Chapter 1: The Knitter in the Lab
Becoming Sand in the Gearbox

To challenge the idea of one coherent robotic future is a technofeminist intervention into the idea of linear technological progress. I understand such an intervention in figurative terms as becoming the sand in the gears of what appears to be an overwhelmingly well-oiled machinery of 'our' robotic future. The picture of *sand in the gears* might at first glance seem like an undesirable disturbance and a very destructive endeavour. However, from my technofeminist, interventionist perspective, a second glance can reveal the productive and desirable effects of such a disturbance. In its disruptive momentum, to become the sand in the machinery of 'our' robotic future, means to take a break from technoscientific acceleration and its almost unlimited promises of improvement and optimisation of 'our' everyday lives. The sand causes a break that is involuntary and very material. At the same time, this break allows me to take up my knitting needles and yarn as tools for a queer use of the cobot.

Furthermore, becoming sand in the gear is how I imagine the workings of Haraway's figure of the cyborg—a figure that not only reclaims a techno-driven term, but also relies on such moments of involuntary break with coherent and linear stories. These moments are the motor of technoscientific worlding because they bring the potentiality to intervene into linear stories. With Nina Lykke (2010, 39), "The cyborg mobilizes other, critical stories that have the potential to undermine hegemonic power and dualisms." In this regard, I consider becoming sand in the gears as a cyborgian, technofeminist way of mobilising critical stories from within robotics. More precisely, if hegemonic narratives present collaboration as key to increasingly robotised futures, challenging human-robot collaboration (HRC) will work exactly in this way of mobilising different stories of relating and interacting between humans and machines. In addition, to fundamentally query current forms of

storytelling also entails questioning the concomitant distribution of responsibility for 'our' robotic futures, as well as who is acknowledged as an expert in designing and realising liveable, sociotechnical futures. Becoming sand in the gearbox then is about reclaiming not only HRC, but also expertise in telling and enacting different stories.

Sand is also a very relevant and ubiquitous construction material with multiple fields of use. Sand can be composed of components of different sizes, encompassing gravel, pebble, and crushed rock. Indeed, sand is one of the most needed natural resources in Germany, amounting to an average use of 19 kilos per German citizen per day.[1] Quartz is one of the most important components of sand as it is not only one of the sturdiest natural materials, but also contains silicon. Its sturdiness makes it the perfect component for manufacturing glass and concrete, while the silicon has the ability to transform alternating current into direct current. With these qualities, sand is one of the foundational components for the development of microelectronics and devices like the computer chip. 'Our' techno-driven societies, and with them robotic technologies, are literally built out of sand. With regard to sand's material qualities, it is sand's sturdiness and flexibility, and other physical properties, that secure the triumph of information technologies.

In its figurative meaning, sand commonly stands for evanescence, the non-tangible, disruption, or even failure—as many popular sayings show. Pondering here about sand, my writing does not unfold linearly, but rather comes to a halt—a halt of thinking with sand. It is thinking in a different direction which orients me towards wanting to write about robots as powerful figures of seemingly linear technological progress and as solutions to societal challenges like the lack of human labour in different fields of work. Thinking with sand means to engage with sand as a basic material component of robotics, and at the same time as a potential disruptive force on two levels: First, in developing a position of critique that means to become the sand in the gears of narratives of robotic technology development. Second, in becoming aware of the materiality of robotics, including the limited availability of this natural resource. Its limitedness reminds me of the limitedness of the things 'we' build from sand—a fact that is mostly neglected in the idea of "the robots are coming". Inducing a disruptive halt appears to be an auspicious mode of engagement with productive and desirable effects for producing situated knowledge, that is, critical stories, on the contemporary robotic scene.

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1   https://www.planet-wissen.de/technik/werkstoffe/sand/index.html

Cobot Technologies—A New Kind of Machine?

As many others have pointed out before me, the technology *robot* literally embodies the automation of work. The term robot derives from the Czech word for working, *robota*, and was coined by the brothers Karel and Josef Čapek in 1920.[2] It represents the automation of human labour. Robotic knitting pivots around the technofeminist engagement with one specific robot automation technology, namely the collaborative robot, or in short, the *cobot*. The terminology and the idea of a collaborative robot has existed for more than 20 years. The term was coined by US-American roboticists James Edward Colgate and Michael A. Peshkin in 1996, who also hold the US patent for cobots, since 1999.[3] The basic idea behind the cobot is to develop and implement robots with which new forms of collaboration—based on new forms of proximity between robots and humans—are possible. In contrast to the industrial robots successfully operating in factory halls since the second half of the 20th century, the cobot no longer has to be caged and the worker no longer protected from the large-scale, powerful robotic workforce. Rather, this new generation of collaborative robots are "interconnected, intelligent, adaptive, and are beginning to emerge from their protective cages" (Pfeiffer 2018, 21).

I suggest grappling with the cobot as a key element of the current robotic imaginary that is not only a potentially powerful labour source, but also a culturally powerful figure. When attesting that "we are in the midst of a robot invasion", David Gunkel (2018, ix) nevertheless points out that a distinction has to be made between science-fiction imaginaries of a robotic takeover and the myriad ways in which robotic technologies in different shapes and sizes have already become part of 'our' everyday tech-environments. They have historically been and continue to be important for processes of industrialisation. They are currently implemented in workplaces in industry as well as increasingly implemented in the service sector (including technologies of the so-called *Smart Home*). In this line of thought, the robotic takeover can be understood more in terms of a lingering event or a subtle set of events rather than an invasion. The picture of a subtle, successive integration of robotic technologies instead of a hostile, warlike invasion marks a shift in the narrative of technological progress as a linear, inexorable process and demands to look

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2   In Karel Čapek's theatre play *Rossum's Universal Robots (R.U.R)*, in short, artificial humans are developed in order to take over human labour as cheap work force.

3   https://patents.google.com/patent/US5952796

into mundane experiences of use, and previous decisions of introducing certain technologies into 'our' everyday lives. This shift in narration also makes necessary a shift in cultural understandings of what a (collaborative) robot is. Clearly, the idea of robots as, for instance, a tin robot moving in a very mechanical manner is not sufficient and needs to be complexified. However, the contrast model of a somewhat human-like machine, with a mostly white plastic covering and represented as an autonomous agent in Kantian terms, as pictured not only in science fiction movies but equally used in popular scientific and scientific discourses, also fails to capture the quality of contemporary robot technologies geared at human-robot collaboration.

In this regard, I consider HRC a black box and suggest opening it by understanding collaboration as a cultural *and* bodily practice that can be traced along story- and timelines, as well as through sociomaterial configurations and enactments in the robotic lab. HRC, as a complex phenomenon of new, proximate relations between humans and machines, is in need of a perspective through which a "critical examination of relevant discourses [is combined] with a respecification of material practices", as articulated by Lucy Suchman (2008, 140). This book presents such a combination of a critical reconstruction of discourses with a respecification of material practices, given through the example of the cobot. More precisely, my performative account of robotic futures brings the discourses of "the robots are coming" together with the auto-ethnographic experience of engaging with one robot technology and a technofeminist perspective on human-robot interaction (HRI). Thus, my approach to opening the black box of HRC encompasses such an opening on both the discursive level and a very literal level where I become the "affiliate human" (Suchman 2011, 119), not only in care of probing collaboration with a specific cobot model but also, and importantly, the engineering of collaboration through hand knitting.

Drawing on the legacy of feminist Science and Technology Studies (FSTS), technofeminist approaches analyse modern divides (for instance, between design and use, subject and object, and autonomy and dependency) not as given and fixed, but rather as emerging from practices of engaging, enacting, and relating (Wajcman 2004; Suchman 2007; Sollfrank 2018). As Wajcman (2004, 54) puts it: "Sociotechnical systems are not merely performed symbolically; they are also enacted materially." Technological artefacts such as the cobot are developed and brought into use through entangled sociotechnical networks of symbolic performance and material enactment. This insight opens up possibilities to explore, analyse, and transform emerging relations between

cultural norms and technological artefacts through *re-configurations* of matter and meaning (Haraway 1997; Wajcman 2004; Suchman 2007). The performative framework of robotic knitting enables an intervention into the process of realising robotic futures on both the level of symbolic performance and that of material enactment of cultural and bodily practice. The focus of this chapter is on mapping the methodological and analytical approach of robotic knitting with an emphasis on the relevant debates on the symbolic order that hegemonic human-machine relations are built on and which they perpetuate.

Sociotechnical systems such as HRC are imbued with power relations and the normative operations of ordering, sorting, and constituting sociomaterial worlds. Notably, I understand neither the reproduction of a discriminatory and oppressive social order, nor the transformation of such an order, as solely either the result of human agency or provoked by technological artefacts. Rather, I am interested in exploring the interplay and multiple entanglements between humans and machines, emerging from and embedded in a historically specific set of symbolic ordering and physical conditioning, and how they either allow transgression from or perpetuate the already existing norms of what a human or a robot is, and how these can relate.

Working towards a more capacious vision of the cobot, I trace the porous and provisional nature of the performative enactment of HRI in general, and HRC in particular, as a cultural and bodily practice. Suchman (2011, 123), for instance, underlines that "the laboratory robot's life is inextricably infused with its inherited materialities and with the ongoing—or truncated—labours of its affiliated humans." Robotic knitting is interested in becoming exactly this: an affiliated human to the latest generation of cobots. This enables me to trace the truncated labours of the emerging relationship of collaboration through my own bodily experience of having to perform these labours, as I will show in Chapter 2. Thus, robotic knitting allows me to gain insights into existing technologies by experiencing what it means to become an affiliated human while blurring the boundaries between user and robotic engineer—to a certain degree. This encompasses experiencing the practices of what Benjamin Lipp (2019, 12) frames in terms of *interfacing*: "Interfacings describe the manifold processes, by which elements in various forms are rendered available for one another." The analytical reframing of the interface speaks to my approach to HRC as it emphasises the doing of interface, that is, interfacing, and attunes to the ways in which enacting human-robot interaction is based on practices of becoming available for one another. The latter encompasses forms of reciprocal relating and underlines the situational character of

human-robot legibility. It is precisely such a fine-grained perspective of analysis that is needed in order to generate a more capacious version of HRC, and to become accountable as *staying with the trouble* in a Harawayan (2016) sense when implementing the collaborative task of hand knitting with a cobot. Thus, this book and the research on which it is based asks what kind of human-machine interface are collaborative robots constitutive of? What forms of interactive collaboration are they capable of? Which forms of human engagement, including the neglected, invisible labours of affiliating and interfacing, do they require? And, how and in which ways does collaboration at a given interface enable or disable certain tasks of human-robot interaction?

Becoming sand in the gear, in the manner described here, then finally aligns with Maria Puig de la Bellacasa's (2017) onto-ethico-epistemological notion of *matters of care.* De la Bellacasa (ibid., 6) works with an account of care in which "the tensions between care as maintenance doings and work, affective engagement, and ethico-political involvement…opens a terrain for exploring, in situation, the subtle thought of care, by reading these dimensions through each other." In this sense, I understand practices of affiliating and interfacing as practices of care, while practicing care in settings of HRC mainly involves *assembling neglected things* (ibid., 18), taking into account the politics of knowing in representing the actions, material entities, and affects in HRC. Furthermore, as Tania Pérez-Bustos (2017) carves out in her ethnographic research on the Columbian *Calado* embroidery: Performed by *caladoras*, needlework practices such as "unravelling and mending are constituted by care in relation to bodies and materialities" (a). Pérez-Bustos deploys an understanding of care as both constitutive for practicing needlework and constitutive for practicing an ethnography of needlework when she underlines "the knowledge dimensions…[of] craft" that are "emerging from the intimate relation between caladoras and calado materialities" (c). In this sense, I understand the practice of hand knitting with a cobot as a tool for making HRC my matter of care, including tracing neglected, invisible labours as well as cultural and bodily practices and materialities of collaboration. Acknowledging knitting as a doing and knowing, while also a very unusual scene of HRC, opens up multiple possibilities of inquiring taken-for-granted certainties and norms, and for exploring ways of relating bodies and materialities in and experiencing HRC differently.

In what follows, I will zoom in on hegemonic ideas of how humans and robots will relate in the future as a key part of the contemporary robotic imaginary. This will allow me to grapple with the overlapping storylines and cultural

meanings of "the robots that are coming". Based on that, I will introduce my methodological toolbox of robotic knitting.

Hegemonic Figures: On the Symbolic Meaning of Robotic Visions

That robotic technologies historically had, have at the present, and will continue to have an impact in the future on societies is unquestioned. As Donald MacKenzie and Judy Wajcman (1999, 2) remind me: "Technology matters. It matters not just to the material condition of our lives and to our biological and physical environment—that much is obvious—but to the way we live together socially." This line of thought stipulates the following foundational question: How are robot technologies supposed to become part of 'our' societies? Becoming part of society implies becoming socially meaningful, which means becoming part of 'our' social, physical environments, but also implies pertinence to the realm of the social and forming social relations.

From a perspective of techno-determinism, there seem to exist only two ways in which the social and technology can relate: a techno-optimistic or techno-pessimistic view on a future with robots. In the first vein, the emerging robotic technologies will become useful and therefore carry with them the potential for positive change (for instance, in service sectors, including elderly care). In the second view, robots will steal 'our' jobs and therefore stand for negative effects on societies (for instance, raising—if not exploding—unemployment rates). This juxtaposition of understanding and evaluating relations between human-machine (and society-technology, respectively) in terms of either resulting in positive or negative effects, is exactly the point of departure for the longstanding technofeminist endeavour to open up, as Wajcman (2004, 6) underlines, "a way between utopian optimism and pessimistic fatalism for technofeminism, and between cultural contingency and social determinism in social theory".

Foundational for such a way beyond an either-or positioning is the rich corpus of (feminist) science and technology studies (STS) research from which technofeminism draws. Basically, technology and the social are not separate realms, but rather are conceived of as the always entangled *sociotechnical*. Then, "technology is a sociotechnical product, patterned by the conditions of its creation and use" (Wajcman 2004, 34). Every technology is characterised by *interpretative flexibility*, which highlights the role of sociotechnical relations for assigning meaning and value to a certain technology. However, and importantly, from a non-determinist perspective, sociotechnical relations have to be

thought of as *reciprocal* relations of a co-constitution. Thus, Wajcman (2004, 39) concludes that "the construction of technologies is…a moving, relational process achieved in daily social interactions: entities achieve their form as a consequence of their relations with other entities." The use of the term "entity" points to the more-than-human, material entities actively involved in building and maintaining relations.

Summarizing here, my technofeminist, non-determinist account of technology means to adhere to several insights, including that technology is first and foremost a sociotechnical system, but also that: (1) sociotechnical systems are never fixed or given, but are rather processual, interactively stabilised phenomena; (2) sociotechnical processes involve humans and non-humans, persons and things; (3) these heterogeneous entities enact a technology, not only symbolically but also materially; and finally, (4) the process of enactment cannot be analysed without taking into account power relations in their normative operations, and how these are either perpetuated or transgressed.

The cobot embodies culturally powerful images of a future with robots that mainly pivots around the promise to free 'us' humans from the burdens of labour, also in spheres of labour which have been exclusively human so far—like the work of a clerk who is able to communicate in human-like ways, or even taking over as a nurse or more generally in medical care. While this might sound promising to some and terrifying to others, the potential for automating the yet non-automatable remains the same. In this regard, the cobot is envisioned to become a part of 'our' societies by stepping into multiple work relations with 'us' humans. These are necessarily *sociotechnical* relations: 'we' humans will have certain expectations of how the human-like Other will look, how it will behave, and how 'we' can engage with it. I suggest grappling with these expectations, identifications, and associations with the robot worker as foundational for the symbolic articulation and material enactment of HRC. The resulting sociomaterial configurations of HRC then emerge from a composition of social conventions, individual and collective expectations, images of robotic co-worker figures, ideas of collaboration, technological possibilities, embodiment, a range of affects such as desire, fear, frustration, but also spatial arrangements. These multifaceted ways of how technology *comes to matter* are my *matters of care*.

Against this backdrop, I will continue to explore, probe, and challenge human-machine relations of collaboration on the level of symbolic performance and material enactment as always entangled. This involves analysing the physical design, or *embodiment*, of robots, but also the resulting interactive capaci-

ties through which sociotechnical relations (that these robots should suppos-edly form and are forming) are made possible. Sociotechnical relations are always including human and more-than-human entities and are formed in both robotic lab settings and the realm of the envisioned use of a technol-ogy. Both realms are pervaded by power relations and concomitant cultural codes, and in both realms certain sociotechnical relations of substituting, co-working, or collaboration between humans and robots become (im-)possible over others. This forming of relations, however, is not dissolvable from bodies with capacities, expectations, and experiences, and is also mediated through visions of future scenarios of use. Hence, scenarios of use regulate and at the same time are dependent on the sociotechnical relations that can be formed between the entities involved (human and more-than-human).

Zooming in closer on the more-than-human in sociotechnical relations, I categorise cobot technologies in line with Suchman's (2011, 121) take on Har-away as "almost Human," meaning that they corporealise claims about hu-manness, and therefore function as *subject objects* in which the machine "Other [figures as] a differently embodied reproduction of the Self". The emerging class of current robots which are supposedly able to become agents in a so-cially meaningful manner is imagined and built in a way that I, 'the human', should be able to associate myself with the almost-human Other and vice versa (see Treusch 2015, 88). This should supposedly enable robots to also be-come social agents in private realms, that in consequence would allow new forms of automation of what used to be exclusively-human labour. Moreover, the almost Human embodies at the same time a figure of humanness as well as of the difference between 'the human' and its non-human Other. The hu-man-like robot allows associations of humanness with the machine Other, for instance, by recognising the human Self in the humanlike Other. This, further, appears to be an essential form of relating in HRI.

Essential for a technofeminist approach, however, is to not fall into the trap of attributing a human-like agency to the robotic Other, but rather to make intelligible the more-than-human active involvement in HRI. The challenge then becomes to care for the more-than-human articulations of meaning- and matter-making beyond the pattern of the human in contrast to the human-like. How is it possible to allow for new patterns of relating to emerge? Pivotal in tackling this question is the relationality of proximity between human and robot in human-machine-interaction (Treusch 2015) that has been analysed, for instance, for its evocative (Turkle 1984), enchanting (Suchman 2007) and posthumanist, performatively enacted (Suchman 2007;

2011; Treusch 2015) qualities. These insights help me to grasp the ways in which narratives and their cultural codes, entities, affects, experiences, expectations, and space—the social and material circumstances of interaction in robotics—are factors in the realisation of HRC, as I will continue to show.

Robotic Workforce—Human Workforce—Human-like Workforce —and the Need for Clarification

This book is interested in a particular form of interaction between humans and robots—namely, collaboration. The notion *collaboration* comes from the Latin *collaborare*, to work with, and therefore implies a certain form of partnership between entities in working on reaching a certain goal or solving a specific problem together. In this regard, the idea of collaboration is tied to the idea of robots becoming somewhat complimentary to the human workforce. I argue that it is not sufficient to question how realistic or socially desired such techno-optimistic visions are. Rather, I view it as a necessity to (1) delve deeper into the complex power relations inherent to the contemporary mode of capitalist production as the globally prevalent form of production, and to (2) bring these explorations in conversation with my observations of and experience in the emergence of collaborative agency in settings of human-cobot interaction.

Key for stipulating this conversation are the processes of differentiation between 'the human' and its Others. Haraway (1991, 210) reminds me that the *universal Human* as a historically contingent figuration of power is the result of

> "the great historical constructions of gender, race, and class [that] were embedded in the organically marked bodies of woman, the colonized or enslaved, and the worker. Those inhabiting these marked bodies have been symbolically other to the fictive rational self of universal, and so unmarked, species man, a coherent subject."

What becomes crystal clear in her derivation of the figure of the Human is that processes of differentiation and hierarchizing govern and regulate not only bodily norms, but also the social affiliation of differentiated (sexed, gendered, racialised, colonialised, classed) bodies to varying societal spheres (private/public), and further, positions bodies in relation to responsibilities for and the valuation of labour. In this regard, analysing the current capitalist production and its societal labour division, in order to examine its (possible)

transformation through robotic technologies, also needs to take into account the normative orderings of fields of labour, and the subjective labour force associated with this field. It cannot dissolve the universal Human in its powerful operations of differentiation and hierarchizing from capitalist production in its link to technology development. As Neda Atanasoski and Kalindi Vora (2019, 4) further highlight: "Present-day racial capitalism…posits humanity as an aspirational figuration in a relation to technological transformation, obscuring the uneven racial and gendered relations of labor, power, and social relations…of capitalist production." Asking for the ways in which cobots will shape work in the future necessarily means to ask *whose* work, including questioning which tasks are regarded as having potential for automation, who will benefit, as well as who makes these decisions.

Popular headlines mostly fail to address these complex power relations of in- and exclusion of *present-day racial capitalism*. Rather, they deploy the idea of freeing 'us humans' from the burdens of labour —whether wanted or not—and speaking to a somewhat homogeneous group of universal humans. This book works with an account of cobots that necessarily adjoins these neglected dimensions to discussions of a future with robots, and thus makes them one of its matters of care. Exploring what kind of sociotechnical relations are becoming im-/possible necessarily involves reconsidering these relations as intersectional, colonial, race, gender, class relations of the robotic history, present, and future.

Sociotechnical relations along intersectional categories of mattering are an intrinsic aspect of the power of "the robots are coming". They encompass not only the ways in which seemingly neutral robotic bodies are coded, for instance through cultural genitals (Robertson 2010, 5; Treusch 2015, 209), but also how seemingly neutral agential capacities are constitutive of specific sociotechnical relations through which culturally coded subject positions (for instance of 'the nurse') become possible at the human-robot interface.

My technofeminist intervention assesses the technological changes foreseen and envisioned to happen through robotic technologies, in order to open up ways for a renegotiation of the mattering of this technology. This then becomes a stance of critique to analyse technological change in its promise to free 'us humans' from the burdens of labour beyond determinist terms, while acknowledging the powerful differentiations between *whose* work and *what kind* of work is envisioned to be automated. Or put differently: Who is supposedly going to be freed from the burdens of what labour? How is labour redefined and revalued in robotics? Which tasks are regarded as worthy of

being automated, which are not, and in which ways? And, which subject positions are made im-/possible through those design decisions? Finally, how is it possible to make a difference? This set of questions orients my analysis towards human subjectivity and agency and how lines of differentiation in their powerful operations of valuing the one over the other are renegotiated. At the same time, I situate my critique in a specific laboratory setting and a practical engagement with one cobot technology. Through robotic knitting, as I will continue to show, I immerse myself in the enactment of HCI, and therefore also in the re-crafting of a future populated by cobots.

Donna Haraway's rich work is a companion to my approach: from her foundational work on how to playfully engage with the *Cyborg* (1985) as a figure of technoscientific processes of boundary re-/drawing between human, machine, and animal, as well as between nature, society, and technology, to her more recent work on *staying with the trouble* (2016) in multispecies assemblages. One key guiding aspect of her work is how she realises a playful engagement with dreadful earthly constellations through the tools of story-retelling and re-figuring. Both take seriously the complex ways in which discursive and material mattering are entangled. Thus, the remainder of this chapter builds the ground for retelling and re-figuring robotic futures through robotic knitting.

1.1   Discursive Certainties? Engaging with Cobot Discourses

In the following subsections, I will delve deeper into the idea of a robotic workforce, how this idea takes shape in different discourses, propels new forms of automation encompassing the not-yet automated spheres of human labour, and I will present selected strands of feminist and postcolonial critiques of these visions.

Exploring different narratives and imaginations of (future) relations of humans and robots, I identify three storylines within the contemporary robotic scene. This division into three storylines is my analytical suggestion for grappling with the multi-layered dimensions of cultural meaning of the complex contemporary robotic imaginary. These storylines vary in the ways that sociotechnical relations of human-robot interaction are imagined, discussed, and critiqued. I differentiate between the storyline (A) of machines becoming workers; the storyline (B) of machines not only becoming workers,

but also social agents; and the storyline (C) of machines as substituting the human workforce.

Furthermore, reading insights from these different strands together—or rather through one another—depicts a diffractive methodology of assembling the discursive formation of the contemporary robotic imaginary. Iris van der Tuin (2018, 100) writes that "diffraction is first and foremost a reading strategy that does justice to cracks in the academic canon." In the case of the picture painted on 'our' robotic future, I consider the narrative of "the robots are coming" as part of both academic and popular canons that are deeply enmeshed. Further, I understand the gap, for instance, between the announcing narrative and the robots rolling and stepping around in labs, founding the state of the art in robotic tech development, as one major crack in this enmeshed canon. The task then is to find and do justice to this and further cracks. Instead of re-narrating discursive certainties of a robotic future to come—a re-narration that literally performs frictionless automation—I, again, suggest challenging this mode of narration through disruption and deceleration. I follow the arguments of authors from different disciplines, contexts, and views that are concerned with a robotic future in one way or another, and who have sparked my interest during my project work on realising robotic knitting as a collaborative task. Further, I understand the latter in terms of making the three selected storylines players in my feminist, technoscientific recrafting of dimensions of future HRC. Haraway's take on the game of *cat's cradle* is vital for this diffractive reading—a reading in which strands become strings, and therefore introduces yet another dimension of yarn as material and metaphor to think and act with.

In 1987, *Paper Tiger Television*, a non-profit video collective, produced a video, entitled *Donna Haraway Reads 'The National Geographic' On Primates*. In the beginning of the video, she explains her approach of analysing relations of entangled nature and culture. While doing so, she holds half-unravelled balls of yarn in her hands that are messy and entangled. She then uses the yarn in her hands to describe the complexities of modern culture while she describes this as "untangl[ing] the ball of meanings" (Haraway 1987, 02:00). Untangling the yarn, pulling out strings, and thereby following one string as it leads to another that can be pulled out and followed again, is how Haraway engages with multiple layers of meaning and mattering. Notably, this is more than simply a reconstructive engagement. Rather, playing with yarn can be considered as a practice of producing new stories.

This becomes even more tangible when looking into Haraway's more re-cent work in which she continuously worked on the re-figurative nature of playing with yarn. Adopting the game of cat's cradle, she underlines the pos-sibilities of generating new thoughts, but also new ways of coming to matter through string figuration. Cat's cradle is a game of producing string figures by passing loops of yarn between players. It is a practice of producing pat-terns with yarn. Further, she most popularly coined the game of cat's cradle as an "everyday analogy" (Lykke 2010, 155) for the technofeminist analytical tool and methodology of diffraction. Haraway (2013, 1) takes the movements of the yarn to develop a method of thinking which she describes as in the following: "Relays, cat's cradle, passing patterns back and forth, giving and receiving, patterning, holding the unasked-for pattern in one's hands." This description illuminates the ways in which yarn is a navigational tool, which one can follow, while at the same time, it is never possible to control the yarn fully and predict what will happen, how the yarn will form patterns of entan-gling and knotting. The yarn plays not a passive role in string figuring, but rather an active part.

As will also become tangible in the next chapter of the book, in which I will re-enter the project's robotic lab, one cannot predict the behaviour of yarn when engaging with it. Engaging with yarn thus means to take on responsi-bility for how stories are told, to do justice to the cracks in a canon and to acknowledge the more-than-human factors in thinking. In addition, the act of unravelling entangled yarn is also an activity that demands patience, atten-tiveness, and deceleration. Engaging with yarn is un-/making stories and un-/making worlds—in Haraway's (ibid.) words: "It matters what matters we use to think other matters with; it matters what stories we tell to tell other stories with; it matters what knots knot knots, what thoughts think thoughts, what ties tie ties. It matters what stories make worlds, what worlds make stories." Hence, playing with strands that become strings, forming patterns, allowing unasked-for patterns to emerge, giving and receiving, are all aspects of doing justice to the canon on cobotic futures.

Haraway's figural engagement with yarn has become central to my think-ing since the very beginning of my academic work. It made me start learning how to knit during my doctoral studies and I am sure that it has also stip-ulated me to come up with the idea to bring a ball of yarn to the robotics laboratory where I was working when I was introduced to cobots for the first time. In this subsection, I intend to generate a more capacious vision of the human-cobot-interface. Even though built on the discursive figures available,

this work exceeds a 'pure' reconstruction. Rather, I understand it in terms of identifying strings, pulling on strings, and following where they lead me. In this regard, the diffractive method of string-figuring structures my thinking and therefore also my reading and assembling of insights into the contemporary cobot discourse in what follows.

Storyline (A): Promises of Acceleration: When 'Machines Become Workers'

Reviewing current book publications on the topic of how technologies are changing and will continue to change work, Wajcman (2017) explores the status that is given to technology in narrations of future Artificial Intelligence (AI) and of robots as workforce. In line with her, a central aspect of the contemporary *futurist discourse* is the relevance of "automation, robotics and AI" (ibid., 1) in painting pictures of 'our' future. The future robot belongs to a new class of machines in these discourses. As Wajcman (ibid., 2) observes: "Machines are no longer tools; they are turning to workers themselves." Curious about how these technologies are imagined to transform society, insights into the discursive figure of the robot as worker will reveal details on the emerging relation between society and technology.

To begin with, one central dimension of how robotic technologies are imagined to change society is a shift in time as robotic workers stand for new forms of increasing efficiency through automation. Thus, the idea of a machine as worker is strongly tied to the promise of acceleration. This tie becomes tangible in popular statements like "'race with machines, instead of against them'" (ibid.). The metaphor of a race implies a relation between humans and technologies that is full of competition and the potential to lose this competition. What can be lost is open to speculation, but also indicated: If one does not engage in the race or even works against the race, one is in danger of losing one's access to (economic) prosperity, while those who engage in the race will profit. Intriguing in this is the assumption that everyone has the same chances to race with machines.

The idea of equal chances for everyone has to be read against the backdrop of the insight that hegemonic discourses tend to treat technology as a neutral and inevitable force. Challenging this suggested neutrality of AI technologies is at the core of technofeminist research and has lately become popular through work such as Safiya Noble's *Algorithms of Oppression* (2018), Kathy O'Neill's *Weapons of Math Destruction* (2016), and Mar Hicks's *Programmed In-*

equality (2017)—but also through long-standing, classical work such as Alison Adam's *Artificial Knowing: Gender and the Thinking Machine* (1998). All four books show extensively the ways in which seemingly neutral AI technologies such as the highly praised and applied methods of *Deep Learning* are shaped through the values and biases in which 'our' societies are grounded, and therefore also perpetuate sexist and racist power relations.

These works also make tangible the ways in which algorithms cannot be un-biased. Rather, the very idea of technology as neutral and free from social relations reveals itself once again as a myth. Claude Draude et al. (2019) have suggested a situated account of algorithms as a method for de-biasing, that is, becoming responsible—and through this to also acknowledge, reflect, and possibly reduce bias in algorithms. In addition, the computer scientist Anna-Katharina Zweig (2018) argues for an understanding of algorithmic decision-making as a sociotechnical system in which the social and the technical are entangled in co-constitutive relations at different stages of choosing and training algorithms, generating data, and bringing algorithms to use.

While the insight into the biased, sociotechnical nature of algorithmic decision-making appears to have been established as relevant knowledge (at least to a certain degree) across disciplinary boundaries in public and academic discourses, it can be said that this insight has *not* found any corresponding argument in the debates on the promises of new forms of robotic automation. As Wajcman (2017, 3) underlines, "political questions are too often lost in our obsession with the robotic revolution we are set to witness." In this sense, the tie between neutrality, inevitability, and robotic automation amounts to what I analyse as another crack in the canon and as the first knot in the yarn—if thinking of the canon of "the robots are coming" in terms of entangled balls of yarn. This knot is about the figure of robots as workers and in need of a careful dis-and re-entangling that consists of both untying the knot between neutrality, inevitability, acceleration, and robotic automation, and making possible new knots and patterns of robotic automation.

The robotic future deeply deploys the machine as a worker and as a neutral and inevitable force of technological change connected with the capitalist promise of acceleration. What appears to be a central dimension of the idea of the machine as worker is what Wajcman (ibid.) calls *our obsession* with emerging robots. What is the nature of this obsession? I raise this question through the perspective of making it a technofeminist matter of care. Obsession can be read as denoting a relationship towards a certain object that is characterised by a fixation on that object. Thus, I understand the use of that term here as in-

dicating a fixation on the object 'robot as worker' that is charged with certain values. The promise of machines as workers embodies the potential of optimisation of capitalist production through both freeing 'us' humans from the burdens of labour and increasing the efficiency of human labour forces. I will return to the first dimension in storyline (C) on substituting human labour, and delve deeper into the second dimension, the increase of efficiency of human labour forces and the promises of acceleration as a sociotechnical issue, in what follows.

Again, Wajcman's rich technofeminist oeuvre is one resource for challenging the implicitness of acceleration in processes of automation by creating the seemingly universally-useful machine worker. More precisely, I am interested in her research on the relation between technology and time with her main diagnosis that "we are pressed for time" (Wajcman 2015, 4): that is, the paradox between the development of more and more supposedly time-saving technologies and the contemporary "shared experience of time poverty" (Wajcman 2018, 169). However, and importantly, the condition of being pressed for time cannot be explained through a techno-determinist perspective, but rather through sociotechnical relations of a co-shaping between technology and society. As Wajcman (ibid., 171) points out: "If we feel rushed and pressed for time, it is because of the priorities and parameters we set ourselves rather than the machines per se." One example she gives is the acceleration of communication through email. While the internet and computing capacities deliver the technological infrastructures for fast communication, Wajcman (ibid.) underlines that it is the "collective norms about appropriate response times" which have been established and which dictate an acceleration in communication combined with a constant availability. In this regard, the relation between technology and time is a sociotechnical relation that is neither determined by the technologies themselves (which guarantee absolute availability), nor by the norms about fast response times alone, but through their interplay. Further, many factors can be relevant for how this interplay takes shape: for instance, how and why certain norms are collectively accepted. These insights alone challenge the idea of a robotic acceleration in particular, but also, more generally, of the neutrality of technology and of the inevitability and the linearity of technological development.

In addition, there exists plenty of work from a historical technofeminist perspective on the introduction of household technologies, the so-called whiteware, and their promises of saving time doing chores. Classic studies are Ruth Schwartz Cowan's *More Work for Mother* (1983), Cynthia Cockburn's

and Susan Ormrod's (1993) study on *Gender and Technology in the Making* that traces the development and use of the microwave, and Martina Heßler's *Mrs. Modern Woman* (2001). All three studies carve out the paradox between the promise of a relief from the burdens of chores through new technologies, and the increase of working hours despite the use of these technologies. In general, the listed studies point towards the transformation of work through the introduced technologies as a main reason for an increase in working hours: Essentially, tasks become more differentiated, refined, and specialised so that the number of tasks is growing. However, and importantly, all three studies also show how the development and the bringing to use of technologies cannot be dissolved from the power relations pertinent to the different societal spheres of production, consumption, and reproduction. From the perspective of contemporary studies on household and care work, the private is a sphere in which the distribution of and responsibility for work is divided by a global labour division along the categories of race, gender, and class. Thus, the promise of being freed from the burdens of labour in the private realm, through machines that become workers, raises multiple questions, such as: What kind of tasks are the machine workers going to take over? Whose work? And, more generally: Who is going to profit, and at what and whose cost?[4]

Raising these questions here, I underline the decontextualised nature of a promise of acceleration and the need for challenging such de-contextualised imaginations of how technologies will change societies—regardless of whether this change is believed to be for the better or for the worse. A linear acceleration of work processes depends on multiple sociotechnical factors that cannot be predicted, involving the interplay of technological artefacts, collective norms, and societal organisation of work in their regulative operations and individual everyday practices in accomplishing a task. In this way, what is needed is a more capacious understanding of the details of what 'becoming a worker' of machines implies to present and future forms of work, encompassing the societal division of labour and modes of current capitalist production, as well as the divide between production, consumption, and reproduction.

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4   For a discussion on care in the context of the hospital and future robotic co-workers, see for instance: von Bose & Treusch 2013; 2018.

Storyline (B): When Robots Become Social & Emotional Machines

In most narratives on machines becoming workers – regardless of these workers being rather physical robots or mere virtual chatbots – the emerging workers have in common that they are portrayed as machines that will engage in proximate relations with 'us' humans. In both spheres, that of physical and that of virtual interaction, a prerequisite for such proximate relations is that "interaction between people and machines implies mutual intelligibility or shared understanding" (Suchman 2007, 34). Thus, a major concern in technology development has been the realisation of capacities for such a mutual understanding. Accordingly, a large corpus of work in the interdisciplinary field of HRI focuses on two characteristics in researching empirically and conceptualising interaction between humans and robots, namely *sociality and emotionality*. Both appear to be regarded as central premises for a successful interaction between humans and robots, and as a guarantee for increasing the mutual intelligibility between both entities.

In this subsection, I will delve deeper into the idea of robots as social and emotional machines as another crack or knot in the canon, and I ask how both aspects of mutual intelligibility are modelled onto human-machine relations. In so doing, I show how this idea connects behavioural characteristics with a corporealisation of the almost Human, with ways of finding the Self in the machine Other, and with forming bonds that are consistent with existing norms of human-human relations.

Thinking with Jutta Weber (2005, 209), I identify the emerging figure of the robotic worker as belonging to a class of technology that is characterised by a shift from "model[ling] rational-cognitive processes and...solv[ing] problems using formal structures...to socio-emotional interaction." This foregrounding of socio-emotional interaction involves both defining and modelling the social, including emotions, and based on that, designing and realising machines coherent with the established models. One early and quite famous example is the work of roboticist Cynthia Breazeal. Her key technology, the robot head Kismet, was developed in the early 2000s, with the goal that "interacting with it is like interacting with another person" (Breazeal 2002, cited in Weber 2005, 210). Here, I am not so much interested in if and how Breazeal managed to realise that goal, but rather how the robot's design was built on introducing the social and emotional robot.

When Breazeal becomes more specific about her goal, she reveals that she has a distinct form of human-human relationship in mind: that of infant-

caregiver (ibid.). Suchman (2007, 237) poignantly analysed the implementa-tion of the figure of the child as follows: "The figure of the child in Euro-American imaginaries carries with it a developmental trajectory, a becoming made up of inevitable stages and unfulfilled potentialities, that in the case of Kismet simultaneously authorizes the continuation of the project and ac-counts for its incompleteness." Thus, the machine's becoming social is tied to a developmental trajectory and to existing forms of relating between humans. In the case of the figure of the child, this is justified in applying the find-ings of developmental psychology to the design of a social robot (Suchman 2011). Notably, what is not taken into consideration are the cultural meanings of the figure of the child. This includes the care work implemented through the infant-caregiver relation and the responsibilities for this work which have been unevenly distributed individually and societally. Weber (2005) reminds us of the gendered, but also heterosexual dimensions at work (210), when she points out: "Sociality and emotionality have been deeply gendered categories in western thought that have hitherto been assigned to the feminine realm" (213). The infant robot as social robot is modelled after the symbolic ordering of the social that differentiates between a feminine and a male realm, with the effect of naturalising such binary differences when a robot is supposed to be-come social through female-coded modes of bonding, such as care, including physical and emotional care.

Beyond a critique of the reproduction of social relations as naturalised re-lations through the infant-caregiver metaphor, others have also argued that the application of certain theories of 20th century developmental psychology in robotics also serves the purpose to generate knowledge on the Human, and seeks to verify these theories through their application to machines. In this regard, Evelyn Fox-Keller speaks of a "circular trajectory" (2007, cited in Such-man 2011, 129). The danger then is that the enactment of the infant-caregiver relation between a robot and a human is not only heavily entrenched in ne-glected cultural norms, but also forecloses the question of what the robot's potential is with regard to the technology itself, and of what relations with humans are possible. According to Raul Hakli and Johanna Seibt (2017, 2), this foreclosing is "deeply unsettling" as it results in a "social robotics [that] is not only the engineering of robotic movements, [but also] the engineering of human social actions." This analysis of how engineering a machine that is supposed to fit into 'our' everyday lives encompasses the engineering of human social actions, first and foremost addresses how certain concepts em-bodied by the robot through specific design decisions are determining not

only the capacities of the robot, but also what 'social interaction' with this robot means, and are therefore also defining human-human social interaction. While Hakli and Seibt underline the dimension of a potential undesired transgression of moral and ethical norms, I am—in line with technofeminists such as Susan Leigh Star (1995) and Haraway (1996)—more interested in asking: *Cui bono?* By asking who profits, I situate processes of engineering social action within specific arrangements of time, location, and power on the one hand, but I also, on the other hand, raise questions of responsibility for such an engineering of the social.

In this sense, it is important to acknowledge the individual, but also collective, dimensions of the normative character of the infant-caregiver relationality. In fact, the modern gendered, racial, and colonial labour division is key in establishing the divide between the public and the private realm, as well as between production and reproduction. As put by Sandra Harding (2008, 2), *Western modernities* are built on these foundational divides which

> "enable elite Westerners and men around the globe to escape the bonds of tradition, leaving behind for others the responsibility for the flourishing of women, children and other kin, households, and communities…. These others must do the…reproductive and 'craft' labor…. These others are mostly women and non-Western men."

Thus, the metaphor of infant-caregiver is also problematic with regard to its obscuring of the social ordering of responsibilities for reproductive and care labour, and its uneven distribution along the intersectional category of gender that privileges elite Westerners and men.

Moreover, a core component of reproductive work is emotional labour, as Jennifer Rhee (2018, 101) writes: "The robotic imaginary highlights the normative assumptions that structure emotional labor, yet another gendered and often devalued form of reproductive labor." As she further explains, emotional labour is tied to "the expression of normative emotions" which works as an "evidence for humanness" (ibid.). In this regard, the capacity to express normative emotions is held as a core capacity of humans and therefore as a requirement for robots to become intelligible, that is, social agents. The interest in emotions as a core component of humanness has been a long-standing aspect of research in AI; or as Suchman (2007, 233) underlines, "emotion is another component…needed for effective rationality." While acknowledging the value of emotions for intelligence in humans and machines, emotional-

ity here remains nevertheless conceptualised in hierarchy to rationality and is reduced to a factor of functionality.

Furthermore, returning to emotional labours, what appears to be a dominating assumption is that the right emotions in machines will serve both to make machines more legible as social agents, but also to evoke certain behaviours in the persons engaging with such emotional machines. Kismet is one such example. As Suchman (2007) and Rhee (2018) both have carved out, the basic mode of relating at the human-Kismet interface relies on what can be understood as an activation of the person engaging with Kismet on an emotional level: The person has to not only read Kismet and in turn make themselves emotionally legible to Kismet, but also to adjust themselves to available emotional states pre-defined by this interactive setting. This host of emotional labours has to be invested in order to make the machine successful in social interaction. This also encompasses training oneself when interacting with Kismet in reading the machine and making oneself emotionally legible to it (Suchman 2007, 246). They appear to be foundational practices of interfacing and thus becoming available for one another. Working with a set of emotional labours that furthermore defines emotions through *emotional states* (Suchman 2007, 234) is based on the formalisation of emotional expression into circumscribable states that are treated as a universal quality of humanness. In addition, against the backdrop of a hierarchy between emotions, these emotional states can be considered to amount to the kind of emotions appropriate for humans, separating between appropriate and other emotions, while the latter remain not only as opposing reasoning humanity, but also as a threat to this reasoning humanity.

The seemingly paradoxical process between a valuing and devaluing of emotions in relation to rationality aligns with Sara Ahmed's (2004, 3) contemplation about the politics of emotions, when she writes: "The hierarchy between emotion and thought/reason gets displaced, of course, into a hierarchy between emotions: some emotions are 'elevated' as signs of cultivation, whilst others remain 'lower' as signs of weakness." Only a certain kind of emotions, the right kind of emotions, are tools for reasoning. In the case of AI, this functional approach to emotions is displayed in the robot Kismet's emotional setup: It is built on an established model of emotions which differentiates between six different states of emotional expression (Rhee 2018, 106). Underlying is a concept of emotions as internal states that become legible through their bodily expression. This bodily expression then has to be within one of the six states in order to be legible. Thus, the hierarchy between emotion and

reason also includes the hierarchy between legible and illegible forms of expressing emotions, and is therefore normative on different levels of universalising humanness. With Ahmed (2004,4), the interrelatedness of emotionality and subjectivity secures social hierarchy while "emotions become attributes of bodies" – involving individual as much as collective bodies.

Resuming here, it is vital to dis-entangle how care as social and emotional work and expression matters, in order to re-entangle relations of mattering through care in human-robot collaboration. The expression of emotions as foundational for the robot becoming a social machine can be analysed through the powerful operations of connecting some emotions with reasoning over others, as gendered and racialised operations. A normalisation of the expression of a certain emotion over another carries with it the normalisation of a specific subject as the universal Human. The belief in a universality of emotions deployed by the idea of a mutual readability between humans and the machine, in short, is in danger of a normalisation of humanness as *Whiteness*. It is not taken into consideration, as Rhee (2018, 105) points out, "how different women perform this work and what this work looks like varies significantly across gender and racial identification." In case of the infant-caregiver relation and the implied emotional labours of care as mothering, this includes the normalisation of *White motherhood*. The engineering of the social means more than just a potential transformation of ethical and moral codes of 'human sociality'. Rather, what is at stake is how emotions are categorised as either inside or outside of a certain norm of mutual readability. Those outside of this norm become illegible and therefore the individual and collective bodies to which these emotions are attributed, too, become illegible. I might even argue that emotions different to the six model emotions are dehumanised and therefore those who embody them are also dehumanised.

This book centrally aims at re-crafting the human-robot relation of interaction—more precisely, of collaboration—through first taking into account that this interface is loaded with cultural meaning, and therefore not only reproduces existing power relations, but also determines how robots and humans can relate. Based on that, re-crafting will also include to reclaim care in its emotional labours and corporeal forms as a substantial dimension of collaboration between humans and robots, and through the practice of hand knitting collaboratively, while establishing that this care is not based on the infant-caregiver metaphor, but rather carved out as a foundational practice of engineering (see Chapter 3).

Storyline (C): Robots as Replacing the Human Workforce

When machines are portrayed as becoming workers, it is not a stretch to ask what their role will be in capitalist production: If they are going to automate labour that has been exclusively human labour before, will this in consequence mean that robots will replace humans at work? Raising this question here, I want to identify and emphasise, again, two cracks in the canon of "the robots are coming": first, the universality of this claim in relation to humanness figured by *the worker*, and second, the gap between the robots rolling, jumping, or walking around in robotic laboratories and hegemonic imaginations of a robotic future that is near. Even if termed a co-worker, the robotic worker signifies a takeover at work. While I am not interested in assessing if this will happen and within what time span, I am interested in understanding the sociocultural framing of such a takeover and its concomitant redefinitions of labour, collaboration, and automation. My game of string-figuring with storylines in this subsection is geared at tracing operations of in- and exclusions inherent to the contemporary robotic imaginary around the idea of robots as replacing human workers.

Given the insights of the previous subsections, what can be immediately problematised in promises of a robotic takeover at work is that both the supposed fields of work expected to be taken over and the human labour forces expected to be replaced by robots are culturally coded as universal, that is, as the unmarked. As emphasised by Atanasoski and Vora (2019, 2, emphasis in original), "the inevitable incursion of robotics into domestic, social, military, and economic realms is commonly figured as a potential boon or threat to *all* of humanity, the figure of the human most threatened because it is iconically human...is white and male." This is foremost caused by the new forms of automation heralded by emerging robots. Fields of work and expertise have been excluded from former processes of revolutionising industrial production through automats as the non-automatable. While former industrial revolutions have mostly automated what has been classified as unskilled labour, largely performed by women and Non-Western men, the emerging robotic workforce stands for a redrawing of the boundaries of what are considered replaceable, boring tasks—a redrawing that in line with Atanasoski and Vora (ibid.) will effect *a White loss*. The promises of replicability that go hand in hand with a White loss are understood in terms of a form of liberation, which they analyse as *technoliberalism* (ibid.). Technoliberalism obscures the power relations, inequities, and hierarchical social order of racial, colo-

nial, and gendered processes of capitalist production behind the design and development of automation technologies. It defines "what kind of tasks are replaceable, and what kind of creative capacities remain vested only in some humans" (ibid., 4). Selected tasks are considered to be replaceable while the decision behind this categorisation is presented as neutral and based on obvious evidence, rather than power relations.

One example that immediately comes to my mind is that of a receptionist robot. Existing receptionist robots are either humanoids in a white plastic covering or anthropoid robots that are endowed with robotic skin and supposedly all features of 'a human' head and torso, or sometimes even a 'complete' body in accordance with the able-bodied norm. The anthropoid body, for instance, of the robot Nadine, which was assembled in 2013, is modelled after her creator, Nadia Magnenat Thalmann (IMI Singapore).[5] One can find plenty of videos on the Internet showing either Nadine by herself or Nadine with Nadia. Nadine is supposed to figure the ideal robot receptionist: female, middle-aged, able-bodied, dressed in what can be described as formal office wear for women completed by an adequate hairdo and make-up. Watching videos of Nadine in action, the viewer can only get an impression on how the robot functions under the staged conditions of such a representative video. However, what seems intriguing is that the work of a clerk or receptionist is regarded as a replaceable task. Further, and even more intriguing, by seemingly realising these capacities in Nadine, the envisioned replacement moves from receptionist to social worker (ibid.): "She is part of the human assistive new technology which is badly needed as society cannot afford a full time social worker for each person with special needs. She can play the role of a personal, private coach always available when nobody is there." At first sight, this statement gives a strong impression that there exists a techno-fix for every societal challenge, such as integrating persons with special needs into society. This technoliberal claim does not allow one to ask, for instance, why it is regarded as not affordable to have a social worker for everyone who might need assistance. In fact, why should it be more affordable to delegate the care work and emotional labour to machines? Here again, it appears as if engineering social and emotional machines, such as the robotic assistant and social worker, are tied to an engineering of the social beyond engineering social

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5   Citations from Nadine's webpage at IMI Singapore: https://imi.ntu.edu.sg/IMIResearch/ResearchAreas/Pages/NadineSocialRobot. aspx

action. Rather, social engineering involves both defining a problem in society (like the lack of institutionalised social work and a resulting lack in social workers) and delivering a possible tech-solution. At the same time, the envisioned assistive robot is also described as a personal, private coach that helps against social isolation as *she* will be "always available when nobody is there" (ibid.). Social isolation appears to be another issue that is in need of social engineering through techno-solutionism, while the position of the personal coach furthermore combines a spectrum of roles and functions: This can be the role of a here female-coded assistant in a difficult situation in life, or the role of a guide on reaching a certain goal, mostly geared towards an optimisation in one's personal life. In addition, the receptionist as well as the social worker are both job functions that are predominantly pursued by women and that require different forms of training, from an apprenticeship to college education. Modelled after her creator, Nadine becomes the representation of the White, college-educated, middle-class woman, and at the same time the representation of the fields of work this kind of robot will take over (namely those of White, college-educated, middle-class women, supposedly including social work, but also the whole range of the education system). She might be regarded as emblematic for a (gendered) White loss.

Debating Dehumanisation: Robots as Workers with Rights or Robots as Slaves?

While robots seem to advance into machines that are not restricted to the category of so-called 'unskilled' work, they should become, at best, useful machines to 'us humans'. Staging the useful machine as an auspicious technology *because* of its potential to replace human labour force, this narrative requires the figures of thought to tell the story of both the potential and the harmlessness of this technology. These figurations also regulate 'our' relationship with the future robots. There exists a long-standing tradition in robotics to draw on the metaphor of master-slave (see Weber 2014; Gunkel 2018), which in line with Weber (2014, 192) "describes a control relation between the expert and the machine." While Weber (ibid.) attests that the word robot etymologically contains the notion slave through its root in the Czech *robotnik*, she also argues that this metaphor loses its relevance as soon as the robots are stepping out of their formerly restricted contexts of industrial work into unrestricted settings of human everyday lives, as the latter context no longer relies on machine control as the guiding principle of relating between human and ma-

chine, but rather on interaction. However, reading through contemporary, mostly philosophical, literature on human-robot interaction, the question of control, and with it that of abuse of power, over the machine Other becomes of new relevance.

This relevance is articulated in what Gunkel (2017, 9) frames as *Instrumentalism 2.0*, which takes the advances in robotics figured for instance in machines like Nadine, but also constantly announced through the narrative of "the robots are coming", to argue for a human-robot relationality in which robots remain the "mere tools of human action," regardless of "how sophisticated they become." Thus, the robot is a technology that is constitutive of what Gunkel (ibid.) calls "a new class of instrumental servant or slave." What intrigues me is the seemingly unquestioned equation of instrument and slave in the canon on HRI and the de-thematising of the dehumanising quality implied in this equation. This also becomes very tangible in Gunkel's interchangeable use of the notions *Instrumentalism 2.0* and *Slavery 2.0*.

However, Gunkel is not an agent of deploying the perspective of instrumentalism or Slavery 2.0. Instead, his concern with this wording is that it might no longer be an appropriate choice when robots become social. His primary argument for a cessation in using the slave metaphor is not the violent and still harmful colonial legacy of this term, but rather the limits of what is thinkable if the very debate on robot rights is dismissed as not worth having (see Gunkel 2018). Furthermore, this leads to Gunkel (ibid.) to becoming a kind of advocate of *robot rights*. As he explains, the issue of robot rights mainly encompasses two dimensions: the dimension of *ontological capacities* and that of *normative obligations* (ibid., 20). With this, Gunkel raises the important issue of first asking if robots can become social agents with moral subjectivity, and second if 'we' humans think that this is a desirable status, taking into consideration the societal consequences this will have. As he further underlines, his goal is not "a simple 'yes'/'no' response" (ibid., 40) to this question. Rather, Gunkel (ibid., 42) is interested in the "critical task…to identify, explicate, and evaluate the oftentimes implicit operating systems that makes the discussion and debate about robots and rights possible in the first place." Thus, he is interested in re-envisioning categories of thought with regard to sociotechnical futures, and a special attention towards the denial and dispossession of rights as they have been essential to Western modernities.

In diagnosing that robot rights currently account for *the unthinkable*, Gunkel (ibid., 99) is working towards an expansion of the imaginable limits of envisioning how robots will matter as social agents and workers in the

present and in the future. However, reading through Gunkel's *Robot Rights* (2018), one can acquire a quite comprehensive impression of how common the use of the terminology slave is, while the dehumanising effects deployed by the appellative practice of equating robotic instruments and slaves remains unnamed. Notably, this practice is far from innocent. Rather, drawing the boundary between machines as slaves and machines as social agents almost equal to the universal Human is in danger of ignoring the deep connections between dehumanisation and labour, as well as of reinforcing historical racial oppression—also in its histories of emancipatory resistance.[6]

In this regard, the very vision of robots as replacing the human labour force cannot be dissolved from asking, again: *Cui Bono?*—Who will profit from a replacement of human workers thought of and realised as an enslavement of the machine? Whose work is regarded as replaceable by whom or what? And, whose work will remain undervalued and not worthy of automation with regard to a continuation of current modes of racialised and gendered capitalist production? These questions point toward processes of boundary-drawing between the Human and the dehumanised Other through the societal reorganisation of the establishment of robotic labour forces. What is feared as either an impending White loss or as the lost chance to acknowledge the emerging robots in their capacities for humanlike labour and for the same rights as human workers, is a discursive configuration that fails to address the intimate tie between dehumanisation and labour in its colonial and sexist histories. This failure can be regarded as a crack in the canon.

Disentangling the tie between dehumanisation and labour further, I briefly look into strands that (1) connect the emergence of robots as workers with the question of *human welfare* (Birhane & Dijk 2020), and (2) develop an account of the *surrogate human effect* as "the racial 'grammar' of technoliberalism" (Atanasoski & Vora 2019, 5). Reading these strands as strings that become partners in my game of cat's cradle with the figure of the robotic worker, I regard my feelings of unsettlement with hegemonic debates on a replacement of human workers through the enslavement of robots as guiding this selection of strings.

Abeba Birhane and Jelle van Dijk (2020, 1) argue for a shift in debate – from asking if 'we' should grant robots rights or not, to making human welfare the primary concern. Mainly, they argue that

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6   It also ignores current feminist, afro-futurist re-workings of the relation between slavery and robotics (see especially the work of Janelle Monáe in Rhee 2018, 207).

"robot rights signal something more serious about AI technology, namely, that, grounded in their materialist techno-optimism, scientists and technologists are so preoccupied with the possible future of an imaginary machine, that they forget the very real, negative impact their intermediary creatures—the actual AI systems we have today—have on actual human beings." (ibid., 2)

Reducing the analytical perspective on the future robotic worker and their rights, first, relies on a belief in techno-optimist fantasies of creating a machine that will be human-like—at least human-like enough to grant rights similar to 'us' humans, and second, de-thematises the sociotechnical effects of already established technologies for individuals and collectives.

Birhane and Dijk (ibid., 2) offer a perspective in debating robots as a replacement of the human labour force that is not blinded by techno-optimist visions of the capable machine, which they frame as *techno-arrogance*, but instead articulates through an "ethical stance on human being...[through which] being human means to interact with our surroundings in a respectful and just way." Furthermore, they regard the role of technology as that of promoting exactly such a stance. Technology then becomes a mediator, in a phenomenological sense of a "lived embodied experience, which itself is embedded in social practices" (ibid.). This then leads to a shift in conceptualising the human-machine relationality, in short, along phenomenological insights into the embodied, distributed nature of sociotechnical interaction.

Focusing on the reduction of debates on robotic futures through the enslavement or rights divide, I agree with positions such as Gunkel's that plead against such a reduction and for a critical revision of how the relations between humans and these robots have been and still are debated. However, I am less concerned with arguing for the liberation of the one over the other or vice-versa. The master-slave-metaphor, as so commonly deployed in this debate, seems to allow only one view, namely precisely that of pinning the liberation of the one against the oppression of the other. Either the universal Human is liberated from labour at the costs of robots as mere tools, or robots become fully acknowledged as (potential) social agents with rights which means that the universal Human has to give them a place in the as yet exclusively human-confined sphere of the social. Such a place brings with it both the privilege of the robots' protection against destruction by humans, but also the potential to become a threat to White Human privileges. It matters how 'we' imagine robots as becoming a workforce equal to human labour forces.

Birhane and Dijk argue in a similar vein when dismissing the enslavement/rights debate. They differentiate between varying intentions in using the term *slave* for future robotic workers. They draw, for instance, on the plea to understand robots as slaves exactly for its dehumanising qualities (ibid., 1). In this line of view, the dehumanising logic of the slave as a social status is willingly employed to draw a boundary between 'us' humans and the machines. For Birhane and Dijk (ibid.), however, this practice of classification is built on a false logic when they explain that "one has already implicitly 'humanized' the robot, before subsequently enslaving it." In their reading, enslavement is problematised not only because of its dehumanising logics, but the implicit humanisation, which in the case of robotic workers, means to fall into the trap of techno-optimistic fantasies. Moreover, they emphasise that "By putting actual slaves, women, and 'other races' in one list with robots, one does not humanize them all, one dehumanizes the actual humans in the list" (2020, 3). What appears important to bear in mind is that the debate on the status of robots as either slaves or humanlike workers with rights seems to lead to what I identify as an impasse. The operations of enslavement certainly are foundationally based on the violent, radical challenging and even neglect of humanness in the enslaved. Acknowledging the dehumanising logics of enslavement, however, cannot be dissolved from rebellion and the emancipatory liberation from enslavement. Cutting them apart by insisting on the fact that robots will always remain non-human machines, is in danger of erasing histories of enslavement and emancipation from individual and collective memory. This then perpetuates racial and sexual oppression in the name of liberating robots when 'we' humans would, in consequence, become *slave owners* (ibid., 4). Nevertheless, a call for an emancipation and liberation of robots in the name of racialised Others and women is not a solution here, as it buys into the logics of dehumanisation with its relational ordering of formerly categorised groups of humans, an ordering that serves the purpose to secure the privileges of some at the costs of others. What seems to be at stake here is to overcome both the master-slave relation in robotics as much as the idea of robot rights in their implicit and explicit logics of Othering and dehumanisation.

Finally, I briefly turn to what Atanasoski and Vora (2019) term *the surrogate human effect*. In short, following their arguments, the task becomes to overthrow the whole idea of robots as workers in the first place. This is because they analyse the idea of replacing human workers through robotic workers, which are idealised as the more-efficient, stronger, and faster labour force, as

a form of surrogacy that is foundational for Western modernities and deeply entrenched in racial and sexist operations of power. Replacement through automation technologies thus exceeds its meaning as a simple substitution of labour forces. Rather, it plays a key role in sociocultural processes of differentiating, classifying, and ordering humans with the effect of producing the figure of *the liberal subject* (ibid., 5). The liberated status of this subject depends on—in line with Atanasoski and Vora—"the racial unfreedom of the surrogate" (ibid.). In this regard, they underline how the very idea of substituting depends on processes of dehumanisation through which the Human as a concise figure emerges. Notably, Atanasoski and Vora (ibid., 7, emphasis in original) deliver a very rich analysis of "the social impact of design and engineering practices intended to replace human bodies and functions with machines *and* the shift in the definition of productivity, efficiency, value, and 'the racial' that these technologies demand in their relation to the post-Enlightenment figure of the human." I regard their work as a vital and important contribution to and necessary complement to feminist concerns with transformations of the sociomaterial grounds of agency and lived experience, as well as with transformations of the symbolic through changing relations across human and machine from a postcolonial perspective. Again, the idea of replacement is far from innocent, and the technologies developed to take over (such as the robotic worker) are not neutral artefacts, but are rather political sociotechnical agents. Their design, development, and use are processes that stipulate the production of difference between humans, but also between humans and non-humans; and at the same time, these practices are pertinent to existing forms of differentiation. To grapple with *technoliberalism*, in its logics of liberation and oppression, requires such a comprehensive account of current and historical powerful operations of differentiating and hierarchical ordering in order to open up possibilities for more just visions of human-machine relations. With Atanasoski and Vora (ibid., 8), what is needed are "projects focused on creating technologies that blur the boundaries between subject and object, the productive and unproductive, and value and valuelessness, thereby advancing structures of relation that are unimaginable in the present." I consider robotic knitting such a project, precisely concerned with advancing structures of relation that are unimaginable in the present, as I will continue to show.

Notably, while Atanasoski and Vora are also working on the imaginable limits of the present, their work presents a different approach to the unthinkable: Their engagement with the unthinkable is not about deciding whether or

not the robots that supposedly will become advanced enough machines to re-place 'us' humans at work should have the social status of slaves or be granted the same rights as the liberal subject. Rather, as they show, it is about dismiss-ing the idea of a replacement from the start, and with it the very operations of ordering in which those differentiations are grounded. Instead, debating robotic futures then becomes a point of departure to open up possibilities for imagining a redistribution of responsibilities for, and the burdens of, labour beyond the *racial grammar* of the *surrogate human effect* of capitalist production.

Moreover, drawing on Haraway's string-figuring as a method for rereading insights through one another, to ignore the tie between dehumanisation and labour, in all of its facets, as it is foundationally implicated in the fig-ure of the robotic worker, performs a cut through an existing knot —instead of engaging in the work of carefully disentangling strings in order to trace how race, slavery, robots, and labour are knotted together. The consequences of such a cut are not only epistemological, but also ontological. Re-crafting robotic futures necessarily means to explore how humans and machines can, could, and even should relate, and how responsibilities for labour of various kinds should be distributed among newly emerging robot-human interfaces. A narrowing of this relation to one of control over mere tools that assigns all responsibility to 'the human' appears to be too reductive in light of emerging robot technologies, but also with regard to a theorising of the sociotechnical in its co-shaping relations. What is at stake here is to imagine and to create new possibilities of relating that move beyond the humanlike partner/dehuman-ised slave divide. As I will continue to argue, this issue necessarily needs to be tackled through interdisciplinary, empirical, qualitative research that nev-ertheless takes into account long-standing power relations, inequalities, and bias. Working towards an erosion of the *surrogate human effect* of technoliber-alism, I ask: How can the inevitable connection be dismantled between future robots becoming social agents and becoming workers that take over 'our' dull and dirty work? Robotic knitting tackles this question through a performa-tive stance that combines the implementation of the practice of knitting with a cobot with delivering conceptual impulses for a re-crafting. A description of my methodological approach is at the centre of the next subchapter, while Chapter 2 will present the practice of robotic knitting. More precisely, my game of cat's cradle will interchange between enacting a diffractive method-ology with yarn as a metaphor and a material of re-crafting in theory and in practice, blurring the boundaries between both. In this way, I take up wool

as literally the material for creating new patterns of thinking and enacting human-robot relationality.

1.2   Situated Co-Engineering: An Interdisciplinary Account of Engaging with the Cobot

One core challenge of robotic knitting was to establish an interdisciplinary practice of realising collaborative knitting between humans and a cobot. While interdisciplinarity has advanced into a kind of buzzword for research, especially for research which addresses fundamental societal issues such as the future of (the automation of) work, what kind of research practice and knowledge exchange interdisciplinarity can instigate, may nevertheless differ a lot. In what follows, I will first discuss why and how robotics is a highly interdisciplinary field, identify some boundaries of interdisciplinarity as (not only) I have experienced them so far, then present my suggestion for an account of situated co-engineering, as evolving through the project work of *Do Robots Dream of Knitting? (DRDK)*.

Robotics can look at a long-standing plea for and practice of interdisciplinarity, which has been deployed by roboticists such as Rodney Brooks in the early 1990s. In short, Brooks (1991) argued for a bottom-up, instead of a top-down, account of intelligent behavior in humans and in machines that centrally builds on the relations between perception and action, as well as bodies and environments, advancing into the *embodied and embedded AI* paradigm. He also flags the importance of a collaboration between diverging fields of knowledge, for instance, when reviewing biological fields of knowledge (especially neuroscience, ethnology, and psychology) as delivering important insights into the very nature of cognitive behavior in humans and other animals that robotics should take into consideration. Brooks (1991, 23) closes his influential paper *Intelligence Without Reason* by asserting that the project of AI "is a complex endeavor and we sometimes need to step back and question why we are proceeding in the direction we are going, and look around for other promising directions." For Brooks, biological fields of knowledge are such other promising directions. Notably, what he underlines is the need to question and to look around as forms of reflecting on both disciplinary knowledge and the established canon, while he does not formalise this process or the relationship between the cooperating disciplines.

Since Brooks' new foundation of AI, robotics has advanced into a field of research and engineering which has become increasingly important, not only for developing automation technologies in the sphere of industrial production, but rather also for every sphere of human everyday lives, as argued throughout this book. Even though most robots are not yet stepping or rolling out of their protective cages in factory halls, or their confined lab environments, the popular discourse as well as the scientific endeavor are pivoting around such visions of "the robots are coming". In 2007, the roboticist Stefan Schaal announced *The New Robotics – Towards Human-Centered Machines*. Schaal (ibid., 1) defines such new robotics as targeted at the realisation of "more human-like robots [that] can live among us and take over tasks where our current society has shortcomings." The everyday robotic interface, however, brings a range of challenges with it when the central technology, the human-like robot, supposedly should be operated in everyday life and should be operable by possibly every person, regardless of their technical affinity, age, educational background, and abilities. This, in Schaal's (ibid., 3) view, should be reached by a new robotics as "require[-ing] a new kind of scientist that can traverse a very broad range of different disciplines." These different disciplines encompass—besides the classical discipline of mathematics—also biology, neuroscience, psychology, and ethics. All disciplines named here are potentially regarded as a resource for improving the engineering of human-like robots as social agents. Mentioned, for instance, is the acceptance of a robot among two social groups, namely the elderly and children. The suggested solution is—in line with Schaal (ibid., 2)—that the robot "needs to adhere to certain social behaviors and standards that we as humans find acceptable." This, then, is also where psychology and ethics are supposed to come into play.

What reads at first sight as a meaningful division of tasks along a complex goal, namely, to create human-like robots useful to humans in their everyday lives (more specifically, to the elderly and children), also operates with certain unquestioned assumptions, mostly around hegemonic beliefs in the necessity of human-like, anthropomorphic machines, in order to realise human-centeredness and user-friendliness. In the preceding sections, I already problematised this belief with regards to its perpetuation of power relations along the categories of race, gender, and class, given the example of the human-like co-worker or worker robot. My argument here is that the ideal of the anthropomorphic robot in its status as a taken-for-granted certainty and scientific foundation of (new) robotics equally needs to be questioned and revised. It

cannot be factored out from the reflective process of knowledge practices as stipulated by Brooks and continued by many others, among them Schaal's proposal for a renewal of robotics.

The hegemonic belief in human-likeness as the foundational, unquestionable design scheme for realising collaborative, human-centred, and user-friendly robots is a core example for what I identify as current, but nevertheless longstanding, boundaries of interdisciplinary research. As many (feminist) humanities scholars have pointed out, this belief follows a circular logic: Katherine Hayles (2005), for instance, shows that such a belief in human-likeness can be analysed as a two-cycled co-shaping phenomenon at work. Hayles (ibid., 132) describes these mechanisms as the "use [of] a rhetoric that first takes human behavior as the inspiration for machine design and then, in a reverse feedback loop, reinterprets human behavior in light of the machines". The reverse feedback loop in its two-cycled movements makes tangible the circular logic between arguing for a human-like shape of the robot as a seemingly intuitive design decision and the idea of engineering social action: for instance, defining social behaviours and standards for homogenous conceptions of groups like 'the elderly' that the robot, in turn, will embody and that the users will have to adhere to. Thus, to leave the design ideal of human-likeness out of the realm of questionable knowledge and practices in robotics privileges the design decisions based in computer science and engineering over investigating the social, and more specifically, social practice in all its diverse shapes. In this regard, I argue, first, for including critical, social research of diverse, lively, sociomaterial worlds into the list of resources for reflecting on processes of technology development in AI in general, and more specifically in robotics. Second, I argue for re-considering the relationship between humanities, computer science and engineering, with regard to interdisciplinary collaborations.

To reflect on the scientific foundations and knowledge practices of robotics necessarily also has to involve taking into account existing power relations on both levels: the level of knowledge politics and the level of sociomaterial everyday lives, as they both condition possibilities for (inter)action. Feminist science and technology studies (FSTS) have argued for this for more than 30 years, if beginning with Haraway's influential *Cyborg Manifesto* (1985). It is indeed the emancipatory, transformative potential of FSTS in its call for a critical reflection of knowledge and engineering practices that I regard as the grounds for interdisciplinary research across disciplinary boundaries and barriers.

From my experience, there exist plenty of barriers in interdisciplinary project work, deeply rooted in disciplinary cultures. One that I have been confronted with in the past is that humanistic perspectives too often appear to be understood as just another tool for re-assuring that there exists a techno-fix for every issue or problem that might be raised through the process of tech development: from de-biasing algorithms, making robots social agents, to data security concerns. Jutta Weber (2010, 12), for instance, analyses the increasing evolvement of interdisciplinary approaches within the last two decades as part of a transformation of scientific cultures towards the implementation of a *technorationality*, characterised by a reductionist tendency and geared at ever new technoscientific solutions. In contrast, Gender Studies, as an inherently interdisciplinary field, is built on implementing the tools and methodologies for critically reflecting disciplinary certainties and taken-for-granted knowledge (see Lykke 2010). However, there also seems to exist a gap between what could be analysed as imaginations and expectations of what humanistic inquiry is and does, and what I, for instance, as an FSTS scholar with a certain specialisation of research, can contribute to HRC. I identify with this a gap between problem-solving and problem-raising cultures of research that divide between useful and useless perspectives in reaching a certain goal. Further, from the long-standing feminist concern with the politics of knowing, I also identify politics which assign value to some perspectives over others. The result of such a valuing, in short, is a hierarchisation of views and disciplines with regard to their relevance to AI research. An essential part of my research is to work against such a hierarchisation, exploring how to overcome such barriers and to engage with each other's work in a manner which leads to new, interdisciplinary insights, based on the radical, critical reflection on scientific foundations and certainties. The remainder of this chapter will present how robotic knitting not only invites such interdisciplinary research in theory and practice, but also how it became a prerequisite for realising this technofeminist intervention into hegemonic imaginations of a future with cobots.

Entering the Lab to Play with Wool & Knitting Needles

The idea to engage with a cobot through knitting grew out of a situation in which I was already working at the robotic lab of the BMBF Nachwuchsforschergruppe MTI-engAge at TU Berlin as a parental leave cover. During that time, I was asked by the head of the lab to conduct qualitative human-robot interaction studies with the robot *Pepper*. More specifically, the task was

to generate knowledge on what we called the *grasping rationale* in scenarios of HRI in which the robot hands over an item to humans. A core question was: How can this almost always naturally occurring motion between two (universalised) humans be formalised and transferred onto the robot? Of course, we also defined a specific case and focused on the concomitant motion: The robot was imagined to hand over a ball while our interest was to understand when a person can rationalise which arm to use in order to take the ball from the robot. Basically, the idea was to improve the coordination between a robot's programmed intention and the humans in interaction, and thus mutual legibility. Of course, this setting operates with a set of pre-assumptions about the nature of human-human interaction and the model quality of these for HRI. Thus, conducting the experiments, my role was at the same time to deliver insights into the grasping rationale given our specific setting of HRI and to attest, and evaluate the conditions for and practices of enacting successful interaction at the human-robot interface. One salient practice was how each individual tried to realise mutual legibility between the robot and themselves with varying degrees of success (see Graf & Treusch 2019). Such a perspectivation works with Suchman's (2007, 69) ongoing work on "situated action", which "underscores the view that every course of action depends in essential ways on its material and social circumstances." As our experiments with *Pepper* have also shown, interaction between humans and the humanlike Other is enacted in such HRI settings. Key for understanding and developing the interface are the sociomaterial conditions and practices of enactment.

Furthermore, robotic knitting also tweaks the hegemonic understanding of agency as it is deployed by the category of the human-like, in comparison to the human. Petra Gemeinboeck and Rob Saunders (2016, 159) carve out that "robots play an important role in probing, questioning and daring our relationships with machines". They further suggest "[looking] at a machine's agency through the lens of performance" (ibid., 159-160). Such a lens enables a probe of relations *in practice* while taking into account the cultural codes relevant to a device's social meaningfulness and the performative quality of a machine's agency. Both are not simply characteristics and abilities a device is endowed with, but rather they emerge from its context of interaction. With Gemeinboeck and Saunders, performance is "a bodily practice that produces cultural meanings by 'translating' software scripts into an 'experienceable' reality" (ibid.). According to this, I understand the abilities of a robotic technology to interact, less as a fixed set of capacities, but rather as culturally-coded,

bodily practice in a configuration of agents—that is, the more-than-human performance of robotic presents and futures.

With Suchman (2011), to study human-robot relations in practice encompasses reconstructing the practices of enactment through not only the "truncated labours of [the robot's] affiliated humans" (123), but also through "the figuration of subject object intra-actions in contemporary robotics" (121). Intra-action derives from Barad's (2007) account of *posthumanist performativity* and underlines the co-shaping relation between entities—instead of working with given, autonomous stable entities, namely the subject in opposition to the object. It depicts an onto-epistemological expansion of the analytical lens that takes into account that social practices shape material technologies, while they also become part of social practices and shape them themselves. Interaction at the human-machine interface does not follow a prescribed plan, but is the situated practice of intra-action which involves a set of sociomaterial conditions and a collective achievement of different sociomaterial instances that have to align in order to realise a certain goal (see Suchman 2007; 2011). This perspective depicts a shift from planning grasping as a movement which can be isolated, trained to and executed by a robot, and in turn always be legible in every setting and by every human as 'grasping', to understanding grasping as the result of such a collective effort that might rely on a host of different, not pre-planned movements and bodily experiences in order to be carried out between the in-practice differentiating entities of human and machine under specific sociomaterial circumstances.

Given these onto-epistemological insights into the nature of human-machine configurations of interaction as intra-action, I began to wonder how to open up possibilities for not only probing possible human-machine relations, but also enacting them *differently*. This centrally involved drawing on insights of FSTS in the process of imagining and realising a setting of HRI. My point of departure was the urge to scrutinise and move beyond hegemonic ideas of the universally useful robot that will become a co-worker or worker, taking over from 'us humans'. This entails to reflect the seeming inevitability of a robotic invasion through a more playful, experimental, and open engagement with one of the key players of such an invasion, namely the figure of the cobot. If I take the role of practices of enactment, such as the intra-active alignment of entities, experiences, and expectations seriously, what kind of setting and practices of relating and daring to enact human-machine-relations differently will become necessary?

What appeared intriguing as soon as I started contemplating about this, was to become curious about tweaking usefulness in HRI. Becoming curious describes an affective stance which I took on and which can be traced back to the very beginnings of AI research, for instance in Alan Turing's work, as Elizabeth Wilson (2010) has shown. More generally, affect plays a significant role in the relating of humans and machines. Sherry Turkle (1984) prominently analysed the human-machine interface as one in which machines are at the same time designed artefacts and evocative objects as they become interlocutors. The goal to create devices embodied with capacities to interact with 'us humans'—for instance through spoken or written language, but, depending on the artefact, also through gestures and morphological design decisions—is built on the idea of evoking affect in the affiliated humans, as also discussed in the preceding sections on robots as (co-)workers. However, beyond the endeavour to engineer affects as supposedly formalisable aspects for an increase in human-machine legibility, affects are also a core element of AI beyond such a formalisation. Wilson (2010) illustrates the ways in which the very foundations of AI are built on a curiosity about how thinking and feeling, as well as abstraction and embodiment, are deeply imbricated. In short, relations of intra-action between humans and machines are always affective. Precisely this affective quality articulated from the very initial moments of DRDK when I—amongst others of the MTIengAge team—was asked which scenarios we, members of the MTIengAge team, can imagine to be realising with the PANDA robot arms, I immediately said: "Knitting!" Then, this suggestion amused all of us, bursting out in laughter, including me, while at the same time, it started to fascinate us. We were immediately affected by robotic knitting and the idea to wrap our heads and hands, literally, around this playful challenge of implementing HRI through knitting.

I regard wool as a simultaneously disruptive and productive object in the setting of the robotic lab. Wool is a very stubborn material; wool can also be either very cosy and comforting, or itchy and unpleasant on the skin. As a knitter, I can tell that sometimes a specific yarn can break my patience when knitting, for instance, when the individual strings of the yarn unravel so that individual stitches start to dissolve and make it almost impossible to continue knitting. Of course, this depends on many sociomaterial circumstances, such as the quality and material of the skein and the needles, the knitter's experience and with it the embodied tacit knowledge around knitting, the comprehensibility of the used knitting pattern, as well as the lighting conditions. I give these details here in order to make tangible the scope, sociomateriality,

experience-ability, and fragility of knitting. These multi-faceted dimensions of knitting as a practice are equally pivotal for establishing robotic knitting as those of human-robot interaction. Can knitting be transferred to a cobot? And: How can knitting become a test bed for probing the emerging cobot-human interface in practice, but also for re-crafting human-robot relations beyond this exemplary practice?

Clearly, bringing wool into a robotic lab at a technical university appears at first sight counter-intuitive. How and why a second look reveals a thread of long-standing overlaps between craft and technology will be the topic of the following chapter. Here, I want to dwell on the counter-intuitive momentum of the warm softness of wool and the practical character of knitting in the seemingly purely technological context, associated with cold metal and abstract programming. I regard this as the central interventionist momentum of robotic knitting: it disrupts the common understanding of proper objects in the robotic lab, while it also becomes an exemplary scenario of knitting thinking and feeling, as well as abstraction and embodiment together. In addition, while I, the FSTS scholar, had the idea of robotic knitting, it was at the same time important that the leader of the lab and roboticist, Raphael Deimel, could imagine this idea as not only potentially realisable, but also as a challenge for the lab's development of robot control. Thus, robotic knitting turned out to be an intrinsically integrative endeavour, crossing disciplinary boundaries.

Making the Queering of the Useful Robot a Matter of Care

Knitting with a robot amuses, as it appears to be an improper use of the robot and knitting needles, while this improperness invites me to pause for a moment and ponder about the very question of properness with regard to the implementation of HRC.

Bringing wool and knitting needles to a robotic lab as materials to engage with might cause irritation for several reasons. One quite obvious reason turned out to be the question of usefulness. Especially with regard to narratives of the cobot as becoming a worker, to work on realising the leisure activity of knitting with one's hands as a collaborative task with a cobot as partner does not contribute to narratives of useful cobots. Rather, the idea of realising a useless task with the coded-as-useful cobot stipulates an examination of the very notion of usefulness in the context of human-robot relations. These thoughts align with Sara Ahmed's (2019) *queer use*. Ahmed (ibid.,

2) delves into the question *What's the use?* as a "question of being" that points towards positionality and value. When Ahmed (ibid., 199) explores a potentiality in things that can be opened up through queer use, this entails to ask "how things can be used in ways other than for which they were intended or by those other than for who they were intended". Thus, with Ahmed (ibid., 7), "use is distributed between persons and things", while she also considers queer use to be *a start* for "making connections between histories that might otherwise be assumed to be apart" (ibid., 198). Bringing queer use into the context of the robotic lab, I regard robotic knitting as depicting such a queer use; a use which insists on the capacious nature of usefulness at the human-cobot-interface, and not only to queer what something is good for, but also for whom. Robotic knitting literally complicates use. With the situation in the lab in which I was asked to come up with a potential scenario of use, I was affected by the practicality of the robot arm, queering what a proper use supposedly should look like. In this sense, I consider the specific constellation of persons and things as foundational for stipulating the possibility to make not only a cobot, but rather equally the wool and knitting needles, in addition to the disciplinarily diverse situated subjects, the things and persons of queer use.

Moreover, queer use's emphasis on the potential and the distributedness of use can be brought into conversation with Maria Puig de la Bellacasa's (2017, 18) work on *Matters of Care*, for which "assembling neglected things" becomes central. More precisely, I suggest an account of queer use that involves queering as an activity of relating, and thus is constitutive of a method of caring for the neglected dimensions of an object's usefulness: its intrinsic potential to affect different uses and to transgress imaginable limits of what is considered to be the proper use of an object—in this case a set of objects, the knitting needles with wool and the robot arm. Hence, with Puig de la Bellacasa (ibid., 5), I understand care as "one way of looking at relations". Further, such looking at relations can involve both analysing the complex relations through which, for instance, human-robot interaction emerges, but also probing the very possibilities for relating differently. Care, then, is an affective stance of making the transgression of the limits of what is considered a useful use of the objects involved in robotic knitting, as well as what is considered proper knowledge and engineering practices in the involved disciplines, my matter of care.

While emerging robot technologies of a robotic future are ubiquitous, I also argue that they are at the same time elusive and intangible. It appears as if there exist a lot of ideas around 'our' robotic future, including automating

the non-automatable, however, these narratives and images seem to mainly evoke pictures and suggestions on how 'our' robotic future might look. But how such interfaces will look like in detail and what it will actually be like to socially and physically interact with a robotic co-worker does not become tangible through most of these pictures. Thus, existing narratives mainly do not deliver insights into the nature of human-machine collaboration implemented through emerging technologies—especially its quality of a new, collaborative proximity between humans and robots. How proximate will these robots be and with which social and material consequences? As technology development has been heavily leaning on the graphical paradigm in computing (see Dourish & Bell 2011), for instance, embodied by the current models of PC, smart phone, and tablet, I wonder in which ways robots that clearly pertain to a different kind of machine than PC, phone, and tablet, are supposed to become part of 'our' technological everyday-environments. However, the inescapable and at the same time intangible quality of visions of 'our' robotic future makes it almost impossible to grasp the nature of action or even interaction attributed to emerging robotic technologies. Thus, from a performative perspective of a technofeminist intervention into the contemporary sociotechnical robotic imaginary, I am interested in exploring what I frame as the sociomaterialities of collaboration: that is, the practicalities, embodiments, and practices of relating.

String Figuring with Wool in the Lab: From Reflection to Diffraction

Bringing wool and knitting needles with me to the robotic lab depicts not only an intervention on the level of HRC. Rather, it is also an intervention on the level of knowledge and engineering practices, disciplinary expertise, and interdisciplinary processes. Reflecting taken-for-granted knowledge, it also raises the questions of who and what is included in designing and realising proper HRC, and who and what gets neglected. Finally, it deploys the conditions for an improper, queer use of cobots, knitting needles and yarn. This multi-faceted quality of robotic knitting is enabled by what I frame as engaging in situated practices of a co-engineering. Situating means more than adhering to the seemingly mere physical context of the robotic lab in which we (the persons with disciplinarily diverse backgrounds), the robots, the wool, and the needles met. Rather, it is about taking into account the sociomateriality of imagining, designing, and enacting HRC. It follows the impulse to situate knowledge claims, as it emerged from a feminist concern

with the politics of location. Haraway (1991) popularly coined the term of *situated knowledges*. Suchman (2007) moves in a similar vein with her account of *situated action*. Situated knowledges and situated action are foundational to robotic knitting: while the first underlines the historically, socioculturally, spatio-temporally, and materially specific conditions of knowledge production, the second underlines the ways in which interaction between humans and machine results from a collective achievement that does not follow a plan, but the situational context. Situatedness here means, first, to take seriously the ways in which knowledge and artefact production cannot be cut off from their sociomaterial and political situation and context, second, a plea for a reframing of universal objectivity in terms of partial objectivity, and third, to become accountable for one's research in its reality-producing effects.

Moreover, in Haraway's (1997, 267) account of "situated practices or witnessing," she explains these practices of situating as analogous to witnessing, while she (ibid.) describes the latter as composed of forms of engagement with objects and knowledge production as "seeing; attesting; standing publicly accountable for, and psychically vulnerable to, one's visions and representations." My role in the lab became one of the *queer witness* (ibid.; see also Treusch 2015; 2017) who sees and attests the potential of human-cobot-inter- as *intra*-action for re-posing questions of automation, the organisation of work, robotic futures, and responsibility for technoscientific worldings.

A technofeminist, critical intervention then serves the purpose to both erode certainties and create further possibilities. With Haraway (1997, 95), "critical means evaluative, public, multiactor, multiagenda, oriented to equality and heterogeneous well-being." I understand this in terms of working towards visions of a robotic future which do not have to choose between a dismissive or an overly welcoming stance, but rather are guided by sociomaterial practice. Thus, the situating or queering witness is not to passively observe, but rather to become a part of the co-shaping of possibilities for making a difference in envisioning, representing, enacting, and becoming accountable for sociotechnical, robotic futures. It is precisely this role of the queering witness, to become accountable for the reality-producing effects as well as the partiality of observing, that is made possible by robotic knitting.

In Barad's (2007) continuation of Haraway's work on situated knowledges, she draws on Nils Bohr's quantum physics to further contemplate the relation between observer and observed. Barad (ibid., 196) basically asserts "that there is no unambiguous way to differentiate between the object and the agencies of observation". In this regard, Barad (ibid., 195) pushes further a shift from uni-

versal objectivity and representationalism to a "proto-performative account of scientific practices". Such a proto-performative approach foregrounds contingency, agency, and relationality, and necessarily involves tracing and engaging with the operations of power, namely, the dis- and enabling sociomaterial configurations of science and technologies. As Josef Barla (2019, 128) puts it vividly,

> "performative approaches circumvent the need for...a correspondence between world and words, matter and discourse by focusing on the question of how not only meanings but also particularly (re)configured bodies, identities, and hence realities, are enacted through particular generative practices."

In consequence, the matter of care in making a difference in 'our' robotic futures is not to find more adequate representations of what visions and realisations of collaboration between 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. The queering witness as the observer, however, can never be located outside of these generative practices of probing. In this regard, the boundaries of the persons and artefacts involved do not pre-exist their encounter, but rather materialise from this encounter. All involved entities are in a Harawayan (1991, 200) sense *generative nodes*—a term that accentuates the formative, co-shaping power of materialising locations in a net of actors.

Barad's account of the generative quality of sociomaterial practice is not only guided by Bohr's and Haraway's work, but also by Judith Butler's (1990) take on the performativity of gender and gender relations. In line with this, I work with the concept of performativity in the context of the robotic lab as a tool for acknowledging the powerful operations of social norms in the enactment of human-cobot relations—a tool which highlights that such a reproduction of norms holds the potential for an undoing of these very norms. Becoming a queering witness to the performative enactment of human-cobot relations is key in this.

It is again Barad's (2007) work and her expansion of the concept of performativity through a posthumanist lens, which has proven to be especially productive for researching human-robot relations in the making (Suchman 2011; Treusch 2015). This perspective allows me to understand every actor and artefact as a generative node, taking part in the crafting of robotic futures.

Hence, interaction is not regarded as the result of pre-planned affordances and constraints in the machine and (able-bodied, racial, gendered) norms in the human, but rather the result of co-constitutive relations emerging from a sociomaterial practice of relating between entities without pre-determined boundaries, which are immersed in and emerging from intra-active entanglements. These onto-epistemological insights into the performative, more-than-human nature of HRI make the processual, affective, and generative-subversive my matters of care—over the pre-planned, rational, and representational-normative—in understanding how humans and robots already do, but also could, relate in practice and in theory. As I will continue to show, this opens up the possibility to generate a more capacious understanding of HRC, including all actors and activities involved.

During HRI experiments prior to DRDK, I have witnessed many times that persons will hold their bodies in what I would call the outmost uncomfortable postures in order to increase the chances for mutual legibility between the robot, modelled as a child-like figure, and themselves, while also orchestrating their gestures, speech, and eye-contact, again, with the purpose to make the robot understand them. Not seldom, such situations were experienced and interpreted by the persons afterwards as exciting and pleasant, while I, as the observer, felt like my back was hurting just from watching and I assumed that having to go to all this effort would necessarily result in frustration. The positive evaluation of these persons can be read as emerging from an encounter between an evocative object and a person, in this specific case propelled and guided by the anthropomorphic, child-like robot figure. It limits the possibilities of relating on the one hand, and on the other disguises and neglects the labours invested in interaction in this setting. Clearly, the material, morphology, and behaviour of the machine play an important role, but also if and how the persons are given an instruction on what to do with the robot, the previous knowledge on the robot, personal and collective expectations of everyone involved, the setting of the room, the functionality of the robot on that day—all these sociomaterial circumstances condition not only how the HRI is enacted, but also how the self and the machine Other is experienced in intra-action. In this case, the machine Other becomes a capable interlocutor, embodying a set of capacities to interact. With Suchman (2007, 239), I understand this practice of enacting human-machine relations of sameness and difference as relying on practices of *enchantment* and *mystification* of the machine, installed by the human-like design of the machine,

and as relying on the alignment of meanings and materials in this setting of intra-action, from which relations of sameness and difference materialise.

Returning to Brooks, the starting point in implementing my approach of a situated co-engineering through robotic knitting is the cross-disciplinary impulse to reflect on, in Brooks' words, where robotics is going and why. The wool then is a tool for tracing practices of enacting human-cobot relations, but also, and importantly, to open up possibilities to knot different strings together, forming generative nodes and opening up pathways of queer use which are to be explored. Here, the yarn's material and metaphorical meanings conflate. Especially, as the framework of co-situated engineering, as described here, also implies a shift from reflection to diffraction. Haraway (1997, 16) argues that "reflexivity has been much recommended as a critical practice, but my suspicion is that reflexivity, like reflection, displaces the same elsewhere." She (ibid.) continues to underscore that "what we need is to...diffract the rays of technoscience so that we get more promising interference patterns on the recording films of our lives and bodies.... Diffraction patterns record the history of interaction, interference, reinforcement, difference." Thus, diffraction allows stepping outside of the logics of finding the self in the Other, the mirroring relation of reflection, as well as the idea of a pre-existing ontology—existing prior to a reflexive practice. The second dimension becomes especially tangible through Barad's (2007, 72) work on a diffractive methodology as "a tool of analysis for attending to and responding to the effects of difference." As Barad (ibid.) further explains, this is about the "differences that our knowledge-making practices make and the effects they have on the world." Robotic knitting, hence, enmeshes different actors, discourses, and activities in order to establish a practice of situated co-engineering which does not rely on reflection, but on diffraction, as a method of inquiring into knowledge practices and not only practices of engineering HCI, but also of experiencing HCI. It is a diffractive practice of technofeminist intervention in its disruptive and generative momentum.

With Lykke (2010, 155-156), "diffraction and the cat's cradle game are two ways of describing an analytical process that is continuously innovative because of the ever-changing patterns of foregrounding and backgrounding, which aptly put the complexity of...objects at stake and thereby create new understandings of them." Thus, diffraction as a methodology is basically a generative practice of allowing new patterns of interference between different entities-as-nodes to emerge. Notably, in bringing the wool into the robotic lab, we were literally following strings of wool, dis- and re-entangling yarn

with hands and grippers, and, in result, received (unasked for) patterns. This description not only depicts the everyday analogy for diffraction, but rather, in the context of robotic knitting, describes the very everyday practices of stipulating processes of a situated co-engineering through handling a yarn and knitting needles. The wool's stubbornness had an impact on how we worked, as well as on the pace of our progress in realising robotic knitting, as much as the stubbornness of the technical components (hardware and software), and finally, on the differing ways that individuals, as part of not-only-disciplinary collectives, enrolled in this process and experienced HCI. Every person involved in robotic knitting had to literally wrap their hands and head around the yarn, needles, robotic arm with user interface, and the practice of knitting, while these human engagements cannot be cut off from the more-than-human entities and sociomaterial circumstances involved.

Robotic knitting is my account of playing string figures with different sociotechnical, critical approaches, contemporary cultural imaginations of human-robot interaction, a host of materials like yarn, knitting needles, a robot arm, computers, and computer screens, as well as other persons. The idea behind such a string figuring in the robotic lab that necessarily involves engaging with a cobot technology is about re-crafting the story of robotic presents and futures. Notably, in its diffractive approach, re-crafting here is not about reflecting representations, but rather about diffracting entanglements. Finally, Daniela Rosner (2018, 56) reminds me that "the game of cat's cradle—composing string figures on multiple hands — …is more than a form of illustration through storytelling; it is a material practice that makes way for new modes of being." Hence, situated co-engineering is about adhering to interference patterns as they emerge.
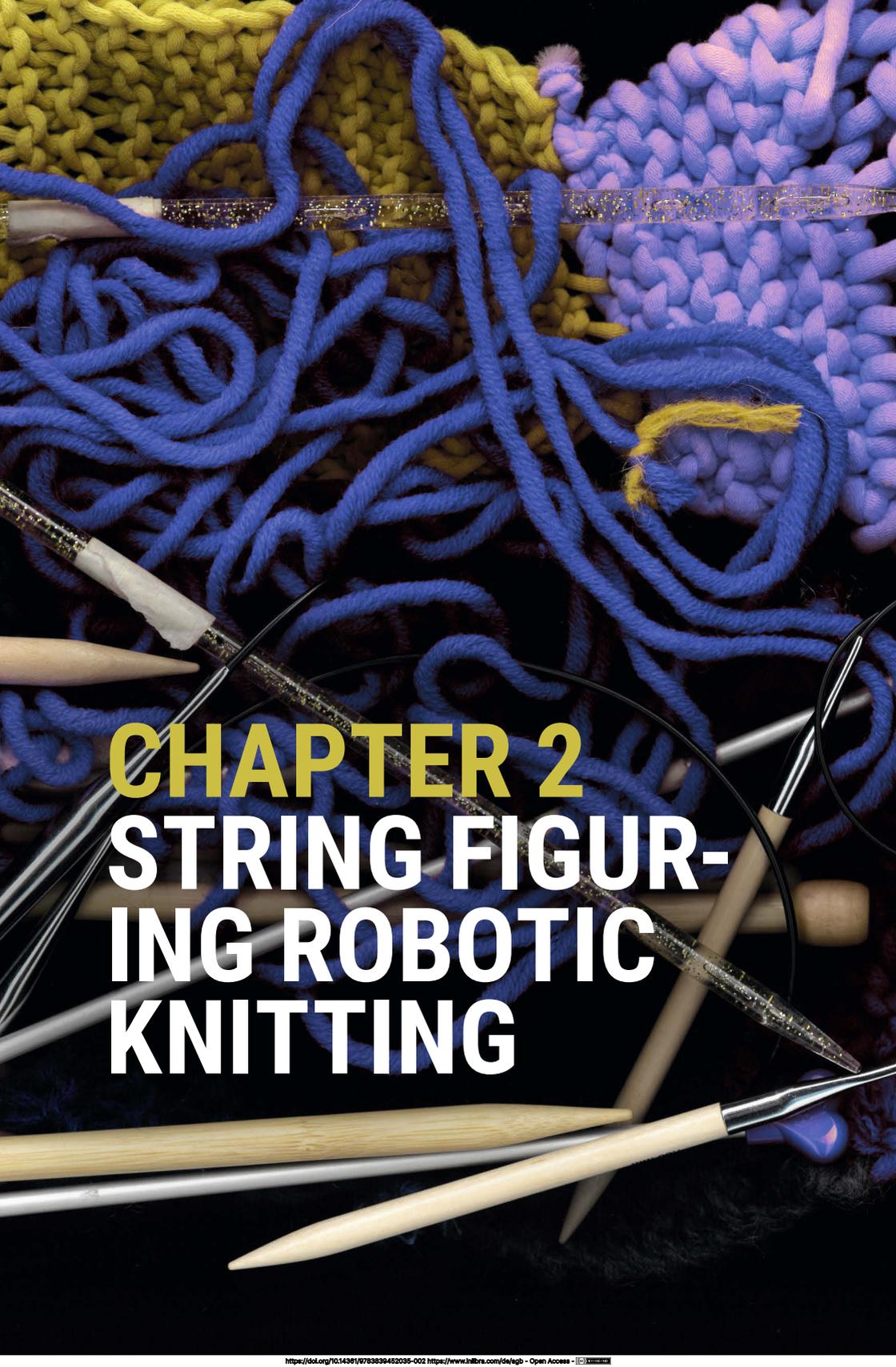
CHAPTER 2
STRING FIGUR-ING ROBOTIC KNITTING