Chapter 3: Knitting Together
Collaboration as Careful Coboting

This third and closing chapter knits together debates on cobots as co-workers or substitute workers (Chapter 1) with the insights from realising knitting collaboratively with a cobot (Chapter 2), in order to generate a knitting-related configuration of present possibilities of collaboration between a cobot and humans, as well as to open up points of departures for speculating about technological futures of re-crafted human-robot-collaboration.

More precisely, I develop an account of human-robot collaboration as *careful coboting*. This term signifies first that HRC is not based on capacities either embodied by the human or the robot, but rather emerges from the entanglement of the cobot and its affiliated humans in their intra-active encounter, captured by the term *coboting*. Second, it defines the analytical sensitivity towards coboting through a stance of *care*, making the situatedness of HRC the matter of care in designing and debating 'our' robotic futures. Finally, careful coboting is a navigational tool for exploring new modes of relating between human and machine through embodied experiences of caring for HRI, as I will continue to argue throughout this chapter.

Robotic knitting diffracts the relations between the cultural technology of knitting and the cutting-edge technology of the robot arm—in each, their multiple meanings—as well as those relations between entities knitting collaboratively with each other. Through this, my approach to human-robot-collaboration enables me to constantly probe ways of relating, and therefore modes of being, through collaborating. Thus, the needles and yarn in the robotic lab became the tools to think and act with: To inquire how 'we' imagine collaboration between humans and robots and to challenge this thinking by probing the enactment of hand knitting as a collaborative task.

Starting with a project that appeared at a first glance either amusing or astonishing, then writing a book documenting my project work, I wove together

a critical examination of discourses relevant for understanding the sociomaterial figuration of the robotic (co-)worker with a respecification of material practices through my and my team's engagement in HRC through knitting. Thus, this book shows the myriad and complex dimensions of what started as a somehow funny idea, namely to knit with a cobot, leading to a practice of handicraft as engineering and vice versa. Culminating in the notion of careful coboting as a key concept for re-crafting robotic futures and engaging with robots differently, this notion centrally assembles (1) the neglected labours, (2) the intra-active processes of co-shaping, and (3) the situated, sociomaterial conditions and practices of enactment, including (4) the material and the metaphor of the yarn and textile structures as foundational matters of care for human-cobot-relating.

3.1   String Figuring Storylines & Sociomaterial Configurations

Continuing to be guided by my experiences in the lab, in this chapter I will revisit Chapters 1 and 2 through remembering selected encounters between me, as the PI of the project, and a mostly academic audience interested in DRDK during the time the project was running. Essential to becoming a robotics practitioner through DRDK was to communicate the project in a documenting manner via different media, such as a blog, but also other channels of science communication inside and outside of the Technical University of Berlin (TUB), like the monthly news magazine of the TUB, and Open Science Events, including the open lab events at the MTIengAge lab and conferences of diverse disciplinary audiences. In addition, the project also developed quite a momentum with regard to invitations for project presentations on different occasions and in varying disciplinary circles, ranging from STS meetings with a focus on robotics and AI, to courses in machine learning and textile technologies, to robotic working groups.

These encounters not only shaped my thinking, but they also expanded the frame and re-designed the course of the project. Thus, realising robotic knitting was not confined to the space of the lab, but was rather also effected by the constant exchange through science communication channels. In re-narrating selected experiences of presenting and debating the project while we were realising robotic knitting, I take these experiences and debates as my points of departure to outline here the main results of robotic knitting, in-

cluding the argument for an account of human-robot-collaboration as careful coboting.

I can generalise my experience presenting DRDK, across very different audiences and occasions, as mainly causing two different kinds of reactions, either scepticism or fascination. I experienced these situations as sometimes quite overwhelming. They were not only densely composed of strong emotions of either rejection or enthusiasm, but also had a tendency to make me feel like I was turned into some kind of mediator between the robotic imaginary and a 'robotic reality' for different crowds. Oddly enough, this was prone to make me feel like I was pushed into a position of *objectivity* and 'telling the truth' about robotic presents and futures, while to me, it remained crystal clear that my position has been and remains to be that of a queering witness to string figurations of robotic knitting with the aim to produce situated knowledge on human-cobot-relations in practice *as* theory through knitting collaboratively.

In addition, speaking from my experience of engaging with robotic matters already in my dissertation project on *Robotic Companionship* (Treusch 2015) and since then, what becomes tangible on this and other occasions is that the topic itself, especially through its ubiquity in popular media, is one almost every person has an opinion on. This is not something I find problematic, quite the contrary, it can be an important means for sparking a conversation across diverse groups of persons. However, at the same time, it seems unavoidable for a person living in the Global North to not develop an idea of a robot, what it will look like and how it will behave, how 'we' humans will relate to it and if it is a potential threat or a helpful machine. The challenge I countlessly encountered and encounter is to find a way of avoiding being, again, pushed into a position of *objectivity*, letting my conversations end at the point where I am to tell what current cobots really can and cannot accomplish. Rather, this can only be the point of departure for what I framed earlier as a process of becoming the sand in the gearbox of a too well-oiled *technoliberal* machinery. It is the disruptive momentum of becoming the sand in the gearbox which further allows me to dis- and re-entangle strings of story- and timelines, as well as of sociomaterial configurations of robotic present and futures and concomitant relations of HRI. Instead of delivering clear answers to questions such as "Are the robots really coming?" or "Should 'we humans' reject or embrace this technology?," I offer to become *response-able* (Haraway 1991, Schrader 2010) to the challenge that the contemporary robotic imaginary poses. As Haraway points out, to become response-able is about becoming "answerable [and accountable] for what we learn how to see" (Haraway 1991, 190). Thus, in becoming

response-able, that is, becoming responsible through becoming able to re-spond, to knitting as a craft practice of fabricating worlds and as a practice which entangles matter- and meaning-making, in what follows, I will revisit three different conversational agglomerations which I encountered through-out the project. In this, I draw results from insights presented in the previ-ous chapters, and in navigating through these debates and the results of this book, I will dwell on my technofeminist way between utopian optimism and pessimistic fatalism.

Furthermore, I essentially regard this form of concluding as continuing with playing with strings, following them, mapping nodes and paying atten-tion to (unasked-for) patterns of interference that are constantly moving from the background to the fore and vice-versa. Writing this sentence, I sit in front of a green cardboard box in which we used to store our needles and balls of yarn, as well as knitted artefacts, during the project, where they remain now that DRDK has ended and we have had to move out of the robotic lab. I open this box, grab two balls of yarn and start engaging with individual threads, caught up in the unavoidable mess produced by the unravelled threads in the box, while re-visiting scenarios of the project that form a node and a pattern to hold nodes and patterns of yarn from the project in my hands. Playing with strings of yarn, following this string leads me to another one, one that enabled me to find the words to express the complexity of knitting collaboratively with a robot.

"But—How is this Feminist?"

One articulation of scepticism and sometimes even rejection towards the project, which—to my surprise—I have encountered many times, relates to the feminist dimensions of the project. In my view, it should have been obvious that my project was deeply rooted in technofeminism with its foci on (1) epistemological inquiries of what can be known by whom and what that are always entangled with ontological dimensions of knowledge practices, including agential configurations and sociomaterial conditions of knowing, and (2) on exploring possibilities for making a difference in the design and development of technologies that pivots around the first focus. Further, I regard a diffractive methodology in its aim to find the cracks in the canon from the position of the queering witness as emblematic for this. However, when communicating the project outline and its goals to various audiences, I was facing one re-occurring challenge, namely being asked: "But—how is

this feminist?" When I was asked this the first time, I was baffled, tempted to answer with "But—how is this not feminist?" and it took me a moment to understand where this question was coming from. More precisely, I figured out two different expectations towards the project from which these questions were raised: first, the expectation to target the unequal representation and access of women* in the field of robotics and computer science in Germany, and second, the expectation to show that robots are not and will never be ready to become (human-like) cobots, but that claims of a robotic future with co-workers is rather a techno-fantasy emerging from a predominantly White and male robotic culture that 'we feminists' should dismiss—at least more than I do. The assumption around the first was that bringing females with knitting needles into a robotic lab in which exclusively male engineers are working, that I would perpetuate existing sexist stereotypes and cultural codes which associate females with 'soft handicraft' and males with 'hard technology', reproducing the gendered labour division already in place. The bone of contention here was hand knitting and my female-coded team, including me, and I remember conversations with very different persons in which—after convincing my conversation partner that I was indeed a technofeminist—I was continually asked several times: "But—why knitting?" It was not in the least my attempt to convince anyone that either knitting should be regarded as by itself not only a political, but somewhat emancipatory activity, nor that this scepticism towards the project seems to be based on an underlying perpetuation of the very dichotomy between knitting and robotics in its gendered coding. Consequentially, this kind of conversation ended at an impasse.

The second expectation appears to be built on the assumption that realising knitting with a robot means contributing to a techno-solutionism inherent to contemporary technology development, prone not only to attesting that there exists a techno-fix for every societal problem, from de-biasing algorithms, making robots social agents, to data security concerns, but also that contemporary cobot technology also already embodies the potential of cobotic futures. Realising hand knitting then is under the suspicion to be just another contribution to propelling processes of automating every sphere of human everyday lives further. With the project's goal to intervene exactly into this debate, through becoming the sand in the gearbox as a move for performative re-figurations of human-machine collaboration, conversations which reached this point also ended at an impasse.

Writing about these feelings of impasse, I aim at resuming my project work here, while taking into account the affective landscape of these experiences in order to become response-able to and for the two described impasses. The work of Anne Cvetkovich on feelings, handicraft and feminism turns out to be vital in aligning my arguments here further. The cover of her *Depression: A Public Feeling* (2012) is illustrated with Allyson Mitchell's artwork called *Hungry Purse: The Vagina Dentata in Late Capitalism* (see ibid., plates 8-11). Depicted is an opening, assumingly a door frame, completely covered in shag rugs, crocheted fabric and other textile materials, all of them recycled (ibid., 185), making up a structure in different shades of pink mixed with red, black, grey, and white. Looking into the opening, I look first at drapes of fabric, representing "labial folds" (ibid., 186) to then look into a kind of a tunnel which ends in a smaller room, representing the female womb (ibid.). Everything is covered in textile materials, either shag rugs or crocheted and knitted surfaces, for instance structured trough zigzag or arrowhead patterns and, later in the tunnel and room, also granny squares. Close to the opening hangs a huge light pink tassel from the fabric ceiling. The amount of fuzziness of this artwork is so tangible that it can be captured by a photo—the cover feels fluffy and always fascinated and provoked me to imagine how it would feel to touch and walk through the Hungry Purse, taking a break on my way to then end up in the womb, the connected room.

Mitchell is working with materials that might be regarded as *outmoded* (ibid., 185). As Cvetkovich (ibid.) further notes, "for her [Mitchell], the strong and frequently negative feelings attached to objects that are sentimental, cute, garish, cheap, or excessive resemble the feelings associated with both fat girls and feminisms, and this reservoir of shame, abjection, and mixed feelings is a resource for queer reparative strategies." Mitchell thereby engages foremost with negative feelings associated with a certain kind of feminism, namely that of lesbian feminism as a form of feminism which appears to be as outmoded as the rugs, plaids, and other textile materials and the artistic handicraft practices, the crocheting and knitting. Mitchell coins her thinking and art practice as *Deep Lez* (Mitchell cited in Cvetkovich 2012, 186), a perspective of "acknowledg[ing] and address[ing] histories of conflict" (Cvetkovich 2012, 186) and of "seek[ing] to avoid political depression by seeing the past as a potential ally and resource" (ibid., 187). Thus, such acknowledgment does not mean to reinforce these conflicts in their political, collective, and personal dimensions, but rather to open up possibilities of learning from lesbian histories for queer-lesbian presents and futures in a non-dismissive way—a way

which avoids shame on a personal level and incapacitation on a collective level. In addition, the affective stance of Mitchell's Hungry Purse literally embodies this queerfeminist reparative strategy: It evokes feelings of comfort and invitedness, that can be experienced as an individual but also across individuals, while the fuzziness of the handcrafted artwork also interweaves feminist pasts, presents, and futures. When Cvetkovich (ibid., 188-189) remembers the happening of a *Public Feeling Event* inside of the Hungry Purse, she describes that "it felt like there was room both to express loneliness and to feel a little less lonely," to then conclude that they have experienced the *utopian performative*.

Mitchell's artwork and Cvetkovich's engagement with it attribute to an account of handicraft and feminism that is different to the craftista movements mentioned in Chapter 2—or at least displays a positioning of its own within the more recent craftista movements. Cvetkovich's work, especially, pivots around a *reparative perspective* (ibid., 10) which works with "legacies of 1970s feminism such as consciousness-raising, personal narrative, and craft" as well as "contemporary queer culture" in its reviving of craft "in order to explore practices of living that both accommodate depression and alleviate it" (ibid., 26). Furthermore, Cvetkovich (ibid., 177) points out that Mitchell's artwork, among others, does not only "embody a reparative response to conflicts within feminism and between art and craft, but the utopian spaces of their large-scale installations produce a reparative experience of depression by literally engaging the senses in a way that makes things feel different." I am intrigued by the experienceability of reparation realised by the overly textile-decked example of the Hungry Purse. Furthermore, revisiting the course of DRDK, I feel like the balls of yarn distributed over the robotic lab might be read as evocative objects in such an affecting sense. Could robotic knitting be considered as an attempt at establishing everyday practices of probing human-machine relations in the robotic lab that hold the potential to amplify utterances of reparative responses to conflicts within and between feminisms, robotics and craft?

The way I assemble strings and allow interferences to emerge, robotic knitting as a practice and as a technofeminist tool embodies the historical relevance of knitting for not only processes of automation, but also processes of cultural ordering along gender, race, and class. At the same time, it neither attempted to reproduce gendered, racial, and classist patterns of cultural coding, nor to prioritise certain feminist goals over others. Rather, robotic knitting is a practice and tool of navigating between uncomfortable processes,

like discovering gaps and conflicts made very tangible to me when, for in-stance, feeling laughed at as a female-read, queerfeminist knitter standing in a robotic lab or when explaining my project to a few, rather sceptical femi-nists, and the more comfortable engagements with fuzzy yarns and a multi-tude of human and cobotic knitters, enjoying the individual and collectivizing pleasures of producing a textile, material artefact collaboratively. In this re-gard, the performative enactment of robotic knitting might also contribute to a utopian performative, as a space in which interdisciplinary research is about more than finding the solutions to previously defined problems and thus moves beyond technorationality. As a navigational tool, it helped us to orient ourselves in our practices of working towards the shared goal we de-cided to commit to, namely knitting with a cobot, while allowing to constantly question our chosen means of and concomitant assumptions about reaching this goal.

Robotic knitting works towards rec-rafting sociomaterial configurations of HRI in a material and metaphorical manner. Thereby, hand knitting with yarns expresses my deep commitment towards conflicting realities in their desires, understandings, and practices. I do not suggest that everyone should start knitting in a robotics lab, but rather to open robotics culture up for such performative explorations of human-robot-relations, involving equally 'our' bodies as 'our' senses and affects, and deploying diffraction, the game of cat's cradle, as a methodology for taking on a reparative perspective in technofem-inist engagements with 'our' technoliberal, techno-driven worlds. Not in the least, this perspective leads me out of the feelings of an impasse emerging from debates over the feminist aspects of DRDK: The disruption produced by my engagement with yarn in the robotic lab is generative, producing patterns of interference, and reparative, allowing conflicting perspectives to co-exist instead of excluding each other.

"This is Deep Collaboration What You are Doing!"

During my project work at the MTI-engage lab over the course of in total about two years, I was able to witness the increasing interest in robotics as a popu-lar topic. For instance, the lab hosted *Open Lab Days* every first Friday of the month that were only announced on the project's homepage, and I could reg-ularly see groups of up to 10 people showing up in order to learn more about current robotic technologies. This could be students or researchers from other departments of the TUB, and from other Berlin-based universities, but also

journalists or curious citizens. In addition, the TUB internal media department showed an increased interest in dropping by the lab and producing short video clips or photos for different occasions, but always for science communication purposes, like advertising a lecture on future technologies. On one such appointment, two persons from TUB showed up who had scheduled their appointment with the head of the MTIengAge lab. Part of my new role when becoming a robotics practitioner encompassed a set of activities, including the engineering of collaborative knitting and becoming active in demonstrating the execution of collaborative knitting. This entailed communicating and representing this project in a manner that can be regarded as usual for projects in robotic tech development. Since we were present and working on the DRDK project that day, we decided to also offer to talk about our project and to show them what we were doing. Despite showing an initial interest in the knitting, it nevertheless quickly became clear that this would not become the focus of their shooting. Instead, the persons in the lab, including my team and me, were asked to enact specific scenes with the cobot, mostly scenes of PANDA handing over or grasping an item. The suggested items ranged from a bell pepper to a plastic water bottle to a smaller ball. Contemplating this situation, I figured out what this scenario delivered that the knitting with a cobot did not: It was presumably immediately intelligible for most kinds of audiences that the robot is giving an item or taking it from a human, and in consequence, that it can grasp and interact in a meaningful way. In addition, 'we', the informed public, are already familiar with these kinds of images of robots and humans. Knitting is not legible in the same manner—as visible for instance in *Figures* 14 and 18. Our knitting practice, first of all, involved not only the cobot and a person, but rather more than one person. Furthermore, the knitting movement (unlike handing over or grasping) consists of a set of complex, smaller sub-movements, and it appears impossible to produce one picture which is able to tell the story of this practice in all its dimensions, that is, a legible output. In this regard, the challenge of depicting knitting collaboratively with a cobot makes tangible what a queer use of the cobot and of the knitting needles and yarn causes: the necessity to ponder about the way 'we' are used to thinking of robots as useful machines, by allowing new images to evolve.

At a first glance, the small knitting movements might appear as rather non-spectacular, especially in the context of HRI and HCI. Basically, when filming or taking a picture, one does not see that much, besides a person next to a cobot and knitting needles with yarn. When taking close-up pictures of

the needles and yarn, the bodily arrangements become invisible. Sadly, at this exemplary occasion of taking photos for a science communication purpose, I was not able to intervene in what appeared to me to be a reification of the already well-known images of how humans and robots can relate, including the idea of what a robot is. At this point in time, I also realised that I myself did not really have the words at my disposal to express how and why when looking at it more closely, knitting collaboratively between human and robot turns out to be at least equally spectacular as the handing-over-an-item scenario. My struggle for words and with becoming able to express why it might be worth looking into our robotic knitting, insisting that the complexity and spectacularity of this practice of enacting HCI will become intelligible, made me feel, again, at an impasse.

Re-narrating in Chapter 2.1 the historical relevance of the yarn for digital technologies and automation technologies, and therefore also robotic technologies, it becomes crystal clear to me that the yarn not only matters on a metaphorical level, but also equally on a material level, in re-crafting human-robotic-futures. The yarn cannot be reduced to either dimension, but rather becomes a powerful tool when acknowledging both in their interrelatedness. Thus, depicting the robot with humans and yarn can be said to have a historical legacy of playing a role in the development of automation technologies as the predecessor for digital computer technologies.

Highlighting the historical prevalence of needlework for automation, including digital technologies, however, is not only about recuperating a relation of kin rather than kind between handicraft and high-tech, viewed as dichotomous spheres. Rather, it is also about exploring the interconnectedness of practices at the textile/technological interface. What becomes very vivid in Chapter 2.2 is that hand knitting displays a challenge for HCI. This largely results from the gap between hegemonic ideas of automation and the everyday practices of realising automation in a robotic system. Entering the lab as an FSTS scholar specializing in human-robot relations, I was well aware of the circumstances of HRI, how messy and ridden with experiences of machine failure it can be to operate a robotic system and to realise the execution of a certain task with the robot. Practices of engineering a robot system to execute a certain behaviour rely on the alignment of things, persons, affects, and actions (Suchman 2007, Alač 2009, Treusch 2015, Lipp 2019).

Thus, the challenging character of hand knitting as a task also works with the potential to tweak the picture of a frictionless operation of a robot, as well as that of engineering as the frictionless mastering of hard- and soft-

ware. It is not only about producing images of a robot doing different things than what 'we' are used to as citizens informed by the idea that "the robots are coming"—a narrative which evokes the robot as essentially human-like co-worker or substitute worker. Rather, it is equally about making a difference in the doings of HRC in particular and HRI in general. Hence, depicting robotic knitting is about picturing the diffraction of frictionless automation through neglected practices of engineering, involving care on an emotional and corporeal level as it shows, for instance, in practices of attaining a sense for krn.

Again, however, one challenge remained how to communicate the essential aspects of picturing robotic knitting in a more accessible manner. During a research stay in Copenhagen, I was invited by Kasper Støy to present robotic knitting at the REAL (*Robotics, Evolution and Art Lab*) at IT University. This was a very pleasant experience as the context of REAL, first, is that of an interdisciplinary robotic lab, and therefore open to the idea of an FSTS scholar becoming a robotics practitioner, and second, as I had already been in conversation with the roboticist Kasper who was not only interested in this specific project work, but is equally interested in bringing humanities, especially FSTS, in conversation with robotics. After my presentation, Kasper suggested understanding knitting collaboratively with a robot in terms of *Deep Collaboration (DC)*.

I was immediately intrigued by this framing. It depicts a twist of the hegemonic AI machine learning paradigm, namely *Deep Learning (DL)*, through a very hands-on scenario, namely the knitting hand and knitting gripper. DL, basically, is grounded in the machine learning technique of so-called (*artificial) neural network*s. Such artificial neural networks are conceived of as modelled after "the mechanism of learning in biological organisms" (Aggarwal 2018, 1). This "biological mechanism" encompasses, first and foremost, the neurons and synaptic connections (ibid.). In short, applying this model in machine learning means working with "computational units [that] are connected to one another through weights" (ibid.). This assemblage of artificial neurons and artificial synaptic connections leads to an artificial neural network which, in short, consists of the networked input neurons, an unknown middle layer of abstract operations, and the output neurons. For a neural network to become a functional method of data processing, it has to be trained with so-called *training data* as a foundation for the model generalisation, that is, the capacity to generalise models from the training data. After that, the DL technique is expected to produce the most highly reliable output data when

properly trained, and to be especially suitable in operating with large data sets, so-called *big data* (ibid., 4). Despite this very technical description of DL, Zweig (2018, 33, translation: PT) reminds us that "systems of algorithmic decision making should…not be considered in isolation, but always as part of a sociotechnical overall structure"—a fact that can be easily neglected in the selection, training, and modelling of DL techniques.

Even though Deep Collaboration points towards the contemporary figuration of the robotic imaginary and the larger framework of AI with its focus on Deep Learning and its concomitant modes of datafication, formalisation, and statistical (machine) learning, it, at the same time, distances itself from this very framework and brings to the fore the *collaborative as physical, embodied and social-cultural* nature of AI, and especially of interactive machines such as the cobot. Furthermore, it does so on a very hands-on level, namely through the collaborative handling of yarn and needles as a technique and the forming of new stitches as a skill. Thus, I regard robotic knitting as foundational for DC and the latter as a necessary completion of DL.

As illustrated in Chapter 2.2, the neglected skills of hand knitting encompass adherence to the process of forming new stitches, including engaging with the flows and transformations of the materials of hand knitting. Resulting from this is an account of hand knitting as exemplary for being possessed by action—a form of emotional and bodily care for the flows and transformations of materials as well as the activities of all agents and things aligned in this process. This quality of robotic knitting articulates itself in working with yarn as a tool for making the practices and practicalities of collaborative knitting a matter of care. Hand knitting and collaborating with PANDA both rely on tactile and tacit knowledge, both are precarious in nature and require a person to be creative, tinker, and test improvements spontaneously. Hence, diffracting engineering and handicraft, their relations have to be reconsidered as that of kin instead of kind. DC captures precisely these dimensions of robotic knitting.

Further, I imagine Deep Collaboration to establish into a paradigm not only of re-crafting engineering, but equally of working towards new images of HRC, making the spectacular nature of the micro-practices of collaboration tangible to different audiences. In the case of robotic knitting, however, this always encompasses acknowledgment of the potential of hand knitting for developing and practicing DC. Thus, my account of DC also necessarily involves challenging contemporary ideas of knitting between knitting as an outmoded, and "most boring cultural technology of the world" (Wallnöfer 2011,

47, translation: PT) and knitting as means for *technoliberal* subjectivity, propelling an *aesthetic capitalism*. The *textility* of knitting reveals the potential to amplify the utterances of a reparative response-ability to contemporary conflicts between digital and analogue, robotic automation and human (creative) work, as well as *technorational* solutionism and a diffractive inquiry across disciplinary boundaries along the process-oriented practice of attaining a bodily sense of robotic knitting, and following flows and transformations of yarn, hands, and grippers, all working together.

"You Invented the Embodied Turing Test!"

Even though I was immediately intrigued by the idea of having a robot arm knit, the realisation of this idea also made me curious about how the complex task of knitting could be automated through a robot arm, and how this might change the activity of knitting, but equally my concept of automation. Would this still be the handicraft of 'human knitting' or would it become something else?

Already the very first practice of knitting in the robotic lab propelled me to develop robotic knitting as a technofeminist tool for not only re-engineering collaboration with robot technologies in a hands-on manner, but also for re-crafting contemporary robotic cultures of striving for robots as co-workers. Notably, it was the initial attempt at turning knitting into data, as well as the concomitant enactment of this data, which lead me to contemplate hand knitting with a cobot through different eyes, making me wonder how robotic knitting is more than a simple transference of movements onto a robot, but rather the beginning of an exploration of practices of knowing and being in the cobotic lab. In this view, the seemingly useless task of knitting with a robot can become the utopian performative.

In contrast to this experience, machine automation is held as excluding human creativity by necessity. Thus, a core challenge then became to re-join both practices in a non-exclusive manner. However, this challenge articulated in different forms. This became especially tangible to me through one situation. Quite early in the project, I decided to participate in the yearly *Open Science Event*, the so-called *Lange Nacht der Wissenschaften (LNDW)*, at TUB in the following year. Part of this was to submit a short description of what I would like to offer (a robotic knitting station) and an accompanying picture. At that time, I only started to think about images of robotic knitting and was quite fascinated by a couple of pictures that Katrin had just shot. One of them

showed two PANDAs facing each other and the camera, while the robot on the left holds a knitting needle with a red knitted piece on it and the robot on the right holds two long metal knitting needles in its gripper that are plunged into the red ball of yarn. The background is bright green—a background paper that was already available in the lab. I thought this was a nice arrangement of robots with needles and yarn—what I did not think was that this picture would—from then on and until this book—determine and define the appearance of DRDK.

Later on, I noticed that the picture was liked by the TUB press department, and from there even evolved into the guiding theme for the LNDW in 2019. The latter meant that it was on the cover of the LNDW magazine of the TUB, the different sections of the magazine were separated by various shots of the described scenario, posters announcing the LNDW with one or two robot arms with needles and yarn could be found all over Berlin, and finally, even the president of TUB, Christian Thompson, drew on the *knitting robots* in his foreword to the LNDW magazine, speaking of the knitting robots as providing a red thread through the programme of the LNDW. I was at the same time amazed and puzzled. It was amazing how much the university seemed to identify with a quirky, technofeminist project; but at the same time, I was also puzzled as the situatedness and outlines of DRDK did not become visible, as I quickly realised—neither through the image nor the texts around it. To me, this was a very interesting experience in science communication. Again, one part of the project, namely that it has something to do with robots, is made visible while making invisible the other part of the project, namely that it is a technofeminist intervention. In my view, this is not about silencing the technofeminist part, but more about the customs in science communication which, as already explored in the subsection above, seem to entail encountering the gaze of the hegemonic robotic imaginary. What the picture (which I delivered in the first place) transported in result, was the image of a robot as emblematic for the potential to possibly automate every sphere—and therefore also every task—of human existence. It became the picture of a story on multi-capable robots that can even knit. Here, I found myself again in the position of taking on the role of the witness to robotics—however, in this case, not to tell how far actual robots are from the narrative "the robots are coming", but rather to affirm how far robotic tech development has come when the robots can even knit. Clearly, I found myself again at an impasse.

Facing this dilemma as part of a more foundational mismatch in aligning robots as cultural figures, contemporary robotics, and the hegemonic robotic

imaginary, my task was again to become response-able to conflicts as a tech-nofeminist robotics practitioner. This involved, first, producing flyers for the actual event of the LNDW, and second, being present with my team, Melanie, Anne, and PANDA throughout the LNDW. The flyer re-situated the project and aimed at making visible what did get lost in the image of the two robots with yarn and needles, while over the course of six hours, Melanie and Anne were knitting collaboratively and I was speaking into a microphone, explaining the practice of robotic knitting. As the robot that can knit was the guiding theme of the whole event, we were granted a prominent spot in the main building of the TUB. After the first hour, we decided to run hourly demonstrations. Groups of up to 80 persons came to these demonstrations. Thus, the inter-est in the project was overwhelming. Simultaneously, I considered this also a great chance to engage in conversations with the persons visiting our demon-strations in order to debate with them the outlines of the project. Further, I hoped to gain insights on what was needed on a visual and textual level to make the project work tangibly for the persons I spoke with—of course, to examine the intelligibility of robotic images would be a project on its own (see Hasse 2019), but, nevertheless, I was curious to hear about the expectations that our visitors had.

In the end, a very large number of persons clearly had the expectation that our demonstrations would show two robots knitting with each other and expressed their disappointment. However, there were also others. What es-pecially caught my attention were grandmother-grandson tandems. It hap-pened a couple of times that a grandmother came up to me, explaining that she came to this demonstration because her grandson is fascinated by robots, while expressing her fascination with needlework. These situations proved to be of special value for communicating the project work. I could easily re-duce this situation to one of a gender-stereotypical expression of interest, but through a reparative lens, I discovered that these situations brought the potential of an intergenerational conversation about both needlework and robots that then allowed me and my team to argue why and how both are interconnected and to explain what DRDK does. In general, I was surprised how many persons—even those disappointed that we did not show two robots knitting with each other—were keen on learning more about our exploration of HRC through knitting. Thus, in the end, the impasse turned into a sur-prising experience of not only communicating the project work, but also of generating a more complex understanding of my role as a technofeminist robotics practitioner, engaging in the usual formats of science communica-

tion. Nevertheless, the two robots potentially knitting together, representing DRDK, continued to bother me. How could I re-integrate the collaborative aspects into that image?

During a presentation of DRDK at the *GeDIS* (*Gender/Diversity in Informatics Systems*), at Kassel University, led by Claude Draude, Claude suggested that the implementation of robotic knitting in which the robot is supposed to learn 'human hand knitting', that is, how to knit like 'us' humans, depicts an *embodied Turing Test*. In what follows, I will develop this idea further in order to explore the possibilities to tweak the idea of automation as substituting humans towards a more collaborative understanding. Developing impulses for a re-crafting of robotics, I suggest a re-working of the popular and well-established *Turing Test* through robotic knitting, inspired by Claude. Based on Turing's challenge of 'our' humanist scientific foundations in conceptualising the machine Other, the Turing Test has advanced into the gold standard of determining the human-like intelligence, and thus successfulness, of AI. However, this test and how it is implemented focuses on purely cognitive, immaterial terms. Hence, the material and embodied nature of collaboration through hand knitting appears as an ideal example to revisit the Turing Test in terms of embodiment and embodied affects.

Again, as a hand knitter, I can say that yarn is quite a stubborn material when having to master it with needles. It can start dissolving itself into individual threads, it can form knots when unravelling, and it can be either too slippery or too cumbersome when forming new stitches. Hand knitting, hence, requires a precise handling of both the yarn and the needles. This requirement makes it a human-exclusive activity—in contrast to its automated form, performed by knitting machines. In fact, it was by no means necessary for me to invite a cobot to join me in mastering yarn and needles successfully. Thus, I assumed from the very beginning of DRDK that robotic knitting as a task requires a high degree of adaptability between human and robot—a requirement which also shows very vividly in my recounting of realising robotic knitting in Chapter 2.2.

Beyond this, I suggest contemplating about this adaptability as a possible way out of defining human-likeness as the only possible form of reaching a mutual understanding between human and robot. Thus, I am curious about the idea of connecting human knitting performed by a robot, in its potential to conflate human and machine action, to the Turing Test. The latter, in short, was proposed by Alan Turing in 1950 and tests the indistinguishability between human and machine interlocutors. Notably, and as Draude (2017,

191) reminds me, "before Turing develops a scenario for human-machine interaction, he invents a gender imitation game, in which different roles are attributed to each gender." The *Imitation Game* first invented a situation, in which one person (the interrogator) engages in a conversation with two others (a man and a woman) via typewritten questions and answers, while located in separated rooms, and then must determine the gender of each person. Furthermore, the goal was to confuse the interrogator as the two others were instructed to both take on the female-coded role of assisting the interrogator and therefore "both players try to convince the interrogator that they are the woman" (ibid.). For Turing, if a man can convinced the interrogator that he is a woman, then "the imitation of the woman by the man may be replaced by the imitation of the woman by the machine" (ibid.). Foundational to both the Imitation Game and the Turing Test are to separate between sign and body/materiality as the basic principle to enable such imitation. As Draude (ibid.) resumes, "according to the Turing Test, the sign is treated ... as freed from the connotations, restraints, and limits that an embodied existence brings along." In this regard, Turing's work can be read as potentially encompassing a queering of boundaries between meaning and matter, female and male, and human and machine. Elizabeth A. Wilson (2010) argues in a similar vein when she attests that when Turing raised the question of *Can machines think?* (Turing 1950, 433), he opened up the possibility of challenging modern thought with its concepts of thinking and intelligence as solely properties of the human subject (ibid., ix). Against the backdrop of these readings, how could the practice of knitting with a robot contribute to the queering and curious nature of the Turing Test?

First of all, it is pivotal for robotic knitting to take up the queer momentum implied in the Turing Test as a mostly neglected dimension. It basically works towards a de-essentialisation of a determinist relation between matter and meaning. At the same time, the momentum of curiosity equally deployed by the Turing Test, opens up the realm of the unthinkable. Together, my account of the Test propels the probing of human-robot relations beyond the category of the human-like as that which allows a mutual understanding between humans and robots. With this, I bring to the fore the Test's capacity to de-couple form and function and to allow the unthinkable to take shape while I insist on the embodied nature of experiencing human-robot relations *differently*.

Robotic knitting moves beyond narrative formations which operate with universalising claims about who will be affected and how by an increase of

automation technologies. It does so by challenging the very notion of automation. Passing the embodied Turing Test is a prerequisite for this. It allows me to develop a more capacious understanding of *collaboration*, and thus also of the relation between the cobot and the different humans involved, in terms of *careful coboting*: Taking into account the practices and practicalities of collaborative knitting means to acknowledge the sociomaterial configuration of robotic knitting. It opens up a field between *techne* and *logos* through which the transference of a skill onto a robot stipulates a re-signification of labours and affects invested into HRC, that works more in line with an intra-active than interactive paradigm. The latter is geared at assembling the actors and actions in their entangled nature in order to foreground the co-shaping character of human-machine relations, from which entities with boundaries emerge. The question of what a robot—and in this relation, also a human—is, then, cannot be cut off from the multi-faceted enactment of relations as well as their experienced reality *in situ*. This also opens up possibilities to re-pose questions of responsibility for the distribution of labours between humans and robots: From gestures of propelling either promises or fears to becoming accountable for and through situated practices of relating.

Not in the least, these insights are diametrically opposed to discourses which confine 'the human' to the *technoliberal* subject in danger of a White loss, as described in Chapter 1. Careful coboting places human and robot together, underlining their dependent and entangled relation—neither 'the human' nor the robot can be erased from this picture. Rather, what needs to be erased in order to engage in careful coboting is the very logic of technoliberalism, including the pattern of surrogacy in its oppressive operations of ordering. Robotic knitting is constitutive of a utopian performance that articulates in the mundane practices of being possessed by hand knitting across human and robot, possibly evoking human-machine co-creativity and therefore also re-joining human creativity and machine automation. It cannot provide one picture that captures an ontological essence of HRC, but rather has to stay with the trouble of constantly engaging with mundane practices of HRC, or, put differently, with the realisations of Deep Collaboration and with passing the embodied Turing Test.

3.2   Careful Coboting through Hand Knitting – and Beyond

> … the thing has the character not of an externally bounded entity, set over and against the world, but of a knot whose constituent threads, far from being contained within it, trail beyond, only to become caught with other threads in other knots.
>
> Ingold, *Bringing things to life*, 4

Bringing yarn to the robotics lab is more than what appears at first sight as an amusing and playful, but nevertheless interventionist, endeavour. It is also not limited to challenging contemporary automation technologies through the implementation of an unconventional task of HRC. It centrally aims at re-crafting the human-robot relations of collaboration—through first taking into account that the human-robot interface is loaded with cultural meaning, and therefore not only reproduces existing power relations, but also determines how robots and humans can relate in imaginations of HRI, but also *in praxis*. Second, and based on that, such a re-crafting includes to reclaim care in its emotional labours and corporeal forms as a substantial dimension of collaboration between humans and robots, while establishing that this care is not based on well-known images like the infant-caregiver metaphor, but rather understood as a foundational practice of engineering human-robot-relations. The latter is where practices of hand knitting and practices of engineering in their textility of creation, including their precarious, provisional and tactile nature, conflate.

The category of the human-like should supposedly evoke visions of specific figures, thought of as enabling socially meaningful relations with robots, such as the maid or that of the slave. At the same time, the ways in which these figures are charged with social relations of power, exclusion, violence, and oppression, but also of resistance and overthrowing, are largely ignored. However, acknowledging existing power relations in the development of human-likeness is not sufficient in overcoming the restrictions of the category of the human-like. Rather, robotic knitting, in its disruptive and generative engagement in forming new stitches, not only explores the sociomaterial limits of that category, but also traces the potential to transgress these limits by advancing structures of relations that are not yet imaginable. In this sense,

the here carefully assembled, detailed account of knitting with a robot—as a practice of coboting—illustrates the ways in which the technological realisation of abilities in the robot cannot be exclusively confined by the category of the human-like. Further, essential for transgressing the limits of the category of the human-like is also the acknowledgment of the ways in which HRI cannot be planned or captured through a fixed set of affordances and constraints embodied by a concrete artefact. Rather, the cobot's capacities exceed the pre-planned 'pure functionality' of a device. They emerge from the intra-active encounter between robot and human. Illustrating this intra-action in Chapter 2.2, then, shifts the focus from the human-like as the primordial category of human-legibility to the multi-dimensional practice of enacting collaboration with a focus on care as a stance of caring for how people and things matter together. While these assembled factors of collaboration are foundational for becoming socially meaningful, they are mostly neglected. Assembling the neglected factors in turn is then a practice of care.

Robotic knitting works with and through the complex interrelations of culturally charged attributions, agencies, affects, and the embodied practice, as well as the experience of human-robot relations of collaboration, by moving beyond the usual scenarios of the helpful or useful robot. Essential to this is to remember the historical traditions of needlework as a means of patternmaking and communication that are foundational for 'our' contemporary everyday technologies (see Monteiro 2017), as well as the gendered coding of handicraft in opposition to technology development. Furthermore, even though realising collaborative knitting between humans and a cobot might appear at first sight as a clear-cut goal, central to this project was the constant examination of the everyday practices of engineering through which we, the interdisciplinary team, were implementing this goal, as well as becoming attentive to the host of labours, materials, affects, and agents involved in this process. Robotic knitting thus serves as a tool for probing taken-for-granted knowledges, and practices of engineering such a goal, while at the same time, it also functions as a tool for re-engineering and telling a different story. It enabled us to performatively test the handling of yarn and knitting needles by humans and a cobot in order to not only probe, but also re-craft human-robot collaboration. This encompassed translating the negotiations of what HCI means and could mean into experienced reality of human-machine co-creatvity. Hence, robotic knitting is about creating an account of HRC that blurs the boundaries between subject and object, the productive and unproductive, and value and valuelessness, and thereby is geared at advancing structures of relation

that were unimaginable before. The conversations that ended at an impasse, which I recounted in this closing chapter, bear witness to the fact that articulating human-cobot relations of careful coboting through knitting is in need of the foundational work on advancing structures of relation that were unimaginable before the project.

Robotic knitting turns out to be (1) the complex effort of re-joining legacies, (2) allowing counter-intuitive relations of kin instead of kind between seemingly dichotomous realms to unfold through a queering of use, (3) a momentum for a yarn-related process-ontological account of generating a more capacious vision and version of collaboration between human and robot, and (4) opening up a field of tensions between the cobot and knitting, in which the cobot is simultaneously a technology rooted in and emerging from normative orderings of present-day capitalism, while hand knitting evokes the potential to subvert this very normative order.

The partial nature of the knowledge produced here does not pertain to a relativist or fatalist stance—rather, quite the opposite: Situating knowledge claims allowed me to cut through what I frame as the ubiquitous and confusing sociotechnical formation of the contemporary robotic imaginary. This then builds the backbone of the book: To separate strings of story- and time-lines, as well as of sociomaterial configurations, in order to diffract these strings on entangled narrative as technological as narrative levels. Realising robotic knitting then is reached through a set of practices of diffracting the different strings of robotic knitting, conceived of as human and more-than-human generative nodes, accentuating the formative, co-shaping power of materialising locations in a net of actors. This perspective became vital for me to establish a practice of care in the dis- and re-entanglement of threads. I frame the set of technofeminist practices around robotic knitting in terms of a careful coboting, which deploys (1) a perspective of reparative response-ability, (2) the paradigm of Deep Collaboration, and (3) the embodied Turing Test.

The wool and the knitting needles served me as literal and metaphorical tools to bring the well-oiled machinery of technoscientific envisioning, in its determinism and implicitness, to a halt. This halt then allowed me to explore different possibilities for HRC, not only in theory but also in practice, entangling both theory and praxis in an experimental manner. This exploration is based on the belief in the openness of the robotic future as well as the need for making a difference in 'our' robotic futures that is not about finding more adequate representations of what visions and realisations of collaboration be-

tween humans and robots really looks like, but to radically open up possibilities for new realities of human-cobot-relating—possibilities that might not have been explored before and that cannot be determined prior to probing them.

Laying out the strings of robotic knitting here, I wish for them to get caught up with other threads and form new nodes, constantly queering the what and who of a proper use and working towards a more tangible and situated debate about human-robot futures also beyond robotic knitting. Pivotal for this is to continue insisting on the circumstance that 'our' human-robot futures have not yet been written, but rather are indeed open. Human-robot relating is a practice of culture, working with operations of hierarchisation and in- and exclusion. However, it not only matters how and under which auspices 'we' tell the story of a dawning of an inevitable robotic future, but it is also, and importantly, the enactment of the very mundane relations through which robots are woven into 'our human' sociomaterial fabric that matters. Thus, making a difference in relating is about engaging in careful coboting.

Finally, the last two pages of the book depict the collection of knitted artefacts that were produced during the project. As every knitted artefact embodies the history of its production, I regard the knitted artefacts of DRDK as a manifestation not only of its story, but also of the story of careful coboting. We did not produce nicely uniform knitted artefacts. Instead, they are marked by holes which I understand less as failures, but rather as exceeding such simple assumptions. They are *Leerstellen* (gaps), literally translating to empty spaces. Becoming accountable for what and how I see, I speculate about these Leerstellen as signifying the openness of what robots and how they can be woven into 'our' sociomaterial fabric, and who should participate, as is articulated through DRDK and beyond. These Leerstellen interweave technofeminist robotic pasts, presents, and futures as a matter of careful coboting.