Perspectives on the Internet of Skills: the next tech wave?

Michele Colli, *Industrial IoT Specialist,*
IoT, Data & Services Innovation, FORCE Technology (mic@force.dk)

Morten Wagner, *Head of Department,*
IoT, Data & Services Innovation, FORCE Technology (mw@force.dk)

Anders Mynster, *Head of Department,*
IoT, Data & Services Innovation, FORCE Technology (apm@force.dk)

Søren Bronnée Sørensen, *Vice President,*
IoT, Data & Services Innovation, FORCE Technology (sbs@force.dk)

Table of Contents

1. Introducing the “Internet of Skills”

The **latest advancements in the Internet of Things (IoT)** domain – namely the arrival of 5G, enabling high speed, low-latency and ultra-reliable communication – have enabled new opportunities linked to the fast transmission and use of large quantities of data. One of these opportunities concerns the **adoption of these technologies to transfer practical skills**.

Although isolated examples and pilot applications in these regards have been developed and implemented in the past few years, the general concept of transferring practical skills over a network had been formalized in 2017 by a team of researchers from King’s College in London, which labelled it as “Internet of Skills” (IoS) (Dohler et al., 2017; Jung et al., 2020; Kim et al., 2018).

The **Internet of Skills** concerns the general **ability to transmit practical skills in (near) real-time through the internet**, so third parties all around the world (either humans or machines) can take advantage of such skills to support their activities, despite physical boundaries such as distance or environmental dangers (Dohler et al., 2017; Jung et al., 2020). This could include highly specialized doctors remotely performing surgery in particularly inaccessible locations by visually guiding a robot located as well as world-class piano players remotely teaching the way they perform a sonata by recording and sharing their wrists’ and fingers’ movements (Koucheryavy et al., 2017) or production specialists supporting untrained operators in performing assembly, inspection or maintenance processes on the other side of the globe by using augmented reality.

The Internet of Skills as a scalable concept addresses the need for making very specific or **best-in-class practical skills available, often on a temporary basis and “on-demand”, in parts of the world that are particularly inaccessible or very costly to reach, as well as in situations that require them immediately.**

There **are three main application domains** that have been discussed so far in the scientific literature addressing the Internet of Skills concept:

- Medical
- Education
- Industry

Medical. The medical domain includes the remote application of medical skills for supporting both diagnoses and surgeries. This would be particularly relevant in third-world countries, where highly qualified medical personnel is often unavailable or simply not able to cope with the demand (Brown-Acquaye et al., 2019), as well as in dangerous environments hit, for instance, by war or an epidemic (Dohler et al., 2017), or in environments where the cost linked to medical operations need to be optimized (Kim et al., 2018).

Education. The education domain includes remote training from highly skilled practitioners in niche areas of expertise, including music or painting, to users all over the world who may not have direct access to such skills (Koucheryavy et al., 2017; Dohler et al., 2017).

Industry. The industry domain includes the remote decommissioning of industrial operations, such as control operations, which may be performed taking advantage – remotely - of a digital twin of a factory for instance (Tsokalo et al., 2019), and service operations, which may be supported remotely by highly skilled experts, reducing their need for continuous travelling and increasing their capacity, hence reducing the service costs (Dohler et al., 2017). Moreover, IoS could be deployed for the next generation of robots (3.0+), where machines will be supposed to transfer their learned skills to each other (Haidegger et al., 2019).

2. The anatomy of the Internet of Skills

The transmission of practical skills over a network and their remote application is catalyzed by technologies such as haptics – kinesthetics and tactile -, audio and video technologies. On one hand, these and other **technologies support the skills holder** - whether a human or a machine - **in "reading" the environment** where the skills will need to be applied (e.g. providing data about the status of a machine) **and translating its own actions in actions that can be replicated remotely**. On the other hand, these **technologies support the skills user** – whether a human or a machine - **in replicating the actions performed remotely by the skills holder** as well as in providing the latter with feedback regarding the result of such actions (Figure 1).

In order to be successful, Internet of Skills solutions may be required to transmit these skills with a **"zero latency" feeling**. This, from a numerical perspective, is translated in less-than-10 milliseconds latencies – what is called "low-latency". 5G can ensure these latency levels while covering 1000-1500 km distances (Dohler et al., 2017; Kim et al., 2018; Brown-Acquaye et al., 2019)[1]. Nevertheless, when the distances to cover are higher (i.e. covering the whole world), the use of 5G may not be enough. Solutions may involve the combination of different technologies, such Edge Computing for further reducing the data that needs to be transmitted through the 5G network, and Artificial Intelligence for forecasting future data inputs from the skills holder and feedbacks from the skills user – an expedient to reduce the perceived latency (Dohler et al., 2017; Kim et al., 2018; Brown-Acquaye et al., 2019)[2].

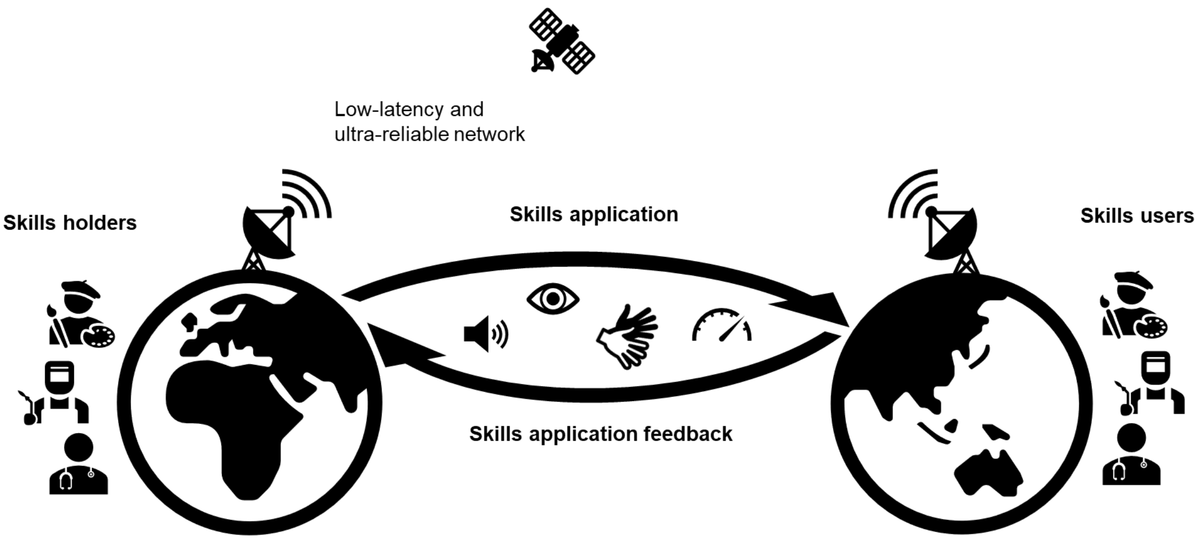

Figure 1 - Internet of Skills principle: the remote transmission of practical skills

Given these premises, the anatomy of an Internet of Skills solution consists of three main domains (Brown-Acquaye et al., 2019; Lema et al., 2017):

- **Controller** – Skills holder remotely controlling the application of the skills
- **Network** – Means for transmitting the skills from one location to another
- **Controlled** – Skills user applying the skills where needed

[1] *Another research area, concerning "Tactile Internet", is aiming at remotely providing "tactile feelings" to, for example, remotely test the quality of textiles. The required technologies, which are currently being investigated, will have to deal with < 1 ms latencies (Le et al., 2020)*

[2] *For more information about 5G and Edge Computing, you can access dedicated whitepapers on forcetechnology.com/en/articles*

Extant research suggests different elements that may be included in such anatomy. These are ultimately **dependent on the application case** – skills to be transmitted, transmission distance, skills holders and users characteristics, etc.. Below, we are going to provide, for each domain, **a description of the elements to be included** (or potentially included) in such anatomy (Dohler et al., 2017; Kim et al., 2018; Brown-Acquaye et al., 2019; Jung et al., 2020; Lema et al., 2017; Al Ja'afreh et al., 2018).

The controller domain may include:

- Specialist (human or machine) holding the "skills"
- Technology (e.g. haptics, audio, video) to translate skills into data that can be transmitted from the "skills holder" to the "skills user" as well as to receive feedback data from the "skills user"
- *Possible:* Edge Computing to locally process data inputs from the "skills holder" and minimize the data that must be transmitted to transmit the skills, consequently reducing the required processing time and latency (Brown-Acquaye et al., 2019)
- *Possible:* Artificial Intelligence (AI) to analyze the data transmitted from the "skills holder" and forecast the future data transmissions (e.g. movements), supporting a further reduction of its perceived latency from the "skills user" (Dohler et al., 2017; Kim et al., 2018)

The network domain may include:

- Network (e.g. based on 5G technology) to transfer data from the "skills holder" to the "skills user" as well as feedback data from the "skills user" to the "skills holder", ensuring ultra-reliability and low-latency (< 10 ms within 1000-1500 km distance)
- *Possible:* Slicing of the signal, separating different data sources concerning the skills to be transmitted (e.g. haptics, audio, video) to reduce the required bandwidth and improve the reliability of the transmission (Lema et al., 2017)
- *Possible:* Priority system which identifies and prioritizes the transmission of data for applications that require a low-latency transmission, to ensure the minimum possible latency (Lema et al., 2017; Al Ja'afreh et al., 2018)
- *Possible:* Path reservation, end-to-end, for high priority data, to increase the reliability of the transmission (Brown-Acquaye et al., 2019)

The controlled domain may include:

- Code/coding techniques to translate data inputs from the "skills holder" into outputs for the "skills user"
- "Skills user" (human or machine) applying the skills transmitted from the "skills holder"
- Technology (e.g. haptics, audio, video) to receive data inputs from the "skills holder", support the "skills user" in its remote application of the skills and transmit feedback data back to the "skills holder"
- *Possible:* Artificial Intelligence (AI) to analyze the feedback data patterns to be transmitted to the "skills holder" and forecast the following feedback (e.g. movements), supporting a further reduction of its perceived latency (Dohler et al., 2017; Kim et al., 2018)

3. Reflections from an industrial perspective

The industrial domain certainly has its fair share in terms of potential application cases for the Internet of Skills. By discussing the topic with some of the largest Danish manufacturers, we identified seven main application areas: supervision, control, training, support, maintenance, inspections and calibration.

3.1. Supervision

The adoption of the Internet of Skills concept in a production environment would enable the remote supervision and continuous guidance of manual activities, such as assembly processes. This would be particularly relevant in three cases: (1) when processes are particularly complex, (2) when processes are performed on components and products that are continuously changing (i.e. high level of product mix or customization) and (3) when resources trained for specific processes are not available on a production site.

In the first case (1), by having an additional support to ensure the correct performance of a complex manual process would enhance its efficiency, increasing productivity and manual labor capacity.

In the second case (2), by taking advantage of “digital” guidance when dealing with continuously different products would both support an increase of process efficiency and make sure that quality standards are met.

In the third case (3), by having specialists remotely supervising and assisting non-specialized manual labor in their activities would both enhance process efficiency and provide the foundations for reducing potential quality issues caused by the lack of specialization of the deployed manual labor.

In all three cases, the adoption of Internet of Skills based solutions would act as a catalyst for improving the productivity of manual labor, either by enhancing a higher efficiency level or by ensuring that quality standards are met, or both. This would support the reduction of the overall cost of production operations.

Vestas

“Wind turbines are constantly increasing in size and, to facilitate logistics operations, they are more and more frequently assembled on the installation site by a local team. It is paramount to be able to supervise and, when needed, to provide practical support to the local team to ensure an optimal installation of the wind turbine. Because of that, companies like Vestas are facing an increasing need for decentralizing their practical skills to support their operations on a global scale, and the Covid-19 pandemic highlighted how this can become a significant challenge. This is why we just launched a new AR-based solution to support our technicians in their assembly operations”.
- **Emre Yldiz, Digitalisation and Simulation Lead.**

3.2. Control

On top of the supervision capabilities remotely provided by Internet of Skills solutions, there is the possibility to remotely control operations. This would be particularly relevant in highly automated environments where control activities are rarely needed yet, when needed, they depend on highly skilled personnel. Examples of application cases can be a ship passing through a channel during its intercontinental journey, or the need for setting up production equipment every time a new product is introduced in the mix.

In these type of scenarios, a remote control solution would either support labor cost reduction by cutting the need for having highly specialized manual labour constantly available, or the reduction of downtime by cutting the need for waiting for highly specialized manual labour when this is not constantly available.

Furthermore, the ability to remotely control operations would enable their centralization. In the case of complex production or supply chain systems, this can facilitate the improvement of the overall operational performance, by optimizing the orchestration of its different activities from a system perspective, ensuring a global optimum instead of sub-optimizing each one of them.

Stenhøj Holding

"The Internet of Skills concept has already been partially explored from Stenhøj Holding, especially in regard to augmented reality. While there is still some hesitance about the adoption of these tools for supporting daily operations – mostly due to employees not feeling "natural" using them on a continuous basis - augmented reality is currently being applied for facilitating training activities dedicated to the improvement of internal safety - for instance, facilitating employees in learning how to deal with a new plant layout". – **Henrik Berg Jepsen, Head of Digitalization.**

3.3. Training

The Internet of Skills concept may act as a natural extension of existing training tools. One of the most relevant examples are learning platforms collecting documents and videos about different business procedures. Over the past years, these platforms had been increasingly deployed to decentralize training activities, increasing their flexibility and reducing the related cost.

While these platforms concern the transfer of knowledge, the Internet of Skills promises to extend the training capabilities to a practical level, spanning from the execution of production activities in a new factory to the assembly of a completely new product.

This would support companies in improving both the efficiency as well as the safety of their operations at a reduced cost and with a significantly higher degree of flexibility. In fact, employees would have access to new practical skills "on demand", anytime these are needed and anywhere these are needed, cutting all the lead times, costs and disturbances related to the physical presence of a trainer.

Nevertheless, this would also act as a further support for any change process due to its time- and cost-efficiency and to its scalability, as different people based in different locations could be trained simultaneously.

3.4. Support

The application of Internet of Skills solutions would enable equipment producers to provide prompt support anytime one of their customers experiences issues while using their equipment.

This would be particularly valuable, for instance, when unplanned breakdowns are experienced in remote locations - such as on ships located in the middle of the ocean, where normally it would require few hours or even days for the support team to physically reach the problem, entailing a long equipment downtime and the consequent missed profits.

For the same reason, the application of Internet of Skills solutions would also be beneficial in environments where fast problem solving is particularly important – such as in fish processing companies, where an unplanned production stop implies high costs related not only to the missed profit, but also to the perishability of the high-value raw material which, after a certain amount of time, would be discarded.

3.5. Maintenance

The capability to remotely transmit practical skills would enable equipment producers to outsource to their customers the maintenance of their own equipment. Examples of relevant application cases may be the maintenance on an oil rig, where today the equipment producer has to send a team of highly specialized technicians in the middle of the desert or the ocean. Through an Internet of Skills solution, the maintenance provider could be able to notify their customers when maintenance is needed, and to have specialists' remotely assisting a local maintenance team while performing maintenance activities.

This would lead to a reduction of the maintenance costs obtained by cutting the travelling time and costs required for making maintenance specialists from the equipment producers available. Nevertheless, this would remove systematic uncertainties related to possible travelling restrictions.

3.6. Inspections

The adoption of Internet of Skills solutions would support the feasibility of inspection activities, such as Field Intensity Gradient Scanning, Non-Destructive Testing or Concrete inspections. These inspections are not only very time consuming, but they also require very specific skills in order to be performed successfully. As these skills are held by a very limited amount of people in the world, the performance of such inspection activities entails a high cost and a long lead time due to the travelling time required for them to reach the different inspection locations. The Internet of Skills concept could be used to make these skills available remotely, digitally connecting operators located where the inspections need to be performed to the highly specialized skills holders, so they could remotely guide and supervise the inspection processes, after shipping the needed equipment.

By reducing the need for travelling, the number of inspections that the few specialists holding such skills would be able to perform in one day would increase, leading to an increase of their capacity and related turnover and to a reduction of the inspections' cost. This would lead to an increase of the profit margin for the companies providing the inspections and/or to a reduction of the related costs for the companies needing the inspections.

3.7. Calibration

The possibility to transfer practical skills taking advantage of the Internet of Skills could also be applied to remotely support (or perform) the calibration of production equipment. This is particularly relevant for production equipment suppliers which, due to a servitized business model, are responsible for its correct functioning during its entire lifecycle.

Coupled with the capability to remotely monitor the performance of the equipment, the possibility to remotely calibrate it could save the equipment supplier a significant amount of man-hours and of travelling related costs as well as provide it with a competitive advantage, by reducing the downtime experienced by the equipment users anytime a calibration is needed.

4. Conclusions and “call to action”

In the analysis of its anatomy, we could see how the Internet of Skills concept is enabled by several different digital technologies. Nevertheless, through the study of its application cases, it had been made clear how **the Internet of Skills is not about the technologies themselves, but about their use to transmit effectively practical skills from one place to another over a network**.

Depending on the case, an Internet of Skills solution may be supported by different data inputs and outputs - such as audio, video, haptics, machine data or all of them at the same time – and, consequently, by different technologies. The same discussion goes with the latency requirements: depending on the case, low-latency may be required - with the adoption of AI and Edge Computing for supporting its reduction – or not. In other words, **the “center of gravity” for the anatomy of any Internet of Skills solution is represented by its application-specific needs**.

By successfully addressing them, the remote transmission of practical skills – whether from- and to humans or machines – might be paving the way for significant productivity improvement and cost reductions, as well as for the enabling of entirely new ways to take advantage of practical skills and to generate revenue streams out of them.

4.1. Advantages

These possibilities depend on the ability to make best-in-class (or simply “good enough”) practical skills available potentially anywhere and anytime, depending on the actual needs.

When contextualized in the industrial domain, the Internet of Skills concept shows undoubtedly interesting potentials. All of the discussed application cases seem to be able to translate the adoption of Internet of Skills solutions into an increase of productivity and production capacity, leading to cost reduction and competitiveness increase.

From the skills user perspective, these benefits would be linked to, for instance, the reduction of potential quality issues, the increase of process efficiency or the reduction of downtime. From the skills holder perspective, benefits would be linked to the reduction of “non-value adding activities” - such as travelling – and the increase of utilization of specialized workforce. This would increase capacity and output with the same amount of resources, leading to a reduction of the cost (and/or an increase of profitability) related to the provision of such skills. Nevertheless, this would also reduce the “cost barrier” that skills users have to deal with when in need of specialized skills, hence increasing their applicability in the market.

From a general perspective, we can say that the Internet of Skills concept is particularly interesting for all those whose success-critical skills are either continuously available but poorly or inefficiently utilized, or unavailable and challenging to retrieve when needed.

> “..the Internet of Skills concept is particularly interesting for all those whose success-critical skills are either continuously available but poorly and inefficiently utilized, or unavailable and challenging to retrieve when needed”.

4.2. Implications

Together with the advantages, the capability to digitally provide or take advantage of practical skills remotely and on-demand brings several implications that must be taken into account.

One of the research papers that had been reviewed argued that as the internet enabled the democratization of knowledge, the Internet of Skills will enable the democratization of skills. Nevertheless, as the democratization of knowledge also led to what we call “fake news”, the democratization of skills may also lead to the diffusion of “fake skills”. It will become fundamental to verify their legitimacy.

In the same way, cybersecurity will play a crucial role in avoiding skills hacking, which may cause disastrous situations such as the crash of a container ship in a channel, or the physical harming of a welding operator which has been wrongly guided during a welding process.

In addition to that, it is worth considering that, having such skills available remotely and on-demand, there will be less need for specialists – the fewer will be higher utilized – and more need for generalists that could digitally interact with the remotely located specialists.

At the same time, there will be a positive impact on the capability to handle a high variance of tasks, facilitating the increase of customization possibilities and decoupling it from an increase of the cost. This would deeply affect several make-or-buy decisions.

Moreover, the ability to collect specialists digitally and on-demand from different areas in the world will affect competition: low labor cost countries will more easily scale up the selling of their practical skills to high labor cost countries: dental and mechanical skills will, for instance, be outsourced to low labor cost countries, as programming skills are outsourced nowadays.

4.3. A new wave?

The Internet of Skills discussion is certainly in an emerging phase: the availability on an academic portal such as Scopus of only 11 papers, all published after 2017, clearly shows it. However, as it often happens in technology, the concept behind the label is not entirely new: what has been labelled as "Internet of Skills" is, in fact, an umbrella that covers all of those application cases involving the use of technology for transmitting practical skills. Assistance tools based on augmented reality to support assembly or training activities are not new, as we heard from Vestas and Stenhøj Holding. Nevertheless, the availability of new technologies supporting it – such as 5G – and the establishment of a term that collects them focusing on the core intention – the remote availability of practical skills on-demand - may indicate an increasing interest in this domain, and may result in a growing trend, both development and adoption-wise.

For sure, the travelling restrictions that characterized the past 17 months due to the COVID-19 pandemic highlighted how the availability of practical skills can be critical for all kinds of businesses worldwide, and how this topic can be extremely relevant.

From our end, it was important through this work to investigate the current state-of-the-art concerning the Internet of Skills, providing practitioners with a clear overview of the topic and understanding where some of the future competences, technologies and business models might have to be focused.

4.3. The next step

Although both the research and the industrial communities highlighted what are the key elements composing an Internet of Skills solution what are the currently most relevant application cases, there still are gaps that need to be closed to ensure the adoption of the Internet of Skills on a larger industrial scale.

From a technology perspective, the main gaps regard the availability of more efficient codes for processing skills data, the standardization of such codes to enable the scalability of IoS and avoid vendors lock-ins, and better use of Edge Computing and AI to reduce latency during the transmission of skills data.

From an application perspective, the main gaps regard the understanding of the most relevant users and application cases to focus on as well as practical guidance concerning the implementation of such solutions and the assessment of their business cases.

FORCE Technology is closely following the continuous evolution of the Internet of Skills and is trying to close some of these gaps, in collaboration with its industrial and academic partners. If you are part of a company or an institution that is dealing with Internet of Skills-related projects, or if you would be interested in exploring its potential applications in your context, you can reach out to us (Michele Colli, corresponding author, mic@force.dk).

References

Al Ja'afreh, M., Adharni, H., & El Saddik, A. (2018). Experimental QoS optimization for haptic communication over tactile internet. In 2018 IEEE International Symposium on Haptic, Audio and Visual Environments and Games (HAVE) (pp. 1-6). IEEE.

Brown-Acquaye, W., Arthur, J. K., & Forgor, L. (2019). Developing A Framework for A Tactile Internet Enabled Robot Assisted Real-Time Interactive Medical System. In 2019 International Conference on Communications, Signal Processing and Networks (ICCSPN) (pp. 1-4). IEEE.

Dohler, M., Mahmoodi, T., Lema, M. A., Condoluci, M., Sardis, F., Antonakoglou, K., & Aghvami, H. (2017). Internet of skills, where robotics meets AI, 5G and the Tactile Internet. In 2017 European Conference on Networks and Communications (EuCNC) (pp. 1-5). IEEE.

Haidegger, T., Galambos, P., & Rudas, I. J. (2019). Robotics 4.0–Are we there yet?. In 2019 IEEE 23rd International Conference on Intelligent Engineering Systems (INES) (pp. 000117-000124). IEEE.

Jung, T. H., Yoo, H., Jin, Y., Rhee, C. E., & Chae, C. B. (2020). Wireless VR/Haptic Open Platform for Multimodal Teleoperation. In 2020 IEEE Wireless Communications and Networking Conference Workshops (WCNCW) (pp. 1-2). IEEE.

Le, D. T., Nguyen, T. G., & Tran, T. T. T. (2020). The 1-millisecond challenge-tactile internet: From concept to standardization. Journal of Telecommunications and the Digital Economy, 8(2), 56-93.

Lema, M. A., Antonakoglou, K., Sardis, F., Sornkarn, N., Condoluci, M., Mahmoodi, T., & Dohler, M. (2017). 5G case study of Internet of Skills: Slicing the human senses. In 2017 European Conference on Networks and Communications (EuCNC) (pp. 1-6). IEEE.

Liu, X., & Dohler, M. (2019). A data-driven approach to vibrotactile data compression. In 2019 IEEE International Workshop on Signal Processing Systems (SiPS) (pp. 341-346). IEEE

Kim, S. S., Dohler, M., & Dasgupta, P. (2018). The Internet of Skills: use of fifth-generation telecommunications, haptics and artificial intelligence in robotic surgery. BJU international, 122(3), 356-358.

Koucheryavy, Y., Kirichek, R., Yastrebova, A., & Shilina, M. (2017). Data, 'dusha', and the Internet of Skills music: would a connected Art Glove help to preserve heritage better? Russian Journal of communication, 9(3), 263-267.

Tsokalo, I. A., Kuss, D., Kharabet, I., Fitzek, F. H., & Reisslein, M. (2019). Remote Robot Control with Human-in-the-Loop over Long Distances Using Digital Twins. In 2019 IEEE Global Communications Conference (GLOBECOM) (pp. 1-6). IEEE.