Great Expectations & Aborted Business Initiatives: The Paradox of Social Robot Between Research and Industry ⋆

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Abstract. The recent years witnessed a significant increase of interest in social robots whose main aim is to assist human users in their social and home environment. In academia, numerous successful results and proof of concept implementations have been published and demonstrated. Examples of promising social robots research topics include care of the elderly, education, and entertainment. Therefore these successes have generated high expectations for social robotics. Despite the hype, the last decade have seen the failure of many social robotics start-ups and initiative from the industry that appeared to be very promising. This article attempts to understand this paradox, and analyzes why breakthroughs achieved by the research community are not easily transferable into success stories in the industrial and entrepreneurial landscapes.

Keywords: Social Robotics · Human Robot Interaction · Industry

1 Introduction

Over the recent decade, the domain of social robotics witnessed a significant evolution both in research and industry.

Social Robotics aims to improve the robots' social capabilities and enable robots to work alongside with humans by providing emotional, cognitive and social cues to encourage the user(s) development and achieving a given goals [47] [31]. Social robots tackles the challenges of motivating the end-users, coaching, entertaining and rehabilitating by focusing on non-physical interaction.

Consequently, the social robots domain has recently received considerable attention. Despite the great expectations [54], the hype and some promising initiatives, the integration of the social robots into humans environments asks the

⋆⋆ Silvia Tulli is supported by the European Union's Horizon 2020 research and innovation program - grant agreement No 765955 ANIMATAS project

research community, in addition to other effort, to address more comprehensively a specific set of technological, economic, and societal issues [33]. The failures of social robotics companies reflects some of those concerns. As researchers, debating the business outcome of our research can provide a valuable contribution to the field by fostering the discussion towards potential solutions to existing and future problems facing the social robotics industry. The following analysis tries to identify the key challenges of social robotics investigating the paradox between the high expectations towards the social robotics research and the aborted business initiative in this field.

The paper is organized as follows. In Section 2 we provide a short overview about social robotics companies. In Section 3 we discuss the discrepancy between the user expectations, the market expectations and the companies' expectations. We conclude with the Section 4 identifying future directions for filling the gap between research and product development.

2 Background

Social robots are a disruptive technology, poised to have a profound impact on business, society, and the global economy [54]. A recent report from the United Nations about the the impact of the technological revolution on labour markets stated that AI and robotics are expected to radically change the labor market world-wide *destroying some job categories and creating others* [32]. The impact of AI applications and manufacturing robots on economies and labor markets is already tangible. Yet, this is not the case for social robots despite the fact that this technology is expected to have a significant impact on different application areas such as care for the elderly, customer service, education, child development, and autonomous vehicles [28].

As a matter of fact, in the past years promising companies are facing crises. Some of them are being bought by multinationals, such as Aldebaran, Boston Dynamics and Scharf, acquired by Softbank Group, while others shutdown (e.g., Willow Garage, Anki, Jibo). Developing and selling robots is challenging and require market knowledge that companies born as a spin-off from Universities may not have. This can be the case of Rethink Robotics founded by Rodney Brooks and Jibo co-founded by Cynthia Breazeal, both of them from the Massachusetts Institute of Technology. After releasing the collaborative robot Baxter and its counterpart Sawyer, Rethink Robotics has been acquired by HAHN Group, a German automation specialist [25]. Jibo stopped operating nearly one year after it first came to the market [23]. The same end has been encountered by Anki, a robotics and artificial intelligence startup founded by three graduated students from Carnegie Mellon University [3].

The failures of companies like Jibo [10], Kuri[11], Willow Garage [19] and Anki [3] are examples that bring some values to our reflection. Consumer robots may not be for general-purpose, as a matter of fact the majority of robotics companies who succeeds, design and build robots are meant for specific tasks: autonomous cleaning devices (e.g., iRobot Corporation, Samsung Electronics,

Neato Robotics, LG Electronics) surgical robots (e.g., Intuitive Surgical, MAKO Surgical Corporation), drones (e.g., Parrot SA, 3D Robotics, D-Jing Innovations Science and Technology) and toys (e.g., Hasbro, WowWee Group Limited). Examples of successful commercial social robots are robotic pets developed in largest public research organization and companies, such as Paro Therapeutic Robot (AIST [1]), PLEO (Innvo Labs established by Jetta Corporation [9]), AIBO (Sony Corporation [16]), Keepon (BeatBots [4]), and iCat (Philips [15]). Other examples can be found in the context of smart home assistants; Mykie robot [5] is a side project of BOSCH connected to an IoT ecosystem. The robot is designed to support users while they cook providing assistance for recipes and stock market prices. Mykie robot is activated and controlled by Amazon's Alexa, conversational virtual agents that nowadays dominates the market of smart homes devices [49] [51].

Having social capabilities embedded in robotic systems provide an additional emotional grip and more fluid interaction with humans, but is not enough for justifying the needs of social robots over long periods [44] [29]. The human-robot interaction should be driven by clear scopes, and the robot should be able to adapt to diverse and unstructured environments [24] [35]. However, notwithstanding the improvements in computer vision and machine learning, very few fully-developed intelligent autonomous systems capable of learning from the real-world and successfully interact with humans are currently available to consumers [38]. Thus, all these companies are trying to adapt their business principles and products for surviving against competitors breakthrough technologies and new customer demands. The paradoxes encountered by the research and industry involve three main actors: final users, organizations (companies) and researchers.

2.1 Challenges

Most of these social robotics companies follow what's known as *The Icarus Paradox* [48] . Securing an overwhelming amount of initial investment. Subsequently, due to *unforeseen circumstances* going out of business. In Section 3 we provide a more comprehensive examination of different factors and challenges the companies must endure. It's our belief that besides the technical, economical, legal, and/or ethical challenges listed below, the main affliction may come from a disparity between the expectations and *the reality* these companies have to endure.

Technical Factors Robotics industry suffers of the same obsolescence problem result of the rapid growth of the electronics industry [50]. The complexity and heterogeneity of the hardware and software behind the robotic systems generates problems of compatibility that are not solvable by the existing communication middleware software (e.g., ROS, YARP, URBI, ORCA Robotics, Miro).

Economic Reasons The inability of robots to escape the single turn structure of an interaction is one of the factors that determine the gap between the

promises of the robotics research and the expectations of the final users. In addition, robots still required specialized and costly hardware [18]. Unlike processors and sensors, the cost of the actuators strongly affect the final cost of the robot [2]. This first hinders both the placement into the home market which social robotics is mostly tailored for. Secondly, the feasibility to guarantee and reach the state of mass production without a yet established consumer base is a hard to withstand. Hardware also suffers from localization issues such as, different standards and certifications, language support and many nuances that are inherent to cultural diversity. The table below 1 reports the actual status of the company, the application context, the cost in euros per unit, the amount of units sold and the invested founding of some of the most known social robots [7] [4].

Table 1. List of companies targeting social robots.

Company	Stat[1]	Robot	Context[2]	Cost/Unit[3] (EU)	Units Sold[3]	Funding[3]
Jibo	c	Jibo	Comp	∼682	n/a	$72.7M
Anki	c	Cozmo, Vector	Ent., Edu.	∼127, 135	1.5M	$182M
Mayfield Robotics	c	Kuri	Comp	∼637	n/a	Bosch's Startup Plat.
UGOBE (Jetta Corporation)	c	Pleo	Ent.	300	100k[5]	$23.3M
Aldebaran Robotics (today Softback Robotics)	a	NAO, Pepper	Research, Ent., Edu.,	8k, 15k	10k, 1k [30]	20.3M $100b
PARO Robots	a	Paro	Res., Healthcare	4k	1.7k[6]	AIST Japan Gob.
SONY	a	AIBO	Res., Ent	3k	150k+11k[7]	SONY
Beat Bots	a	Keepon Pro	Res.	30k	n/a	n/a
Blue Frog Robotics	a	Buddy	Res. Ent.	$1550	+1000[8]	$617k
Hanson Robotics	a	Zeno	Res.	n/a	n/a	$21.7M

[1]Status: (c)closed, (a)active
[2]Application context: (Ent)Entertainment, (Edu)Education, (Res)Research, (Com) Companion.
[3]Costs, Units sold, and Funding are orientative and extracted from crunchbase and news sources

Legal, Ethical and Societal Issues Advanced AI systems able of collecting and analyzing data from their surrounding increases the possibility associated with inappropriate behavior [45]. The absence of a shared ethical code and moral requirements turns to be a determinant barrier for the success of any robotic company, especially when the products are supposed to interact with sensitive populations (e.g., children, subjects with psychological disorders, older adults). Recently EPIC, Electronic Privacy Information Center based in Washington DC, warned the Congress about the risks of the Internet of Things, and banished two internet-connected toys, My Friend Cayla dolls [14] and i-Que Robots [8], for violating the federal privacy law for children [17]. Likewise, robots as a product, must comply with all European Harmonized Standards (Directives) [21] [20] [22]

[4] The prices are not supposed to be compared between robots with different application context and functionalities

and/or internationally recognized Standards (or its localized version) [27] [36] that apply to any other (electronic) product placed into market.

3 Discussion

The breakthroughs achieved by the research community have to face several challenges that make them struggling to transfer encouraging research projects into success stories in the industrial and entrepreneurial landscapes. However, the growing number of attempts in the social robotics industry introduced noticeable technical advancements that can be beneficial for the field (e.g., ROS, developed by Willow Garage) such as tools for software implementation, and End-User Development Interfaces for personalizing the robot's functionalities (e.g., Choregraphe, Qt, Scratch, Yarp, Furhat Developer Docs [6]).

As aforementioned, our main hypotheses, the struggle and challenge of companies, relies on a misalignment of the expectations vs. the actual state of the stakeholders. We analyze this discrepancy in what follows.

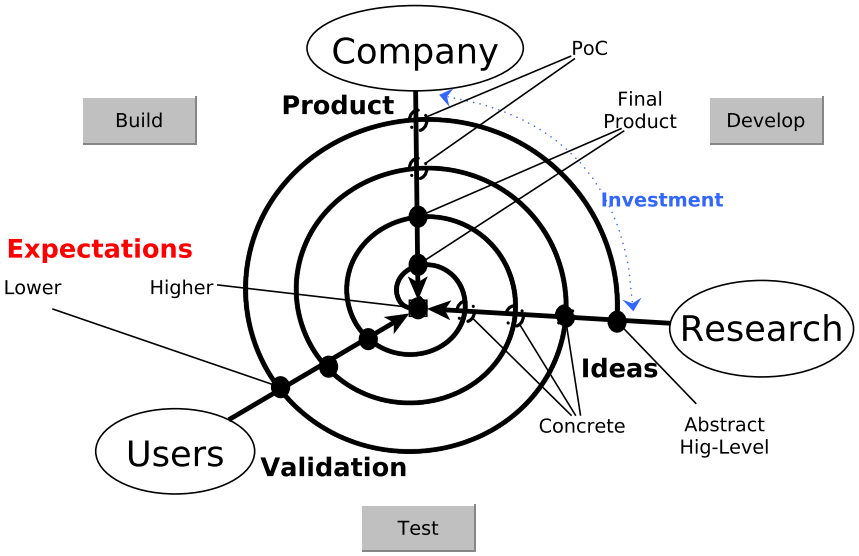

Fig. 1. Spiral of expectations for a product release.

3.1 The Spiral of Expectations

Three main actors are involved during the development of any robot. Research actor: that provides the ideas at different level of abstraction; Company actor,

provides the way and experiences for building products; and users, that validate the ideas and products generated by previous actors. Thus, it is created the Spiral of Expectations. This spiral defines several steps where a product or even a company/research could fell down to close. Fig 1 presents graphically the spiral and the milestones associated to each actor. These actors are under a common spectrum of expectations associated to services [42] [55]. In particular it is enumerated five levels: 1) ideal expectations, 2) normative expectations, 3) experience-based norms, 4) acceptable expectations, and 5) minimum tolerable expectations. The report presented by Shipton et al.[42] proposes a clear example thinking in a restaurant. It could be translated by a AI reporting service in the cloud: 1) The company is well known for their reports to business 2) When working in business account it offers an awesome service 3) The service is nice but they send a lot of spam after the registration. 4) The system will give us a report for continuing the research. 5) In free mode it will take hours, but finally we will have our report.

These five levels apply to each actor enumerated in our spiral of expectations. The expectation level in a step of the spiral depends by the previous actor in the spiral and has effects to expectations of the next one.

Users expectations Users generate it's own presumptions regarding robots capabilities. Several aspects influence this expectations such as, robot's appearance, social capabilities and actual autonomy and intelligence [29]. This generates an *expectations gap* between the robot capabilities and those projected by the user [43,41]. For example, anthropomorphic robots are expected to behave in an analogous way to humans, being the most important misalignment speech recognition. Users will expect full language recognition. It's important to note that these false expectations don't arise in the context of Industrial robots given the highly specialized nature of their application.

Researchers Expectations Researchers expectations[46] are mainly guide by the university expectations. These universities favours different items such as leadership, publications, citation rate and knowledge interchange. This knowledge interchange has in mind the industry collaboration and entrepreneurship of the researchers [53] [52]. However, researchers experience would be highly linked to single-topic experience in one academic field and this background does not prepare researchers to perform a straightforward jump from an idea to a product for consumers, and it is necessary an interdisciplinary approach.

As soon as the researchers lands in the entrepreneurship field, they have to adapt their expectations. Attending the classic perspectives of predictive and normative expectations, the researchers has to adapt their predictive perspective. This adaptation is based on what the researchers believe is likely to happen with their product out of the lab, but also, in normative perspective, what researchers believe that their product should offer. In both cases, they need to face these expectations with a team able to fulfill the gap existed between the academy and the market.

In addition, researchers lack of knowledge about the economic revenues associated to their entrepreneurship. Elements such as patents, licenses and royalties, would be out of their management, and they need a *driver* for guiding their assumption about the product path.

Companies' Expectations Given the misaligned user expectations, early adopters of the technology might not consider social robots a final product. This also generates a *market gap*. Thus companies must focus in delivering the *expected product* in order to cross the market gap with respect to its final user base or even early adopters of the technology. This gap is also identified by the type of approach the company has towards the market segment they target, being either mass consumer market of a niche application. Furthermore, a company that is ready to jump over the market gap may fail due lack of experience in addition the inability of implementing large scale/long term production plan. Careful planning is required to successfully withstand the uncertainty of a sudden grow on demand [56].

4 Conclusion and Future Work

There are few scientific papers that addresses the issues related with the deployment of research projects into the commercial products. Our analysis underlines the existing gap between social robotic research and industry. Further investigation should regard the factors that positively influence the success and the deployment of social robots in the human environment, looking at promising case studies such as LuxAI [12] and Mu Design [13]. Moreover, a data collection about the challenges of the social robotics industry and its relationship with the academic research and the end-users should be conducted. Online survey and in-depth interviews involving the marketing and business members of the companies should contribute to a more detailed overview of the real issues faced by the sector. A participatory design approach should be applied to deal with the users' expectations and provide solutions capable of meeting the needs of the population that actually is supposed to interact with the robots [37]. Future research should address the need of system's transparency to face the ethical issues raised by the opacity of complex decision-making systems, and to improve human-robot collaboration, trust and long-term acceptance [40] [34] [39] [26].

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