Robotics and Care: A personal engineering journey

Anders Stengaard Sørensen[1]

Abstract

This paper presents the author's experience of gradually applying robotic technology to traditional areas of Care, along with relevant observations on how Care for technology and processes converge with Care for people in the field of *welfare-technology*. It describes an evolution from experimental industrial automation to almost commercial welfare-technology over a 15-year period. It is driven by the author's gradually increasing curiosity and Care for physical interaction between humans and robots, combined with an increasing awareness of the potential of caring technology in welfare.

Keywords

Robotics; Care; Ecology of Care

Introduction

During 25 years of experimental robotics, my projects have gradually changed from showcasing the potential of mechatronics and robotic servants (replacing human effort), toward technology that acts as an extension to humans, in welfare-technology (expanding human effort). As I was introduced to the Ecology of Care (EoC) framework, it became clear that my experience and journey through experimental engineering was closely entwined with the Care concept. By considering the following project portfolio through the lens of Care, it becomes evident that I have started by caring about technology for its own sake, and then, project by project, changed my focus to how technology can be applied to Care for people.

My current position on technology and Care can be summed up as:

- technology has always been about Care;
- technology never cares in itself;
- Care is in how people use technology;

✉ Associate Professor Anders Stengaard Sørensen: anss@mmmi.sdu.dk

[1] Training and Technology Lab, University of Southern Denmark, Denmark

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- in welfare-technology, Care is a prime objective; and
- contribution to "self-reliance" is an important measure of Care in technology.

Background

With a Master's and a PhD degree in computer systems engineering I am a very geeky engineer. I find great joy in studying, teaching and using engineering mathematics such as how Euler and Fourier used imaginary and complex numbers to unify the exponential function with sine and cosine, the benefits of using hexadecimal numbers when programming robots, or the finer differences between different types of transistors.

Figure 1. 10 degrees of freedom hybrid robot.

Most of my career has been dedicated to experimental robotics, developing the electronics and control software that enable extremely complicated robot mechanisms to be controlled accurately enough to perform useful processes. A passion for connecting the physical world of reality with the virtual world of computers (Cyber-Physical systems) is my primary driving force. I have no formal education or experience with Care, and hence no strong professional opinions on the topic. My opinions and observations are entirely based on experience and the observations obtained from developing technology intended to assist humans in various ways.

The *DockWelder* and *SmartPainter*

From 1998 to 2003, I was involved in the development of a robot technology with long horizontal reach, based on combining off-the-shelf robot arms with a "variable

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geometry truss" mechanism originally devised by NASA for space-robotics. The basic concept is clearly visible in Figure 1 and the most complex setup is shown in Figure 2.

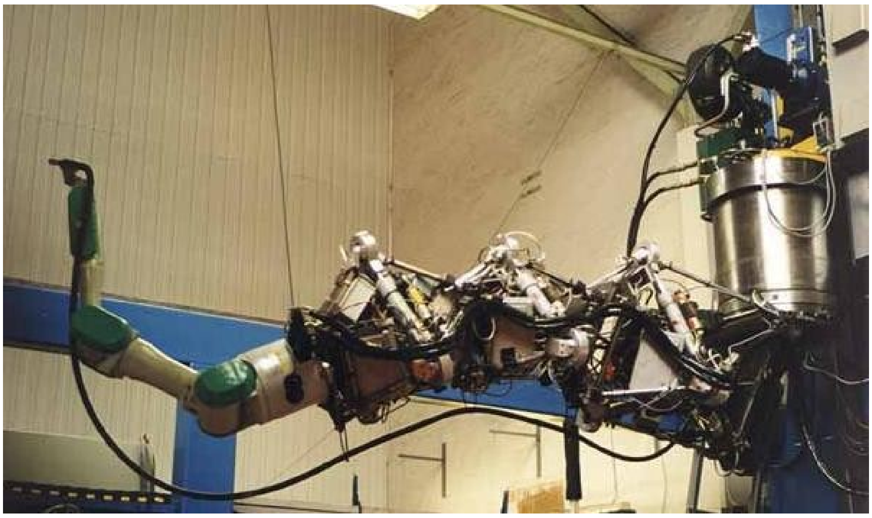

Figure 2. 18 degrees of freedom hybrid robot.

The projects were an ambitious attempt to automate the dock assembly and painting of prefabricated ship sections, and were named *DockWelder* and *SmartPainter*. The projects proved that the concept was technologically feasible, but was not an attractive business case due to its vast complexity. With the clarity of hindsight, these projects expressed an almost desperate imbalance between technology and practicality. If we crudely consider the "focus of Care" in these projects, it can be claimed that:

- engineers Care about enhancing and demonstrating skills and creativity;
- company and public investors Care about maintaining productivity through automation; and
- public investors Care about increasing technical knowledge in society.

In these cases, any Care "about people" is indirect, accomplished by maintaining and creating new jobs using technology. We are clearly considering an attempt to create "robots that do something for people", i.e. welding and painting ships.

RoBlood: A blood sampling robot

From 2006 to 2011, I headed *RoBlood*, an effort to develop a robot to automate the process of drawing blood samples in hospitals. The number of samples had increased steadily by 7% annually and was at that time a strenuous 9-to-5 job for 5 to 20 people at each major hospital. Most employees changed jobs after 2-4 years, due to the physical strain involved in doing the job.

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The *RoBlood* project was co-funded by the Vejle Hospital, the University of Southern Denmark and Kolding Design School. It was conducted in an open, transdisciplinary project environment, including personnel and students from all three institutions.

Many interesting lessons about detecting blood vessels, inserting needles, transfixing arms etc. were learned, but the most interesting were the lessons about psycho-physical interaction. It was proposed that a person's discomfort about blood samples stem from the violation of their preferred body language. During blood sampling, patients are asked to sit with arms apart and forward; a completely open "come and bite my throat" posture (see Figure 3). The design students proposed a system that allowed users to partially fold their arms; a reserved and reluctant posture adopted during each procedure. They made a procedural "mock-up" to demonstrate the psychological difference. Although it was never formally tested, the students had made a good point. It did feel much better.

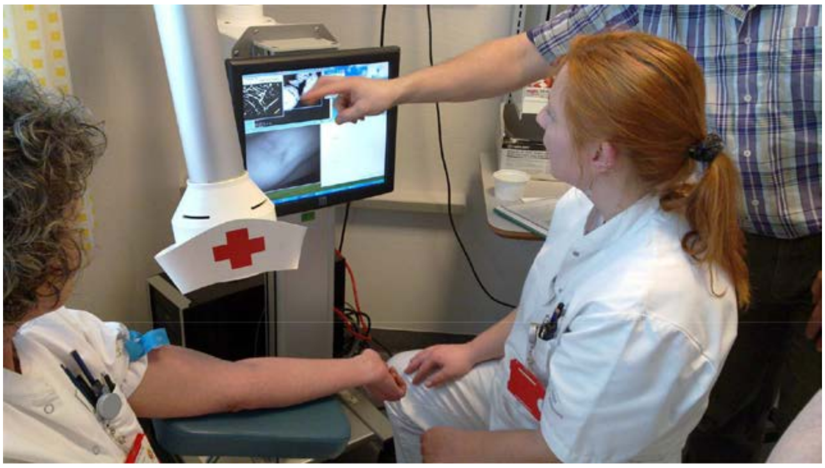

Figure 3. PhD student Thiusius Rajeeth Savarimuthu, demonstrating his vein detection prototype, using the traditional posture for blood sampling.

During the project, it became increasingly apparent that successful automated blood sampling would have to be something the patient did with the robot, rather than something the robot did to the patient.

Considering the "Focus of Care" within the *RoBlood* project, it can be claimed that:

- hospital administrations Care about maximising efficiency, decreasing cost and increasing productivity;
- hospital departments Care about reducing strain on personnel and improving conditions for patients;
- a large segment of experienced patients Care about maximising efficiency and decreasing waiting time;
- the smaller segment of inexperienced patients Care about comfort and support;

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- the engineers started out caring about a robot applying a process to an arm, but ended by caring about how to create an interaction between the robot and the user;
- Care for the personnel is indirect, as they are merely relieved by technology; and
- Care for the patients was originally concerned about comfort, pain and anxiety when the robot was doing something to them; it changed to concerns about how to get patients to interact with a robot that did something to them.

Butler robots

In 2009-2010, I was briefly involved in a project to develop an advanced service robot, a *ButlerBot*. The intention in this project was to help disabled people in their households; not unlike a service dog or personal assistant. Such projects are very important as they are the only way to eventually derive robot servants that might be actually useful and worthwhile. One particularly interesting feature of the project was the participation of rehabilitation therapists. They were very clear about the dangers of robots providing too much service as they pointed out that this could pacify patients and inhibit rehabilitation. It was very surprising to meet project partners who seriously tried to restrain the ambition level of the project, out of Care for the end users, while everybody else seemed frustrated that the level of ambition in the project was perhaps too high for contemporary technology.

The project was successful in reaching important conclusions regarding remote control of robots, and clarifying the need and possibilities for remotely moving personal objects in private homes. However, it will still be some years before flexible service robots will be able to compete with human assistants both in the lab and most certainly in everyday situations.

The “Focus of Care” when I left this project appeared to be:

- municipalities Care about boosting patient's self-reliance, to reduce the need for personal assistance;
- therapists and caretakers Care about boosting the patient's self-reliance, to improve the citizen's quality of life;
- some patients cared about boosting their self-reliance to improve their quality of life; others cared about reducing the daily physical challenges to a minimum;
- engineers Care about increasing the ability of service robots, by solving a small and well-defined subset of challenges that occur to robots in private homes;
- behaviourists Care about the technology’s ability to instigate changes in patient behaviour; and
- the Care for people was disjointed as some project participants were motivated by the technology’s potential to directly increase a patient's self-reliance. Other

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participants were motivated by the potential to avoid physical challenges. Some were motivated by the sheer challenge of getting robots to work in private homes where the patient and their possessions could get in the way.

Figure 4. *ButlerBot* demonstration.

Rehabilitation robots

1. *RoboTrainer®*

The therapist's notion from the *ButlerBot* project (see Figure 4), that "robots should not pacify users with too much assistance", prompted a deeper question: should robots actually provide patients with resistance? The immediate answer was "Yes, it's called training and it's great for rehabilitation". A short time later, in 2010, I was approached by Allan Lauritsen (a patient recovering from a serious injury), who wanted a robot training partner to help with his strenuous and monotonous rehabilitative training program.

Together, we created *RoboTrainer®*, an automated biceps/triceps training machine, with a powerful computer controlled motor replacing the normal weight load. Meeting Allan brought my academic and theoretical skills together with his specific personal needs, ideas and focus. Allan has been a tremendous inspiration and catalyst for my decision to focus on technology that is available to ordinary people, in terms of simplicity and cost.

During 2011, *RoboTrainer®* was made available to a student – Jesper Kiersgaard – who had suffered 90% paralysis in his left arm and shoulder, due to a traffic accident (see Figure 5). He had previously attended three years of normal rehabilitative training, which was terminated by health authorities due to lack of progress. *RoboTrainer®* was programmed to counteract the gravity on Jesper's arm, allowing him to perform full curl repetitions, almost indistinguishable from normal training. Over a period of six months, Jesper trained 3 x 20 minutes a week. In that period, the strength of his upper arm progressed from 1 kg to 7 kg, constituting an almost full rehabilitation of the arm

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(see Figure 6). After the first training session he exclaimed: “For the first time in three years, I feel tired in my arm”.

In this project the focus of Care can be summarised as:

- the user cared to participate in effective training, hoping to improve;
- the engineer cared about applying his skills to the specific problem and helping the patient; and
- the training expert cared about embodying his knowledge about training in a robot that could be a training partner for himself and others.

It is important to note that the technology in *RoboTrainer®* is really quite simple. *RoboTrainer®* could easily have been created 25 years ago or even earlier. This constituted the first project where I was not driven by my Care for new technology. It was still driven by curiosity, but for a new way to use a robot, rather than by the novelty of the robot itself. This robot only does something with people.

It is also interesting to reflect on whether the training expert and the engineer’s “Care” for the patient has been embedded/embodied in the robot. Especially since the “interesting” part of the robot behaviour is only a few lines of code.

Figure 5. Jesper Kiersgaard using *RoboTrainer®*.

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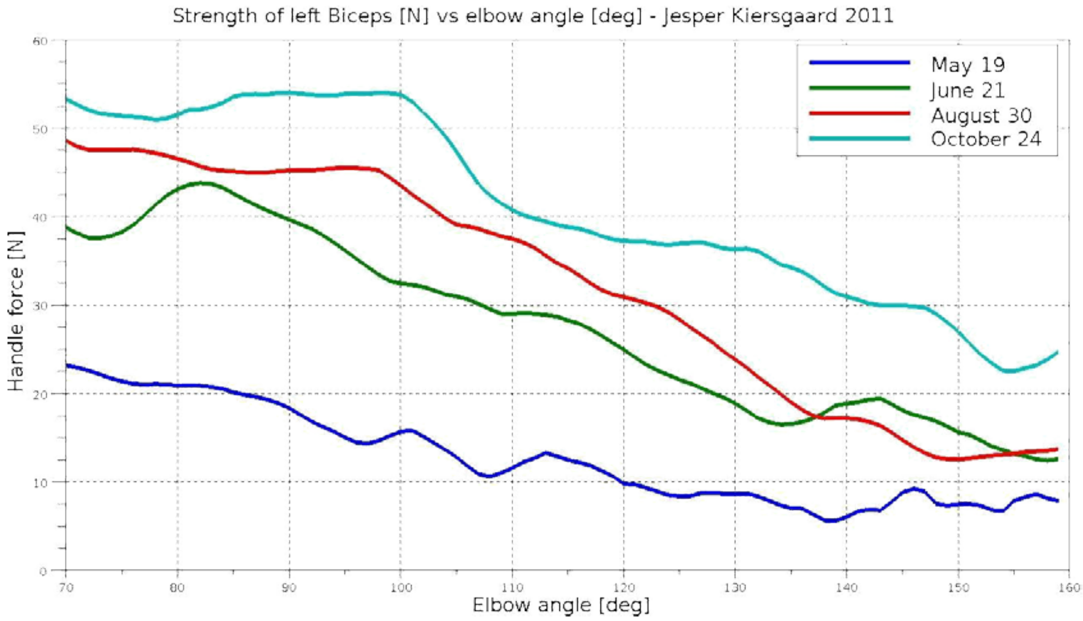

Figure 6. Graphing Jesper Kiersgaard's progress.

2. Universal *RoboTrainer*

From a practical standpoint, *RoboTrainer®* (described above) is limited to one function: biceps/triceps training. To address a reasonable segment of patients, we would have to construct a whole spectrum of similar machines dedicated to shoulders, wrists, hips, knees, etc. This would be highly impractical and expensive for the health sector and for patients. Since the training is constituted by the interaction of the user and the "handle", we simply moved the handle to a commercially available off-the-shelf robot arm and programmed it to move the handle along any path desired by the patient or training expert. After three years of advanced mathematics and programming, a patient or therapist can now teach the robot a path by demonstrating the desired path using the patient's own arm movements, perhaps assisted by a therapist. The robot can then repeat the path over and over while mechanically counteracting gravity on the user's arm. We expect to enable patients with up to 90% paralysis to train any repetitive motion that they or their therapist desire.

The focus of Care in this work can be summarised as:

- hospitals Care about the ability to improve rehabilitation results and/or reduce therapy costs;

- therapists Care about contributing to future tools for rehabilitation and learning about new possibilities;

- engineers Care about developing and improving the robot control to enable the motion and interaction specified by the therapists; and

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- patients have scarcely been involved yet, but are assumed to Care about participating in effective training.

The need for a large technical effort has offset the focus of Care in this project with respect to its origin. When the project enters a phase with more patient interaction – deploying and testing the robot – Care about the patient's perspective will become more focused; however, we are concerned that the technical complexity of the robot will inhibit the robot in "projecting Care" in the same way as the original *RoboTrainer®* did.

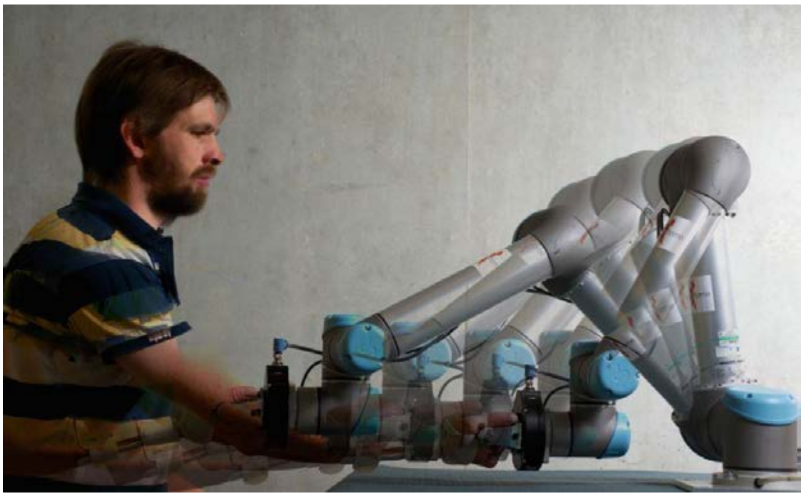

Figure 7. Jacob Nielsen and Universal *RoboTrainer*.

3. *RoboTrainer*-Light

As Universal *RoboTrainer* (see Figure 7) is likely to be too expensive for decentralised deployment, we fear that it will only be part of a patient's daily training, as long as the person is in the hospital. We would like to develop a technology that is simple and cheap enough to be used in private homes. Thus, the challenge became: what is the cheapest possible training robot?

RoboTrainer-Light was our answer (see Figure 8). It is simply a motor pulling a string, using a fast and precise force, position and speed controller. In mass production, it can be marketed for a few hundred dollars, and thus become available as daily training for a large number of people with partial paralysis, from accident victims to stroke patients. The simplicity of *RoboTrainer*-Light has enabled us to demonstrate and test it with a large base of users, therapists, doctors, technological experts, students and so on, while developing ideas, applications and software for it.

The focus of Care in the *RoboTrainer*-Light project can be summarised as:

- the users Care about participating in effective training;
- doctors and therapists Care about keeping patients active across the transition from hospital to home, as well as monitoring and evaluating training remotely;

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- therapists Care about the ability and motivation to train at home as well as the potential for increasing and documenting the effectiveness of home training; and
- engineers Care about enabling patients to train with the simplest possible equipment, in order to maximise availability.

Making the robot simple is a prerequisite for enabling users to afford and operate the equipment. Making it work is a prerequisite for the robot to have an effect. The drive toward simplicity and availability is partly a technical challenge, catering to the engineer’s Care for challenges. This happens to coincide with Care for helping the user rehabilitate by making the equipment feasible and available.

Figure 8. Jørgen Maagård and *RoboTrainer*-Light.

Conclusion

Everything we do is motivated by Care, including the development of technology. Technology has always been about Care. The development of a baby's pacifier is motivated by Care for the baby's and adults’ comfort, and probably also by Care for producing, marketing and earning money from it. When discussing and evaluating Care in the context of welfare-technology, we need some more specific benchmarks.

The impact on “self-reliance” is an important benchmark in any health ecology based on Care. It is an underlying theme in all the cases presented above. Every case has been about technological solutions with the potential to offset or augment self-reliance in some way. Industrial automation (like *DockWelder*) enhances the self-reliance of the company and hence employees and owners, as manufacturing processes become faster, cheaper, more reliable and less straining.

RoBlood enhances self-reliance for chronic patients, by reducing the amount of time and hassle spent on blood sampling. It also enhances the self-reliance of the health service in the same way as industrial automation. Home automations like *ButlerBot*

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enhance the self-reliance of the person they serve, as more processes in the home come under that person's influence/control. Robot training devices enhance the self-reliance of patients by restoring strength and mobility. All four case studies can be said to exert "Care" linked to "self-reliance", but our valuing of Care varies with our perception of the way the robots service us: specifically, whether they do something for people, do something to people, or do something with people.

Another important benchmark for technology and projects versus Care is practical feasibility, as it can be useful in resolving the balance between caring for knowledge/technology/equipment/process and caring for the people that need it. I do not advocate any particular balance, but I find it extremely important that the balance is consistent with the expectations of all the stakeholders in a particular project. Many of the projects presented above have been very successful, even though they were obviously unfeasible. They were successful because their stakeholders were interested in new knowledge, rather than the specific application. Others were partial failures, as people-focused stakeholders were disappointed by the excessive technological ambition coming from technological stakeholders. This resulted in a lot of learning, but little direct caring.

Adherence to the goal of achieving an Ecology of Care is a deciding factor for the success of technology and related services. In practice, technology will only be meaningful and hence useful, to the people who use it and the stakeholders, if the technology satisfies their needs and expectations. It is, however, vitally important to realise that Care is in fact a part of a wider ecology, not a single definable goal all stakeholders can agree about.

Developing a framework for discussing, and perhaps even comparing Care and different aspects of Care, will be an excellent supplement to existing project and technology assessment tools. It is especially valuable when technology enters into areas where Care is focused directly on people, rather than abstractly via processes and tools.

About the author

Anders Stengaard Sørensen is an Associate Professor in training technology electronics and robotics. He is Head of the University of Southern Denmark's Training Technology Lab and founder of the startup company BandCizer, who develop and market sensors for resistance band training and other widespread home-training devices.

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