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Encoding Proximity: Intuition in Human–Robot Collaborations

Dawid Kasprowicz

The growing field of human–robot collaborations has raised questions of how to behave when interacting with speaking and moving technological objects. One key idea here represents the notion of intuition as the promise of natural and effortless interaction with non-living objects. But intuition also refers to a non-rational, affective mode of reasoning. This article argues that in human–robot collaborations, intuition is not exhaustive in the promise of fluid interactions. In showing how social expectations are encoded in collaborative practices, the text argues that intuition becomes a modus operandi for the programming and modeling of affects.

1. Technics of “Natural” Feedback[1]

A body of two split ellipsoids, one ellipsoid mounted on top of the half-round of the other, with smooth edges and a light circle that expands and shrinks from the middle of the upper split-ellipsoid to signal a communication with the target person, an elderly lady. This strange-formed object is a social robot who at first sight reminds us more of a designer lamp kept in the back corner of the living room than of a private companion. But its producers, the American company Intuition Robotics, gave her a name and a voice. In the eyes of the company, ElliQ is this new member of the daily lifeworld for elderly people living alone, which can be placed between a design object and a living companion, between the non-living agent and the agent elderly people would like to talk to: “She sounds like a machine. She feels like a machine—but she has that one-of-a-kind personality that will help her users develop an enchanting feeling towards her.” This intermingling of bodily passivity and social activity should form a core for users, as the company writes, “to intuitively understand the object in front of them so that they could naturally access this intelligence they perceive” (fig. 1).

[Figure 1] Intuitively to understand, the object ElliQ, Credits: Intuition Robotics

1 This article draws on ideas from another article dealing with the question of practices with robots, entitled “New Labor, Old Questions. Practices of Collaboration with Robots” (Kasprowicz [in preparation]).

ElliQ's main functions resemble those of Amazon's Alexa. She calls relatives, reminds us of dates in the calendar, and suggests activities for us from the collected user-data. ElliQ represents the revival of inanimate and lively objects, which "our primitive forebears" still had, as Sigmund Freud noted ([1919] 2003, 155), and which we re-establish today in our digitalized world. The notion of intuition plays a central role in this context. In the quote above, "intuitive" is used synonymously with the adjective "natural." Besides, the semantics of "intuitive" promise simple and effortless access to highly techno-sociological interactions. In all its semantic impact, intuition enables an assumedly unbiased and unmediated interaction with media. This function of the term has a long history in the field of human–computer interaction (HCI). Whether for an operating system or for the navigation of a homepage, an interface should be able to reduce complexity while at the same time referring to the symbols and processes of the user's experience. In the ideal way, the computer becomes itself the invisible machine in this interaction, hidden behind the operation of an intuitive, natural interface design (Norman 1998, 2011). One can call this intuition an *effect* because the success of the design can only be assured through the user's interaction.

However, with ElliQ as our example, intuition deals with something different, namely the formalization and coding of *affects*. Here, the social habitus of bodily proximity, gestures and haptics are discussed and transformed to target the human as the environment for a robotic system. Being intuitive therefore means creating an expected proximity that includes the potential affect of the human partner in the calculations of the robotic system. On the following pages, I will refer to a special field of human–robot interactions, so-called human–robot collaborations in industrial labor, to show how the notion of intuition transforms from a guiding concept for human–machine or human–computer interactions to a complex procedure entailing practices of modeling, simulating and materializing human–robot relationships. First, I will argue that within this transformation, intuition turns from the magical semantic of a "gut instinct" into a *modus operandi* to communicate social expectations, bodily routines and the tacit knowledge of labor between human and non-living agents. Secondly, I will use a case study of human–robot collaborations to demonstrate how these operations create a new interface that does not relate to displays or design objects, but to the space in between the heterogenous ontological agents. In this example, the operation is the robot's task of carrying a table with his human partner. Here, the coding of intuitive haptics not only regulates the sequence of actions but also the social status of each of the collaborators—either as the leader or the follower of the movement. But before we turn to the case study, I will go deeper into the problem of intuition as the natural and unmediated immediacy from a historical perspective.

2. Mediated Immediacy—The Meaning of Intuition

In a general sense, a better understanding of what intuition might be can be given by explaining what it does not mean: a discursive formation to describe the world, to represent an idea, and therefore to activate something that mediates between the subject and the object—like concepts, images, or symbols. From this point of view, one could trace this idea back to Plato's "eidos." On the one hand, we can only think of the archetype through the image as a reproduced being that we can perceive. On the other hand, the image—as the "idea"—always belongs to the archetype and is derived from it at the same time. Here, the unity of being and the manifold of the sensually perceived world need something that mediates them.

However, regarding the modern age, the conception of a mediator for the transcendent world (whether it is the Platonic "eidos" or God's will), is suspended by the consciousness of a self. Intuition turns from the contemplation of God to an unmediated access to truth via the reasoning human self. This meaning of a clear, non-synthetic insight is made explicit in René Descartes' *Rules for the Direction of the Mind* when he writes:

> By 'intuition' I do not mean the fluctuating testimony of the senses or the deceptive judgement of the imagination as it botches things together, but the conception of a clear and attentive mind, which is so easy and distinct that there can be no room for doubt about what we are understanding. … intuition is the indubitable conception of a clear and attentive mind which proceeds solely from the light of reason. (Descartes after Williams [1684] 1996, xxiii)

As the philosopher Bernard Williams writes, the light of reason is similar to a classical Augustinian and Platonic sense of seeing intelligible things (1996, xxiii). In the philosophy of Immanuel Kant this god-given light of reason (or better: cognition) has nothing to do with intuition. For him, intuition means to synthesize the received manifold impressions of our sensibility to an apprehension. The intuitive use of reason is here, again, opposed to the discursive, which necessitates concepts. But—and this is an important turn—without explicit intuition, no conceptions of our apprehensions can be made. Finally, Kant's use of intuition defines access to the world that is only mediated through our sensibility—it neither depends on a *cogito* nor on a special quality of the world outside. Without our "sensible intuition" of the world, there can be neither any perception nor judgment of the world (Kant [1791] 1998, 288). However, all perceptions depend on two "axioms of intuition," as Kant calls them—the inner intuition of time, which combines the manifold sensations in the mechanism of causality, and the outer intuition of a "unity of space," which is based on the axioms of Euclidean geometry (262). These two "*a priori* conditions of intuition" ground the existence of our perceptions as the contingent "empirical intuitions" (284).

In these examples from Cartesian and Kantian philosophy, intuition maintains its enchanting power as unmediated access to *a* world or *to the* world outside. It comes together with an ambivalent status of something that is pre-conceptual, but which requires the discursive elaboration of a (self-)observing philosopher. This ambivalence continues throughout the 19th and 20th centuries, although here, intuition turns its meaning to a non-rational, non-analytic technique of reasoning. Philosophers like Henri Bergson see intuition as a method against the empirical and axiomatic definition of Kant. For Bergson, intuition opens up the questioning of the metaphysical absoluteness again ([1934] 1946, 32–34). The other significant approach comes from Edmund Husserl. Like Bergson, Husserl understands intuition as a method. But for him, it is the key to overcoming the Cartesian legacy of a world-constituting *res cogitans* on which all perceptions depend. Instead, Husserl calls for a "pure intuition" by which all external and historical circumstances are detached and only the unmediated, perceptual act of seeing can be used for statements about the world ([1929] 1977, 24). Whether as a concept for the unmediated access to our perception of the world or as a method for the genesis of knowledge, intuition keeps its ambivalent status and represents a special technique of thinking, which must be made explicit but that also withdraws from analytic concepts.

Today, this mixture is the dominating idea in the myriad books on business management. Economic success is something nobody can predict but nevertheless, some managers have a special talent for choosing the right option. Here again, it is a kind of "gut instinct" that enables some decision-makers to recognize a situation and then to decide more habitually than analytically, since they can't have access to all relevant information. The social scientist Herbert A. Simon termed this mode of intuitive decision-making "bounded rationality," and opened up the way for numerous theories and research projects on the affective constraints of *Homo oeconomicus* (1947, 1987; for a historical overview see Akinci and Sadler-Smith 2012, 109–16).

Another big influence on the question of decision-making and intuition in economics came from the psychologists Daniel Kahneman and Amos Tversky. Their research about gambling behavior in lotteries from 1981 showed an alternative to the Utility Theory. The premise of the Utility Theory is the *Homo oeconomicus* and rational mode of thinking, which can be derived from any economic situation if all conditions have been considered. But for Kahneman and Tversky, as for Simon, these models have been much too normative and ignorant about the hidden parameters influencing the human decision-making process (Kahneman and Tversky 1981, 5). Again, intuition is the hidden source underneath rational conclusions—it is, as Kahneman and Tversky write in one of their earlier publications, “our lay model of the world” (6).

In all its modes and meanings, whether as the intelligible insight into truth, or as the *a priori* for perceptions in space and time, whether as a method of metaphysics or as the “informal and unstructured mode of reasoning, without the use of analytic methods or deliberate calculation” (5), intuition represents both unmediated access to knowledge and a set of expectations for meeting the world. Thus, intuition does not only refer to a philosophical discourse, but it embraces the communication of different layers of a world, to paraphrase the term of Kahneman and Tversky. It is here where philosophers and engineers meet and where the construction of collaborative robots requires the formalization of those hidden, affectual layers.

3. Encoding Proximity: Man, Robot and the Interface

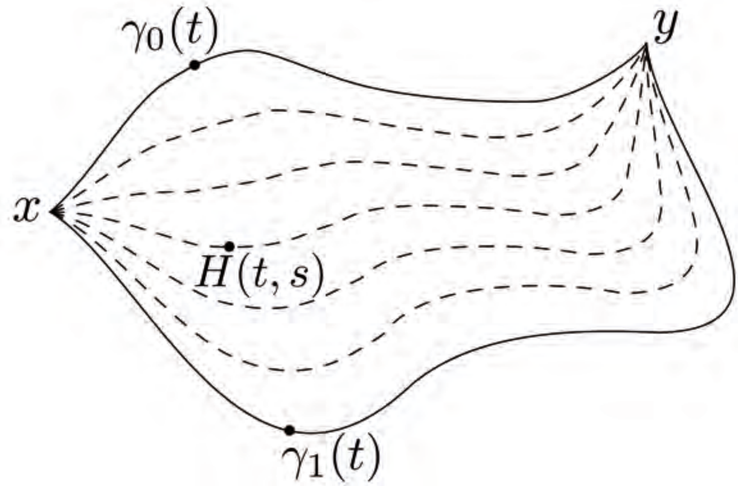
How does this relate to the actual questions around human–robot collaborations? First, the use of intuition in robotics aims to build up expectations of a direct and “natural” way of communicating with technical objects. The technics of gestures, signs and haptic commands open up a wide space of possible executions. The idea of a collaboration, as the agreement to pursue a single goal together, demands a mutual understanding between partners of the other’s intentions, as well as the negotiation of one’s own next movement. Hence, collaboration always implies not only the recognition of a partner’s intentions but also the renegotiation of one’s own intentions about the possible actions of the other, which are at the same time the variables for one’s own movements. This mutual inclusion of the other, which Niklas Luhmann in his *Social Systems* called "interpenetration"[2] (1995, 213), entails another dimension of intuition in human–robot collaborations, in which gestures, signs and haptic commands have to be both "explicit and intuitive" (Gleeson et al. 2013, 349). It is here where the process of en- and de-coding proximity becomes crucial, because the practice of bodily routines and their assumed intuitive affect depends on the practice of formalizing movements and gestures to make them explicit. The Austrian-British philosopher and chemist Michael Polanyi called this the relation between "knowing-that" and "knowing-how." While the first designates the "proximal" term about the circumstances we are aware of but are not yet able to express, the second refers to the "distal" term that denotes the execution of the action (1966, 9–10).

In human–robot collaborations, the so-called tacit knowledge of the proximal must be modeled and materialized. An often-cited example of this logic is the task of carrying a table by two agents. In the following passages, I will describe the formalization of this tacit knowledge using the example of a project of a French group of robotic engineers from the University of Montpellier.

The goal of the project, which ran from 2009 to 2013, was to construct a robot that is able to execute simple tasks together with its human partner. In the group's project, to move the table with the human partner, the robot should not react to the fixed cues of a follower or a leader in the sense of stimulus-reaction chains. Instead, it should "recognize" the intentions of its human partner and interpret them so that it can anticipate the next movement and negotiate "its own programmed intentions" (Evrard and Kheddar 2009, 45). In this case, negotiating means to program subtle changes in body postures and movements to avoid uncomfortable table positions or too intrusive recommendations that could confuse the human partner. Hence, the formalization of haptics in the collaborative task of carrying a table does not refer to what autonomous agents *can do* in the first place, but how their haptics can be *en*coded to meet the social expectations of their partners. Encoding haptics of autonomous robots initiates the modeling of social values into a collaborative task.

2 It is important to indicate that for Luhmann, interpenetrations are intersystem relations that are environments for each other. Therefore, the collaborations are a mode in which the human becomes the environment of the robotic system. Moreover, one can't reduce interpenetrations to stimulus-response chains. Luhmann describes them as reciprocal penetrations that one can observe as the determination of the penetrating system by the receiving system. Each system does not react to the other but creates its own complexity with regard to penetrating systems (Luhmann 1995, 213).

For this collaborative setting, the French research group used a model called "homotopy switching," after the mathematical principle of homotopy (greek, homos=same and topos=place). A homotopy takes place between two topological spaces X and Y that are defined in the functions γ_0 and γ_1. If all points of the space X are identical and the same is the case for the space of Y, then the two functions γ_0 and γ_1 connecting the spaces are called homotopic. In a simple sense, these functions (which are also paths in a topological sense) have two parameters [0,1]—"0" for the initial condition with two topological spaces and "1" as the time that runs while the two functions deform into one another. The salient point is that X and Y are not only identical, but equivalent, defined by the two functions creating the homotopic space between X and Y (fig. 2).



[Figure 2] Homotopy of two paths y: [0,1] → X, Credits: Archibald, Wikipedia, https://commons.wikimedia.org/wiki/File:Homotopy_curves.svg

Thus, in the case of human–robot collaboration, the model is implemented to compute the robot's desired joint positions after sensing the haptic cues of its human partner. Through the continuous deformation of one space into another, the robot's and the human's inputs are programmed as a homotopy between two impedance controllers—or in other words, the internal forces of the agent's haptic cues (Evrard 2013, 35). In this sense, the encoding of the homotopy model entails the transformation of social codes into a "haptic language." Intuition becomes a modus operandi in which "the robot can be shaped between the extreme leader and follower roles" (Evrard 2013, 35). As the engineers write, the robot cannot differentiate between the intention of its partner or a "misunderstanding" of the human's intentions. What the robotic agent senses as internal forces and what it computes as an adequate answer for being *in between* the role of a follower or leader is only materialized by the position of the table. Hence, intuition as the modus operandi defines technics as making the bodily and social routines of postures and haptics explicit and transforming the so-called tacit knowledge into a field of computerized models for robotic controllers. From this point of view, intuition cannot be exhausted by a technological euphoria of robots facilitating or taking away the job of the human employee. It addresses a sensible domain of socio-technological entanglements that are displayed on three levels—the modeling of the interaction as "homotopy switching," the computer simulation of the models, and the materialization of the robot.[3]

The transformation of social values into programming language and then mechanical executions are phenomena that have been neglected so far in social studies on robotics. Concerning the question of the social in robotics, ethnomethodological approaches in Science and Technology Studies describe how bodies are shaped through the maintenance of interactions between heterogenous agents (Alač 2016a; 2016b). Also, increasing numbers of theorists of the Actor–Network Theory (ANT) will include a dialogical and psychological dimension in their concept of communication, which refers not only to actions but to the challenge of a narration of the mechanical self (Jones 2017).[4] However, the imaginations of the social are also interwoven with the engineer's models and their chosen collaborative tasks. The aforementioned ambiguous situations of indecisive or misinterpreted haptic cues call for the mediation of factors like trust, autonomy, and the creation of an addressable self in the partner's actions. So, here the question arises—How to extract these factors from the data of the agent's movements?

3 The materialization and design of the robot are not explicated here further with regard to the collaboration. For a wider discourse on the engineering of anthropomorphic robots in the laboratory, see Suchman 2011.

4 In her article "What makes a robot 'social'?", Rashad Jones criticizes the ethnomethodological approaches for being too restrictive in only focusing on the interactions observed by the researcher. Therefore, the thesis of anthropomorphic relations is maintained through a one-dimensional focus on the interactions between technical objects and humans. Jones formulates this as a critique of the STS approaches to social robotics and pleads for an ANT concept of the "social" that embraces non-human, non-anthropomorphic entities and the modes of creating a kind of general acceptance of them, which also includes new ways of attributing personality to technical agents (2017, 568–70).

Today, the challenge of predicting upcoming states with incomplete datasets is often solved with so-called Nearest Neighbor algorithms. One such algorithm is the estimation-maximization (EM) algorithm taken from stochastics. Since the robot's perception of bodies is always incomplete due to the complexity of changing movements and the noise and range limitations of sensor technologies, a procedure is needed to automatically complete the data until something like a body posture has been "recognized." At the same time, the robot must remain aware of its own location in space. This problem of mapping several sensorial inputs within a certain time frame, while it remains uncertain what will be sensed and where, is called the "data association problem" (Thrun 2002, 56). Thus, the EM algorithm calculates an expectation based on the associations of sets of sensed data. If the datasets are incomplete, as in the case of haptic communication during a collaborative task, the algorithm does not and cannot wait until the data are complete but calculates new expectations of incoming data iteratively. After this step, the algorithm generates so-called posterior sequences with an increasing likelihood of them happening.

As for the question of an operative intuition in human–robot collaboration, this leads to several more questions. First, the importance of the social aspect of collaborations, the weighting of one's own intentions with that of your partner's, depends on mapping and training algorithms. Whether the robot suggests movements like a leader or stays passive as a follower depends on the calculated expectations and the mapping of a contingent environment. The algorithm is part of the internal state estimation, which turns into a social factor that becomes observable through the interface of the carried table. On the one hand, the notion of intuition embraces still the meaning of a non-discursive, effortless but effective way of formulating a phrase or executing a movement.

> Intuitively, when the trajectories are the same, it is likely that no conflicting situation occurs; on the contrary, different desired trajectories induce a situation of conflict that needs to be negotiated and resolved. (Evrard and Kheddar 2009, 47)

On the other hand, intuition refers to a complex procedure of modeling and simulating the tacit knowledge of bodily communications between two agents. Negotiating a desired trajectory does not only mean designing a solution and programming its conversion through the robot. It also embraces a conglomerate of media like models, programs, algorithms and— not least—the material for the construction itself to articulate the social bond between the mechanical and human agents. This complex can be illustrated with Bruno Latour's concept of "delegation." Delegation, from the human point of view, contains both the expectation and the trust that the other agent will meet one's own intentions, as well as the new, passive status of the human in the network of non-human agencies. Latour takes his example from the traditional practice of a shepherd who guides his flock:

> As a common shepherd all I have to do is delegate to a wooden fence the task of containing my flock—then I can just go to sleep with my dog beside me. Who is acting while I am asleep? Me, the carpenters, and the fence. Am I expressed in this fence as if I had actualized outside of myself a competence that I possessed in potential form? Not in the slightest. The fence doesn't look at all like me. It is not an extension of my arms or of my dog. It is completely beyond me. It is an actant in its own right. (Latour 1996, 239)

Although, seemingly, the gap between Latour's shepherd laying in the countryside and the collaborating robots could hardly be wider, the means by which the fence becomes an agent "in its own right" takes up the withdrawal of the human subject and the opening up of a new space of expected and executed delegations. This is a space of intuition as operation. In opposition to Latour, the time of negotiation here is infinitely more critical, as is the impact of sensing each other's bodies. That's why the homotopic model represents both—the ideal of a collaborative task with agents leading and being led as well as the model to program controllers who manage flexible and fast force changes. The result is an en- and re-coding of proximity in man–robot collaborations that not only program bodily movements but also new ways of computationally dealing with social affects. Therefore, instead of maintaining its magical role of an unmediated immediacy, intuition is here the term for a transformation of knowledge—from body postures over haptic communications to the standardized ways of carrying a table.

Conclusion

The human "gut instinct" of intuition does not only belong to the depths of human thinking anymore. The concept of intuition has undergone, as I argued, an important semantic shift that relates it today to affective media technologies like human–robot collaborations. Due to our embodied media habits and screen environments, intuitive gestures belong meanwhile to a tacit user knowledge. Hence, on the one hand, this knowledge entails finger movements, body postures, screen-gaze couplings—all those little acts that don't have to be demonstrated because they are performed every day. On the other hand, intuition turns also into an operative mode that constitutes new interfaces as in-between spaces—like the carried table as a task modeled after the mathematical model of "homotopy switching." Thus, the notion of intuition refers to this twofold meaning: a tacit knowledge in interaction with media and an operation that constitutes new interfaces between man and technology through the formalization and simulation of this tacit knowledge.

In this sense, the table becomes the materialization of an algorithmic proximity. This does not lead to another turn of hybridized embodiments, but to human–robot practices that involve the formalization of gestures, the encoding of a semantics of routine bodily practices, and of haptic codes for social questions of leading and being led as well as the numerous indefinite states of transition. It is here where intuition becomes a modus operandi for the computerization of affects.

Therefore, to describe the phenomena of human–robot collaborations as an example of a posthuman society to come would be shortsighted (Gladden 2016). This overlooks the importance of the messiness of the transformation of our bodily tacit knowledge through models, simulations, and constructions. Instead, the formalization of tacit bodily knowledge retroacts on the social space—in other words, to sense and read human bodies presupposes to model the human as a part of the robot's environment. Drilling down to the level of routine bodily practices, the encoding of proximity becomes a research object for new ways of describing human-centered concepts like autonomy and free will. This shift then triggers also the question of how these new companions should address us in order to be understood as easily as products like ElliQ promise to be.

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