# "Man's (and Sheep's) Best Friend": Towards a Shepherding-based Metaphor for Human-Computer Cooperation in Process Control

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## ABSTRACT

Metaphors can be helpful in human-computer interaction in various ways, e.g., for user-appropriate design of interfaces, naming of functions, or visualization. In the field of process control, paradigm shifts are imminent under terms such as smart control rooms or pervasive computing environments. However, there is a lack of suitable metaphors to accompany this development. This paper examines the extent to which sheep herding and the relationships between humans, dogs, and sheep can be a suitable model for shaping human-computer cooperation in process control. Even though sheep herding has already been discussed in various relationships to HCI, a systematic discussion of the factors that underlie successful human-animal cooperation is lacking. This is introduced in this paper based on an expert interview and literature research. Based on this, it is discussed to what extent the success factors can be transferred to the design of technical systems and human-computer cooperation.

## CCS CONCEPTS

• **Security and privacy** → Human and societal aspects of security and privacy; • **Human-centered computing** → *Ubiquitous and mobile computing theory, concepts and paradigms.*

## KEYWORDS

Control Room, Metaphor, Safety-Critical Systems, Shepherd, Pervasive Computing Environment

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## 1 INTRODUCTION

Metaphors, as "familiar framework[s] of concepts to ground user interface actions, tasks, and goals" [21], are a common approach in human-computer interaction (HCI) research efforts. Among other things (see section 2), they can be used to describe "a vision" [9] as well as to guide "importing consistent affordances from one domain to another" [10].

One of the application areas where a vivid description of visions and ideas is currently needed is process control, i.e. the monitoring and control of processes by means of targeted measures carried out by operators using (computer-based interactive) process control systems [12]. Under terms such as "smart control room" [11, 19] or "pervasive computing environment" [8], nothing less than a paradigm shift is being discussed. Stationary workstations with a multitude of monitors and mouse/keyboard operating concepts are being complemented by mobile and wearable devices supporting multimodal forms of interaction. Beyond the actual interaction, in the sense of actions by operators and reactions of the control room systems, forms of human-computer cooperation, in terms of interference management and goal facilitation [20], are explored [17]. These measures are intended to ensure that operators can continue to perform their responsible duties in the future and in the face of growing demands; whether in organizing rescue operations, ensuring the basic supply of electricity, gas and water to the population or managing complex facilities.

Following the statement that good design "does not necessarily happen through a mere sampling of technologies packaged together, through pure analysis, or just by following procedures" [9], the aim of this work is to find a conceptual metaphor for human-computer cooperation in control rooms that could be described as "smart" or that resemble pervasive computing environments. In more detail, 3 research questions will be addressed:

- **RQ1:** Which source domain could serve as the basis for a metaphor of cooperation in control room contexts?
- **RQ2:** Which attributes/aspects characterize the source domain?
- **RQ3:** To what extent can these aspects/attributes be transferred to the target domain control room?

Based on the state of the research (see section 2), section 3 explains methodology (brainstorming, literature review, one expert interview). Results, more specifically the determination of sheep

herding as source domain, are explained in section 4. Section 5 discusses transferability of findings to human-computer cooperation in process control, particularly with respect to the identified success factors for successful human-animal cooperation in sheep herding.

## 2 BACKGROUND AND RELATED WORK

In the following, metaphors in the context of human-computer cooperation in general (see section 2.1) and with respect to process control and control room settings (see section 2.2) are summarized.

### 2.1 Metaphors and Human-Computer Cooperation

While metaphors related to human-computer interaction in general have been discussed for decades and, like the desktop metaphor [21], have significantly shaped developments, metaphors more focused on collaborative aspects are rarer. One of the best known metaphors in this regard is the "H-metaphor", which represents the rider-horse relationship in the context of cooperative vehicle guidance [2, 7]. Its basic idea is that humans and automation act together, but in different ways depending on situation and configuration, on vehicle guidance via haptic actuators and visual displays.

Another vivid metaphor with reference to cooperation in security-critical contexts is that of the orchestra, in which each "agent" has a contribution to make in a coordinated manner and a conductor orders [5]. With respect to cooperation in "smart environments" in general, various metaphors, e.g. "like a friend" [13], have been considered. In their generality, they are initially difficult to transfer to safety-critical contexts of process control.

### 2.2 Metaphors for Process Control and Control Rooms

With respect to process control, metaphors referring to the control room as a whole can be distinguished from those referring to single artefacts. One of the few examples of the former category are the 3 metaphors created "in order to conduct case studies about the form and meaning of interaction that takes place in a control room" [15]. These are "interactive control rooms" combining physical and social space qualities, "intuitive control rooms" combining physical and virtual space qualities, and "boundless control rooms" combining virtual and social space qualities.

Examples of the second category are the Personal Bucket Organizer, a handheld device in control room settings, following a bucket metaphor [22] and the affordance tablet, a "collaborative smart interface for process control" [14].

In summary, none of the established metaphors are entirely suitable for describing the vision of human-computer cooperation in future control rooms. The most promising ones do not share the characteristics of control room work (H-Metaphor) or are devoted to state of the art control rooms [15].

## 3 METHOD

The procedure to find a metaphor for human-computer cooperation in process control was characterized by 3 phases:

- **Brainstorming** guided by specific aspects of control rooms (e.g. trained professionals, levels of authority) [18],
- **Literature review** based on the results of the brainstorming phase,
- **Expert interview** based on the results of the first two phases.

The **Brainstorming** was conducted by 2 researchers involved in the project "PervaSafe Computing" devoted to the design of future control rooms. Starting point was the state of the art of research, especially the H-metaphor. The search was explicitly for other, i.e. not riding-related, cooperation between humans and animals characterized by dynamics and a variety of partially independent elements. As dogs are considered "man's best friend" by many, the mental leap here was not too far. Furthermore, they are involved in various safety-critical tasks, e.g. as drug detection dogs, rescue dogs, avalanche dogs, customs dogs and police dogs. With regard to the control of dynamic processes characterized by a multitude of elements, the image of sheep herding emerged in the further discussion.

After the initial determination on dogs and the context of sheep herding, **literature on this area was reviewed**. This revealed that the topic has already been addressed in works in the humanities and social sciences [3, 4, 24] as well as in computer science [1, 16]. While works from the former spectrum have investigated, for example, leadership behavior in sheep herding and their transferability to organizations, technically oriented works have dealt, among other things, with robot navigation or human-swarm interaction [23].

While the aforementioned work provided valuable insights into the topic of sheep breeding, the link to human-computer cooperation in process control was not elaborated in a targeted manner, especially with regard to aspects of cognitive ergonomics. For this purpose, **experts** (e.g. sheepdog trainers) in the context of sheep herding whose expertise was particularly evident through winning competitions were researched online and requested for **interviews**.

Of the 5 people who were mentioned on relevant online websites and had provided contact details, one person could be recruited for an interview. As of 2022, she had more than 40 years of professional experience, had been successful in various international trails and tended hundreds of sheep in huge areas (> 5000 acres) on her own (supported by dogs). The interview of just under one hour was conducted using a videoconferencing solution, recorded, and transcribed. After a short introduction on controls rooms as pervasive computing environments and personal background, questions (samples below) were structured according to major topics of computer-supported cooperative work as described by [6]:

- **Training:** Could you describe your approach to training dogs? Are there any preconditions?
- **Awareness and Communication:** How does communication between man and dog work? Are there aids?
- **Coordination Support:** Are there any constrains on the tasks of human or dog?
- **Appropriation and Malleability:** Presumably, man and dog also grow closer together over time? If so, how is that supported? Would a dog disregard commands/misbehave for a better reason?

## 4 RESULTS

In the following, we will explain the aspects that, from the expert's point of view, are crucial for the success of the cooperation between shepherds and their dogs. They are each illustrated with concrete statements in the wording.

(1) **Not every dog can be a herding dog:** "They need to be able to run, they need to have stamina, they need to have the intelligence, they have to have good hearing, they have to want to listen, they need to have natural instincts of working on their own on initiative."
(2) **It's a process of learning slowly. Breed young dogs the qualities that you need for the job:** "If you have a talented student, it's about 18 months to 2 years [...] it takes a year to get the basic foundation and then it takes another 6 months to get the commands and some kind of expertise. And then it takes another year to get experience [...] they are developing over a time scale. You can't force it. You got to wait for the dog [...]."
(3) **The human needs to learn the language of the dog:** "[...] which is body language, gestures, the way you use your vocal noises, the sound and it's put together by very certain signals to the dog, what your intent is and what you want him to listen."
(4) **The human teaches the dog how to communicate with the sheep:** "I analysed my pack of dogs (15) and I watched how they interacted, so I could then effectively communicate with them. [...] their instincts telling them one thing and I keep manipulating their instincts in order to manage the sheep the way I want it managed."
(5) **The way the human communicates with the dog has to be fair, to build a partnership:** "So you have to have boundaries in place, they have to know the consequences if they step over a boundary. But they also have to be [...] loved and cared for and touched [...] to feel confident and safe in their environment."
(6) **The dog is much better at reading a human than a human is reading a dog:** "[...] because he relies on his instincts. He is not relying on the language [...]. We have become less used to use an instinct since we learned a language, so we rely on words, rather than relying on our instincts."
(7) **The hierarchy has to be correct. The human has to be an alpha in order to lead the pack:** "A dog is a hunting animal,[...] we have manipulated the ability to hunt into a working ability that helps us. [...] Otherwise one of the pack members is going to hunt and kill the sheep."
(8) **The human is a manager, not a boss:** "I'm managing the various talents of my dogs [...] you have to delegate the right tasks for the right dogs. I have to ask them questions and we will have a discussion about the best solution [...] my dogs know that they are allowed to think [...]. I want them to think about what require them to do the job. And then I want to use their own initiative to use that goal. So, I learn a lot from what my dogs do."
(9) **The dog just reacts, he has not to think about his reaction if its right or wrong:** "Whereas we've been brought up on to have empathy think about it before you react, and so we are more reserved [...]"
(10) **The experienced dog uses his initiative:** "There was a sheep stuck upside down in a hole and he would not leave that sheep until I gone over there and see for myself what the problem was [...] If he is an experienced and have the intelligence [...] to know how to get my attention, for me to go there."
(11) **The longer the dog and the shepherd work together, the better their connection gets:** "If you give him responsibility but you also not insulting his intelligence, that he is quite capable of thinking, on working out how to manage things and do their job on his own initiative. That's what actually makes everything work."

## 5 DISCUSSION

In the following, the research questions posed at the outset are addressed as well as limitations and future work.

### 5.1 Shepherding as a Metaphor for Human-Computer Cooperation in Process Control

With respect to **RQ1** it can be stated that shepherding seems to be a promising source domain to serve as the basis for a metaphor of cooperation in control room contexts. The attributes/aspects that characterize this source domain have been presented in the previous section (**RQ2**). To what extent these aspects/attributes can be transferred to the target domain of process control (**RQ3**) will be discussed subsequently:

With regard to the design of cooperative technical systems, the statement **"Not every dog can be a herding dog"** can be understood to mean that basic requirements for software quality (e.g. reliability, security, maintainability, usability) must be met so that cooperation between humans and technology can succeed.

**"It's a process of learning slowly"** can be directly referred to iterative approaches of human-centered design. Advanced concepts of human-computer collaboration should not be directly incorporated into real-world process control operations, but should be tested and refined through simulations for longer periods than usual.

From the explanations for aspects like **"The human needs to learn the language of the dog"** and **"The human teaches the dog how to communicate with the sheep"**, it can be deduced that a common understanding and language are important. Technical solutions must be able to capture the condition of the operators and their workflows. Operators must have a thorough understanding of potentials and limits of technical solutions. Multimodal interaction options could be useful in both directions (e.g. analysis of operators' posture and tone, feedback on different channels).

Several statements (e.g. **"The human is a manager, not a boss"**, **"The hierarchy has to be correct"**) relate to levels of authority. With respect to process control cooperation, the principles in sheep herding would mean that operators would continue to be in charge. They have to "manage the various talents" of their control room applications and delegate accordingly. Mode errors and flexible allocation options are two keywords in this regard.

Finally, statements like **"The experienced dog uses his initiative"** can be related to long-term cooperation efforts and learning efforts (machine learning as well as human learning). Feedback and corrector mechanisms must be integrated directly into the control room systems so that, for example, insufficient suggestions or faulty automation solutions can be reported back directly by the operators.

## 5.2 Limitations

Some limitations need to be addressed. First of all, with only one expert interview, there is a risk that the subjective impressions of the interview partner will overly influence the findings. However, in view of the proven expertise and decades of experience, it can at least be assumed that the statements are well-founded. Nevertheless, it is likely that other aspects are relevant for other experts. Feasibility of the metaphor must be examined with the help of implementations. Likewise, the risk of "breaking" that inevitably accompanies metaphors in the safety-critical context of control rooms must be examined particularly carefully with regard to the potential danger. Accordingly, the risk of focusing on this metaphor too early, possibly from too one-sided a human-computer interaction perspective, must also be considered.

## 5.3 Future Work

The next step is to expand the survey of experts in order to identify any contradictions or additions to the previous findings. On the other hand, the idea of a control room as a pervasive computing environment will be practically investigated using the example of a wearable assistance system as part of the PervaSafe Computing project. Here, the metaphorical approaches will be incorporated into the design.

# 6 CONCLUSION

Shepherding seems to be a promising candidate as a source domain of a metaphor for human-computer cooperation in process control contexts. Some of the factors that, according to one expert, account for the success of cooperation between shepherds and dogs can be applied to the design of cooperation between humans and technology. Familiarization phases are just as important as the aspects of continuous mutual learning and multimodal interaction. Risks fundamentally associated with metaphors as well as context-specific risks have to be taken into account in future research.

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