Biotechnology and the Climate Emergency: Speculating with *Grow Your Own Cloud*

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Abstract

This article brings us into the world of Grow Your Own Cloud (GYOC), a speculative design intervention exploring the role of DNA as a storage technology. With a focus on two design prototypes, the authors draw the contours of a speculative world in which flowers and gardens become the environmental forms through which digital data is translated into DNA acids. As an art-science project at the edge of developments within synthetic biology, GYOC asks: what if data could be stored in plants? From this question emerges a conversation around, amongst other things, how we might re-imagine the role of digital infrastructures in the climate emergency: from scorching the earth to its potential regeneration. At the same time, such a question provokes thinking around the immense challenges and potential flourishings of emergent forms of collectivity (plant-data-human hybrids). And particularly because this project involves interacting with living systems through the transformation of genetic information, the ecological ethics of uploading and downloading data into plant life prompts important reflections upon intra-species caring. In essence, a more-than-human sensitivity is brought to bear on how we think about the environment, its potential collectivities, and their concomitant ethics.

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Figure 1. Data Garden installation (Photo by Monika Seyfried)

Introduction

This special issue argues that it has become increasingly difficult to address environmental questions without considering their digital constitution. Conversely, it is equally difficult to consider computational practices without reference to the various environmental forms that infuse and enliven them. To navigate this relationship, the editors evoke a *double vision* with inspiration from Donna Haraway: a situated analytic prompting scholars to see how these putatively separated worlds are very much folded within one another. This is an exploratory effort to bring these folded concerns into view simultaneously, while being sensitive to the emergent forms of politics they generate. It is also a call to specify the multifaceted and complex relations that take shape along the contours of these folds and through which articulations of digital anthropocene(s) might potentially be seen.

The following conversation with *Grow Your Own Cloud* (GYOC) seeks to brings these potentials to light as we journey through a series of articulations of digital anthropocene futures. Co-founded by interaction designers Cyrus Clarke and Monika Seyfried, GYOC bring us into a world of design interventions that provoke us to speculate about the role of biotechnology in the

climate emergency. While their particular interest resides in the role of DNA as a storage technology for digital data, their design prototypes facilitate a re-imagining of nature-culture relationships through particular DNA-data foldings.

GYOC started its life as a design exploration of climate futures but has, over time, matured into a broadstroke critique of planetary digital infrastructures. This critique roams far and wide, encompassing the datafication and surveillance tendencies of late capitalism, the mystifying rhetorical devices of the platform economy (think the 'cloud' metaphor), and the planetary environmental costs of digital infrastructures. But as designers within the speculative tradition, their urge to critique the 'internet complex' (Crary 2023) is married with an impulse to imagine its regeneration. Their development of various speculative prototypes (discussed below) has become the primary *method* for such regenerative imaginings.

With a background in research on datacenters and digital infrastructures, I (James) was keenly drawn to GYOC's desire to materialise the rhetorical 'cloud.' Although much work has been done in this vein from within STS, anthropology, and media studies (Hogan 2015; Johnson 2019; Maguire and Winthereik 2020; Maguire 2023; Starosielki and Walker 2016; Velkova 2023; Vonderau 2017), the organic materialities with which GYOC designs – including DNA, flowers, plants, and trees – are arguably as novel as they are problematic. It is within the fold of this tension that the promise (and perils) of their work resides.

GYOC sits squarely within forms of *futuring work* that have a long history within design thinking (Bleeker 2009; Dunne and Raby 2014; Jenkins et al. 2020; Rosner 2018) as well as Science and Technology Studies (STS) (Downey and Zuiderent 2022; Haraway 2016; Jungnickel 2022; Wilkie, Savransky, and Rosengarten 2017). They are inspired by scholars interested in both *speculation* and *intervention*: the use of design objects to provoke thinking about the future by facilitating spaces where users (or collectives) can speculate about, and hence re-imagine, the world. Whilst the methods for achieving this are quite variable (classic design, co-production, ethnographic), what these authors share is a commitment to speculation as a device for imaginative intervention in the course of things to come.

GYOC began their journey in this vein, developing three speculative prototypes for reimagining the role of digital data in climate futures. The conversation to come will unfold these prototypes in more detail, but what we get a glimpse of is the project's own journey from classic design prototypes towards an art-science based intervention at the edge of developments within synthetic biology. Collaborating with researchers from the University of Washington, one of their interventions showcases an end-to-end *data garden* storing small segments of poetry and songs in

DNA formats. This art-science intervention into data-environments asks a simple, yet strange, question: *what if data could be stored in plants?* From this strange question emerges a conversation around, amongst other things, how we might re-imagine the role of digital infrastructures in the climate emergency: from scorching the earth (Crary 2023) to its potential regeneration. At the same time, such a question provokes thinking around the immense challenges and potential flourishings of emergent forms of collectivity (plant-data-human hybrids). And particularly because this project involves interacting with living systems through the transformation of genetic information, the ecological ethics of *uploading* and *downloading* data into plant life prompts important reflections upon intra-species caring. In essence, a more-than-human sensitivity is brought to bear on how we think about the environment, its potential collectivities, and their concomitant ethics. But envisioned through a particular relationship between DNA and digital data.

And this is, in many ways, where the potential of projects such as GYOC resides: in bringing various digital anthropocene *futures* within our horizon of (double) vision. In one sense, the critique they bring to bear on the environmental ravages of digital capitalism is well known. But their interventionalist response to this critique is less so. They do not, for example, explore the somewhat oversaturated pathways of green transition thinking: the pursuit of decarbonization strategies or more sustainable mineral extraction practices. Nor do they venture into post-capitalist terrain: the pursuit of a radical re-scaling of the role of the digital in our lives. What they do envision is a folding of digital anthropocene futures where the environment becomes more than that which enlivens the digital (its minerals, materials, resources and so forth). Or where the digital becomes more than that which mediates environmental knowledge and action. More radical still is the envisioning of the environment and the digital as folded together. And not in any metaphorical sense. In such a folding, various living organisms *become* speculative technologies (Hong 2020) of data storage. But such an enfolding is far from unproblematic. This is a form of programmability that is somewhat more layered and more penetrative than the imaginaries emerging from either the 'internet of nature' (Galle, Nitoslawski, and Pilla 2019) or the 'internet of trees' (Gabrys 2020).

One obvious counter-critique to projects such as GYOC is that in their desire to find a technicalised means of addressing a planetary wide problem – organic storage devices that sequester rather than emit carbon – they reproduce some of the same logics of extraction that epitomize our current predicament. If, as it's possible to argue, the entire problem of the climate emergency is embedded within a Euro-American desire to conquer and colonize the planet's

resources at will – evidenced in the countless, and all too familiar, narratives of empire – then asking in what sense such projects are dissimilar is a legitimate question. If the colonizing logics of extraction have envisioned the environment as but a set of resources to be harvested in order to, at first, build 'civilization,' then what does it mean to invoke the same logics in order to putatively save it? As we learn more about the (near magical) mycelial networks through which inter-species forest communities live and thrive, what does it mean to speculate about their instrumentalization as storage devices for digital data? This is why the question of ethics is, and must be, at the heart of speculative design imaginings. So, while we hope that the conversation to follow gives the reader some insight into various articulations of digital anthropocene futures. At the same time, we leave it up to you to speculate alongside, keeping in mind the ethical dilemmas in play.

Figure 2. A drop of synthetic DNA (Photo by Monika Seyfried)

JM*: Could you tell us a little about the inspiration or provocation that initiated your thinking around the Grow your Own Cloud Project?*

GYOC: Grow Your Own Cloud is a project that begins with a simple yet strange question. What if we could store data in plants? Through this question the project explores how reforming

human associations with something as *seemingly* abstract and immaterial as data, can create opportunities to regenerate the environment. It does this by reimagining the cloud as a series of relationships with data and living systems, while building upon breakthroughs in synthetic biology.

Initiated as a speculative exploration of alternative data storage methods, the impetus behind the project was borne from a desire to imagine a new model for digital data management outside the realms of the current information capital and technocentric models; developing secure, regenerative, decentralised data management techniques, which in turn counteract the destructive anthropogenic activity of data storage itself.

Designers who work with technology increasingly use speculation as a means to trigger reflections about the future worlds we are making today. Oftentimes, technology is characterised as a runaway juggernaut, with certain outcomes deemed almost inevitable. Yet, such a metaphor also belies the weaving, interconnectedness of the technological worlds that we inhabit. It is our sense that today's technologies are constantly shaping and reshaping potential tomorrows.

Conceptualising the consequences of change borne by technological development and adoption is challenging. For example, during the early days of the internet few could have predicted the enormity of the value created by instant information access, nor the polarization and division caused by social media or the rise (and societal impact) of the influencer class. Today, with so many emergent technologies and resulting possibilities including AIs, metaverses, blockchains, and biotechnologies, it has never been more important to explore how novel technologies might shape possible futures. On the one hand, it's inspiring to combine our imaginations with scientific and technological knowledge to envision new solutions or beautiful opportunities for alternative collectives gathered around alternate purposes (less growth infused, less extractive, and so on). On the other, it's vital to consider the unintended consequences, to help avoid potential disasters and harms.

JM: *This is interesting, and it makes me think about the idea you mention above: that it has never been more important to explore emergent technologies to see where they might lead. From a more critical perspective, this very idea might itself be seen as part of the problem. That is, the reproduction of the idea of technology as a solution to a problem of its own making only replicates the logics and structures that we are trying to move away from. And that's not to suggest a turn away from technology and back to some more analogue version of the world (although*

there might be some road in that idea). But more a way of asking how we can unbind ourselves from a state of affairs (material, conceptual, structural, ideological) that feels somewhat circular?

GYOC: Originally GYOC was a research project critiquing and exploring the state of digital infrastructure, especially the predominant imaginary of infrastructure as cloud. But with backgrounds in interaction design and design research, our initial research framing shifted to combine elements of speculative design alongside anthropology. Having worked a lot with computational technologies, there was also an innate desire to work *with* living systems.

Within design circles, working with living systems is hugely inspired by influential thinkers like Bruno Latour and Donna Haraway. Currently, we are inhabiting a moment in time where scientific discoveries are accelerating, the environmentalist movement is growing, and design is increasingly interdisciplinary. This means that designers are, more than ever, involved in addressing ecological, ethical, and philosophical ideas. They are taking a more active role in trying to help create regenerative, inclusive, and ethically responsible worlds.

Situating human beings as part of a wider system, rather than locating them at the centre of everything is both valuable and provocative in and for the field of design, a field which has become obsessed with the idea of human centeredness; building worlds around users to create solutions that help to reinforce the status quo. While valuable for helping tackle interhuman issues, or improving the usability of a computational interface, a human-centred approach increasingly feels incompatible with a world of abstract, difficult to grasp hyper objects like global warming, radioactive waste, and the cloud. Leaning into the multispecies optic of Haraway for example, more-than-human design offers a way to explore the interconnections between humans, other species and nonhuman objects which feels more relevant to the current societal and ecological context.

This combination of speculative design, anthropology and computation led us to conduct a form of preliminary ethnographic fieldwork in Christiania, a freetown located in central Copenhagen, Denmark. Christiania has been an alternate living space in Copenhagen for over forty years and is well known for being what you could call an idiosyncratic place: an alternative community with various elements of self-governance, including, for example, decentralised systems for water, energy and waste collection beyond municipal infrastructures. Such a setting offered a vast number of contextual references for inspiration, for example, learning how residents built and modified their own homes through community agreements. Communal infrastructure is at the forefront of life in Christiania as residents focus on sharing tools for

transportation, equipment, even leisure facilities (a shared sauna). At the same time, one could also see how living systems were more deeply integrated into the fabric of the place. In many instances this was quite literal given that many homes were built around trees or gardens, rather than these ecological features being additive, decorative, elements. Conducting research in this setting led us to think about and explore radically alternative models for future data systems.

Given our interest in rethinking digital infrastructures, our immersion in this environment led to unorthodox ways of examining issues such as technological ownership, data storage and community governance. Using a multispecies optic, the interconnections between humans, other species and nonhuman objects became more apparent. Thus, the foundations of a speculative idea began to grow, situating human beings as part of a wider multi-species system.

To supplement our own design and ethnographic instincts, we began collaborating with scientists quite early on to understand the current state of the art within plant synthetic biology and DNA data storage. This involved visiting the University of Copenhagen and running workshops with plant geneticists to learn not only more about the science, but also to see how they interact with plants and the types of processes and tools they use. It was through a combination of these approaches that we refined the concept of plant-based data storage in order to examine its potential from an experiential and storytelling point of view. Focusing on the experience of data, beyond the purely functional or technical aspects, the project was initially more interested in the aesthetic, sensorial and emotional qualities that could emerge from interacting simultaneously with living organisms and the digital data cloud.

JM: *It's interesting that the speculative idea was nurtured through multi-species design thinking and particular places, in this case Christiania in Copenhagen. I'd like move into talking more concretely about the two speculative prototypes GYOC developed, but before doing that might you say a few words about the type of speculation that interests you?*

GYOC: We can start by saying that what we are doing is not just speculation for speculation's sake. We feel that doing speculation simply *as critique* is increasingly redundant in an age where possible futures are surpassed and replaced by actual presents at rapid rates. For us, it is possible for speculation to take on a new role. In this new role, speculation can become a critical platform for long-term vision creation. Through identifying possible, plausible and preferable futures, alongside negative externalities and unintended consequences, this process can assist in the conception and creation of technologies which address ethical, environmental and economic

concerns. By asking if we could store data in plants we broaden the scope of what we imagine is possible while reflecting on the ethics, interactions and consequences of today's and tomorrow's realities.

Figure 3. Data Garden installation (Photo by Monika Seyfried)

Our form of speculating explores different ways of relating data and nature. We started off by looking into the ethics of the data industry's environmental impacts and we wanted to find solutions for the complex problems we uncovered. For example, the material and resource uses of the data industry are well known. Its sprawling planetary infrastructures leave vast quantities of waste and toxicity in its wake, and usually in countries and places that continue to be the extraction sites of global capitalism. Whether it's the rare earth minerals and metals that supply the materials to build our digital infrastructures, the energy and water needed to process them, the cheap labour needed to assemble them, or the waste accumulation in our disposal of them, the environment is very much under siege. So, our response came in the guise of two speculative prototypes, developed as experiments in generating alternate relational forms.

The first was a project called Data Flower Shop. This served as the initial tangible manifestation of the concept of storing data in plants. While this idea initially felt futuristic and

unachievable, it sparked important questions and provided an opportunity to create an immersive experience that could effectively express the concept. The idea of bringing this speculative technology into reality for others to test became the guiding star for the project's exploration.

Figure 4. Speculative Data plant injection during Flowrshop experience (Photo by Monika Seyfried)

Imagining a future where this technology is accessible to everyone, we transformed a local flower shop into a space that allows data storage in plants on-site. The flower shop became a character within the larger ecosystem we envisioned at the time. In its real form, it provided a calm and familiar space, acting as a means of conveying the intended message about a possible future. The ambiance of plants and the familiarity of purchasing a piece of nature created a safe environment for engaging in fascinating yet challenging conversations. It became a space for unleashing dreams in a common setting.

As an initial step, the concept involved creating a website with a digital invitation to an exhibition located in a local Copenhagen flower shop (see https://growyourown.cloud/the-flowershop/). This digital experience allowed the audience to select and upload pieces of data that they would later store in a plant of their choice. This process resulted in a database of

wonders and ideas, showcasing the kind of information that everyday people would willingly entrust to plants for storage. The choices were unexpectedly diverse, ranging from specially written poetry for the occasion to pictures of recently deceased dogs. The selection of information was emotional and beautiful, emphasizing that when it comes to embracing our relationship with nature through technology, people are particular about conveying the right message. It sparked a sense that when choosing to store a certain digital file in an organism, humans tend to be careful about what they choose to store. Making the selection process was, in a sense, quite ritualistic.

The entire experience was divided into four stages: onboarding, plant selection, data injection, and wrapping. Upon arriving at the Flower Shop site, the audience was welcomed by an assistant who helped them locate the data they had sent in advance of our meeting and initiated the process of selecting flowers. During this stage, the audience was asked about the desired functionality of the plant. Should the plant pollinate? Should it have a long or short lifespan? Together, we explored different options for the desired duration of storage. A bouquet, for example, was an organism that was selected to store the information for a short period of time. Or a small bonsai tree for a longer duration. Throughout the process, the audience was immersed in this new environmental-data collectivity, offering them the freedom to speculate on the implications of this technology. In this moment we had a lot of interesting conversations about the aspects of care related to this *new type of nature.* People felt protective about the plants they selected to carry their precious information. This stage served as an opportunity for us to conduct research, gather initial responses to the idea, and identify the questions that such a product should address in the future.

Next, the audience was invited to enter a lab set up within the flower shop. An actor, playing a biotechnologist, explained the process of storing data in plants and performed the injections. The audience had the option to choose different injection techniques, each resulting in a distinct way for the plant to absorb and carry the data in the future. This step evoked strong emotions, as people witnessed the process of leaving their data behind forever, stored within the organism. The relationship between humans and the selected plant would forever change from that point on.

Lastly, reflection time was provided as flowers were wrapped and readied to be taken home. It became a moment to learn how to ensure the proper care of the plant and its associated data. During this stage, conversations on data care took intriguing turns, fostering emotional and sentimental connections. These conversations opened up a new space to discuss fascinating

topics such as the future of work, where people require a basic understanding of gardening to utilize advanced, yet everyday technology.

The overall journey laid a solid foundation for further project explorations. Although the experience itself was fictional, it strongly implanted the idea among those who had the opportunity to participate. It highlighted the crucial need for ethical discussions surrounding the technology, especially regarding the potential consequences if it goes beyond our control and starts adversely affecting the environment. Moreover, it provided valuable insights into data ecologies and the political aspects of data storage in our daily lives. Many people were particularly enthusiastic about the idea of forming gardening and DIY communities that could create spaces independent of big corporations through gardening data. The prompts used throughout the journey, such as the interactive onboarding website, posters, scientific tools, and data care card information, helped us create a speculative world in everyday Copenhagen. These tools served as conversational prompts to facilitate in-depth discussions and explanations of complex scientific topics.

JM: *Can you talk a little about your thinking and practice in the move from the first to the second speculative prototype? What was shifting here, and in particular, what were you learning from the world of synthetic biology that you wanted to engage with?*

GYOC: Initially we used speculation as a method for engaging with plant-based data storage to *engage the public in conversation and debate* across a broad range of topics including DNA data storage, the environment, collective memory, data ethics and genetic modification. As a socially engaged art and design project, we saw ourselves as architects of socio-artistic situations, with the audience as collaborators or participants.

From this starting point, and through further research into synthetic biology and DNA data storage technology, the theoretical possibility of this speculative idea became apparent. Over the past few decades there have been significant advances in synthetic biology as scientists have learnt to engineer and transform organisms. Synthetic biology diverges from its biological origins by employing engineering principles with potential applications across fields such as industry, agriculture, environment, and healthcare. Core to this advancement has been a greater understanding of genetic code, a rapid reduction in costs associated with reading (sequencing) and writing (synthesising) DNA, as well as an enhanced ability to manipulate DNA through genome editing techniques such as CRISPR Cas-9. Following the early growth of synthetic

biology, the concept of utilising DNA as an information systems language began to emerge. Although speculated upon by Richard Feynman in 1959, it wasn't until the 2010s that scientists like George Church were able to really begin experimenting with storing digital information in DNA molecules. By leveraging synthetic biology techniques, researchers have been able to take digital data, which is fundamentally a binary string of 0s and 1s, and represent it in a string of A T C G to represent the four nucleotides of DNA.

The field has seen a swell of interest due to the fact that DNA is a highly dense medium for information storage. Some of the more robust claims from the community suggest that it has potential to store all of the world's data in just 1 kg of liquid since a single gram of synthetic DNA could store 215 petabytes of information. It is also of course a format that has survived billions of years, and therefore unlikely to be rendered obsolete. It is also highly durable when kept in cold conditions as witnessed by the longevity of DNA in the fossil record.

Around the same time, scientists demonstrated that they were able to manipulate plants using CRISPR-Cas9. While genetic modifications of plants and other model organisms was possible prior to discovery of CRISPR-Cas9, this revolutionary gene editing tool enables precise modifications to the DNA of living organisms. Using an RNA guide and the Cas9 enzyme to target specific DNA sequences, researchers are able to edit the genes of living organisms such as plants.

The idea behind GYOC is therefore rendered possible through a combination of these new areas of scientific research. Firstly, digital data is transformed into synthetic DNA to be stored in a biological medium involving a change of state from digital bits to physical atoms. This synthetic DNA can then be encoded into the genome of biological organisms, by transforming bacteria, yeast, or indeed plants, through genetic engineering techniques.

It is of course this very ability to manipulate organisms at a molecular level that has generated debate around the ethics of genetic modification. There are valid concerns about the potential consequences of this emerging technology, for example the release of dangerous pathogens, irreversible changes made to a particular species and the wider unintended ecological consequences that may arise from genetically modified organisms (GMOs).

JM*: So, the Data Flower Shop project is still very much couched in the vein of an intervention, or an arts-design project. But what you are talking about here strikes me as being somewhat more. You seem to have moved beyond a speculative tool intended to create dialogue and generate ethical reflections with various publics and moved into work with molecular researchers to do*

something more extensive. Can you speak to this a little and how it was translated into a prototype?

GYOC: While the project originally began as a speculative, creative research project with the intention of proposing an alternative future, there was always a desire to manifest the idea in a more tangible way. Since we are trained in interaction design and fine art, this naturally began with speculative deployments of a futuristic yet possible technology through artistic interventions. With the flower shop prototype, we lacked the scientific equipment, expertise and budget to realise any of the scientific processes. So, while this involved research and experimentation around biological data storage, in practice it became a platform to facilitate a set of discussions around evocative topics such as biotechnology, data and ethics.

We have always had a hunger to do more than a design intervention, but to do this we needed stronger ties to the synthetic biology community. We were really fortunate to meet Jeff Nivala, a research scientist at the University of Washington. Jeff researches DNA data storage, both in vitro and in vivo, and has worked to help develop a novel data decoding pipeline using nanopore sequencers. He was one of the first scientists to encode a moving image into the genomes of a population of living bacteria. Jeff was impressed by our approach and agreed to collaborate with us. One of the principal questions that emerged from the Data Flower Shop was how people could retrieve the data that was encoded into a plant. It was this question that inspired the creation of the Data Garden, a prototype that progressed towards a more experimental collaboration between the arts and science. In this manner, the state of the art informed the design and creative process, while the art itself sought to push the boundaries of what science and technology might deliver.

We began exchanging ideas with Jeff on how to create an experience that builds on the vision and storytelling of GYOC, while bringing in scientific realism and a user-friendly way for the public to experience the underlying technologies (such as genetic sequencers.) The concept for the project was to encapsulate important notions inherent to GYOC; offering an alternative, carbon absorbing manner to store data, presenting people with an opportunity to take back ownership of personal data, while working with nature in a new type of collaboration.

This is how we ended up with the Data Garden prototype: an organism-based data centre and an award-winning contemporary art installation that explores and challenges the enormous data systems that invisibly dominate and infiltrate our world (see https://growyourown.cloud/data-garden/). The Data Garden is a functional prototype of a carbon negative data infrastructure

which uses DNA data storage technology to store and retrieve digital data from the DNA of plants. Digital files created by GYOC were stored in the DNA of plants using the same genetic engineering techniques that were performed in the Data Flower Shop.

We used DNA synthesis to encode a series of artworks, small text files (poems written by Cyrus), and a few very small highly compressed image files, into DNA. The data encoded synthetic DNA was then used to perform plant transformations, using agrobacterium as a vector. These plant transformations were floral dips and foliage injections into Arabidopsis and tobacco plants.

The plants and the files they contained were then placed within an artistic installation created in collaboration with *ab(normal)*, an architecture studio based in Milan. The concept for the installation was to evoke a futuristic data infrastructure that was using, on the one hand, high-tech advanced synthetic biology techniques, while on the other, off the shelf materials readily available at most DIY stores. These materials were supplemented by a construction manual of sorts. It was inspired by a vision of the future where contemporary cloud-based data storage technologies would be no longer available or relevant. Instead, data was stored and accessed locally through dense biologically based data storage. The Data Garden also emphasises data as a collective resource, rather than an individual repository. This positions data storage at a local or community level, rather than the highly individual or highly globalised scales where current data storage solutions typically reside.

The Data Garden invites visitors to experience a new materiality around data and explore a world in which data storage is truly green. As such, the experience of the installation is an encounter with an array of data-encoded plants, rather than computers or servers. The plants themselves, in this case tobacco and *Arabidopsis thaliana*, are rather banal, simple green plants. Within the plant array we included several small test tubes. Some of these contained synthetic DNA containing digital data. Others contained samples of the DNA of the plants that had been engineered via the plant transformations to carry digital data. The synthetic DNA samples were inert, while the samples from the plant included (of course) the plant's DNA as well as an extremely tiny amount of digital data – we're talking bytes rather than kilobytes or megabytes.

Figure 5. Decoding process in the Data Garden Installation (Photo by Monika Seyfried)

This DNA could then be decoded using a nanopore sequencer, which was housed within the installation. Initially it was our intention that this experience could be interactive – that people could for example use the nanopore with a sample of DNA and see the read-out. As we became more familiar with the nanopore sequencer, it became clear however that this would not be feasible. The process is difficult and requires a protocol to be performed precisely and carefully. The process is also highly time consuming, both in terms of preparation, performance and receiving results. It took between 8 and 24 hours to achieve a read out from a sample. All of this meant that in the end it would not be feasible or practical to allow visitors to the installation to decode the data. Once the data had been read by the sequencer, it was sent to Touch Designer, a node based visual programming language, to interpret the data, run an animation sequence which was displayed on a screen at the centre of the installation, and ultimately display the data on a screen within the installation, revealing the digital file.

Various iterations of the Data Garden have been presented around the world, including a fully functional version for South by Southwest (SXSW), a huge festival held annually in Austin, Texas, featuring music, film and new interactive artworks. However, due to GMO restrictions, particularly in the EU, a modified version of the installation has been presented at spaces such as Ars Electronica 2021 and Bozar, Brussels 2022, which does not involve the use of GMO

plants. This means that the experience for visitors is more difficult, and more explanation and information is needed to enable them to have a meaningful interaction with the work.

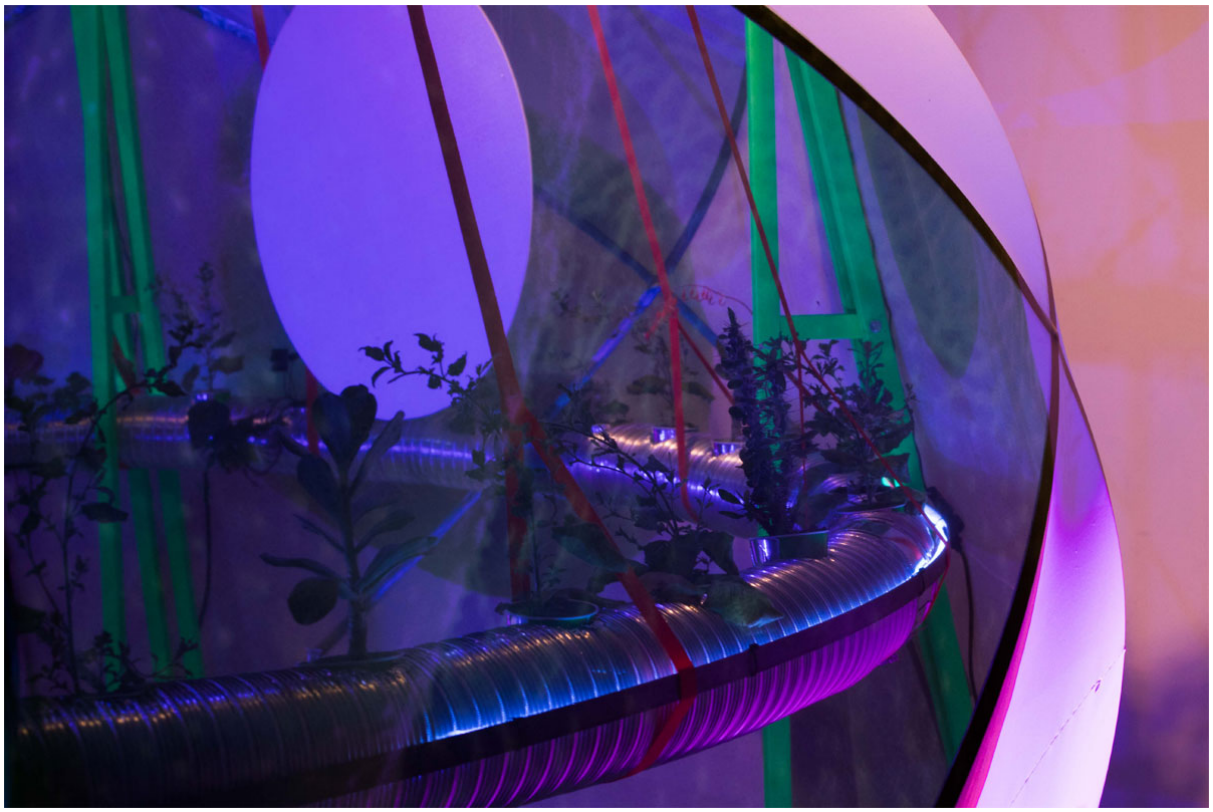

Figure 6. Data Garden Installation (Photo by Monika Seyfried)

As conceived, the creation of Data Garden considers the ethical dimensions of GYOC at the same time as imagining the possible forms that GYOC could potentially take. At the very least, this means better understanding just how much we do or do not consider other entities in many contemporary design and development processes. For example, when creating the Data Garden, we considered the question of who should own and care for data. Could Data Garden suggest an alternative to the current digital data cloud storage model where large companies store data for you ostensibly for free, while in the background they process and sell your information to others? In the Data Garden, the vision is that individuals and communities own their data and tend to their data, as they might tend to their garden. Through this act of maintenance and care, the links between people and their data are potentially strengthened, while new relationships between people and living organisms (which carry the data) are created.

It's important to note that such concerns and questions cannot be considered in isolation and lead to further questions, for example, on what basis can we instrumentalise and use other

living organisms for this purpose? The Data Garden addresses this point by suggesting a vision whereby the system works more holistically in the interest of more than just humans. Here, a new type of plant-based data centre allows organisms of various types to flourish, marrying principles of working with nature and data, to create a self-sufficient plant-data ecosystem.

Interestingly, as the gap between science-fiction and reality narrows with every passing day, the public are now accustomed to seeing technology as something that is ready for deployment. As such, upon encountering Data Garden and reading claims about regenerative data storage with plants, the public imagine that they are indeed seeing a 'ready' piece of data infrastructure and thus begin to layer their own speculations and expectations onto the work.

Indeed, the Data Garden evokes a strong response from the public, many of whom are inspired by the potential of biotechnology to address critical issues like climate change. It seems as if this vision and this technology piques their interest to learn more about data, science and nature, oftentimes generating a sense of hope amongst installation visitors.

Though far less frequently encountered, Data Garden does receive pushback from those who raise questions about the ethics of working with plants in this manner. Some query our right to manipulate the plants' DNA. Others question how we can possibly know that there are no negative effects on the plant or indeed the ecosystem. People often bring up the history of GMOs and mention issues created by Monsanto or Bayer. They ponder, correctly, what might happen if something like GYOC was to scale, and what unintended consequences might arise from this, for example new cash crops and monocropping.

While it is very interesting that an experimental research project can generate such positive and negative reactions, perhaps more interesting is to reflect on why a hypothetical prototype of a technology evokes a critical reaction at all, while real-world, industrialised and commercialised implementations are often ignored. Perhaps the public view a prototype as something they can still shape, whereas Google's data infrastructure, for example, is seen as permanent and unchangeable. Another answer might be that the participatory approach of GYOC successfully enrols people in the design process.

More than an artistic installation or technical demo then, Data Garden was an interactive space for the co-creation of a futuristic technology. It uses storytelling in order to immerse participants and visitors in the possible future envisioned by GYOC and provides them with enough information to participate in a discussion around people's relationships towards their data, towards other organisms and living systems in general.

JM*: Maybe this is the right moment to open up the space of ethics a little more. I appreciate what you say above about how current data infrastructures still remain somewhat taken for granted despite the various critiques that have emerged over the years. Nonetheless, I still think it's important not to pivot too far away from the legitimate ethical concerns about unintended consequences and the spaces of (un)knowability in genetic research. GYOC explicitly articulate an 'ethics-first' approach, so maybe it would be interesting to explore what that means in such a speculative project: how should we begin to think about 'future ethics'?*

GYOC: Right from the beginning, we realised that using DNA to store data would raise a bunch of new ethical questions. In our work, it's important not only to think about the ethics of our own visions and actions but also to imagine what they could look like in practice. We want to incorporate an ecological ethics that goes beyond just human considerations. What this means is including plants, ecosystems, and even the planet, as participants in our design and developmental processes.

Since GYOC focuses on envisioning new technologies with an environment and ethics first approach, our process begins with asking ourselves "should we do it?" This is different from the typical scientific or technological approach that starts with a more market driven 'how' rather than a 'should'. We considered some of the more usual *harms and benefits* questions that classic ethics brings to the table. So, can a project like GYOC be part of the production of better futures? If so, in what ways and with what risks? But what does better even mean in this context? Since the project inherently involves interactions between species and the transformation of genetic information, we gave a lot of thought to the impact of the project on other forms of life. Promoting care and respect, then, is something high on our priority list. But the mechanics of doing this are still somewhat more elusive. Some questions are impossible to answer, nonetheless, their very asking can still be generative. For example, the complex issue of injecting a plant with DNA gives rise to the problematic of multi-species consent – how can we do that in any meaningful empirical way? Even asking the question leads to discussions around the most appropriate and caring way of interacting with plant life.

While ecological ethics can, at times, be overwhelming, they are crucial to consider, especially when we're imagining the introduction of new behaviours, approaches, or patterns into our lives. It strikes us that such ethical reflections are largely overlooked in the rush to develop new frontier technologies, but it's also exciting to imagine how the world would be if all new technologies were developed with an ethics first approach.

JM*: I do like the example of the plant and consent, but I have been wondering about questions of a more biological nature. How, for example, might uploading DNA into a plant affect it as a life form: the way it lives, the duration of its life, its nourishment and reproduction cycles, and so on. So, in what sense have you been exploring the biological basis upon which your ethical reflections can take place?*

GYOC: The whole concept initially emerged from our desire to present a critical perspective on how biotechnology will shape future technologies and, consequently, impact our lives. Regulations around GMOs vary from continent to continent, providing us with a robust framework to comprehend the possibilities within plant modification. Based on our research with biotechnologists, our understanding is that the modifications we are exploring should not affect the plant's appearance or behaviour, as they utilise the part of the plant's DNA considered "empty," meaning it does not influence the plant's life cycle. It seems that the DNA within the organism can be responsible for different things. Some parts dictate the plant's appearance and behaviour, while others are considered "vacant" and as such are open to being encoded with data. Envisioning this technology on a larger scale we imagine plants replicating and storing information within themselves, so in a sense, they could work as an open source resource. In essence, the idea is that the data could spread across the ecosystem via pollination (or other reproductive mechanism) and might become accessible to many more people.

JM*: So, the idea is that there are various non-coding regions of the plant that don't have any reproductive role to play and that don't affect the organism's life cycle, behaviour, or appearance: 'vacant' or 'empty' as you call them. I do wonder, though, about how these 'empty' spaces are constructed at the edges of our understanding, or through particular limits in our knowledge. There seems to be a strong degree of uncertainty or unknowability here and I (again) wonder about what it actually means to characterize such zones as 'empty.' I also have a lingering doubt that what is called 'empty' today might well be full of meaning at some future point in time. I guess this is an ethical question for me: how to think about how future states are imagined through contemporary limits or gaps in knowledge?*

GYOC: From the project's perspective and the very nature of the technology we are working with, more questions emerge with each step we take. Personally, we appreciate the natural cycle

aspect. Currently, we are used to very specific ways the data industry enables us to interact with information. We can send and receive files on demand, often at a low cost. It seems like we are living in a golden age where these interactions feel invaluable. With GYOC, we introduce the concept of working with nature to plant and harvest data. Following this path, we imagine a new set of interactions with information that can be accessed at specific times of the year, such as when the flowers bloom or the plants come to life during springtime. The ethics of creating such an experience, for us, lies in a deep understanding of how to build a resilient and polycultural system capable of supporting such data relationships. Introducing limitations when it comes to how much data we can actually harvest every year and choosing the right organisms that can ensure data is stable.

JM*: So, what you are envisioning here is not just storage of data in organisms, but a temporal cycle of data use that is in sync with biological life (the seasons, etc.)? What might the implications of that be?*

GYOC: Yes, it is a more biologically infused temporality. What we learned from our data flower shop interventions was that this type of data-nature relationship generates a stronger ethical impulse. Storing valuable information within the plant makes us want to take care of it more. We might want to make sure the plant stays alive and keeps our precious information within. It creates the emotional bond between a human and a plant that even though might feel new at first is resulting in finding a deeper connection with nature.

Closing Thoughts

It has become almost trite to say that we need to find more sustainable ways of living in order to ameliorate the impacts of the climate emergency. And there are various propositions currently in circulation: from policy infused decoupling, to more radical degrowth conversations and initiatives. But what remains underarticulated in these accounts is the role that planetary wide computational infrastructures will play in these futures. Even in degrowth circles, there is a somewhat implicit assumption that such infrastructures can be re-appropriated and re-purposed for more just climate futures. This is an assumption that needs careful scrutiny given the broadstroke ways that these infrastructures facilitate global consumption and impose a near-planetary wide administrative form that resists de-westernisation and decolonialisation (Crary 2022, 20).

In some sense, GYOC do not tackle these questions head on. Instead, they re-route the discussion of a more sustainable data infrastructure (and economy) through a radical set of speculative propositions. While the Data Flower Shop is a prototype that seeks to *understand* how people might relate to alternate data-nature constellations, the Data Garden is an effort to *materialise* such propositions in conjunction with genetic scientists. As they aptly put it themselves: while the current state of the art in genetics informs the design process of the installation, the art itself seeks to push the boundaries of what science and technology might deliver. As a functional prototype of a carbon negative data infrastructure—using DNA data storage technology to store and retrieve digital data from the DNA of plants—such propositions leapfrog over various iterations of current debates.

While in one sense, questions of ownership and power are absent—what forms of organization would be necessary, for example, to realise such multi-species collectives—in another, there is a radical re-narrativisation of some of the primary critiques of techno-scientific capitalism (instantiated through genomics). It is here that the question of ethics becomes the obligatory passage point of these speculations. In what sense can we future proof ethical concerns that reside within the gaps of contemporary knowledge practices? In essence, how do we comprehend and deal with the radical environmental alterities (Bonelli and Walford 2021) that GYOC envision for us? No matter what one's response to these charged questions might be, what we get a glimpse of through this conversation is a particular articulation of digital-anthropocenes: a fold through which a variety of eco-tech concerns are enmeshed. Speculating with GYOC, it strikes me, is a provocative means of envisioning various folds within digital-anthropocene futures. In doing so, we get an opportunity to prefigure a form of politics that provokes us to think more lucidly *today* about the ethics of *tomorrow*.

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