Towards Cross-Generational System Design

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Abstract. This paper introduces the concept of cross-generational system, which indicates an information technology system designed to allow different generations interacting through centuries or, even, millennia. In the era of digital immortality and advances in artificial intelligence, there will be not only the problem of preserving and accessing data, but the emergence of digital clones will bring new challenges for technology development, interaction design and ethics. This paper provides an overview of societal transformation towards digital immortality, then describes the vision of cross-generational system design, investigates the relative future challenges and proposes the eventual socio-ethical questions.

Keywords: Digital immortality · Cyber world · Digital curation
Artificial intelligence · Blockchain

1 Introduction

Using the term "cross-generational" in any field and, in particular, in communication refers to the interaction between older and younger people [1]. However, humanity is currently living a transition towards a more and more technological society and, most importantly, growingly composed of digital natives. This means that digital systems have now been present for decades, outliving a growing number of human beings. In this intergenerational change, there is also an exchange of goods and items, which are progressively becoming more and more digitalised. This implies that new trends in society are rising. For example, researchers found that some users already keep talking to deceased people on social media [2]. This phenomenon has been called thanatechnology, which is defined as the use of technology to allow people to remember the deceased loved ones [3].

At the same time, people can communicate messages and ideas to the next generations, leaving a trace for the future. In a landscape where the number of digital items people possess continues to grow, there is also the question of inheriting digital possessions (e.g., photos, books, movies, online videogame characters and items, Inter-net domains, cryptocurrencies). The ubiquitous computing and Internet of Things will provide new opportunities for remembrance and communication with future generations [3]. Enabling the secure transmission of digital information and virtual objects to future generations represents for humanity the achievement of a first type of digital immortality [4].

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In this era of profound digital transformation, where also the fast evolution of artificial intelligence is playing a crucial role, it is important to start thinking about the correct approaches and methodologies for the design of the systems of the future, which will allow cross-generational communication beyond death. This is the right time to start discussing about the importance of developing new systems designed with the purpose of interacting with several human generations through time.

As already mentioned, this paper wants to provide an opportunity for reflection about the challenges in designing systems in the era of digital immortality. It starts providing a description of the ongoing process of digital transformation, which is impacting everyone's life. This description will introduce the concept of digital clones and how these would imply a further evolution of the meaning of digital immortality. Following the analysis of this imminent progress towards digital immortality, the challenges in designing systems in this context are preliminarily explored and exposed. Before concluding this vision paper, a modest Section is also dedicated to the possible ethical questions that this technological evolution will, or at least should, raise in a not-so-distant future.

2 From Digital Dark Ages to the Digital Immortality Era

Because of Industry 4.0, social media, Internet of Things and multimedia, humanity is currently generating data at a record rate (often referred to as "big data") [5]. In 2016, global users produced as much data as in the entire history of humankind through 2015 [6]. Hundreds of thousands of Google searches and Facebook posts are generated every minute. The amount of information generated by users is growing exponentially not only because of the increased time spent on the Internet but also because of the ubiquity of connected devices. Indeed, the number of internet-connected devices is growing and are already exceeding the number of people on Earth. It has been predicted that by 2020, there will be on average approximately seven internet-connected devices per person for a total of 50 billion devices [7]. Ubiquitous computing is indeed enabling a digital transformation towards the so-called cyber world [8]. This term was first defined by T. L. Kunii in 2004 as "worlds on cyberspace as computational spaces, either intentionally or spontaneously, with or without design" [9]. Later, J. Ma provided a further definition, in which the cyber world is "a digitized world created on cyberspace inside computers interconnected by networks including the Internet" [10]. Always J. Ma stated that these cyber worlds represent the next phase of human evolution and will bring a number of unknown phenomena, and novel challenges such as digital explosion in data, connectivity, services and intelligence [11].

2.1 Preserving Digital Human History

It is interesting to note that it is clear that society is building this cyber world as a reflection of the physical one, which represent together two dimensions of future human life. This implies that the cyber world should be built in order to last in time as, at least, the physical one does. However, although it is obvious that the digitisation of

information is already happing fast and at a large scale, the management and preservation of digital information are still not mature, and this raises a number of issues. The euphoria brought by the technological revolution is making everyone focus more on the generation of data forgetting the important and consequent act of preserving digital information. On this matter, T. Kuny wrote "as we move into the electronic era of digital objects, it is important to know that there are new barbarians at the gate and that we are moving into an era where much of what we know today, much of what is coded and written electronically, will be lost forever. We are, to my mind, living in the midst of digital Dark Ages; consequently, much as monks of times past, it falls to librarians and archivists to hold to the tradition which reveres history and the published heritage of our times" [12]. The ongoing process of digitalisation of the society is not taking into account the severe threat of total loss of a broad swathe of the scientific record and cultural heritage in digital form. Indeed, since the democratisation of the personal computer, enormous amounts of digital information are already lost forever. Once lost, digital history cannot be recreated by individuals or organizations. The raising awareness of risking to further extend the duration of these digital dark ages brought the foundation of digital curation domain. The digital curation has been defined as "the act of maintaining and adding value to a trusted body of digital information for both current and future generations of users: in other words, it is the active management and appraisal of digital information over its entire life cycle" [13]. Often, the causes of such losses were as trivial as the lack of archive management or because information was stored in out-dated formats. For these reasons, it is important to start designing systems that can integrate effective fail-safe mechanisms to support the rescue of endangered digital information and the constant update of their storage formats.

2.2 Achieving Digital Immortality

Preserving and transmitting information to next generations has been defined as one-way immortality: allowing communication with the future [4]. This type of digital immortality would already enable sharing ideas and memories through time, making it possible to democratise knowledge and enhance the conservation of cultural heritage.

Passing digital information to next generations could also bring other novel applications and unprecedented opportunities. For example, preserving scientific data in an adequate and intelligible manner may give to those data more than one life: as scientific ideas advance, new concepts may emerge from study of observations that led earlier to different kinds of insights [14]. This would accelerate scientific progress and, at the same time, reduce the cost of research and innovation. In this way, the research could virtually be conducted from researchers lived in different eras giving to collaboration a new dimension independent from time and augment the potential of human intellect.

The relentless evolution of technology is not just touching its pervasiveness but also its potential. The progress made in machine learning in the last decade made the vast majority of the researchers quite optimistic about the future of artificial intelligence (AI) [15]. Several researchers in AI are working toward the ultimate goal: the creation of a machine able to mimic the human mind [16]. Several researchers actually think that the AI is positioned to become smarter than humans [17].

This context stimulated the generation of a further vision, which depicts a future where the evolution of AI will make possible to develop virtual agents based on the personality of deceased users, transferring their minds into the machine becoming digitally immortal [18]. These agents will not only be repository of the dead people's knowledge but will act generating new information in the cyber world according to the personality. This is called *two-way immortality*: "allowing you, or at least part of you, to communicate with the future in the sense that artefact continues to learn and evolve" [4]. This will introduce a new level of interaction between different generations: users will be able to co-create original information with deceased people. A kid can ask his grand-grand-grandfather opinion about the new political scene. Designing such interaction will face many unprecedented challenges, such as the difference of language and the update of the deceased people awareness of new technologies and socio-political events.

Finally, digital immortality can be defined more in general as "a continuum from enduring fame at one end to endless experience and learning at the other, stopping just short of endless life" [4].

3 Emergence of Digital Clones

The process of digital transformation is causing the emergence of the cyber world, which means creating a digital copy of every entity present in the physical world, and this phenomenon includes the human beings. Many research works introduced the concept of digital avatar to model the characteristics of each individual. For example, the European Commission initiated the Virtual Physiological Human (VPH) initiative, which aims at developing an integrated model of human physiology at multiple scales from the whole body through the organ, tissue, cell and molecular levels to the genomic level [19]. The ultimate goal of the VPH is to support the development of patient-specific computer models and their application in personalised and predictive healthcare [20]. This initiative allowed collecting and integrating heterogeneous and data predictive models to obtain unprecedented results in the interpretation and prediction of the progress of diseases and of the effectiveness of relative treatments. Many projects stemmed from this initiative to tackle specific problems or diseases [21], or also to provide personalised motivational interventions [22]. However, the ultimate goal is to have a comprehensive model of each individual to provide personalised treatments. A new European project, with this vision, has just been created: the Health EU. This project aims at developing human avatars that will allow healthy individuals and patients to prevent, intercept and cure any disease [23]. The Health EU project is positioned to revolutionise the human model development by leveraging data from omics analyses, medical and imaging data, environmental and life style big data that are continuously updated by a multitude of biosensors at an unprecedented scale. In particular, this health avatars will be able to update their information directly uploading data from the most advanced organ-on-chip and implantable smart nanosensors.

Although the aforementioned projects already represent the avant-garde of digital avatars, it has been predicted that future digital representations of individuals will be

able to simulate also thoughts, ideas and emotions. Indeed, J. Ma stated that the effort of research to digitise also the human beings will lead to the creation of the Cyber-Individual (or Cyber-I), which is a digital clone of a human individual able to simulate the original human being from the behaviours to the mind/thinking through the continuous collection of personal data [11]. The digital clone is an identical copy of its original individual with the difference that it exists in the cyber world, although it may be embedded within a physical entity or object present in the physical world, e.g., a humanoid robot. Since it has been predicted that it will be possible to copy any entity in the cyber world, J. Ma provided also a more general definition of digital clone, which is "a digital copy of a creature, a plant or something related to an individual with certain life characteristics" [11].

The research conducted by J. Ma on the creation of the Cyber-I aims at creating a digital clone through the continuous collection of personal data not only for precision medicine treatments for life prolongation, but also to make individual-aware applications for the provision of desired services to everyone living in both the physical and cyber world [11]. The Cyber-I would enable new computing modes for personalized services (e.g., individual-aware search engines) and other novel applications (e.g., suitable service discovery and community simulation) [11]. It is possible to imagine that there could be multiple uses of the Cyber-I in favour of the original individual. For example, the digital clone could work on behalf of the original individual, or the Cyber-I could run a myriad of simulations to suggest the best action to the original human being in every context and at every moment. However, it is clear that at this moment in time, there are still many open technical challenges for the realisation of such digital clones, starting from the continuous aggregation of personal data, to running a model of the human mind.

4 System Design in the Era of Digital Immortality

The previous sections introduced the cyber world and the concept of digital clones. In this era of digital immortality, it will be possible to interact with copy of oneself or digital simulations of other people, who could have already died even centuries before. The development of systems allowing to interact with multiple digital clones, to receive and send information through centuries, and generating personalised services will surely introduce new challenges at both user interface and data management levels.

4.1 Interaction

First, it is important to state the obvious: in the era of digital immortality, users will be able to interact with information coming from the past and send data to the future in a deterministic way. These cross-generational systems should be designed following two principles:

1. Link to the past: integrating the possibility of accessing information and inheriting digital items left from the deceased ones.

2. Link to the future: integrating an interface allowing to produce information that will be transmitted to the next generations after the user's death.

These systems will be used by several different generations through time, maybe centuries or even millennia. This means that huge amounts of information will be accumulated through time. This would also imply that the cross-generational systems will have to provide the possibility to users to access data in an effective and agile manner. This issue becomes more evident when considering the fact that the adoption of lifelogging technologies is a current growing trend. Lifelogging offers the ability to capture an individual's life experiences through digital means, and to eventually retell and share them with other people, possibly with future generations. Taming such voluminous multimodal collections is very hard: a lifelogging device collects every moment of one's life [24]. It is easy to understand that this implies that filtering and elaborating the best moments would take more than a lifetime. For this reason, it will be indispensable to automatise the filtering but allowing access to the correct information. A user would like to access a particular moment without knowing specific information concerning the picture and its metadata. For example, the user could search a picture describing the memory of an emotion or the song played when it was taken or an event that occurred the same day. Performing such advanced searches requires the use of artificial intelligence. This implies that users wanting to simply access information should probably interact with an intelligent digital entity. Interaction modalities will move towards more natural language, such as writing and talking like while interacting with another human being. Indeed, this trend can be seen in the current explosion of chatbot services and virtual assistants (e.g., Apple Siri, Google Assistant, Microsoft Cortana). This kind of interface is currently also populating homes for domotics, such as with the use of Amazon Echo and Google Home. In order to provide effective personalised services, the AI should be able to understand the user's preferences and needs.

Preparing the information to be purposely shared with the future generations will require applying advanced techniques of digital storytelling [25]. This will encourage the formation of timeless communities and adding the possibility to reuse and adapt these stories will also represent the opportunity for the generation of collective intelligence and collaborative artistic creation.

The amount of digital information will be so vast that current interfaces will not be adequate to interact with it, not only, as already mentioned, for the difficulty of managing it, but also because devices will be able to record new kind data that will lose their value when just represented in audio-visual formats. In particular, virtual reality, augmented reality and mixed reality will enable new forms of interaction with data and the cyber world. Current interfaces are falling short with reference to the level of immersion, indeed they just rely on two senses, i.e., vision and hearing, missing the opportunity to convey information through the others, which can augment the bandwidth of the communication between digital and physical individual. Future interfaces will probably stimulate all the human senses, probably also through the use of implanted connected technology [26]. So far, implanted systems are perceived as sensors, a useful source of data about the subtlest human signals. Hopefully, the future implantable systems will be able to provide feedback and connect the humans directly to the cyber world through all the senses.

4.2 Technology

The underlying technology will need to evolve in order to allow information preservation through millennia. As already state in Sect. 2.1, cross-generational systems will have to integrate effective fail-safe mechanisms to support the rescue of endangered digital information and the constant update of their storage formats. Currently, the standard procedures for digital curation rely mainly on human labour [13]. Future systems will be required to integrate automatic services for the preservation of digital materials during its whole life-cycle. Automatic and periodic conversion of files and databases will be effectuated. When this would require more complex tasks like translation or selection or restoration, a specialised AI will take on the job.

Another issue related to information that is supposed to be shared by multiple generations in different eras is linked to how granting access and privileges for editing the contents to the different users. When sharing this information, the original user cannot know who her/his descendants will be. Therefore, it will be necessary to develop novel security systems based on heritage rules and biometric data recognition (probably, based on DNA).

As already mentioned, the preservation of digital information through centuries will require conversion and migration of the stored data. Moreover, multiple users will access this information through time, with also the possibility to apply changes. Information will need to be stored in place that could be accessible although in continuous update. A solution could be based on centralised databases controlled by a single society that is able to guarantee security. However, breaches in third parties' data centres could may induce the adoption of new decentralized systems [27]. Moreover, having a third party to control all the data is risky because there is no guarantee that it will last centuries or millennia. For all these reasons, a decentralised system for the preservation of digital information while providing privacy could be based on the blockchain technology. Memories could be stored on blockchain, tracking who accessed them and if they have been modified. Pushing this concept further, it might be possible to work with digital mindfiles (uploads of full human mind files) in the future, which could be also stored using blockchain [28]. This could enable lifelogging as personal thinking blockchains, meaning that it will be possible to "capture and safely encode all of an individual's mental performance, emotions, and subjective experiences onto the blockchain, at minimum for backup and to pass on to one's heirs as a historical record". Hence, the blockchain could be an elegant solution for the storage of Ma's Cyber-I [11].

Although the blockchain can be seen as an excellent technological solution for the storage of the Cyber-I, running the simulation of an individual mind raises new technical challenges. To this day, it does not exist a computer that can simulate the functioning of the human brain. However, the European Commission supported the creation of the Human Brain Project [29]. This project aims at developing a Brain Simulation Platform, which is an internet-accessible collaborative platform designed for reconstruction and simulation of brain models. Hopefully, in a not-so-distant future, it will be possible to run comprehensive simulations of an individual's mind.

5 Ethics

Naturally, the vision presented in this paper about the future of systems in the era of digital immortality brings a number of ethical questions. In particular, a main question concerns the actual identity of these digitally immortal entities that will populate the cyber world [8]. Would this technology be democratic or just an advantage for the rich? Will these digital clones have rights or just treated as property? Will digital clones be treated as physical clones or will their intangibility change their value? Would it be ethical to delete or shut down a digital clone? Who could have the right to do it and why? Would a Cyber-I have a conscience? Would a digital mind be considered alive?

Going beyond the confinement of the definition of digital clones as just a copy of an individual, can they clones have access to unlimited amount of data? Would omniscient digital clones be allowed to evolve? This could imply that they would advance far beyond human capabilities; would they represent the transcendence of humanity towards divinity? Would digital clones with access to unlimited resources become digital gods?

6 Conclusion

This paper wanted to provide an overview of the current transformation of a society apparently destined to achieve digital immortality. This transition towards the digital domain will imply creating a parallel cyber world that will be populated with intelligent digital copies of physical entities. These so-called digital clones will bring a number of unprecedented advantages. However, this transformation is already raising several challenges. In this paper, some of these challenges concerning interaction with digital information, possible technological solutions for its preservation and related socio-ethical questions. This paper is only a preliminary discussion about this complex matter and future work is needed in multiple domains for the development of adequate cross-generational systems.

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