knowledge and/or explore the feasibility of a new or improved technology, product, process, service or solution. For this purpose, they may include basic and applied research, technology development and integration, testing and validation on a small-scale prototype in a laboratory or simulated environment. Projects may contain closely connected but limited demonstration or pilot activities aiming to show technical feasibility in a near to operational environment. *EU funding rate – 100%*

b) **IAs (Innovation Actions, Large Scale Pilots):** Activities directly aiming at producing plans and arrangements or designs for new, altered or improved products, processes or services. For this purpose, they may include prototyping, testing, demonstrating, piloting, large-scale product validation and market replication. *EU funding rate –70% (except for non-profit legal entities, where a rate of 100% applies)*

c) **CSAs (Coordination and Support):** Accompanying measures such as standardization, dissemination, awareness-rising and communication, networking, coordination or support services, policy dialogues and mutual learning exercises and studies. *EU funding rate – 100%*

Most of the Horizon 2020 calls are divided into **topics**. Some topics are **continuously open,** while others have cut-off dates and stablished deadlines, topics are in constant renewal and new ones are foreseen for future work programmes.

The following sections give more details about Robotic related calls and activities in different parts of the work programme. The detailed description of all these topics can be found in the complete work programme with the references available in each section.

Robotics in "LEADERSHIP IN ENABLING AND INDUSTRIAL TECHNOLOGIES (LEIT-ICT)"

[96] https://ec.europa.eu/research/eic/index.cfm

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This action is aligned with the main political priorities in the digital area:

- the **digitization of European industry and services**,
- the **European Data Infrastructure (EDI),**
- the **5G** action plan and connected and automated mobility,
- the **Next Generation Internet** (NGI), including the Internet of Things and artificial intelligence,
- **Cybersecurity**

The corresponding activities are mainly covered through three calls:

- a generic call on **Information and Communication Technologies**,
- a call dedicated to the **implementation of the DEI (Digitizing European Industry) strategy**[97] (through support to digital innovation hubs, the development of platforms and large-scale pilots) and the contribution of LEIT-ICT to the DT focus area of WP2018-20,
- a call on **cybersecurity** (which contributes to the focus area 'boosting the effectiveness of the Security Union')

Between these calls, Robotics can be found in the first two calls, included in the Information and Communication Technologies Work Programme (ICT) and the Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing Work Programme (NMBP).

Information and Communication Technologies Work Programme (ICT-2018-2020)[98]

The topics addressed in this Work Programme part cover the ICT technology in a comprehensive way, from technologies for Digitising European Industry, HPC, Big Data and Cloud, 5G and Next Generation Internet. This Work Programme supports core ICT industries through roadmap-based Public Private Partnerships (PPs). The work contributes to maintaining and developing the technology leading edge in key areas such as electronics, photonics, embedded systems, computing robotics, big data or network technologies and systems, in which the EU has and should keep major strengths. Support to the Focus Area **'Digitising and transforming European industry and services'** will be provided through Innovation hubs and cross-sectorial and integrated digital platforms and large-scale pilots for experimentation and co-creation with users, robotics is addressed in this section.

Among all the calls and topics included in this Work Programme, those interesting for Robotics are presented below, it is important to note that Robotics' actions currently open calls are focused on 4 Priority Areas and 4 Core Technologies:

TABLE IRMASS 13 CORE TECHNOLOGIES WITHIN DIFFERENT PRIORITY AREAS

Priority Areas	Core Technologies
Healthcare	AI and Cognition
Inspection and maintenance of infrastructure	Cognitive Mechatronics
Agri-food	Socially cooperative human-robot interaction

[97] COM (2016) 180 : Digitising European Industry - Reaping the full benefits of a Digital Single Market
[98] Horizon 2020, Work Programme 2018-2020, "Information and Communication Technologies" http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-leit-ict_en.pdf

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All of these technologies are tackled through 5 different types of actions:

d) DIHs (Digital Innovation Hubs): They are one-stop shops where companies - especially SMEs, start-ups and midcaps- can get access to technology-testing, financing advice, market intelligence and networking opportunities, to become more competitive with regard to their business/production processes, products or services using digital technologies.
e) RIAs (Research and Innovation)
f) IAs (Innovation Actions, Large Scale Pilots)
g) CSAs (Coordination and Support)

Some examples of the calls and topics correspondent to Robotics which are still open are presented below, these calls are in constant renewal and new ones are foreseen in the future within this and the upcoming Work Programme:

TABLE IRMASS 14 CALL DESCRIPTION

Topic	Call Identifier	Call type*	Description
ICT-09-2019-2020[99]: Robotics in application Areas	Information and Communication Technologies	RIA, IA and CSA	a) Innovative approaches to hard research problems in new promising robotics applications (RIA: 3-5M€/action – TOTAL: 20M€) b) Large scale pilots in Robotics demonstrating the use of robotics in highly realistic environments of infrastructure, inspection and maintenance (IA: 7-9M€/action – TOTAL 28M€) c) Robotic competitions in healthcare, inspection and maintenance of infrastructure, agri-food and agile production (CSA: 2M€/action – TOTAL: 2M€) Stakeholders: Academia and industry developing or using intelligent robots, and end-users (involvement particularly important in b) and c)) Specific Challenge: Technical and non-technical challenges, reduce the barriers to adoption, user needs, ethical, legal, societal & economic aspects, raise awareness and take-up, privacy and cybersecurity issues, where appropriate.
ICT-10-2019-2020[100]	Information and Communication Technologies	RIA	Objectives: Increased autonomy in robotics systems through research in: AI and Cognition, Cognitive Mechatronics, Socially cooperative human-robot interaction, Model-based design and configuration tools. (RIA: 5-10M€/action – TOTAL: 42M€) Scope: Development of core technology modules and tool kits for use in deployable system platforms that meet the requirements of applications in the 4 application areas: Healthcare, Infrastructure Inspection and Maintenance, Agri-Food and Agile Production. Stakeholders: Academia and industry developing or using intelligent robots.
DT-ICT-02-2018: Robotics Digital Innovation Hubs	Digitsing and transforming European industry services: digital innovation hubs and services. H2020-DT-2018-2020	IA and CSA	Challenge is to provide a sustainable ecosystem of robotics stakeholders covering the entire value network to facilitate and accelerate a broad uptake and integration of robotic technologies and supporting the digitization of industry through robotics. a) Provision of a network of robotics DIH in the four prioritized application areas. Proposals are expected to: develop a network of DIHs, address the delivery of services (technical and non-technical); provide access to best practice and research results in robotics, engaging in the development of industry-led standards and developing and disseminating standards demonstrators, facilitate access to pilots and collaborate with all the robotics actions funded

[99] Robotic in Application Areas ID : ICT-09-2019-2020 https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/ict-09-2019-2020

[100] Robotics Core Technology ID: ICT-10-2019-2020, https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/ict-10-2019-2020

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	in the WP. (IA) b) Provision of a Central Robotics DIH CSA, to support and cooperate with the PAA-oriented DIH actions, to network them, coordinate their activities and develop synergies among them. (CSA:2M€/action)

*RIA: Research and Innovation Actions (100% of eligible costs, unless call provides exceptionally for another rate)
*IA: Innovation Actions (70% of eligible costs (100% for non-profit organizations))
*CSA: Coordination and Support Actions (100% of eligible costs, unless the call provides exceptionally for another rate).

Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing Work Programme[101] (NMBP 2018-2020)

This program covers different areas: Nanotechnologies, Advanced materials, Advanced manufacturing and processing and Biotechnology. Activities of the work programme will address the whole innovation chain with technology readiness levels spanning the crucial range from medium levels to high levels preceding mass production and helping to bridge the gaps ("valley of death") in this range.

Some examples of the calls and topics correspondent to Robotics are presented below, these calls are in constant renewal and new ones are foreseen in the future within this and the upcoming work programme:

TABLE IRMASS 15 CALL DESCRIPTION

Topic	Call Identifier	Call type*	Description
DT-FOF-02-2018[102]: Effective Industrial Human-Robot Collaboration	Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing	RIA	Objectives: Extend the current state of the art of individual HRC to work environments where robots and workers function as members of the same team throughout the factory, proposals should cover two of the following areas: a) Integration in industrial production environments of novel human-centred designed smart mechatronic systems such as, for example, soft robotics for high payloads. b) Implementation of novel AI technologies capable of massive information processing and reacting in real time to enable new levels of autonomy, navigation, cognitive perception and manipulation for robots to collaborate with humans in the process c) Development of methods for robotic hazard assessment and risk management to clarify trade-offs between productivity and safety for mixed human-robot smart devices environments.
DT-FOF-12-2019[103]: Handling systems for flexible materials	Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing	RIA	Objectives: The handling of soft materials with the involvement of robots remains limited. The control systems of the robot need to be very sensitive, accurate and fast to prevent unwanted irreversible deformations and damages. The aim is to research in order to develop handling devices with are not pre-programmed for one specific task but are intelligent and universally dexterous.

[101] Horizon 2020, Work Programme 2018-2020, "Nanotechnologies, Advanced Materials, Biotecnology and Advnced Manufacturing and Processing", http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-leit-nmp_en.pdf

[102] Effective Industrial Human-Robot Collaboration (RIA) ID: DT-FOF-02-2018, https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/dt-fof-02-2018

[103] Handling systems for flexible materials (RIA), https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/dt-fof-12-2019

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Robotics in "Excellent Science"

Future and Emerging Technologies (FET)

FET Open: Novel ideas for radically new technologies[104]

FET Open, which represents 40% of the overall FET budget in Horizon 2020, is entirely non-prescriptive with regards to the nature or purpose of the technologies that are envisaged. FET Open covers all technological areas and no budget is specifically earmarked for ICT or Robotics.

In WP2018-20, FET Open is part of the European Innovation Council pilot and the call text has been simplified for a clearer scope. EIC FET Open supports the early stages of the science and technology research and innovation around new ideas towards radically new future technologies. It also funds coordination and support actions for such high-risk forward-looking research to prosper in Europe, and FET Innovation Launchpad Actions aiming at turning results from FET-funded projects into genuine societal or economic innovations.

- **Research and Innovation Actions (RIA):** FET Open calls for collaborative research and innovation actions that satisfy the FET Open 'gatekeepers': radical vision, breakthrough technological target and ambitious interdisciplinary research.
- **Coordination and Support Actions (CSA):** FET Open also facilitates Coordination and Support Actions. The goal is to create the best possible conditions for responsible collaborative research on FET. This is done by strengthening ne FET research communities and by stimulating the take-up of FET research results.
- **FET Innovation Launchpad Actions (CSA):** In addition, FET Open also offers FET Innovation Launchpad grants to fund further innovation related work, i.e. activities which were not scheduled to be funded by the original projects Funding is used to verity and substantiate the innovation potential of ideas arising from FET projects and to support the next steps in bringing them closer to the market.

FET Proactive: Boosting emerging technologies[105]

FET Proactive helps new research communities to be developed by encouraging researchers from different disciplines to work together on new technologies in specific domains. The aim is to mature four novel areas and themes by working towards structuring emerging communities and supporting the design and development of transformative research themes: 1) Future technologies for societal change 2) Biotech for better life 3) Disruptive information technologies 4) New technologies for energy and functional materials.

In addition to research, FET Proactive activities also include generating a research roadmap of the area, developing appropriate educational materials and disseminating results to raise the general awareness of the new technology benefits.

Robotics in THE 'EUROPEAN INNOVATION COUNCIL' (EIC) PILOT[106]

[104] Horizon 2020, Work Programme 2018-2020, "Future and Emerging Technologies" http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-fet_en.pdf

[105] FET Proactive, https://ec.europa.eu/programmes/horizon2020/en/node/822

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SME participation is encouraged throughout the work programme and in particular in the priorities 'Industrial Leadership' and 'Societal Challenges'. Dedicated SME support is channeled through the **SME Instrument**[107], introduced in the Work Programme 2014-2015, which promotes SMEs' innovation activities from concept to market. In 2016-17, all topics using the SME instrument were grouped in a continuously open common call. For 2018-20, this consolidation is pursued and the support to SMEs through this dedicated instrument takes the form of a single topic with a fully **bottom-up approach** (still with continuously open call with four deadlines per year).

SME instrument comprises two phases to which any eligible company can apply for funding:

- **SME Instrument Phase 1**: Feasibility study verifying the technological /practical as well as economic viability of an innovation idea with considerable novelty to the industry sector in which It is presented. The activities could, for example, comprise risk assessment, market study, user involvement, Intellectual Property management, innovation strategy development, partner search, feasibility of concept.
- **SME Instrument Phase 2**: Innovation projects that demonstrate high potential in terms of company competitiveness and growth underpinned by a strategic business plan. Activities should focus on innovation activities such as demonstration, testing, prototyping, piloting, scaling-up, miniaturization, design, market replication but may also include some research. For technological innovation a Technology Readiness Levels (TRL)[108] of 6 or above are envisaged.

Further to the success of its pilot phase, the **Fast Track to Innovation (FTI)**[109] scheme, which was launched in 2015, is continued and now integrated in the EIC pilot. FTI takes a new approach to give the development of innovations the last push needed before their introduction to the market. It is the only **fully bottom-up** measure in Horizon 2020 promoting close-to-market innovation activities open to **industry-driven consortia** that can be composed of **all types of participants.** It can help partners to co-create and test breakthrough products, services or business processes that have the potential to revolutionize existing or create entirely new markets.

Robotics in 'Societal challenges'

Digitization was retained as one of the five main political drivers to be taken into account in the design of WP2018-20, which led to the development of a major focus area dedicated to this priority (DT- 'Digitizing and transforming European Industry and services') and a further strengthening of the integration of the support to ICT-related R&I activities across LEIT and societal challenges.

Robotic contributions are expected in each of the seven societal challenges in Horizon 2020:

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[106] Horizon 2020 Work-Programme 2018-2020 Enhanced European Innovation Council (EIC) pilot, http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-eic_en.pdf
[107] EIC Accelerator Pilot, https://ec.europa.eu/programmes/horizon2020/en/h2020-section/sme-instrument

[108] https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2018-2020/annexes/h2020-wp1820-annex-g-trl_en.pdf
[109] Fast Track to Innovation, https://ec.europa.eu/programmes/horizon2020/en/h2020-section/fast-track-innovation-pilot

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- SC1: Health, demographic change and wellbeing[110],
- SC2: Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy[111],
- SC3: Secure, clean and efficient energy[112],
- SC4: Smart, green and integrated transport[113],
- SC5: Climate action, environment, resource efficiency and raw materials[114],
- SC6: Europe in a changing world- Innovative, inclusive and reflective societies[115],
- SC7: Secure societies- Protecting freedom and security of Europe and its citizens[116].

In the societal challenges Robotics are addressed through either specific topics or calls or as a part of a broader set of contributing technologies in the description of the targeted activities.

Robotics and cascade funding

Cascade funding, also known as **Financial Support for Third Parties (FSTP)**, is a European Commission mechanism to distribute public funding in order to assist beneficiaries, such as start-ups, scale-ups, SME and/or mid-caps, in the uptake or development of digital innovation.

This funding method aims at simplifying the administrative procedures, creating a light, SME-friendly application scheme, by allowing that some EU-funded projects may issue, in turn, open calls for further funding. Support offered by these open calls, usually consist in funding (typically in the range of €50.000,00 to €150.000,00) but it may also be vouchers for support services or free access and support to use testing facilities.

Most of the open calls issued during this Horizon 2020 belong to one (or more) of the following domains: Future Internet and Next Generation Internet, Smartisation, Industry 4.0 (ICT for industry), Internet Of Things (IoT), **Robotics**, Big Data, Photonics, Innovation throughout value chains, and the nexus between creativity and technology.

Some examples of 'Cascade Funding' programmes for Robotics are presented here below:

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[110] Horizon 2020, Work Programme 2018-2020, "Health, demographic change and wellbeing, http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-health_en.pdf

[111] Horizon 2020, Work Programme 2018-2020, "Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy, http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-food_en.pdf

[112] Horizon 2020, Work Programme 2018-2020, " Secure, clean and efficient energy" http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-energy_en.pdf

[113] Horizon 2020, Work Programme 2018-2020, " Smart, green and integrated transport" http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-transport_en.pdf

[114]Horizon 2020, Work Programme 2018-2020, "climate action, environment, resource efficiency and raw materials" http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-climate_en.pdf

[115] Horizon 2020, Work Programme 2018-2020, "Europe in a changing world. Inclusive, innovate and reflective societies" https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-societies_en.pdf

[116] Horizon 2020, Work Programme 2018-2020, " Secure societies - Protecting freedom and security of Europe and its citizens", http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-security_en.pdf

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- **EUROBENCH:**[117] A project called to build the first ecosystem for testing and validation of bipedal robotics and which finances proposals for participation in the development and construction of the same with up to €300.000,00.
- **RobotUnion:**[118] Acceleration programme for start-ups in the field of robotics and which offers financing aids ranging from €3.800,00 to 1M€.
- **ESMERA:**[119] Objective to finance projects in the field of robotics capable of providing solutions to challenges posed, for which it offers funding of €200.000 per proposal.
- **DIATOMIC:**[120] Call for application experiments that aims to accelerate solutions that apply electronic components, sensors, smart objects and systems across health, agri-food and manufacturing (Industry 4.0) sectors. Up to €200,000 equity-free funding per experiment, tech & business support.
- **RobMoSys:**[121] RobMoSys will coordinate the whole community's best and consorted efforts to build an open and sustainable, agile and multi-domain European robotics software ecosystem.
- **ROSIN:**[122] ROSIN will create a step change in the availability of high-quality intelligent robot software components for the European industry. This is achieved by building on the existing open source "Robot Operating System" (ROS) framework and leveraging its worldwide community.
- **AI4EU:**[123] AI4EU seeks to develop a European AI ecosystem, bringing together the knowledge, algorithms, tools and resources available and making it a compelling solution for users. AI4EU will unify Europe's Artificial Intelligence community.
- **RIMA:**[124] RIMA will select 50 cross-border Experiments through the Open Call application. The focus will be on two types of eligible actions: Technology Transfer Experiments (TTEs) and Technology Demonstrators in the I&M robotics. Start-ups, small & medium-sized companies (SMEs) can apply.
- **DIH-HERO:**[125] DIH-HERO aims to boost innovation and implementation of robotics in healthcare. SME's and midcaps located in Europe can apply for funding in open calls from summer 2019 until spring 2021. Funding will be available for travelling, the development of demonstrators and technology transfer.

Other incentives

R&D TAX INCENTIVES

Governments in the EU and across the world are increasingly using tax incentives for Research and Development (R&D) in an effort to boost business R&D investments, increase productivity and economic growth. Among the most common R&D tax incentives we can find the following:

- **R&D tax deduction** (including super deduction): is a deduction that lowers a company's tax liability by lowering his taxable income. Deductions are typically R&D related expenses

[117] http://eurobench2020.eu/
[118] https://robotunion.eu/
[119] http://www.esmera-project.eu/welcome/
[120] https://diatomic.eu/
[121] https://robmosys.eu/
[122] http://rosin-project.eu/ftps
[123] https://www.ai4eu.eu/#about
[124] https://rimanetwork.eu/
[125] https://dih-hero.eu/

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that the taxpayer incurs during the year that can be applied against or subtracted from his gross income in order to figure out how much tax is owed.

- **R&D tax credit:** is a tax incentive designed to encourage companies to invest in R&D. Companies can reduce their tax bill or claim payable cash credits as a proportion of their R&D expenditure.
- **R&D tax relief:** it allows companies that carry out qualifying R&D related to their trade to claim an extra CT (corporation tax) deduction for certain qualifying expenditure. The level of relief available depends upon the scheme of the company and country
- **Patent box:** is a special tax regime used by several countries to incentivize research and development by taxing patent revenues differently from other commercial revenues. It is also known as intellectual property box regime, innovation box or IP box.

The European Commission carried out a study on R&D Tax Incentives in the 28 EU countries, USA and UK which can be consulted here[126]. This guide seeks to provide country-specific information that summarizes the tax treatment of R&D expenditure, together with specific R&D incentives available throughout the region.

In a globally mobile business world, R&D investment is considered to be a key factor to enhance skills, jobs and economic growth. Governments increasingly recognize the attraction of tax benefits to encourage companies to invest in high-value, knowledge-intensive industries and technologies. An updated guide was made by KPMG of R&D incentives in the EMEA region (Europe, the Middle East and Africa), this guide can be consulted here[127]. EY created a Worldwide R&D Incentives Reference guide which summarizes the key R&D incentives in 44 jurisdictions which can be consulted here[128]. Some examples of how these incentives haven grown in recent years are presented down below, the pace of change is expected to continue as R&D incentives develop and mature:

- Austria has increased its R&D premium from 10% to 12% of qualifying expenditure as of 2016.
- Czech Republic has increased the special tax allowance, which can be deducted from the tax base, by 10% to 110% of the associated R&D costs.
- France has introduced a new R&D tax incentive for operations in relation to prototype designs incurred by small-and-medium-sized enterprises (SMEs).
- Hungary has increased the R&D investments threshold available for the R&D tax credit to 340,000 euros (EUR).
- Italy introduced two new incentives in 2015 to encourage enterprises to invest in R&D: a renewed R&D tax credit and a Patent Box regime.
- Romania has introduced personal income tax exemption for salaries of researchers and other people working in R&D.
- South Africa has introduced additional benefits for expenditure on pilot/prototype plants exclusively used for R&D.
- Spain has introduced cash refunds for taxpayers who are in a tax loss position or who have reached the annual limit on tax credits applications.

[126] "A Study on R&D Tax Incentives Annex: Country fiches" https://ec.europa.eu/taxation_customs/sites/taxation/files/resources/documents/taxation/gen_info/economic_analysis/tax_papers/country_fiches.pdf

[127] KPMG. 2Emerged incentives guide" https://assets.kpmg/content/dam/kpmg/xx/pdf/2017/04/emea-rd-incentives-guide-web-04182017.pdf

[128] "Worldwide R&D Incentives Reference Guide 2017" https://www.ey.com/Publication/vwLUAssets/EY-worldwide-randd-incentives-reference-guide-2017/$FILE/EY-worldwide-randd-incentives-reference-guide.pdf

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- Sweden has introduced an R&D tax relief regime to stimulate investments into R&D activities. The maximum relief is 230,000 Swedish krona (SEK) per month for all R&D personnel for the entire group of companies.
- UK has introduced 10% taxable cash credits for large companies which can be used to settle taxes or be payable in cash. A more generous regime also applies for SMEs, which includes tax credit.

Among other initiatives, the European Commission has decided to re-launch the Common Consolidated Corporate Tax Base (CCCTB) project[129] in a two-step approach, with the publication of two new interconnected proposals: on a common corporate tax base (CCTB), and on a common consolidated corporate base (CCCTB). Companies operating across borders in the EU would no longer have to deal with 28 different sets of national rules when calculating their taxable profits. Consolidation means that there would be a 'one-stop-shop' - the principal tax authority - where one of the companies of a group, that is, the principal taxpayer, would file a tax return. On June 20,2018, France and Germany issued a common position paper on the EU's proposal for a CCTB Directive at EU level, while expressing their support to the CCCTB initiative. Negotiations continue at Council level.

2. Best practices & Success stories

This subsection shows several examples of success stories and best practices of start-ups and SMEs when introducing new products on the market, based on interactive robots.

The information is provided in a table format, following the structure of this chapter 4 of the White paper: sector where the robot is being developed/used, type of business and innovation strategy followed, applied tools for protection of intellectual property, source of funding.

KIRUBOTICS (start-up for surgical interactive robot)

TABLE IRMASS 16 CASE I

CASE:	KIRUBOTICS Surgical Solutions, S.L.
SECTOR:	Service sector / robotics for health/ surgical robotics.
TYPE OF SME / INNOVATION STRATEGY:	"External Open Innovation": The new company has external collaboration for part of its technological developments.
ROBOT NAME:	UR-10 (from Universal Robots)

[129] "Common Consolidated Corporate Tax Base (CCCTB) https://ec.europa.eu/taxation_customs/business/company-tax/common-consolidated-corporate-tax-base-ccctb_en

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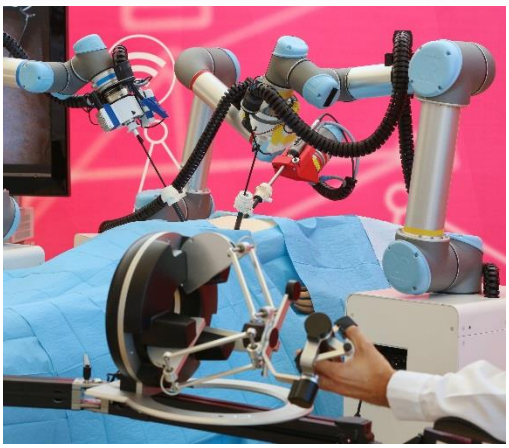
PHOTO OF ROBOT:	
ROBOT TYPE:	The system is composed of 3 UR-5 collaborative robots, which are teleoperated by a surgeon, to perform laparoscopic procedures. The robots have 6 degrees of freedom and are manufactured for general purpose (mainly for industrial sector: manufacturing, assembly, packaging, etc.).
ROBOT MANUFACTURER:	Universal Robotics (Denmark)
VALUE CREATION:	For this specific surgical application, the robots have been integrated together with a specific software development, with the aim to create a modular solution at a low cost.
CASE STUDY DESCRIPTION:	The robotic system from Kirubotics consists of three six-axis UR robotic arms that can be controlled individually or in coordination depending on the operation. The surgeon sees the surgical field on a 3D screen transmitted by an endoscope attached to one of the three arms. The surgical instruments that are attached to the two adjacent arms are controlled via a joystick console. The system's modular construction and the flexible options for using the UR robotic arms are its most advantageous features. Competitor applications are larger and more rigid by comparison and are generally only available in the form of expensive end-to-end packages so that hospitals end up paying for features that they do not even need to use. The UR robots and the software are combined into an open and low-cost system that is compatible with a range of different medical applications from numerous providers. The cost of acquiring, operating and in particular maintaining this innovative system will be significantly below the prices of other products currently available in the market. Robotic surgery is still out of reach for many public hospitals for cost reasons. The company Kirubotics pursues the goal of making an affordable, supportive robot available for doctors all over the world to assist them in operations that are difficult or even impossible to perform manually. Kirubotics will perform this approach through external collaboration with technological companies, specialized in robotics and software development. Also, a strong agreement

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	with the manufacturers of robots is foreseen.
APPLIED IPR:	European patents.
APPLIED FUNDING:	**Private:** Funds from corporate investors (engineering companies and Tecnalia Ventures) and private investors. **Public:** R&D programs at regional (*SOPREA* Program from Andalusian Gov.), national (*Cervera* program from Spanish Gov.), European (H2020 ICT Call).

CYBER SURGERY

TABLE IRMASS 17 CASE II

CASE:	CYBER SURGERY (Grupo EGILE)
SECTOR:	Service sector / robotics for health/ surgical robotics.
TYPE OF SME / INNOVATION STRATEGY:	"Internal Open Innovation" The research and use or IR robots is made by employees of Cyber Surgery with previous expertise.
ROBOT NAME:	They have used several types during the prototype phase. Now they are evaluating Kuka.
PHOTO OF ROBOT:	
ROBOT TYPE:	The system is composed of a 7 degree of freedom collaborative robot (probably a Kuka LBR)
ROBOT MANUFACTURER:	KUKA Roboter (Germany)
VALUE CREATION:	Assistant robot for spinal surgery, to help surgeons to insert prothesis with high accuracy and minimal risks.
CASE STUDY DESCRIPTION:	The EGILE Group started developing prothesis for maxillofacial applications, and later for spinal operations. The next step involved in prosthesis development was the development of its implantation methods in the operating theatre using intra-operative navigation and robotic technologies. They developed an "proof of concept" solution validated on animals. Thanks to the support of the Ministry of Economy and Competitiveness MINECO, through the project ELCANO from

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	the national INNPACTO 2012 programme, they were able to advance in enabling technology integration and design capacity: Infrared navigation and robotics. Following step was the creation of the spin-off Cyber Surgery.
APPLIED IPR:	European patents.
APPLIED FUNDING:	**Private:** Funds from the mother company (Grupo Egile) for the new business unit Cyber Surgery. **Public:** R&D programs at regional (programs from Basque Gov.), national (*INNPACTO* & *RETOS* programs from Spanish Gov.), European (H2020 ICT Call).

GOGOA Mobility Robots

TABLE IRMASS 18 CASE III

CASE:	GOGOA Mobility Robots
SECTOR:	Service sector / robotics for health/ Wearable robots for mobility and neurorehabilitation
TYPE OF SME / INNOVATION STRATEGY:	"External Open Innovation": The new company has received external collaboration for its technological developments.
ROBOTs NAMEs:	HANK (lower limb exoskeleton) / Hand of Hope
PHOTO OF ROBOTs:	
ROBOT TYPE:	Exoskeleton / Robotic hand
ROBOT MANUFACTURER:	The prototype of the exoskeleton robot was developed by the Neural Rehabilitation Group (Cajal Institute, CSIC) in Spain.
VALUE	**HANK** is a lower limb exoskeleton designed for rehabilitation

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CREATION:	of adults between 1.50 and 1.95 m in height, with a maximum body weight of 100 kg, such as stroke patients following neurological insults. It also can be used for gait compensation in patients who have paralysis of the lower limbs following spinal cord injuries. It is conceived for over ground gait training in a clinical environment as a bilateral wearable device with six degrees of freedom (DoF), in which hip, knee and ankle are powered joints. Various criteria informed the mechanical design: an exoskeleton design should be ergonomic, comfortable and lightweight, with a strong structure, adaptable to different users and with safety in mind. In HANK, aluminium 7075 is primarily used in the mechanical structure in consideration of mechanical resistance and lightweight.
CASE STUDY DESCRIPTION:	GOGOA born from a license of the Cajal Institute (which belongs to CSIC, the Spanish National Science Institute), and with the collaboration of Toledo National Paraplegics Hospital (main hospital in Spain focused on this kind of disabilities). The company designs and manufactures wearable robotics to assist and rehabilitate the movement capacity of people with Acquired Brain Damage (ABD) or Spinal Cord Injuries and to increase the movement performance of humans (rescue services, fire fighters, workers under special conditions). GOGOA´s Business model is open and focus on the rent, leasing and sale of wearable robotics for Hospitals and rehabilitation centres, to particulars, to public rescue services and to companies both to rehabilitate the capacity to move and to increase the movement capacities or reduce the lesions risk
APPLIED IPR:	European patents.
APPLIED FUNDING:	**Private:** Currently involved in funding rounds. **Public:** Funds for start-ups from the province of Gipuzkoa (Basque Country, Spain), R&D programs at regional (programs from Basque Gov.), national (*ICEX* & *ICEXNEXT* funds from Spanish Gov.), and European level (FEDER funds & FTI project funds).

ARMASSIST

TABLE IRMASS 19 CASE IV

CASE:	ARMASSIST: Cost-effective, comprehensive upper-limb robotic device for neurorehabilitation

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SECTOR:	Service sector / robotics for health/ Wearable robots for mobility and neurorehabilitation
TYPE OF SME / INNOVATION STRATEGY:	"External Open Innovation": The new company will have external collaboration for part of its technological developments.
ROBOT NAME:	ARMASSIST
PHOTO OF ROBOT:	 
ROBOT TYPE:	2 degrees of freedom, own design.
ROBOT MANUFACTURER:	Own development.
VALUE CREATION:	ARMASSIST is a low-cost portable device to rehabilitate upper limbs in patients who have suffered neuromuscular diseases or ictus. The system uses a mobile base to record shoulder and elbow movements, and monitors patients' improvements. There is a tele-rehabilitation platform that enables the real-time connection with the therapist to correct possible errors. The software platform allows remote patient progress assessment and management of the therapy based on serious games, which motivate patients to actively participate in their rehabilitation and **maximize the**

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	outcome.
CASE STUDY DESCRIPTION:	Robot developed by Tecnalia. Currently is in a TRL 6-7. Tecnalia Ventures is looking for entrepreneurs, investors and licensees.
APPLIED IPR:	2 EPO patents (pending), 2 registered software
APPLIED FUNDING:	**Private:** ReHub Investments S.L. Also, there are contacts with a Chinese licensee to industrialize the system and commercialize it in Europe and USA. **Public:** R&D programs at regional, national and European level.

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8. Summary of the White Paper

As highlighted in the executive summary and along all the sections, this document has been conceived to collect different types of information that could help entrepreneurs operating in two specific fields of the Interactive Robotics (i.e. Wearable Robots and Humanoid Service Robots). Particularly, the document highlights some guidelines found in interviews with experienced entrepreneurs (i.e. founders of companies or long-time members) and a summary of the main business models and the IPR strategies adopted by SMEs.

For the sake of clarity, the main outcomes of the document are reported hereafter.

- IR field is a very attractive and promising market (a lot of new companies have been founded in the last five years, considering only the WR and HUM fields) that, however, presents some negative aspects highlighted by the interviews carried out to the real actors of the market (i.e. the founders of the companies). In particular, most of them identified as blocking factors of the market the certification framework that it is still not mature, the psychological inertia of the stakeholders in accepting new technologies and the selection of the right business model for a SME to be self-sustainable in a market not yet structured (section 3).
- The overview of the robotic companies (section 4) highlighted that (i) most of the companies operating in these sectors are micro (staff headcount<10) or small (staff headcount<50) enterprises, (ii) the company growth trend in the last 5 years is steady growth for both sectors and (iii) most of the companies are located in Europe (50% and 60%, respectively for HUM and WR) rather than in the rest of the world. The overview also outlined the different approach followed in the two fields for the patents: for HUM companies, only 7 out of 27 companies have registered patents, highlighting the difficulties found by these companies to deal with high costs of patenting. WR companies have a completely opposite situation: only 12 out of 41 companies have not registered patents meaning that patents are one of the key factors for differentiating from competitors, creating a real added value to the robotic solutions proposed to the market.
- Database analysis is an accessible tool for companies to analyse the robotic market from different perspectives (section 5): in the case presented in the document, it was very useful to identify most of the HUM and WR companies worldwide (through the Crunchbase database) and to get an overview of the connections with public research grants (funded either by national agencies or by European Union) through the CORDIS database. It is worth noting that HUM and WR companies are in general well connected to the research world, being former spin-off companies and focused on innovative technologies (indeed, companies that are present in two or more research projects have a lot of first-hand access to the innovative results from the projects to eventually improve their products and services).
- Intellectual property (IP) rights are, in general, valuable assets for any business. They keep the business away from competitors, they can be sold or licensed (providing revenues) or be used as security for loans. Ignoring or undervaluing the potential of IP can lead to risky situations especially for SMEs, for example, opening the possibility of competitors of taking advantage of technical innovations, business, ideas, reputation in the market, etc. However, finding the right tool is not an easy task. Therefore, in Section 6, a list of the main tools to protect IP are shown. In addition, to gather information about the knowledge of the IPR aspects in the robotics community as well as the non-technical barriers found by robot manufacturers, a survey was developed, and stakeholders were invited to participate. Preliminary results of the survey highlight that the main concerns for the IPR aspects are

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the lack of knowledge, complexity, cost and lead times when managing IPR process. The most preferred type of IP protection among SMEs is the European and national patent and trade secret.

- Other preliminary results of the survey in terms of development and marketing of IR technologies identified as main concerns of SMEs the access to financial resources and business networks and potential investors as well as collaboration with research centres and integration of the product into existing markets. In addition, SMEs state as the most important issue for marketing of IR technologies the demonstration of the added value, followed by the benchmarking of the product and commercialization of the robot.
- Section 7 proposed a detailed review of the state of the art regarding the Business Model (BM) adopted by SMEs to address with nee ICT technologies (like IR). The section proposed a quick guide to recommend the suitable business model starting from the type of company among four different BMs: evolutionary, Adaptive, Complex and Focused. In addition, as highlighted by the survey conducted in section 6, access to funding, financial resources, potential investors and business networks is one of the pillars for the success of a SME. Therefore, in section 7, the main types of private and public funding opportunities are presented with some case studies. Public funding opportunities are referred to the currently available calls.

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9. (Annexes)

Reference documents for Section 4 - Overview of the Wearable Robots and Humanoid Service Robots companies

The excel table includes the list of companies for Wearable Robots (WRs) and Humanoid Service Robots (HUMs) and their data. The list can be download at http://inbots.eu/contributing-to-inbots/support-to-smes/.

Reference documents and stakeholders in Interactive Robotics

SPARC[130]

SPARC is the partnership for robotics in Europe to maintain and extend Europe's leadership in robotics. SPARC aims to make available European robots in factories, in the air, on land, under water, for agriculture, health, rescue services, and in many other applications in Europe which have an economic and societal impact. With €700M in funding from the Commission for 2014-2020, and triple that amount from European industry, SPARC is the **largest civilian-funded robotics innovation programme in the world**. SPARC is a Public-Private Partnership between the EC, and European industry and academia to facilitate the growth and empowerment of the robotics industry and value chain, from research through to production. SPARC is the agent for implementing robotics strategy within Europe. Its purpose is to connect the science base to the marketplace.

EUROBOTICs[131]

euRobotics AISBL (Association Internationale Sans But Lucratif) is a Brussels based international non-profit association for all stakeholders in European robotics. euRobotics builds upon the success of the European Robotics Technology Platform (EUROP) and the academic network of EURON (European Robotics Research Network). One of the association's main missions is to collaborate with the EC to develop and implement a strategy and roadmap for research, technological development and innovation in robotics, in view of the launch of the next framework program Horizon 2020. Towards this end, euRobotics AISBL was formed to engage from the private side in a contractual Public-Private Partnership, SPARC, with the European Union as the publics side.

euRobotics runs projects funded by the EC as well as initiatives in partnership with other organizations. These projects often allow the development of resources for the benefit of the whole community. Below you'll find a number of past and present projects that euRobotics has been involved in, as well as all public oriented deliverables developed during the lifecycle of the project.

- RODIN- Robotics Digital Innovation Network (2018-2023): RODIN project is key to creating an efficient and effective common European platform for robotics, creating synergies among four Priority Application Areas (healthcare, infrastructure inspection and maintenance, agri-food and agile production) and give a harmonized interface to the community. While each DIH operates autonomously RODIN's role is to identify commonality between them, create linkage, and provide a unified point of access to them.

[130] https://eu-robotics.net/sparc/
[131] https://www.eu-robotics.net/eurobotics/about/about-eurobotics/index.html

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It will promote best practice in the operation and growth of DIH networks and DIH themselves.

- SciRoc/ European Robotics League :The European Robotics League is run by the SciRoc project, consisting in local and major tournaments based in Europe. These competitions aim at replicating consistent benchmarking results more than stating a winner of a single event and have been designed to target three clear objectives: the European societal challenge of aging population, the strengthening of the European robotics service industry and to push the state of the art in autonomous systems for emergency response.

STRATEGIC RESEARCH AGENDA FOR ROBOTICS IN EUROPE (H2020)[132]

This document provides a high-level strategic overview for the robotics community. It is also intended to act as an introduction to the European robotics community for non-robotic specialists, policy makers, entrepreneurs and industries intending to use or work with the robotics market.

The Strategic Research Agenda (SRA) encapsulates the collective consensus of the robotics community in Europe. It sets out objectives and provides a coordinated and definitive view of the robotics landscape. The SRA sets out to achieve the following:

- To promote the objectives of the whole European robotics community
- To highlight opportunities for research and innovation
- To identify the current state of technology and identify future requirements
- To introduce the European robotics community to new stakeholders.

This document is augmented by the more technically oriented Multi-Annual Roadmap (MAR) and together they constitute source documents for the call texts of robotics programmes in Horizon 2020, the eight-framework programme. If you are a policy maker, investor, or entrepreneur trying to understand the robotics market in Europe, you should read this document.

MULTI ANNUAL ROADMAP[133]

The Multi-Annual Roadmap (MAR) is a companion to the Strategic Research Agenda (SRA) providing a greater level of technical and market detail. It is updated annually as priorities, technologies and strategic developments shape European research development and innovation (R&D&I).

The MAR is a detailed technical guide that identifies expected progress within the community and provides an analysis of medium to long term research and innovation goals. This document aims to provide the following:

- Further details of the applications and markets outlined in the SRA
- Background and progress targets for the technologies outlined in the SRA
- Basic information about the Public Private Partnership (PPP) and the Horizon 2020 instruments
- An overview of applications and targets for progress in each area

[132] https://www.eu-robotics.net/sparc/upload/topic_groups/SRA2020_SPARC.pdf
[133] "Robotics 2020, Multi-Annual Roadmap" https://www.eu-robotics.net/cms/upload/topic_groups/H2020_Robotics_Multi-Annual_Roadmap_ICT-2017B.pdf

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- An overview of the contribution robotics technology can make to the European Societal Challenges.

DIGITAL AGENDA FOR EUROPE[134]

The Digital Agenda presented by the EC forms one of the seven pillars of the Europe 2020 Strategy which sets objectives for the growth of the EU by 2020- The Digital Agenda proposes to better exploit the potential of Information and Communication Technologies (ICTs) in order to foster innovation, economic growth and progress.

The Digital Agenda's main objective is to develop a digital single market in order to generate smart, sustainable and inclusive growth in Europe and its made up of seven pillars: Achieving the digital single market, Enhancing interoperability and standards, Strengthening online trust and security, Promoting fast and ultra-fast Internet access for all, Investing in research and innovation, Promoting digital literacy, skills and inclusion and ICT-enabled benefits for EU society.

NETWORK OPPORTUNITIES

- **Robotics Brokerage Days:** They are match-making brokerages events for the robotics community where representatives from the EC and euRobotics provide all the information needed to participate in the calls open for robotics. In these events, euRobotics provide additional information, including on newly selected DIH and the proposers have the possibility to present their project ideas or expertise to the audience, offering them an excellent networking opportunity to complement their consortium. These events can be consulted in the EC agenda.
- **European Robotics Week**: the ERW offers one week of various robotics related activities across Europe for general public, highlighting the growing importance of robotics in a wide variety of application areas and the growing importance of skills in science, technology, engineering and math. *ERW 2019 will take place on 15-24 November 2019.*
- **European Robotics Forum 2019:** the ERF is the most influential meeting of the robotics community in Europe. Over 1000 European robotics top experts attend each year. ERF hosts a major exhibition where companies universities and research institutes will showcase the most advanced European prototypes, products, services and projects funded under EU's Horizon 2020 research programme.
- World mobile congress, International Conference on Intelligent Robotics (IROS), WeRob conference, etc.

[134] Digital Single Market, https://ec.europa.eu/digital-single-market/en

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