*GÖDE BOTH*

## ACCOMPLISHING AUTONOMOUS DRIVING: AN UNFINISHED DESCRIPTION

When I embarked on my study, the questions – What is autonomous driving (or fully automated driving)? What is an autonomous car (or a self-driving car or a driverless car)? – seemed easy to answer. In fact, these questions seemed too simple to be asked. This changed when I started to engage in more detailed ethnographic descriptions. Instead of having one answer to each question above, I had multiple answers. The multiple labels for this type of object beg the question whether this is indeed one object. As for the questions above, there are multiple answers to these questions. For example, you might think of autonomous driving as a vision: One day cars will not require drivers to safely navigate them through traffic. In this sense, autonomous cars exist as a promise. Nevertheless, there are computer scientists and engineers claiming that they have already achieved autonomous driving. For them, autonomous driving may be performed by an autonomous car.

My case study is on a technological project devoted to autonomous driving. This particular collective of computer scientists and their modified cars claims that they and others as well have delivered a proof of concept. In press releases and publications they claim they have demonstrated the technical feasibility of autonomous driving. However, during my field work some project members believed it is still an open question whether self-driving cars can be turned into a reliable and mature product. Can autonomous cars be developed further to operate safely outside of carefully mapped environments and without human drivers as backup?

The following description is grounded in ethnographic field work which I conducted between June 2012 and November 2015. This collective is based at a large German university. In this unfinished description, I am trying to give a preliminary answer to the questions above by locating the autonomous car within the situated practices which generate an opportunity for autonomous driving in everyday traffic. This complicates the notion of autonomous technologies as bounded and self-sufficient with an inherent capacity for autonomous driving. Instead, I argue that autonomous driving is the result of a joint accomplishment of heterogeneous elements – i.e., human and nonhuman.

My analytical commentary is inspired by Jarzabkowski's and Pinch's criticism (2013) of what they label as script and affordance approaches. Within ongoing conversations on sociomateriality, they argue against a "current preoccupation with intentions encoded in objects or materials themselves" (p. 579). They criticize the affordance approach for placing too much emphasis on the intentions of humans mediated by nonhumans. The script approach tends to lead to analyses that "'black box' the social interactions within which activities are accomplished to focus on the materials themselves" (p. 585). Instead, Jarzabkowski and Pinch propose the accomplishing approach – investigating practices as they are accomplished with materials. Following their suggestion, I will analyze the object "autonomous car" by describing the practice of autonomous driving in situ. This text is an unfinished description of the practice of autonomous driving including its site, machines and people that make up the assemblage of an autonomous car. I will introduce some of the key characters (car, laptop, safety driver, co-pilot), but I will not fully engage with them. My aim is to give you, the reader, a sense of why it is so difficult to write about an object that cannot be clearly delineated.

### *DISTRIBUTED TECHNOLOGY*

First answer: Whatever this is that I am writing about, it is not just in one place. It is distributed.

Let me take you back to my field site and start from there: I am sitting in the office next to Michael. We are in a university building that belongs to the computer science department. The project spreads among several offices, a seminar room which is used for project meetings, a shared kitchen, the department secretary's office, but also the soccer robotics lab. In the office building project members work on the software and hold their team meetings and presentations (e.g. defenses of master thesis). They share the building with other working groups from the computer science department.

Michael is preparing the car's laptop for the up-coming test-drive. Michael is working on the car while he's sitting in the office. Does this mean that the car is in his office? In a sense, yes, the laptop is an important element of the car because it operates the car but it is also a mobile element. Where is the rest of the car? From the office building where I am sitting with Michael, it is a brief walk to its "garage". You walk through a quiet street with old trees alongside and enter the physics department, a large concrete building from the 1970s. The 'garage' is actually a huge physics laboratory. Michael enjoys entering the physics laboratory from the top entrance where a metal staircase leads to the ground. He loves this view of the laboratory. The ceiling of laboratory is two stories high. From the top of the stair case you can see over a vast collection of experimental apparatuses from the physics department. Some of them seem actively used; others seem just being stored here. Michael often jokes that the project members started to call these apparatuses "Doomsday devices" because they do not know what they are for but they look as if they belonged to mad scientists.

Physically separated from the physicists' experimental apparatuses by office cabinets and in the corner near the big door, two cars are parked inside the laboratory. Both these cars are computationally enhanced by additional sensors and ICTs (Information and Communication Technologies). My description focuses only on the station wagon Volkswagen Passat due to its special license for autonomous test-drives on public roads. This particular car is claimed to be an autonomous car. As such, the ‘new’ comes in a very familiar shape of popular car model in Germany. To account for this familiarity with the object, I use the label “the car”. During my field work, project members colloquially referred to the project’s computationally enhanced Volkswagen Passat as “the car” (“das Auto”) rather than “autonomous car”, “experimental vehicle”, “test-rig”, or “self-driving car’” like they do in written accounts. Since I maintain the car cannot be separated from the situated practices it participates in, its boundaries differ depending on the situation.

The technological project and the technological object are distributed. While the human members, their offices and computers reside in the computer science building, the car shares its space with experimental apparatuses from the physics department. The human members, the computers and the car are separated. In order to go about their daily work the human project members do not depend on the physical co-presence of the car. What is important, however, is the laptop. They can do without the car but not without the laptop. Why is the laptop so important? To find out, let’s go back to the laptop in Michael’s office.

### *SYNCING THE LAPTOP WITH THE WORLD*

Second Answer: Working properly means to be in sync with the world.

The car’s laptop sits on Michael’s desk hooked up to a large screen. Michael starts the “control center” – a software that is used both for simulating and operating the vehicle. He loads an old log file from a previous test-drive into the control center. On screen I see the map of the road infrastructure and the actual tracks travelled by the car during a particular “drive”. The recorded tracks depart from the roads of the map at some points. Michael activates a second layer visualizing data from a specific laser scanner. He begins to correct the map. I ask him how he can tell the actual road from all the different measurements. Michael explains that he can see, for example, where the bike lane is simply by looking at the visualizations of the sensor data. After a while he says “we definitely have to test-drive this” and continues with a second log file. Michael loads a second log file from another drive into the control center. He comments “a nice drive (...) it definitely matches the map”. The second log file seems to be more in sync with the map. Puzzled by all the deviations, I ask him what those deviations are caused by. He suspects that the first one was logged without correcting the GPS positions. I observe how he follows the map and the tracks on screen and I ask him what he is doing. He says, he wants to know whether the tracks are overlaying.

Autonomous test-drives do not start from scratch. The car does not venture in unmarked territory. Before the car can go anywhere, it requires a map, a very precise one (the error cannot be greater than a few centimeters). However, as we have seen in this vignette, maps are often incorrect. In this vignette the map and the tracks travelled by the car do not overlap all the time. The map and the recorded positions are not in sync. This is one of the main problems of this kind of technology: Getting the representation of the world in sync with the measurements during test-drives. This problem will re-appear during my description of when we hit the real road.

#### *ASSEMBLING AND RE-ANIMATING*

Third answer: Whatever it is, it has to be assembled and re-animated each time.

After Michael has finished preparing the laptop, we pick up Timo from his office and walk to the garage. Once we are inside, we unplug the car from its battery charger and push the car out of the garage to avoid polluting the air inside. On the forecourt the engine is started and the members pop the trunk, booting up the different systems in a pre-determined order. Timo connects the laptop to the ICT systems of the car and launches the control center. The laptop responds with a feminine voice saying “System’s ready”. From now on, the laptop is the center of interest for the crew. It is many things at once. First, the control center operates the car by sending commands to the car’s steering, accelerator, brakes and signals. Second, it draws all the sensor data together to produce a singular representation of its environment. The project members call this process “sensor fusion”. Third, the human members use the laptop to monitor the car. Fourth, the human members use it as user interface to manipulate the car. Operation, monitoring and manipulation are all integrated in one piece of hardware. Hence, the laptop plays a key role in re-animating the car.

#### *IT OSCILLATES*

Fourth answer: Autonomous driving is a volatile technology. Control oscillates between the driver and the laptop.

I take a seat in the back of the car. This is where I usually sit, film or simply observe the action and ask questions. From this position you may notice the cameras hanging at the windshield with cables hanging freely. You might also notice the red emergency switches. These switches can disconnect the additional ICT systems (this includes the laptop) from the rest of the car. They are part of the safety requirements. I have never seen them used, but they seem to have a symbolic value. Once, I observed how a science journalist asked a project member to pose with an emergency switch for a picture. These emergency switches highlight the reciprocal relationship between the desire for automation and the need for human control. A test-drive usually begins with us driving off the court to the test-track manually. Manual driving is a member’s term to distinguish it from autonomous driving. Manual driving is whenever the car is controlled by the safety driver. In autonomous mode the car is controlled by the laptop.

The research vehicle may be driven just like a regular car. In fact, despite of all the modifications, it is still a regular car. The safety authorities would not allow it any other way. The modifications, such as the actor for the steering wheel, can be turned off and on. In fact, the safety driver often switches into autonomous mode in mid-drive or resumes control in mid-drive.

We manually drive to test track in order to drive autonomously. A test-track often used during my field work is close to the garage just in front of the university's main building. This test-track is a section of a public two-lane street. The test-track goes up and down the road separated by a grass strip with trees. In each direction it has a driving lane, a lane for parking and in between a bike lane. On each end of the track the car makes a U-turn to resume in the opposite direction. When we arrive at the test-track, Michael says that a sensor does not work and gets out of the car, opens the trunk and reboots a particular sensor system. He gets back into the car and resumes driving. Michael counts down: "3-2-1". He flicks a switch at the steering wheel and the laptop responds with a feminine voice: „Engaged". Michael takes his hands off the steering wheel and rests them on his lap. Shortly after, Michael takes hold of the steering wheel and resumes control of the car because it does not drive in the lane like it is supposed to. He explains by pointing towards the laptop screen: "You can see the arrow". He continues by stating that due to a problem with the correction data the deviation of the GPS receiver is too big. For this reason, the car assumes it was driving on the other side of the grass strip. The laptop is out of sync with the world. Michael stops the car once again. Michael and Timo fix the problem quickly and we continue to drive autonomously.

As we have seen in this vignette, test-drives oscillate between manual and autonomous driving between the car being operated by the laptop and by the driver. Repair is an essential part of accomplishing autonomous driving. One moment you are in autonomous drive, and in the next moment the car is back in manual drive. Autonomous driving is a volatile technology. It is enacted as part of a mundane practice – manual driving – incorporating a stable technology – the automobile.

***IT DEPENDS ON HUMANS TO BECOME SAFE***

Fifth, coordination is crucial for operating the car safely.

To safely operate the car in everyday traffic a number of precautions are taken. Most importantly, the car is always crewed in operation, even when driving on enclosed grounds. Now let's take a closer look at what the crew is for. There are two roles: the safety driver and the co-pilot (formally labeled "system observer"). The safety driver sits in the driver's seat. From his seat he can resume full control of the car immediately by overriding the laptop's commands. Next to him in the passenger seat, we have the co-pilot. He is in charge of the laptop. This combines monitoring the perception and planning of the car with manipulating the laptop's software, such as selecting maps and missions and turning sensors on and off. When the pilot decides it is safe to hand over control, e.g. no closely pursuing vehicles, he checks with the co-pilot. It is the co-pilot's responsibility to monitor the laptop's perception of its environment and its planned maneuvers. In a sense, the co-pilot can tell about the near future. It is his responsibility to inform the safety driver about any pending maneuvers on behalf of the laptop (e.g. switching lanes, taking a turn etc.) so that he will not be surprised. Thus, it takes two experts to safely drive a driverless car. Or is it more accurate to say, it takes two men to safely drive a driverless car? This research field is heavily male-dominated and so is this particular project. During my fieldwork only – what I designate as – men were acting as crew members. This can be seen as an extreme case of the gendered division of labor.

Coordination is crucial for operating the car safely. By checking with his co-pilot, the safety driver ensures that the laptop is not planning to drive, for example, 0 km/h. In that case the car would come to a full stop, which in the worst case will lead to a rear-end collision by a pursuing vehicle. If everything checks out fine, the safety driver hands over control by flicking a switch at the steering wheel. As a result, the laptop takes over the vehicle's brake, accelerator, steering wheel and signals.

**Figure 1: Driving in "autonomous" mode (still from a video by GB). The safety driver is sitting on the left while the co-pilot is on the right with the laptop on his knees.**

Having their hands close to the steering wheel with no direct contact (figure 1) reminds me of trying to prevent a child from falling while making her/his first steps. This analogy captures the tension in the safety driver's task. Similar to monitoring a child learning to walk, the key challenge of monitoring the car in autonomous drive is to assess whether it is necessary to re-take control of the vehicle without being overcautious.

## *AUTONOMOUS DRIVING IS A JOINT ACCOMPLISHMENT*

We have learnt that the car as a technology is distributed. It demands syncing, assembling, and re-animating. Even when the many elements are in place and working properly, this technology is volatile and depends on coordinated efforts of experts to create a safe opportunity for autonomous driving. Experienced computer scientists accomplish autonomous driving with a number of ICTs and a modified car. The technological project with the car at its core can be grasped as an assemblage of heterogeneous elements. The assemblage oscillates between two versions of technology, a good old-fashioned automobile and an experimental autonomous car, which is the coupling of a laptop with a vehicle, its sensor, and a highly skilled and focused crew.

To talk about an "autonomous car" is misleading if you think of it as a stable and permanent identity. When the "autonomous car" exists, it exists only for limited time as a situated accomplishment. It oscillates between manual and autonomous driving. It is also misleading to think of it as autonomous in sense of self-sufficiency. The car has to be pushed out of the garage, driven to the test-track and constantly cared for. The car is a precarious assemblage that has to be re-animated each time project members take it to the streets. Thus, the capacity to drive autonomously is not an inherent property of the object. Rather, it is accomplished by a collective of computer scientists, ICTs and a modified car.

## *REFERENCE*

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