



INTRO

Simulations, modelling and digital twins are taking huge leaps at the moment, both in early development and practical applications. Computing power and lack of good quality data form barriers to what can be currently modelled, but quantum computing is expected to help solve these problems.

Potentials:

- Improved data use and new digital tools can produce better predictions and help in making better decisions.
- Virtual spaces can complement mobility, replace much of travelling and create new connections without place-dependency.
- Modelling of complex systems (even ecosystems and societies) with quantum computing can help in achieving environmental sustainability and social fairness.
- Digital avatars and working spaces might allow active life for people who can't move and be active in the physical world.
- Visualisation of alternative futures through modelling holds potential for e.g. involving citizens in urban planning.

Risks:

- Living in digital worlds more and more can lead to physical loneliness, as people will likely still crave and need physical closeness.
- Care might become more digital, as it is too expensive to keep human workforce based system running, yet digital twins and virtual environments might not be as good in answering to human needs.
- As data use is amplified, taking care of individuals privacy might become challenging.
- There is a risk of big tech companies attaining monopoly of digital twin and simulation technologies
- The systemic implications of e.g. modeling human activities in industrial settings might ultimately be harmful to humans.

1: Research

- Simulations and digital twins are based on on-going vast research efforts, and the potential complexity of modelled entities gets greater all the time.
- Related to digital twins and simulations, research phase includes development of computing potential for ever more complex systems and researching on new immersive simulation technologies, for example, as well as sensor development to enable information collection and developing a digital twin of a physical system.

Ecological considerations

- Computing power and electricity use: digital twins and simulations use computing power intensively. Even in the basic research phase the question of energy use and needed computing power should be kept in mind, possibly developing solutions that are less intensive or not developing solutions that could replace more efficient practices.

Societal considerations

- Data privacy: at all points in the development of digital modelling solutions, individuals' right to privacy should be respected, even if this puts limitations to the research.
- Inclusion: as new immersive and interactive solutions are developed, usability and functionality to all groups should be ensured as well as possible.
- Purpose: There should be more consideration of the fundamental motivations behind technology development, and discussion in order to define shared visions for the society.

2: Development of concepts and products

- As new capabilities emerge, new application areas are developed all the time. At the moment, digital twin based solutions for industrial environments are envisioned, for example.
- The challenge is how to bridge the gap between the virtual and real worlds, recognising the economic, social, political, psychological etc. constraints.

Ecological considerations

- Modelling environmental impacts: when developing models for application areas that have impact on the environment (e.g. industry), building in environmental optimization with high quality data and enough variables can lead to considerably more eco-friendly results.
- Energy use considerations: Sometimes using modelling and AI applications can be more energy intensive than using human labour. If this seems to be the case, the distribution of work between automation and human workforce is good to consider also from this perspective.

Societal considerations

- Licensing and openness: when developing new products based on modelling or digital twin technologies, it is good to consider the level of openness regarding the data used and the functioning of the application. Generally, openness is considered to lead to more democratic technology environment as consumers can get information about the technology they use.

3: Introduction and early implementation

- Digital twin and simulation technologies are currently entering many new fronts. They are tested e.g. in forerunner companies of manufacturing industry.
- There is a strong need for multidisciplinary foresight units in both business and the public sector to understand the implications of new technologies, using e.g. science fiction prototyping.

Ecological considerations

- Environmental data quality and comprehensiveness: as environmental modelling is taken up, it should be ensured that enough high quality environmental data covering all important environmental issues is used. If a system is optimised only for its carbon balance, for example, it may still end up producing other type of environmental damage.

Societal considerations

- Inclusivity: when testing new solutions with users and starting a scale up, it is important to remember that a solution that works well with some groups might be completely inaccessible for others. Therefore care should be taken to account for the needs of different citizen groups.
- Fairness in using test-phase technology: when new solutions are first introduced, they should be treated as experimental and older, alternative back-up systems should be kept up long enough. A complex modelling technology might reveal some unintended features only when used in large scale.
- Privacy and data security: as data intensive applications are taken up in new sectors and environments, the privacy of users should be carefully ensured.

4: Scaling-up and fine-tuning established technologies

- As new technologies become mainstream solutions, they reach more people and have more impacts than before. They can also become invisible and unnoticed, yet there are many important responsibility factors to consider.

Ecological considerations

- Replacing mobility: digital twin and simulation technology enables conducting many tasks without physical presence. As these established solutions emerge, many businesses can consider using them instead of travelling.

Societal considerations

- Physical needs: as virtual solutions are scaled up, it should be carefully ensured they don't replace important physical services and leave people lacking in their physical needs. In some domains it might be better to not have a virtual solution at all, and in other domains it might be good only as supplementing the physical work.
- Reality +: novel ways of being in the augmented world have broad based implications for societies.