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Archives in DNA: Workshop Exploring Implications of an Emerging Bio-Digital Technology through Design Fiction

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ABSTRACT

Continuing developments in DNA-based digital data storage systems promise us a sustainable, techno-utopian future; propositioning bio-digital solutions addressing the ever-increasing global data production, and inadequacies of conventional storage infrastructure to meet the demand. Distinct attributes of DNA make it an attractive archival medium. With its ability to retain high density of digital information cheaply, and to do so over multi-lifespans, DNA-based storage systems are seen as able to radically shape how we archive and use data, across wide-ranging applications. However, while the stakeholders continue to refine and race towards commercialization of the emerging technology, its sociocultural and ethical implications remain unexplored, limiting opportunities to generate insights on how such systems could be better designed and experienced. This workshop begins to explore what our DNA-mediated archival futures may hold. We learn about the fundamental principles governing the new technology and create stories about its pervasion in our lives, mediated through design fiction and structured discourse.

CCS CONCEPTS

• **Human-centered computing** → *Human computer interaction (HCI)*; • **Information systems** → **Information storage technologies**; • **Hardware** → *Emerging technologies.*

KEYWORDS

DNA, data, archive, bio-digital, design fiction, speculative design

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1 BACKGROUND

1.1 DNA as Archival Medium

While DNAs are most widely recognized as naturally occurring organic molecules that carry genetic information, they can also be synthesized artificially, and to encode non-genetic, digital data as well. The distinct biochemical and physical attributes of DNA make them an ideal candidate for data storage: 1) The ability to store high density of information (10^{18} bytes per mm^3 of DNA [6]), 2) Low energy cost required for maintenance [8], and 3) Durability (outside living organisms, it can be stable for thousands of years, e.g., [1]). As such, DNA-based digital data storage systems (Figure 1) are currently being developed as a sustainable solution, that could address issues of exponentially increasing amount of global data production and the inadequacies of existing methods to store them all [6]. With a total of 175 trillion gigabytes expected to be generated worldwide by year 2025 [22], the global storage demand will outnumber the projected growth of mainstream storage (e.g., magnetic, optical, and solid state). Yet when encoded in DNA, some estimate that the world's data could be stored in just a single kilogram of DNA [12].

1.2 Preferable Futures

The apparent functional benefits of the emerging technology are diverse and bountiful. In scientific research for example, long-term retention of meteorological and genomics data would provide historical insights towards studying climate change and species evolution [7], while the durability and spatial-economy offered by DNA may extend possibilities for communicative and/or interactive artefact designs for space travel (e.g., [19]). Similarly, DNA-based archives could enable curation of multi-lifespan historical events, offering long-term opportunities for international humanitarian justice (e.g., [23]), multi-generational family memory retention (e.g., [15]), and post-death legacy management (e.g., [14]).

2 OPPORTUNITY FOR HCI

Despite the potential significance of DNA-based storage systems to radically shape how we manage data, there is currently a lack of discourse surrounding the upstream technology in the context of human-computer interaction [16]. Current scientific research continues to focus on the technical refinements of the emerging system, while most public dissemination revolves around promises of sustainable futures. Questions within the scope of human-computer interaction, which relate to human implications of the technology, be it social, cultural, or ethical, remain largely unexplored. This hinders opportunities for us to better understand, prepare, and

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shape our future relationship with data archives, specifically with artefacts and possessions that are contained within.

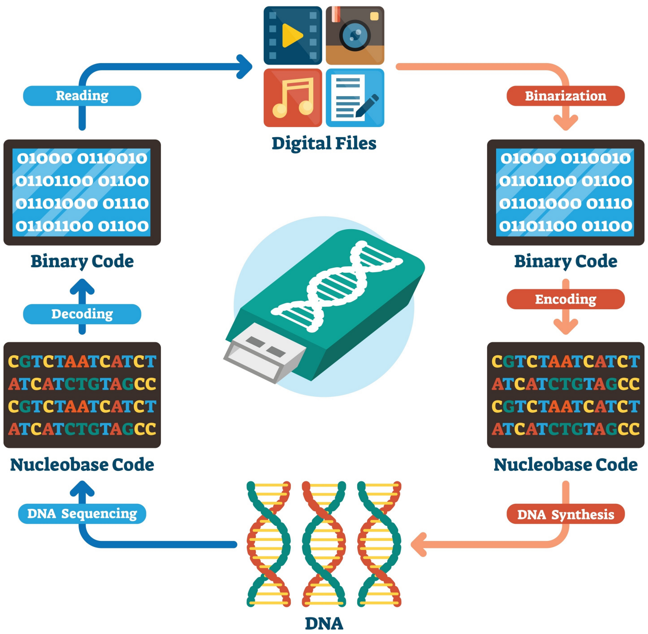

Figure 1: DNA-based digital data storage technology

3 METHODOLOGY

To start addressing the opportunities outlined above, we are organizing a participatory online workshop for *Academic Mindtrek 2021*. It is designed to solicit and generate ideas on how the future integration of DNA-based storage systems in our daily lives may shape the way we perceive and experience archived materials, how we relate to our pasts and potential futures. We will also address questions of access, usage, and impact on different stakeholders of the technology. These ideas would then be used to produce generalizable insights on the sociocultural implications of DNA-storage technology. We propose to run the workshop over two major segments. Guided by members of the organizing committee, each segment is described below.

3.1 Technology Landscaping

To generate meaningful ideas and suitably contextualized discussions on the impacts of technology, necessitate its basic understanding from the participants who engage in the activity. In this segment, we will present, through a keynote, the fundamental concepts involved, covering the *what*, *why*, *how*, *when*, *where*, and the *who* of DNA-storage systems. The idea is to paint a landscape in which the new system could operate in our lives, thus offering participants the relevant grounding required for them to engage in constructive ideation and subsequent discourse. Some of the questions we will address include, but not exclusive to, are as follows:

- *What* is DNA-based data storage?
- *Why* is the technology significant?
- *How* does the new system work? How does it relate to other archiving systems?
- *When* might the technology become ubiquitous?
- *Where* is the technology headed? (trends & developments)
- *Who* are the main stakeholders of the technology? Who are likely to access it?

3.2 Story Building

The second segment will focus on generating ideas that speculate on how our futures may look. Equipped with basic understanding of the technology gained in the initial segment, participants will be encouraged to undertake an informed extrapolation into futures that are mediated by DNA-based archival systems and services. In small groups of two to three, attendees will be asked to come up with a short story and a low-fidelity prop/prototype (e.g., Figure 2) to help illustrate it. We call this activity *Design Fiction*, and it will cover the following questions:

- What kind of product and/or service does the story feature?
- How are the products used, by whom, and for what purpose?
- What are the possible benefits or negative consequences that may arise from using the product?

Our intention here, is through design fiction and its discourse, to identify some of the common themes that are indicative of the potential social and cultural implications that the DNA-based archival technology may bring.

Structuring Cards. To help structure the story, the organizers will provide each group six types of randomly chosen cards. Each card will contain a particular story element, categorized under a specific market condition (e.g., time period, type of archive involved, political climate, etc.). Using the cards as a framework, the participants will weave their stories and the objects around them. This is designed to serve as 1) prompts for the participants to quickly flesh out the specifics of the technology and its environment, 2) guides to help focus on the activity, as some may find the story creation daunting given the overwhelming gulf of possibilities for the technology to operate in society, and 3) a relatable structure that everyone can quickly recognize, thus helping with the subsequent open follow up meta-discussions.

The cards are designed by the organizers: They will include market conditions that are formulated from background research on the DNA-storage technology, and carefully chosen through internal discussions on their relevance and potential to spark debate amongst the group.

Presentation, Discussion, and Debrief. Following the breakout ideation, the groups will gather together as whole, to present their respective stories and objects. This will be followed by an open discussion around the presentation, and a summary statement from the organizers to close the workshop.

4 DESIGN FICTION

Our proposal to use design fiction to generate ideas at the workshop has its origins in speculative design [10], a term that is also occasionally used interchangeably with critical design [9]. Speculative design is a branch of design discipline that investigates human relationships with emerging technologies, and design fiction often forms a part of its methodology. We borrowed this method due to its well-documented history of use in academic research, including those within HCI. These include peer-reviewed publications that 1) guide the crafting process of speculation [2]; 2) illustrate a workshop format implementing design fiction techniques (e.g., [20], [17]), 3) demonstrate in-the-wild case studies of design fiction in action (e.g., [5, 11, 13, 18, 21]); and 4) offer evaluation frameworks to constructively assess the validity of design outcomes (e.g., [3, 4]). These will serve as useful references to fine tune the workshop delivery, to position and meaningfully assess the outcomes in the context of existing HCI research, and to extend the field with our outputs.

5 WORKSHOP GOALS

Our goal for running of the workshop is two-fold. By the end of the workshop, we hope that the participants would have gained the following: First, a better understanding and awareness of the technological landscape of DNA-based data storage systems; on their components, mechanisms, importance, trends, and key players, as well as potential and limitations. And second, an experience to think about the future of the emerging technology, through informed speculations, story building, object making, and discussions.

6 WORKSHOP SCHEDULE

Below is our provisional timeline of the workshop. The duration of each activity is an estimate and are subject to change according to cohort size and conference scheduling. Essentially, the session is divided into four parts, which are shown in the timeline below. A suggested allocation within the day would be to undertake parts I, II, and III in the morning, followed by a lunch break (1 hr), and concluded with part IV in the afternoon.

Part I: Introduction	**10 min**
Part II: Technology Landscaping	**80 min**
- Keynote Presentation	45 min
- Q&A and Discussion	25 min
- Break	10min
Part III: Story Building	**90 min**
(Lunch) Break	60 min
Part IV: Story Showcase/Discussion/Debrief	**60 min**

7 TARGET AUDIENCE

Participants from all backgrounds are welcome, and no prior technical knowledge or experiences will be expected. However, the attendees should be curious and interested in learning about, and in exploring DNA as medium for archiving data.

Compatible Tracks. The workshop may be of particular interest to organizers, authors, and attendees of the following tracks of *Academic Mindtrek 2021* conference:

- Understanding and Designing the Socio-Technical
- Fictional, Speculative, and Critical Futures in HCI
- Datafication
- Dark Side of Information Technology
- Emerging Media

Figure 2: A set of low-fidelity objects to illustrate scenarios of design fiction. Documentation from Kim et al. [17]

8 CALL FOR PARTICIPATION

Participants are invited to submit a short position paper (1-2 pages long, including references), briefly describing their research area and/or interest, and motivations for attendance. Position papers should be in double-column, using *ACM Conference Proceedings "Master" Template*, sent to Raphael Kim (r.s.kim@qmul.ac.uk). At least one author of each paper must attend the workshop.

9 ORGANIZERS

Raphael Kim, Ph.D is a designer and HCI researcher, investigating our fraught relationships with biotechnology. He designs playful artefacts, which often incorporate biological materials with computer systems. Raphael holds a master's degree in Design Interactions, Royal College of Art, where he also taught as visiting lecturer, specializing in teaching about, and guiding designs on emerging biotechnologies. In 2020, Raphael gained his Ph.D from Media and Arts Technology programme, Queen Mary University, London. His Ph.D thesis focused on investigating player experiences of "biotic games", a hybrid bio-digital artefacts that integrate living biological materials in digital environments.

Larissa Pschetz, Ph.D is a researcher and lecturer in Design Informatics and Product Design at the University of Edinburgh. Her research is centred around Interaction Design and related areas of Human-Computer Interaction, Social Sciences and Humanities, and is currently focused on Inclusive IoT, Biodesign and Temporal Design. She has collaborated with biologists, social scientists, and several institutions in biodesign-related projects, running an interdisciplinary course on Biodesign with Naomi Nakayama from 2017 to 2018. She recently edited the book "Biopolis: Tales of Urban Biology" with Jane McKie and Elise Cachat: a collection of stories on the future of the biodesigned city.

Conor Linehan, Ph.D is a Senior Lecturer in Applied Psychology at University College Cork, Ireland, where he is a member of the People and Technology research group. His research expertise lies in games, gamification and behaviour change interventions. His work explores processes for designing and evaluating emerging technologies, with a focus on speculative methodologies such as Design Fiction and Critical Design. Conor holds a PhD in Psychology from Maynooth University.

Chang Hee Lee, Ph.D, FRSA is a Tutor and the 2nd Year Programme Leader in Innovation Design Engineering (IDE) at the Royal College of Art, London. He is interested in finding new meanings for interaction to explore novel methods of communication between human and machine. His works have been published in academic conferences such as CHI, DIS, MobileHCI, IASDR and Acta Astronautica; interviewed and featured in publications such as BBC, WIRED and ACM Interactions. He is a graduate of the Central Academy of Fine Arts (CAFA), and obtained his PhD in Innovation Design Engineering from the Royal College of Art.

Stefan Poslad, Ph.D is an associate Prof. and leads the IoT2US (Internet of Things to Ubiquitous, Computer, Science) Lab at the School of Electronic Engineering and Computer Science, Queen Mary University of London where he is a member of the Centre for Intelligent Sensing (CIS) and Cognitive Science research groups. His research and teaching interests include ubiquitous computing, Internet of Things (IoT); smart-environments, intelligent systems and IoT security and privacy. He has been the lead researcher for QMUL on over 15 international collaborative projects with industry. He is the sole author of a leading book on Ubiquitous Computing: Smart Devices, Environments and Interaction, that has over 850 research citations and is in use for teaching by over 70 institutes worldwide across 6 continents. He has published over 100 research papers in the past decade in high-profile journals and conferences. He can also be found on Google Scholar, Orchid, ResearchGate and Linkedin.

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