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Information Diving on an E-waste Dump in West Africa – Artistic Remixing of a Global Data Breach

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Consumer electronics such as smartphones and notebooks have become an indispensable part of our daily lives. The Internet of Things (IoT) is increasingly adding electronic devices onto our shopping list. Devices that are adding up to a 24h surveillance system that is tracking every aspect of our life. Through planned obsolescence the life cycle of many electronic parts that compose a product is significantly shorter than the life cycle of the product. Some obsolete devices end up in regulated e-waste centers in Europe, yet 47% of European e-waste is illegally dumped on electronic-wastelands in developing countries each year. These devices still contain personal data that can be reanimated and abused when falling into wrong hands. A research team recovered data from hard-drives bought on the biggest West African e-waste dump and shared it with a network of international artists. In a research lab, artists and researchers explored what happens to our electronic waste, what kind of data traces are revealed of the hard-drives prior owners, and what environmental and privacy threats do exist. The artistic explorations were documented in form of a publication and presented as an exhibition series that raise concerns on privacy, data security and illegal e-waste trade.

1 INTRODUCTION

The concept of remixing and recycling ideas and content that others have produced has a long tradition in the development process of human culture. Artists from various backgrounds are applying these strategies in the creation process for their artworks: In past decades experimental filmmakers such as Craig Baldwin, Matthias Müller or Martin Arnold create their collage films and found footage videos with material they bought at thrift stores, yard sales or flea-markets. The VJ-ing culture remixes online archives with real-time effects and styles like glitches or compression artefacts used in popular music-videos make extensive use of the found footage aesthetics. (Vernallis, 2013) Media archaeologists re-appropriate old technology and invent technological glitches and alternative histories of human-computer interaction. (Sommerer, 2015) Contemporary musicians and sound artists are circuit-bending electronic toys or other low-powered devices to create sound generators and effect synthesizers. (Navas, 2014) Street artists and media activists remix commercial or political advertisement for culture jamming practice and other forms of guerrilla communication. Manovich argues that most human cultures developed by borrowing and reworking forms and styles from other cultures, like the ancient Romans remixed the ancient Greek culture. (Manovich, 2010) The convergence of media, the creation of creative commons licensing and Web 2.0 platforms enable to collaboratively edit, remix and share content, and to critically engage with popular culture by revealing social engineering, endemic racism, sexism, and homophobia. (Fagerjord, 2009; Horwatt, 2009) Analysing, reusing or recycling material that others discard can also reveal personal perspectives into one's live. With the social engineering practice of 'dumpster diving' people search for identifiable information, with the intention to collect sensitive information about a company or an individual:



Most people don't give much thought to what they're discarding at home: phone bills, credit card statements, medical prescription bottles, bank statements, work-related materials, and so much more. (Mitnick, 2011)

A.J. Weberman, a self-proclaimed "garbologist", collects, analyzes and archives Bob Dylan's trash since the 70s. As a fan and avid dumpster diver, he waded through his trash in order to gather scraps of evidence to support his interpretations of Dylan's lyrics. (Marshall, 2018) The self-recorded phone conversations with Dylan unveil the musician's discomfort when an unknown person gains insight into the private life by analyzing their trash. Based on these findings, Weberman published a 'Dylan to English Dictionary' and exhibited his former belongings at the Yuppief! Museum in New York City. (Zimring, 2015)

Rather than snooping in the trash of one famous individual the archaeologist William Rathje broadens the dumpster diving approach in the "Garbage project" and analyzes waste dumps of US-cities to gain insights into people's living habits. (Rathje, 2001) Through mobile Internet people share unconsciously sensitive information like geolocation, browsing

habits or personal preferences with marketers. This online tracking also happens in the browser, where companies get a personal insight into our interests, likes and behavior. (Jansen, 2016) Once a service provider gets hacked, personal information can be exposed, data breaches like the Ashley Madison data dump exposed affair-seekers or leak login information to millions of email-accounts. (Brownlee, 2015; Onaolapo et al., 2016)

Propelled by constant technological innovations of consumer electronics paired with faster life-cycles of the smart devices', consumers produce an increasing amount of e-waste each year. If these obsolete gadgets don't get properly recycled, sensitive information and personal data-points can still be found on the devices:

“ Some people will not wipe their hard-drives and obviously if you dispose of that computer it can be accessed by criminals, ... The problem is many of them don't know where they're ending up. (Ensor, Gray, 2012)

In the recycling process, our abandoned electronics go through many vendors who can easily access and exploit our data. Even when exporting e-waste is regulated by the Basel Convention regarding “Control of Transboundary Movements of Hazardous Wastes and Their Disposal”, traders use loopholes such as labeling not functioning consumer goods as “second hand” and “third world help” giving the intention to help to bridge the digital divide. An investigative journalist team from Germany tracked the route of two TV-sets equipped with GPS devices from a German buyback center to the street markets in Nigeria and the Agbogbloshie e-waste dump in Ghana. (Braun et al, 2015) Examples like this makes it clear that we do not have control of what happens to our obsolete hardware and as this paper shows few of us have the technical skills to properly delete data making it sure that it is unrecoverable. As artists, when dealing with data breaches, such as the recovered hard-drives three initial questions emerged. This paper makes the following contributions:

- It provides an overview of the acquisition process of hard-drives from an e-waste dump in West Africa.
- It lays out main research question that were explored in a practice-based artistic research lab:
 - What ethical issues are participants confronted with when treating the data as found footage material for artistic production?
- It explains main parts of the research lab activities, such as: the organization of a symposium and an ArtLab, editing of a publication and curating an exhibition showcasing artistic case studies.

The paper concludes with limitations of the study and provides an outlook on future research.

2 MATERIAL: INFORMATION DIVING IN WEST AFRICA

We as the KairUs collective (authors of this paper) visited one of the biggest and most toxic electronic-waste dump sites in the world, Agbogbloshie in

Accra, the capital of Ghana. (Bernhardt, Gysi, 2013) A local guide took us to the Agbogbloshie dump-site where we witnessed ongoing recycling processes like the arriving of containers full of e-waste from the Tema shipyard, the main harbor of Ghana. At the e-waste dump people mainly try to reuse, repair or recycle functioning components; still, due to a lack of technical equipment, the recycling process is very limited but very toxic for the workers and the environment. Almost all electronics reached their end-of-life state, and by dismantling the devices, components like power packs, batteries, CPUs, storage mediums, casings, motors and circuit boards are collected and sold in bulk. (Oteng-Ababio et al, 2016) Parts that cannot be used or sold in this separation process land on the ground where teenagers handpick cables and PCB parts or use loudspeaker magnets for collecting tiny metal parts. (Caravanos, et al, 2011) This way the scavengers try to extract valuable metals like copper, gold, silver or aluminum from the precious dirt on the ground. Besides this physical separation of e-waste, recycling components and metals, some recyclers search for sensitive information on old hard-drives in order to exploit and harass the former owners. (Warner, 2011). This made us curious to tryout if it is actually possible or how easy it would be to recover data from a discarded hard-drive from the Agbogbloshie e-waste dump. (Kirschenbaum, 2008) Therefore we talked to different recyclers who were extracting hard-drives from desktops and laptops and were able to acquire 3,5" and 1,4" hard-drives for each 10.- respectively 20.- Ghana Cedi (about €2.20.-/€4.40.-, Jan. 2019). In total, we bought 22 hard-drives from varying manufacturers, year of production and storage capacity. None of the sellers could guarantee that the hard-drives were still functioning, so what we could do is to check that the hard-drive pins were not corroded or broken, and that the drives were in an overall decent condition.

2.1 Artistic research lab model: ArtLab - publication- exhibition

Returning to Europe, we proposed a 'data remix' workshop to servus.at, a Linz based internet culture initiative that operates an artist-run data center and who also organizes the biennial art festival *Art meets radical openness* (AMRO). Together we extended the workshop proposal to a funding application for an artistic research lab that would run for a two-year time-frame between two festival editions. The proposed ArtLab was to serve as an incubator where artist groups are provided with resources for their research and artistic production. Topics such as data mining, data security, illegal e-waste trade in relation to the growing Internet of things shall be discussed in a symposium with experts and artists. Recovered data was planned to be shared with artists who would reflect in their artistic practice on the topics discussed in the symposium. In this process a set of research questions were established:

- What do participants expect to recover from the hard-drives?

- Would these hard-drives contain personal data that can be potentially exploited?
- What kinds of questions rise in terms of privacy and ownership of the recovered data?
- What ethical issues are participants confronted with when treating the data as found footage material for artistic production?

Inspired by the open-source movement and remix culture where source material is often re-appropriated by various users in different ways, the plan was to recover data from the hard-drives and redistribute it to a trusted network of artists which became co-researchers and contributors and remix recovered data for production of artworks. Hence an interdisciplinary group of artists came together each with their own perspectives on the data and the underlying problems of illegal e-waste trade and data leaks in second-hand recycling life-cycles. Through this participatory act, the authors gathered an interdisciplinary group of artists, each with their own perspectives on the data and underlying problems of illegal e-waste trade and data leaks in second-hand recycling life-cycles. When the project started the intention was to present the outcomes of the ArtLab in a publication and an exhibition. Early in the process it became clear that the interdisciplinary approach was engaging artists with various skill sets to discuss and reflect on the topic, yet a lack of both technical and experiential expertise in the chosen topics became a blockage for some of the artists to continue with the collaboration. From these challenges developed a model in which the ArtLab served as a kick-off event refining research questions through practical experiments and discussions. For the planned publication, the authors collected artists working with e-waste, hard-drives and more generally investigating critically aspects of saving and erasing data. Consequently, in such a combined artlab-publication-exhibition model the ArtLab and the publication served as preliminary research for curating the exhibition enabling us to gain both the technical competence as well as a wide range of interpretations and provocations of the subject itself.

2.2 Preparations: Recover data & redistribute

A first step in providing artists with data from the hard-drives was to reanimate the data in order to make it accessible. In an initial attempt, all the hard-drives were hooked up to a PC with a commonly available hard-drive adapter. In this way it was immediately possible to access data from five of the hard-drives. Data on four of these five hard-drives had not been deleted by the former owners, making it easy to create a recovered data image on a separate, external hard-drive. The fifth hard-drive's data was recovered using readily available open source programs 'Photorec' and 'Testdisk'. Additional deleted data was also recovered from the other four hard-drives with the help of the software. The remaining seventeen hard-drives were handed over to a collaborating data-recovery company where professional technicians were able to restore one more of the hard-drives. Most hard-drives were 8-12 years old so the company couldn't provide the necessary replacement parts for the

broken components. Since we wanted to investigate the easy attempts of data breaches we decided to not further investigate the broken hard-drives, and rather focus on the ones where the data was easily accessible. In total, about 85 GB (229.446 items) of personal data was recovered from the six hard-drives. During the recovery process, members of the ArtLab contacted artists who expressed interest in becoming co-researchers in the project. Six European artists from Norway, Netherlands, Germany, Hungary and Switzerland were selected, aiming for a diverse mix of young, emerging artists working with various mediums; sculpture, sound/noise art, video-art, performance, and installation. Also invited were Austrian artists and students from the University of Art and Design Linz to participate in the process. In order to bring all participants together a symposium was organized with talks by invited experts and an extended ArtLab weekend that served as a kick-off event for the collaborative artistic research. One month prior to the event involved artists were provided with the recovered data. Local students just copied the data; international artists received the data through the internet net-culture hub's FTP-network. The participants had a first look at the data and were able to develop their own sorting and categorization strategies from the vast amount of data available. In the meantime, together with members of the net culture team we outlined a group of experts for the symposium to speak on topics such data mining, data recovery and data forensics.

2.3 ArtLab part one: Symposium

For an extended weekend, eight international and four Austrian artists gathered for the ArtLab. The first evening kicked off with the symposium and talks from the invited experts including data broker researcher Fieke Jansen (Tactical Tech Collective Berlin), data recovery specialist Can Sintiras (ECS Global) and data forensic expert Prof. Michael Sonntag (Johannes Kepler University Linz). Can Sintiras gave an insight into the data recovery industry and his company that provides data recovery for individuals and small businesses. He explained to us about the process of when a customer needs to get data off a hard-drive recovered. In this case ECS Global technicians treat the client as the legal owner of the drive and the technicians try their best to recover as many files as possible. In order to protect the privacy of their clients the technicians won't scan the content of the recovered data for copyright violations, or illegal activities. For the hard-drives that are physically damaged the team needs additional spare-parts to replace circuit boards, firmware chips or disk heads. Since the replacement parts are often hard to find the company is always eager to buy second hand hard-drives produced by popular brands, sometimes leading to shady offers of thousands of undeleted hand-drives containing personal data of pre-owners.

Fieke Jansen from the Tactical Technology Collective talked about third party trackers and data brokers, and gave an insight into the value of public data-points and the public's role as data subjects. Companies collect data for profiling: who we are, age, gender, where we live, who we interact with, what

we read, or what we're interested in. This information can then be packaged and sold to others like advertisers, other companies, or governments.

Prof. Dr. Sonntag talked about data forensics with a special focus on the upcoming ArtLab weekend. Computer and data forensics focus on obtaining evidence to be used in criminal court cases. It's about finding evidence about the history of the user, and not to assume what the user might have done or not. In forensics, you need to collect more evidence than to find one file that unmasks the criminal. The forensic scientist rather has to develop a case study with solid arguments leaving out any doubts that things just occurred by accident. Forensic investigations are all about keeping a level of integrity, meaning one shouldn't alter anything during ongoing investigations. All changes have to be documented and detectable, so from a forensic perspective, the Agbogloblosie hard-drives seemed to be useless, since there were untraceable gaps between the owner discarding the hard-drive and the time when the drives got picked up by us. This fact didn't discourage the participants from further exploring the hard-drives and using them for their artworks.

2.4 ArtLab part two: Experiments & discussions

As organizers we gave detailed insights into their ongoing research and the data acquisition process of the hard-drives at the e-waste dump in West Africa, followed by short presentations by each artist where they introduced themselves and their prior works. Each artist also outlined their main interest and concerns while looking at the data. A field trip to a nearby e-waste recycling center unveiled how e-waste is recycled in Europe, which heavy machinery is used in the process, health and security standards that have to be considered and which strategies are applied against the illegal e-waste trade. Group discussions with an emphasis on the establishing of personal and collaborative research questions were followed by hands-on experiments such as visualizing data through sonification, microscopic photo scans of hard-drive parts or attempts to reverse-engineer former owners contact details. Each participant found their own working method to carry out hands-on explorations, diving deeper into the data and trying to interpret it or reflect their concepts and ideas with other participants.

2.5 Deeper insight: Publication featuring artistic research approaches

Following the intense ArtLab, the research questions were refined and the research topic was broadened with the intention to reach out to artists who explored issues of saving, deleting and resurfacing of data. For a deeper insight we wanted to trigger a conversation among artists about their research-led practice and their discoveries in order to collect various experiences a book was published in which each chapter, introduced by a theoretical text, providing an overview and raising concerns, followed by artistic and activist strategies that exposed problematic power structures, creatively revealing how we lost control of our data and offering strate-

gies to deal with our data in today's 'smart world'. The publication was produced entirely using open-source editing software, licensed under CC-BY-SA 4.0 and made available through the repository hosting service Github.

The first chapter focuses on 'saving' processes of our personal data and tries to unveil who collects our data, where it is stored and what it gets used for. Fieke Jansen wrote a chapter about the booming industry of data brokers who track our behavior, profile us and sell these data points. Three artists, Ivar Veermäe *Center of Doubt*, Emilio Vavarella *The Google Trilogy* and Leo Selvaggio *URME Surveillance* wrote about their artistic research methods and how they tackled issues of saving processes in their artworks. Vermeer writes about his video-based investigations of cloud computing and data centers, the materiality of the infrastructure and environmental properties of Google's data center in Saint-Ghislain, Belgium. In his multi-channel work *Center of Doubt*, he compiles several video artworks of his observations. *The formation of clouds* uses satellite images of data centers to show the competition between Microsoft, Facebook, Apple, Google and Amazon to gain the best position to run the infrastructure of our everyday, modern lifestyle.

In his chapter *The Google Trilogy*, Vavarella writes about the metamorphosis of humans becoming machines or networks, and his artistic documentation of "uncultured errors", mistakes and glitches that happen on Google's street-view before they are reported and corrected. A second project uses Street-View to collect 100 photographs called *Michele's Story*, an attempt to precariously reconstruct a single human journey and a man's tragic car accident where he became almost completely paralyzed and suffered memory damage. His third work, *The Driver and the Cameras*, merges topics of "uncultured errors" and the human factor similar to the second artwork by showing eleven faces of Google car drivers that were not automatically blurred by the algorithmic anonymizer.

Selvaggio contributes with his *URME Surveillance* project on the topic of mass surveillance and provides the public with a photo-realistic 3D printed prosthetic of his face. If multiple users were to wear his prosthetic and become 'Leos' in different areas of the same city at the same time, facial recognition systems would have conflicting locative information, through this obfuscation the 'real' Leo can hide amongst other users and therefore successfully corrupt digital surveillance networks.

The second chapter is concerned with processes of deleting data. In her text, Marloes de Valk addresses how our "information hungry lifestyles" creates the toxic lakes in China and e-waste dumped in developing countries. Yvonne Volkart examines the topic of waste focusing especially on the recycling and reusing paths of smartphones. Audrey Samson reminds us that the deleting process of data is far more complicated than emptying the virtual trash bin on our desktop or resetting our phones to the factory presets. In her artistic research data gets deleted by physically destroying the storage medium or concealing it, making it impossible to access. Through physical destruction Stefan Tiefengraber's artworks bring forth the materiality of servers in data centers and, at the same time, emphasize how limited our access to these cloud-storage infrastructures are. In

his artwork *User Generated Server Destruction* visitors to a website have the rare opportunity to physically damage and, finally, destroy the server on which the website is hosted.

The third chapter focuses on the resurfacing of data. Since every aspect of our lives is somehow digitally documented, traces of our data can resurface in a number of places in various undesirable situations. This is clearly stated in Prof. Sonntags chapter when he writes about third-person data: data that gets collected, stored and analyzed without our consent. He examines what personal data exists and in what context it might resurface. In a chapter, we write in more detail about the acquisition process of the hard-drives at the e-waste dump in Ghana. The last article, also written by us, focuses on the resurfacing of fraudulent business websites. There are estimates that about 20% of the entire web consists of fake websites, often clones and copies of sites that are published elsewhere. In the article, we illustrate how ‘open source intelligence tools’ can be applied to report websites that are suspected of fraud and are eventually blocked by their hosting providers. Once one domain is blocked, the same website often resurfaces under another different domain name. This phenomenon is presented in the artwork *Megacorp.* that visualizes a collection of 1000 evil web companies.

2.6 Presenting artistic research: Exhibition

For the Art Meets Radical Openness (AMRO) festivals’ exhibition selected participants from the ArtLab and the *Behind the smart world* publication were invited to present their artistic case studies. The exhibition was further curated through network meetings and an open-call resulting in artworks focusing on e-waste and data scraping being included in the exhibition. Throughout the festival weekend, artists organized guided tours through the exhibition and workshops by the Tactical Technology collective and a data funeral performance by Audrey Samson completed the program. In the following paragraphs we want to focus on several artistic case studies that deal with the recovered data and showcase results of the ArtLab.



Fig. 1.
a) Shell performance,
b) Shopimation,
c) DEL?No, wait!REW.

Martin Reiches’ artwork *Shell Performance* (Figure 1a) is heavily influenced by data from the recovered hard-drives. The installation sifts through the masses of personal files of the unidentified previous owners of the hard-drives and transforms them into an ASCII art-inspired digital collage that focuses on audio files, documents, images and videos (mostly pornographic imagery), questioning consumerism, privacy, digital and

electronic waste management and everybody's personal relationship to data and to the devices they are stored on.

The video artist Fabian Kühfuß produced a found footage collage from the browsing history of one hard-drive called *Shopimation* (Figure 1b). He arranged the fashion and lifestyle thumbnails in different patterns in sync with a catchy song he found in the music library of the hard-drive, creating a choreographed animation of the pre-owner's 'aesthetic dreams. As Flusser argues the techno-imagination is an approach of coding a function of the meaning of techno-pictures, the video animation *Shopimation* uses those thumbnails to build up the subjective code of an aesthetic. (Flusser, 2012) Built by the remaining data of an unknown person and the re-arrangement by the artist, *Shopimation* could be a code to translate the very private dream of whom the hard-drives pre-owner would like to be.

We as the KairUs collective created a trilogy of artworks called *Forensic Fantasies* (Figure 2), a series dealing with data breaches of private information. The first artwork of the series is called *Not a Blackmail* (Figure 2a) and examines the possibility to extort the pre-owner of a hard-drive. Besides finding sensitive data of the owner it is crucial to be able to contact the person to make one's demands. From one hard-drive the artists were able to trace the pre-owner, further through social media platforms, they were able to locate his current employer and other contact details. Rather than blackmailing the person, we grew curious if it is possible to get in contact with the person. Therefore, the artwork consists of one ready-to-be-posted package, containing the recovered data and a letter directed to the pre-owner.

The second artwork *Identity theft* (Figure 2b) of the series focuses on the phenomena of romance scamming. Scammers conduct identity theft by scraping images in bulk of attractive people to create fake profiles on social media platforms and dating channels. The fraudsters pretend to be in love with their victims and, after gaining their trust, lure them into fraudulent payments, always hiding behind their fake identity. One hard-drive contained several images of attractive women that showed them in everyday situations.



Fig. 2.

Forensic Fantasies:
a) Not a Blackmail,
b) Identity theft and
c) Found Footage
Stalker. (Photos by
Janez Janša, Aksioma)

We got suspicious when we found scans of the women's passports that unveiled their multiple identities. We suspected that the images were copied to this hard-drive to create and sustain fraudulent profiles and that the women were victims of identity theft.

West African Nollywood films, mainly Nigerian and Ghanaian low-budget films, have their own way of dealing with the phenomena of scamming, which is a recognized problem in these countries. In this installation 18 of the fraudulent online profiles using the same images found on the hard-drive are combined with clips of Nollywood found footage that cover the topic of romance scams.

The third artwork, *Found Footage Stalker* (Figure 2c) of the series takes a closer look at the private images found on one of the hard-drives. Scanning through the private photos permits very personal insights into the lifestyle habits of the pre-owners of this hard-drive. Over a number of years, we follow them to wild parties with friends, trips to amusement parks and private Christmas celebrations with their family. It is similar to the feeling of stalking someone unknown online, despite the rather uninteresting photo material, one starts to create stories and attach a personality to these fragmented digital representations. By presenting photos in a classic photo album, we approach the material as ‘found footage’, ready for remixing and creating new artworks, something artists have done for generations. Hence the artwork confronts earlier practices of using ‘found footage’ and the remixing culture by using personal data found amongst our trash.

For artist Michael Wirthig the most interesting part of these hard-drives is the magnetic disc, the physical place where all kind of personal data gets saved. For his experimental film *Headcrash* he extracted the discs from two hard-drives and explores the surface with a microscope. Over 1.500 photos zoom-in on inside and outside influences of the discs; dust particles, scratches, and other physical impacts are arranged to a fast-paced film sequence.

Michaela Lakovas installation *DEL?No, wait!REW* (Figure 1c) consists of three screens, one of them constantly recovering files from one hard-drive and presenting them to the viewer on a second screen. The installation aims to prompt viewers with a decision or ethical choice whether to save the file by publishing it online or to delete the recovered file – which will start the recovery process again and presents the image to a future viewer. The published images are on display on the artist’s website.

3 CONCLUSIONS

We bought 22 hard-drives on the West African e-waste dump Agbobloshie and brought them back to Europe. The initial aim was to examine how criminals can access personal information from computer hard-drives retrieved from an e-waste dump. In a practice-based research lab we were able to recover data from six of the hard-drives. The recovered data was shared with a trusted network of artists and treated as found footage, remixed into experimental videos and installations. These artistic experiments confirmed that personal data can be easily found, reused and abused by unknown third parties when data on the hard-drives is not encrypted, properly deleted, or the drive itself physically destroyed. The artistic positions, interpretations and provocations were presented in several different iterations at exhibitions and media art festivals. The study

has confirmed the findings of Kirschenbaum who argues that storage mediums collected at e-waste dumps can also become vehicles for data breaches. (Kirschenbaum, 2008) Also, so-called smart technologies are based on data collection which raises privacy and data security issues. The limited timeframe that we spent on-site as well as the small sample size of 22 hard-drives did not allow for scanning of the dumped drives on a quantitative level. Additionally, this paper has described one model of a process oriented, artistic research lab that has evolved through an altering assembly of artist and researchers bringing about interesting interactions between individuals. In hindsight, a shortcoming of the ArtLab is that no local artists from Ghana or other countries affected by the illegal dumping of e-waste were included in the ArtLab. As a spin-off project a group of participating artists created an interactive world-map called *Mapping the Smart World* which examines the life-cycles of consumer electronics and network technologies. Starting from mining of minerals, through refining of elements, to production of metal alloys, magnets, components and, assembly of consumer goods in our 'smart world'. Further, the project maps data centers that hold a key position in our everyday use of devices. In the end of the life cycle, electronic waste becomes once again a source of raw materials such as metals and plastic. This map provides a framework for the future exploration of research topics.

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