2.20 Exploiting Advances in Video Technology for Use in Smart Manufacturing

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Video content and technology is an integral part of our private and professional lives. We consume news and entertainment content, and besides communication and learning there are many more significant application areas. One area, however, where video content and technology is not (yet) utilized and exploited to a large extent are production environments in factories of the producing industries like the semiconductor and electronic components and systems (ECS) industries. This article outlines some of the opportunities and challenges towards better exploitation of video content and technology in such contexts. An understanding of the current situation is the basis for future socio-technical interventions where video technology may be integrated in work processes within factories.

Disadvantages, Constraints and Risks

Certainly, there are downsides to utilizing video technology in factory environments as well. Investing in technology obviously entails cost for procurement, integration and maintenance of infrastructure and devices. Transmitting and recording significant amounts of video data requires IT infrastructure, bandwidth, storage capabilities as well as dedicated interfaces to retrieve, analyse and engage with content.

Apart from infrastructural aspects, another concern is the acceptance of the dedicated users who might have some freedom to decide to which degree to make use of video tools. Any camera that doesn't capture only machines but also monitors employees conducting their work on a permanent basis can become a serious issue with respect to privacy, employee rights and labour law. Even in videoconferencing where an employee takes the conscious decision to start and end the process of being captured by a camera, several participants in our interviews reported that they feel rather uncomfortable and insecure in such situations. Specifically, some who had experience using telepresence tools in meeting rooms felt disturbed seeing themselves when the interface included a self-view. It is yet to be evaluated to which extent such concerns mentioned in the realm of office spaces apply as well for remote video communication within the factory environment.

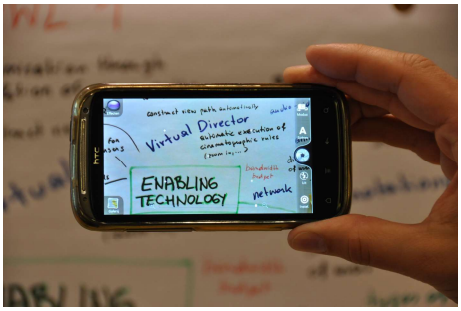
For companies themselves, any remote live video connection bears a risk for the protection of their sensitive, confidential intellectual property. Hence, many companies decide not to allow remote video streams from their factory at all. As a downside, minimizing this risk rules out any benefits based on remote collaboration.

Opportunities and Example Application Areas

In smart factories of the semiconductor and ECS industries complex and multifaceted work processes are taking place. They naturally vary from company to company. Nevertheless, there are common areas which can be talked about in general terms, and in which video content and technology could be employed to provide added value. The following lists some of these relevant areas and concisely discusses video technology which could be utilized to a greater extent.

Video communication or *telepresence* is a basic feature which can be part of many services and work processes and several production companies already use, for internal communication as well as with external sources, for remote maintenance, collaborationwith partners in innovation endeavors and co-opetitive settings, etc. The context of such applications is very different from private social video communication or business videoconferencing in office and meeting room environments.

Beyond 1:1 direct video feeds, in complex communication setups, Virtual Director approaches [104] [51] could help users to make best use of multiple concurrently available video streams. A Virtual Director is a software component which automates the decision making tasks of a human director in a TV broadcast, i.e. taking decisions what camera view to show, and when to switch to another



view. However, in order to adapt this approach for use cases in smart factory environments, first a deeper understanding of user/stakeholder needs and constraints needs to be obtained, especially regarding the user interaction with the system itself:

- What specific features and capabilities are required in specific application contexts within factories?
- What forms of user interaction are suitable to steer semi-automatic content selection and adaptation, given constraints like gloves and cleanroom clothing?
- What characteristics of a viewing experience are relevant to enable efficient and accurate work for both repetitive and challenging tasks, while maintaining work satisfaction long-term?

In environments like clean room production fabs where the number of employees on the shop floor keeps decreasing relative to the increase in productivity, and mobile robots are already present, apart from fixed and human-worn cameras, telepresence robots [218] and indoor/outdoor video drones [150] may prove to be useful, as such mobile cameras quickly allow to reach and inspect remote spaces.

For *machine monitoring* and *steering*, dashboards mostly include textual and abstract graphical representations of processes and states. Integration of video feeds could speed up cause analysis during costly breakdowns or help to visually determine from remote what sensors might not be capturing. Where video is already established in many processes without a human in the loop are machine vision applications, i.e. real-time video analysis coupled with fully automatic decision making, for example to filter out defective products or production equipment.

In some factories, simplistic Virtual Director behaviour is already deployed to enable automatic camera switching in order to help operators follow items along a linear production workflow across multiple fixed camera viewpoints.

For highly monotonous monitoring tasks where many machines have to be observed in parallel, and where fast and correct operator intervention is required in case of errors (related approach described in [103]), specific support needs to be designed and intelligent video processing may be part of novel solutions assisting operators to that end.

While *documentation* for the sake of quality insurance and traceability is typically based on (machine) data logging, in certain cases it would make sense to use video as well. To make use of large amounts of recorded footage whenever necessary, dedicated interfaces for retrieval and analysis are needed as well, but this is typically handled outside the production environment.

Providing individual instructions for workers is an aspect that could become considerably more important due to the Industry 4.0 trends of product customization. Optimizing for *lot size 1* leads to a tendency of less repetitive tasks in some areas and implies that workers require more information about the current products being processed. This is a challenging aspect especially when a considerable amount of products is to be handled in parallel. For ever-changing information and instructions, selective use of video content might be beneficial compared to primarily textual interfaces. More descriptive directions and conveying a better understanding of the desired output may increase unambiguousness of instructions and throughput for manual tasks. It may also help to

reduce mistakes.

For companies, using video for this purpose also depends on efficient means to capture content. While technically it may be straightforward to capture instructions as video clips, one learning of the aforementioned interviews was that many employees have profound reservations recording something not being a cinematographic expert, and especially recording themselves explaining something or showing how a task can be conducted. This is especially the case when video content is supposed to be shared with external parties such as customers, but also when recording informal instructional videos for colleagues.

Apart from concerns to capture evidence of any mistake, people tend to get overly ambitious with respect to the cinematic quality of their recordings. Rather than aiming for what is good enough for the purpose at hand, some employees seem to strive for what what they are used to when consuming entertainment content in their spare time (TV, cinema), and do not want to share content that does not meet these aspirations. The fear of making oneself replaceable is a further reason affecting knowledge sharing in this form. This is one besides many other factors keeping employees from externalising and documenting knowledge, as known from knowledge management research.

Learning or *employee training* is another aspect where video content is already used in terms of courses and seminars. However, the uptake of Industry 4.0 approaches might change requirements towards more short-term, in-situ knowledge transfer and refreshment and require new kinds of video-based technology support. While one current concern to that end is the effort required to keep contents up-to-date, future intelligent video technology may be more flexible by automatic means, and capable of content adaptation and personalization with very little manual effort required.

Future Research

Video content and technology in increasingly smart production areas is a topic that hasn't been addressed by research with emphasis in the past. Due to implications of the Industry 4.0 movement, however, companies keep adapting and improving production processes and so the tasks and required qualifications of workers are changing constantly as well. This development could inspire many production companies to more closely investigate how to exploit video to their advantage.

Towards designing socio-technical interventions as a combination of new tools and adapted business processes, a first step is to understand what reservations users and further stakeholders have towards innovative video technologies. Findings from other working areas such as office spaces may or may not apply to the specific context and conditions of factory environments.

A positive factor contributing towards technology acceptance may be the urgency of certain tasks, e.g. video-based remote maintenance in case of a costly machine breakdown: shyness may be overcome easier by a person understanding the urgency and consequential costs of such situations – at least this was the opinion of one participant in our interviews.

Another positive factor is the intimacy of mediated video communication, i.e. a 1:1 session with a remote person whom the local person has met before face-to-face may be much better accepted than conversations in videoconferences involving larger groups of people. Training employees, informing about what is recorded and what is not recorded, what is used for what purpose and who will have access to content etc., can be another enabling factor.

In any case, video technology needs to be used selectively. Appealing interfaces and ease of use are essential, especially when there is freedom of choice to use a tool or not [88]. Basic training on how to use video based technology, however, becomes less and less important since the young generation of workers is typically very familiar with it due to smartphone and camera use in their private lives.

From a research point of view, a key concept to explore are *experiences* in the realm of video use and consumption in factories (cf. [152]), a concept very well understood by the research community for other application domains but not for production environment contexts. But in

contrast to entertainment, for example, factory workers utilizing video content are driven by their working tasks and there is less intrinsic motivation to engage with video. How could the quality of experience (QoE) be conceptualized and assessed in fab environments?
The availability of the right knowledge in the right form can make an impact on productivity. For repetitive tasks, content presentation may help maintain concentration and not miss important cues. During the execution of very crucial tasks, assistance to focus on what is relevant can also help to concentrate, somewhat related to the concept of *immersiveness* in other domains, especially when AR glasses or VR goggles are used to interact.
Regarding the application of the Virtual Director concept, the most obvious cases we identified so far are for communication when collaborating remotely, and for operators monitoring a significant number of machines via remote video streams in parallel. Compared to entertainment services, the cinematographic appeal and dynamic visual aesthetics are assumed to play a much lesser role. The pragmatic concern of seeing what is currently most relevant appears to be more important in general terms. Nevertheless, it makes sense for production companies to investigate how to support workers in the best way possible. Small difference in tool behaviour could make a great difference especially for daily routine tasks.
One approach towards exploring possible applications of video technology is driven by thinking about its *affordances*. The concept of affordances has been described in various abstraction levels and from different viewpoints across several research disciplines, concerning both physical objects and technical tools and applications. An affordance refers to what actions a user can take with an object.
Gaver [63] defines affordances as "*properties of the world that are compatible with and relevant for people's interaction*" and stresses the importance of understanding both the needs and abilities of users, as well as the capabilities and limitations of technologies. Ideally, any video device, application or service shall serve multiple affordances, possibly even future ones not conceivable yet (extendability). Exploratory research at this stage may be less concerned with the concrete affordances of a particular tool, but rather aim to understand which affordances shall be supported overall.

Acknowledgements

The work has been performed in the project *Power Semiconductor and Electronics Manufacturing 4.0* (SemI40), under grant agreement No 692466. The project is co-funded by grants from Austria, Germany, Italy, France, Portugal and Electronic Component Systems for European Leadership Joint Undertaking (ECSEL JU). The Know-Center is funded within the Austrian COMET Program – Competence Centers for Excellent Technologies – under the auspices of the Austrian Federal Ministry of Transport, Innovation and Technology, the Austrian Federal Ministry of Economy, Family and Youth and by the State of Styria. COMET is managed by the Austrian Research Promotion Agency FFG.

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