

# Location Privacy in the Age of AI and IoT

WHAT ARE THE PRIVACY  
IMPLICATIONS OF AI AND IOT IN  
LOCATION DATA?

By  
Daan Rijnberk

Almere, 2023-06-11  
Aeres University of Applied Sciences

Student number: 3028952  
Student Geo Media & Design  
Graduation teacher: Jan Willem van Eck

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## Preface

Before you lies the graduation paper “Location privacy in the age of AI and IoT.” It has been written to fulfill the graduation requirements of the Geo Media & Design program of Aeres University of Applied Sciences, Almere. I was engaged in researching and writing this thesis from January to June 2023.

During previous years of my education, I found that I had an interest in advanced technologies and the impact they can have on people’s lives. In addition, I have a profound interest in the ethical problems surrounding these advanced technologies, the privacy implications in particular. Therefore, I choose to use these aspects as the basis of my graduation paper and to include location data as the leading subject to match the graduation requirements. I also choose to go for a different approach and to step out of my comfort zone by combining literature research with a trial set up with 15 individuals. By taking on the challenge of setting up a trial, finding participants, and executing this, I have learned that struggling is part of the process. Therefore, this thesis has taught me valuable lessons both professionally and personally.

In closing, I would like to thank my supervisor, Jan Willem van Eck, for the excellent guidance and support during the process. Your experience and calm approach helped me overcome challenges and develop new original ideas, for which I am grateful.

I would also like to thank you, my reader: I hope you enjoy your reading.

Daan Rijnberk  
Almere, June 11, 2023

## Summary

Location data is a sensitive data type that is collected on a wide scale and is easily misused as it can reveal sensitive personal information. Popular and upcoming technologies like AI and IoT devices can play a meaningful role in this as they become more prevalent and integrated into our daily-use devices and surpass human abilities. This research explores how these technologies are used for collecting, analyzing, and utilizing location data and examines the effects on individuals' privacy, as increasing concerns about privacy create the need for effective regulation.

Desk research and field research methods were utilized to gather information on the technologies used in location data, the potential role of AI and IoT devices, and the privacy implications. Desk research involved analyzing research reports and literature, and field research involved tracking 15 individuals to analyze the insights obtained from their location data with publicly available AI to explore the current-day abilities of publicly available AI.

Research results revealed the current methods and technologies used for location data, such as GPS, Wi-Fi tracking, Bluetooth tracking, IP addresses, and data collected from platforms and applications. In addition, they showed that AI and IoT could play a role in location data processes by offering improved insights, data fusion, image/text recognition, and enhanced data collection methods. Yet, the integration of IoT technologies and AI in location data processes is not without negative consequences. Using publicly available AI can already provide meaningful insights about an individual's profile and preferences, with accurate identification of home location, frequently visited places, and certain characteristics.

The research concludes that the combination of Artificial Intelligence (AI) and the Internet of Things (IoT) has revolutionized the collection and analysis of location data, but it raises significant privacy concerns. Constant monitoring through IoT devices allows for the creation of detailed profiles and questions personal freedom. Data breaches and unauthorized access to IoT networks pose risks of stalking and identity theft. In addition, AI can extract sensitive personal information from location data, enabling tracking and prediction of individuals' movements. Anonymization of location data is also challenging, with the possibility of re-identification as AI can be used to analyze the location data to develop new insights. Balancing the benefits of AI and IoT with privacy protection requires ethical decision-making, robust security measures, and transparent data practices. Regulators and technology companies should address these privacy implications alongside technological advancements.

## Samenvatting

Locatiegegevens zijn gevoelige gebruikersgegevens die op grote schaal worden verzameld en die gemakkelijk kunnen worden misbruikt omdat ze gevoelige persoonlijke informatie kunnen onthullen. Populaire en opkomende technologieën zoals AI en IoT-apparaten kunnen hierin een betekenisvolle rol spelen naarmate ze steeds vaker voorkomen en geïntegreerd worden in onze apparaten voor dagelijks gebruik en menselijke capaciteiten overtreffen. Dit onderzoek onderzoekt hoe deze technologieën worden gebruikt voor het verzamelen, analyseren en gebruiken van locatiegegevens, en de effecten op de privacy van individuen, aangezien toenemende zorgen over privacy de behoefte aan effectieve regulering bevorderen.

Deskresearch en veldonderzoekmethoden werden gebruikt om informatie te verzamelen over de technologieën welke worden gebruikt in locatiegegevens processen, de potentiële rol van AI- en IoT-apparaten en de implicaties voor de privacy. Deskresearch omvatte het analyseren van onderzoeksrapporten en literatuur en veldonderzoek het volgen van 15 personen om de inzichten verkregen uit hun locatiegegevens te analyseren met openbaar beschikbare AI, om de huidige mogelijkheden van openbaar beschikbare AI te onderzoeken.

Onderzoeksresultaten onthulden de huidige methoden en technologieën die worden gebruikt voor locatiegegevens, zoals GPS, Wi-Fi-tracking, Bluetooth-tracking, IP-adressen en gegevens verzameld van platforms en applicaties, en toonden aan dat AI en IoT mogelijk een rol kunnen spelen in locatiegegevensprocessen door verbeterde inzichten, gegevensfusie, beeld-/tekstherkenning en verbeterde methoden voor gegevensverzameling aan te bieden. Enkel is de integratie IoT technologieën en AI niet zonder negatieve gevolgen. Het gebruik van openbaar beschikbare AI al zinvolle inzichten opleveren over het profiel en de voorkeuren van een individu, met nauwkeurige identificatie van de thuislocatie, vaak bezochte plaatsen en bepaalde kenmerken.

Het onderzoek concludeert dat de combinatie van “kunstmatige intelligentie” (AI) en “het internet der dingen” (IoT) een revolutie teweeg heeft gebracht in het verzamelen en analyseren van locatiegegevens, maar dat dit belangrijke privacy kwesties met zich meebrengt. Constante monitoring via IoT-apparaten creëert de mogelijkheid tot het maken van gedetailleerde profielen en stelt persoonlijke vrijheid in vraag. Datalekken en ongeoorloofde toegang tot IoT-netwerken vormen het risico van stalking en identiteitsdiefstal. Bovendien kan AI gevoelige persoonlijke informatie uit locatiegegevens halen, waardoor bewegingen van individuen kunnen worden gevolgd en voorspeld. Het anonimiseren van locatiegegevens is ook een uitdaging met her-identificatie mogelijk, aangezien AI kan worden gebruikt om de locatiegegevens te analyseren om inzichten te verkrijgen. Om de voordelen van AI en IoT in evenwicht te brengen met privacybescherming, zijn ethische besluitvorming, robuuste beveiligingsmaatregelen en transparante gegevenspraktijken vereist. Regelgevers en technologiebedrijven moeten deze privacy implicaties samen met technologische vooruitgang aanpakken.

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# 1. Introduction

## 1.1 Motivation

Artificial intelligence (AI) focused company OpenAI recently introduced its software program ChatGPT, which allows anyone with access to the open internet to talk, ask questions, and give commands to a high-end AI chatbot (OpenAI, n.d.). The conversational AI quickly became incredibly popular and reached 100 million active users in January 2023, just two months after its release, making it the fastest-growing consumer application ever (Hu, 2023). ChatGPT was the first publicly introduced accessible AI software. The World Economic Forum called it “the start of the golden age of AI as suddenly AI does not feel like something of a mysterious and obscure technology any longer” (Torkington, 2023). Suddenly, the vast potential of generative AI, described by McKinsey as a form of machine learning or algorithms that can be used to create new content, including audio, images, text, simulations, and videos, is dawning on the general public (McKinsey & Company, 2023).

AI is not the only groundbreaking technology that is developing at a rapid pace all around us. For example, autonomous driving technology, virtual reality, and the Internet of Things are all trying to gain ground and increase their presence in society (Schwab, 2020). And despite their attractive appearances and features, the technologies initiating a fourth (digital) industrial revolution also carry numerous risks and threats due to their fusion, which is causing a blurring of the boundaries between the physical and digital worlds (Schwab, 2020).

Such a revolution comes with a number of challenges, among which is privacy (Crossler, 2011). Privacy has been the center of discussion for years as the digital environment is tough to regulate and secure (Crossler, 2011). With these new technologies being introduced on a large and public scale, there is no end to privacy discussions in sight as digital brings on many privacy risks, primarily related to user data collection (Chamorro-Premuzic, 2018). This requires strict regulations and an ethical approach from technology leaders, governments, and GIS developers alike (Crossler, 2011). Sadly, we cannot always count on this ethical approach as commercial benefits often take priority within these technology companies as illustrated by the many privacy breaches from Facebook parent Meta over the last two decades (Newcomb, 2018).

Location data is one of these user data types that are collected on a wide scale through popular and upcoming technologies like AI and IoT. Location data is very sensitive as it is easily misused and can say more about an individual than one might presume (Furini & Tamanini, 2015). For example, criminals

may be facilitated in their activities (from burglary and theft to stalking, kidnapping, and domestic violence) as location data may reveal personal information such as home, work, and school address (Furini & Tamanini, 2015). Location data is already being collected through smartphones and social media like Snapchat and Instagram, or OS’s like IOS and Android that can track your position every second of the day if you do not tell them not to, for example in photo tagging, as visualized in Figure 1.



Figure 1 IOS photo location tracking in iPhone library (Dove & Hollington, 2021)

Furthermore, as technologies and technology concepts such as AI and IoT become more prevalent and are integrated into our daily-use devices, technology companies find it increasingly convenient to gather and analyze location data. For example, AI can and will be used to analyze the location data to develop insights and to connect dots that were not connected before, making it harder to anonymize location data (Manheim & Kaplan, 2018). As a result, it is hard to believe that location data privacy still exists nowadays as the continued development of new technologies will make it harder to keep your data to yourself. Moreover, with regulators struggling to keep up with technological development, privacy threats are increasing, and location data is becoming more valuable (Lee, 2019). Due to these advancements, preserving a user's privacy is becoming increasingly important for users, governments, and technology companies alike. This involves understanding how new advanced technologies increase privacy threats.

## 1.2 The aim of this research

This research aims to investigate the manner in which fast-growing technologies, namely AI and IoT technologies/devices, are utilized in location data processes like collection, analysis, and utilization, and the subsequent effects on an individual's location privacy. In order to establish a more effective regulatory framework, users, regulators, and developers must comprehend how these technologies can impact privacy. A deeper understanding could potentially influence the behavior of internet and service users, and spur developers, technology companies, and governments to implement safety measures and enact new laws and regulations. As such, this research carries significance for a wide range of stakeholders.

The results of the study can potentially be of importance to society at large as it should give a greater insight into the level of privacy that exists and how these new technologies impact a person's location privacy. This research aims to create awareness around the value of location data and the amount of personal information that can be derived from it. This is not just important for the general public but also for GIS specialists and software developers working on these products and technologies. The study should give them a greater insight into how their products impact a person's privacy. Of course, the study will also be important to both technology companies and governments. By pointing out data collection weaknesses, risks, and biases following the use of these new technologies, governments, and technology companies could be made more aware of the impact of these technologies and of the lack of regulation and laws.

And these privacy issues are more relevant than ever with these groundbreaking technologies growing rapidly, as described earlier. AI has now been introduced to the general public in a way that everyone with an internet connection can access AI services and use them for their daily tasks. IoT devices are also increasing their presence in people's daily lives with a growing number of AI-equipped cameras hanging on street corners, trash bins equipped with sensors, and traffic regulation software monitoring the streets. As a result, it is becoming impossible to avoid these technologies today and all the implications that come with them. As of now, there is yet to be a clear answer to these privacy-related questions. A lot of research will have to be conducted to paint a clear picture of the threats and problems and to find out just how much of an impact these relatively new technologies have on the location data privacy of the user.

In this chapter, a knowledge framework will be introduced to shape this research, laying the groundwork for crucial definitions and establishing a strong foundation. Furthermore, this chapter will delve into a comprehensive exploration of location data, location privacy, IoT, and AI, providing a deeper understanding of their significance. Finally, we will address the knowledge gap, establish boundaries, and outline the research objectives, all to shape this research.

## 1.3 Knowledge framework

### 1.3.1 Defining location data and location privacy

Leda et al. (2016) use the definition of personal data as it is listed in the General Data Protection Regulation (GDPR), which was adopted in May 2016. Article 4 of this regulation defines personal data as follows:

“‘personal data’ means any information relating to an identified or identifiable natural person (‘data subject’); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person;”

In this same report from Leda et al. (2016), for the purpose of that particular study, it also defines personal location data by using the definition of personal data and combining this with location data which covers any data with an implicit or explicit geographic or geospatial reference. The result is that personal location data is defined as any “location data that is directly or indirectly linked to an individual or that can be directly or indirectly used to identify an individual.” Drummond et al. (2006) go a step further by defining location privacy, which involves personal location data and refers to it as a unique form of information privacy that centers around an individual's entitlement to determine the timing, method, and degree of sharing location data with others. Taking both the definition provided by Drummond et al. (2006) and Leda et al. (2016), we can state that the problem with location privacy would mean a lack of control of a person's location information, resulting in privacy issues. This is of great importance to this research as this gives it a location privacy foundation to build on, when discussing privacy implications.

Kar and Ghose (2014) see location privacy as an unclear concept and define it as “the ability to prevent other parties from learning one's current or past location” or “the ability of an individual to move in public space with the expectation that under normal circumstances their location will not be systematically and secretly recorded for later use”. This shows a similar definition as provided by Drummond et al. (2006) and Leda et al. (2016), meaning location privacy pertains to the authority of an individual to govern and possess their location data, ensuring that it is not accessible to third parties without explicit consent. Consequently, this study will utilize the aforementioned definitions for the terms "location data" and "location privacy."

### 1.3.2 Location data collection and user awareness

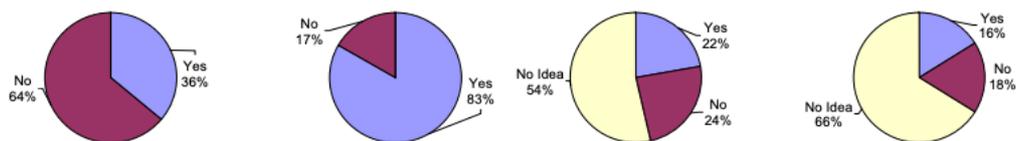
As pointed out by an article from the American Bar Association, location data tracking is ubiquitous (Boshell, 2019). A consumer's data is regularly tracked by multiple systems and devices like mobile applications (apps), including Facebook, Apple, and Twitter (Boshell, 2019). Oikonomidis and Fouskas (2019) confirmed that location data tracking is a significant phenomenon, as more than 60% of the big data on the internet has a georeferenced component. With the increase in mobile devices such as smartphones and technical advances in ambient intelligence powered by the Internet of Things (IoT), location information has become ubiquitous. The age of social media has caused a shift in location sharing, massively boosting the amount of information available to technology companies (McKenzie et al., 2016).

Loebel (2012) notes the surge in data sharing presents a genuine risk of exploitation, as the majority of users are oblivious to the fact that their geolocation data can be readily pieced together to construct detailed profiles of their daily routines, behaviors, and social interactions. Furini and Tamanini (2015) also confirm the unawareness among consumers. They mention that while the social media mobile experience is exhilarating for users, they often fail to recognize that a significant portion of the data linked to their content (i.e. metadata) can be classified as personal and sensitive.

How sensitive this data can be is shown by an example used by Goodchild et al. (2022): GIS engineers working for large technology corporations such as Yelp, Uber, and DoorDash incorporated information about race into the locational data of Black-owned restaurants in an effort to provide assistance to Black communities in the aftermath of George Floyd's murder. However, while this action was driven by good intentions, research indicates that the initiative did not have a sustained positive impact on the Black community and, in fact, generated discriminatory remarks like only sending black community drivers to these customers. The practice of tracking and racializing location data during business transactions can produce unintended consequences and leave vulnerable communities even more susceptible to racial abuse, even if the original intent was to support them.

Another example of how sensitive personal location data can be is given by Bu-Pasha et al. (2016), who point to conclusions that can be drawn about that person's religion or sexual preferences, for example, based on location data after visiting a church or a gay bar. Ultimately, location data is seen as very sensitive personal information that can tell much more about a person than originally perceived (Bu-Pasha et al., 2016). It allows private companies to build a user profile based on a user's location history and predict that person's needs and wishes. Research by Bu-Pasha et al. (2016) shows that collecting personal location data can pose significant harm to individuals. In addition to the potential disclosure of sensitive and private information, the unlawful or unethical collection of location data can also facilitate identity theft, for example (Bu-Pasha et al., 2016).

Still, users are willing to disclose personal location data when perceived as critical for the application, as Furini and Tamanini (2015) illustrated. According to their research findings, the percentage of individuals who disclosed their geolocation data to geomap applications was 97%, while only 53% revealed their location data to music applications. The research group used to gather these results was completely random as people were interviewed to derive these insights. Moreover, the percentage of the interviewed that answered with "don't remember", "don't know", or "no idea" on the question of whether they know they can change privacy settings was high, as illustrated in Figure 2, which shows that a location-aware scenario is still an obscure entity for most of the users, and this gives technology companies and third parties more room to work with.



*Figure 2 Usage of the geolocation feature on Twitter and Instagram (the left two), and changes to privacy settings on Twitter for men and women (right two) (Furini & Tamanini, 2015)*

McKenzie et al. (2016) also confirmed this theory of unawareness as they claim a recent study showed that smartphone users are still unaware of the extent and frequency at which their personal data is being collected. And despite the prevalence of discussions and concerns around privacy issues, users continue to create and use accounts on location-sharing apps and share detailed social and location information with these apps at all levels of granularity (McKenzie et al., 2016). Vgena et al. (2019) call this incompatibility between users' perceptions and their everyday practice the privacy paradox. According to their explanation, users often ignore their privacy concerns while using social media services and willingly disclose personal information, including their age, gender, and other details, as shown in the Snapchat example in Figure 3. So, under the right circumstances, whether under social pressure or a fear of missing out, users are willing to unveil parts of their intimacy in exchange for services. Therefore, the key to the location privacy problem is the fact that people are tempted to share their location information on social media sites, while they are unable to fully comprehend or are unaware of the privacy implications this causes (Kar & Ghose, 2014). Kar & Ghose (2014) continues by saying that this then results in uncontrolled privacy issues and a meaningful power increase for technology companies, fueling location data privacy implications.

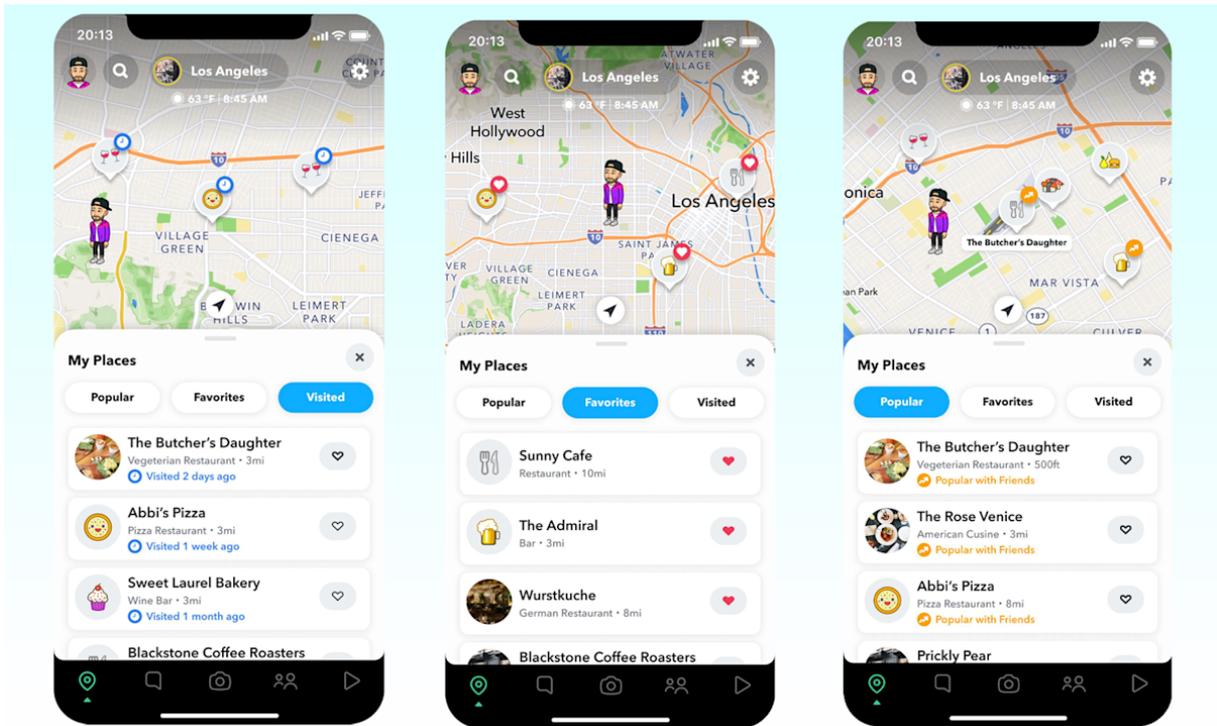


Figure 3 Snapchat's location tracking (Bell, 2021)

As the vast majority of consumers are willing to share their personal location data with these third parties, as described above, it leads to private companies collecting large amounts of data, creating a new industry worth over \$21 billion in 2017 (Valentino-DeVries et al., 2019). Loebel (2012) points to the fact that all this information is being gathered and stored by private companies with a commercial interest as the key factor in the privacy issue. Most of the time, as pointed out earlier, consumers give permission to do this as the app makes it look like it needs the user's location to function properly, or it might even force him or her to give consent in order to use its functionality, like for Google Maps (Furini & Tamanini, 2015). These third parties then combine location data with other information to trace, in real-time, the movement of a single user (Zheng et al., 2018). This strategy of collecting and selling user data without the user being adequately informed is enough reason for privacy concerns (Goodchild et al., 2022).

### 1.3.3 Location data collection motives

But what motivates these technology companies to collect this sort of sensitive data and risk government penalties? According to Boshell (2019), the primary purpose of collecting location data is to enable the data collector to provide a service to the individual. However, location data can also be used in the secondary market to monetize location for unrelated purposes, like enabling a subsequent buyer (3<sup>rd</sup> party) to compile a profile of the individual and use this for commercial purposes (Boswell, 2019). These purposes include targeted advertising and marketing as the most well-known effort (Tungekar, 2021). This is, for example, used by large technology companies such as Google and Meta, which derive most of their revenues and profits from targeted advertising built on a user data profile (Tungekar, 2021). In addition, all the established social media companies are offering services inside the geolocation range so that the advertising will be better targeted to the right audience (Oikonomidis & Fouskas, 2019).

As an example, Boshell (2019) illustrates that when an Apple customer is near an Apple Store, their phone could display advertisements for Apple TV, as the company uses location data for targeted advertising. So, put simply; geotargeting is a marketing strategy (Tungekar, 2021). Advertisers have the

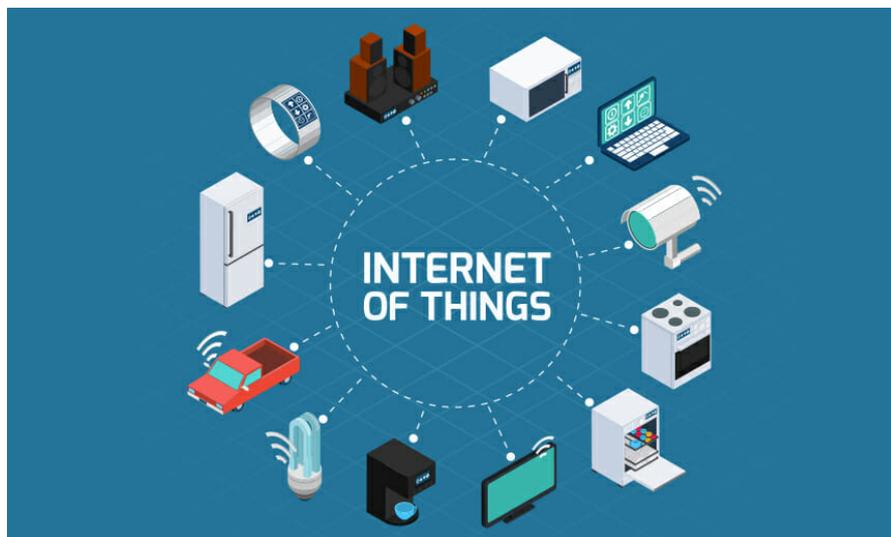
option to select a particular location for their advertisement to appear (Adamczewski, 2021). If a user's location information confirms that he or she is within that area, the advertisement will be displayed to that user. This is the exact mechanism that food delivery applications utilize to suggest nearby restaurants and why individuals often receive an advertisement for a clothing store when they are in close proximity to the shop (Adamczewski, 2021).

Advanced targeted advertising is now feasible due to the technology and big data that companies gather on their users (Valentino-DeVries et al., 2019). Advertising firms can target specific users with specific advertisements as technology grows more advanced (Boshell, 2019). Next-generation technologies such as AI and IoT devices offer even greater abilities, surpassing human capabilities (Manheim & Kaplan, 2018). However, they also enable better tracking and collecting of user data, which could raise privacy concerns (Boshell, 2019). Understanding the impact and function of these new technologies is crucial in navigating the landscape of advanced targeted advertising and addressing potential location privacy concerns. Therefore, the next part of this chapter will attempt to explain and define these technologies.

#### 1.3.4 New and advanced technologies – Artificial Intelligence and the Internet of Things

New technologies are poised to change how large technology companies, organizations, and governments collect, process, and use location data (Quach et al., 2022). Among these technologies are two leaders that are quickly entering our daily lives, as discussed in the motivation of this report, and these are Artificial Intelligence (AI) and the Internet of Things (IoT).

Solangi et al. (2018) described IoT as primarily meaning a “wide range smart devices network that provides smart solutions using internet for automated communication among each other without requiring any human input.” Maras (2015) uses a very similar and basic definition of IoT and refers to it as “the connection of everyday objects (eg TVs, appliances, and exercise equipment) to the Internet.” So, IoT can be seen as a network of devices that all communicate with each other through a 5G network to create a smart network, as illustrated in Figure 4.



*Figure 4 An IoT network and its devices (Fall, 2021)*

Therefore, IoT includes a comprehensive product spectrum, including smart camera devices or sensors in public places, as well as smart fridges, curtains, or thermostats (Solangi et al., 2018). Eventually, the wide range of IoT applications and devices should support the management and realization of smart cities, homes, healthcare, and much more, resulting in a smart future (Maras, 2015).

An essential feature of IoT is its ability to enable real-time monitoring and collection of data about property, people, plants, animals, and everything else (Maras, 2015). Phones and smartwatches are also part of this network and collect vast amounts of data on its user from location to “a user’s distance traveled, steps taken, stairs climbed, calories burned, and quality of sleep, 24 hours a day”, as indicated by Maras (2015). This brings on serious privacy risks as individuals can now be tracked 24 hours a day without a single human being involved as these systems are able to communicate without the need for human interference, massively increasing the amount of data that is being collected (Martin & Nissenbaum, 2019).

Defining AI is everything but easy due to its complexity, illustrated in figure 5, and broad meaning. Yet, IBM provides the best comprehensive definition of artificial intelligence (AI) as it explains the complexity of AI today by stating that it is an interdisciplinary field that merges computer science and high-quality datasets to facilitate effective problem-solving. AI includes subfields such as machine learning and deep learning, which are frequently associated with AI. These subfields utilize AI algorithms that aim to build expert systems capable of making predictions or classifications based on input data (IBM, n.d.).

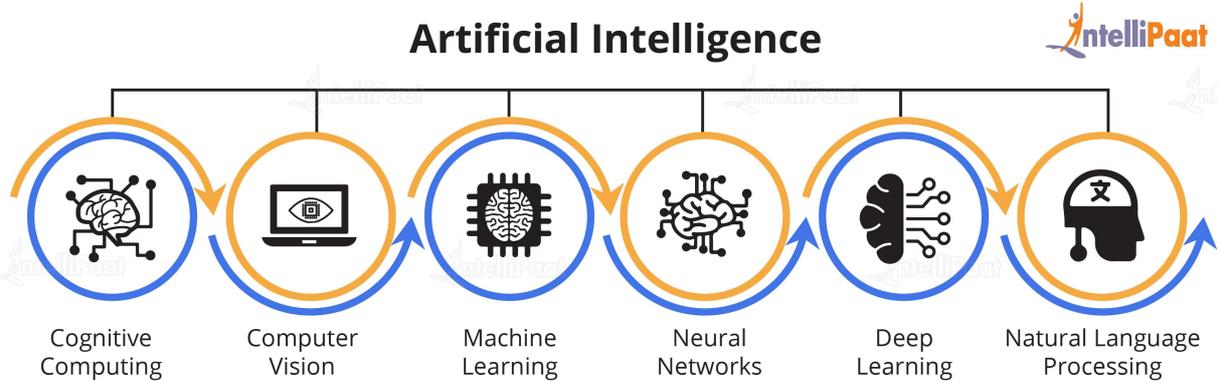


Figure 5 The parts of AI visualized ( Intellipa, 2023)

In addition to this definition of AI, according to a proposal by the European Commission's high-level expert group on artificial intelligence, AI can be defined as systems that demonstrate intelligent behavior by analyzing their environment and taking actions towards specific goals, with varying degrees of autonomy (European Commission, 2018). These systems may exist as purely software-based solutions in the virtual world, including voice assistants, image analysis software, search engines, speech, and face recognition systems, or as embedded hardware devices, such as advanced robots, autonomous cars, drones, or Internet of Things applications (European Commission, 2018).

This might be the easiest-to-understand definition. However, it gets slightly more complicated as we try to define advanced AI, which is used in applications like ChatGPT. This is due to the vast majority of these AI advancements and applications being categorized today as machine learning (ML). ML algorithms are statistical tools used to identify patterns in large amounts of data, which are then utilized to make predictions, as described by Ergen (2019).

With this ability to make predictions based on data also come other abilities. One of these abilities is to quickly process data and find patterns that bring on possible privacy issues if used unethically (O’Flaherty, 2022). Here’s a possible reframed version: “AI can potentially de-anonymize location data when combined with other information” (O’Flaherty, 2022). According to Goodchild et al. (2022), a location "ping" that contains only a device ID and location can be easily reidentified by linking together multiple pings from the same device. Consequently, AI poses a significant risk to privacy as it can connect dots much faster and more effectively (Martin & Nissenbaum, 2019).

As we navigate the evolving landscape of location data, the emergence of technologies such as Artificial Intelligence (AI) and all connected technologies falling under the definition of the Internet of Things (IoT) not only presents immense opportunities but also introduces critical privacy considerations. This underscores the need to better understand the impact these technologies may have on location data and privacy, in order to be able to tackle any privacy-related issues.

## 1.4 Demarcation

This informational background on AI, IoT, location privacy, and the collection and consumer interaction with it, form the basis of this research. Location data privacy issues are a problem of the past, the now and will only become more challenging in the future with new technologies taking the lead and driving automation without human interference, which results in completely new challenges to deal with (Chamorro-Premuzic, 2018). Therefore, within this research, there will be a continued focus on the earlier discussed digital location privacy concerning the new and leading technologies of the so-called fourth industrial revolution. Onik et al. (2019) describe this new industrial revolution as “a connected and smart manufacturing system where internet, machine (physical system) and humans lumped together.”

In this new revolution, artificial intelligence and Internet of Things technologies will be the primary technologies exposed to privacy risks. Therefore, these are the leading technologies that will be focused on in this research. As a result, other promising new technologies like autonomous vehicles, virtual reality, and augmented reality will not be discussed in this study.

The research report will dig deeper into traditional data collection methods and the companies, organizations, or governments using them to fully understand the technology driving this process and how AI and IoT fit into this. In addition, this study will discuss the possible privacy implications, risks, errors, or biases that might occur when using these technologies in all verticals of location data.

Finally, this research will not look for regulatory solutions or suggestions. However, it will merely focus on the impact and changes these new technologies may have and what one can expect from these with regard to location privacy. This includes the impact these technologies can have on users, companies, organizations, and governments.

## 1.5 Knowledge gap and problem definition

These cutting-edge technologies are particularly significant because they can function without human intervention and surpass human abilities (Urban, 2017). This attribute enables companies and governments to undertake or aid in actions that were once impossible, as mentioned in the earlier discussion on AI and IoT. Although certain instances were mentioned in which AI and IoT technologies could have a positive impact, these technologies are capable of more when it comes to location data, which has the potential to jeopardize location privacy.

However, this is still largely unknown, and so there exists a knowledge gap on the ability of advanced AI and the privacy threats of IoT technologies to make a difference regarding location privacy compared to traditional collection methods. This is partly due to the rapid development rate of these technologies, making it incredibly hard to build a solid regulatory framework for governments. Information and research tend to be quickly outdated, leaving technology companies, consumers, and governments with many questions. Although research exists regarding privacy concerns related to location data and emerging technologies, there is a lack of publicly available research concerning the involvement of AI and IoT in location data. As a result, questions still exist on the impact of these

technologies in regard to potential biases, errors, or risks that may arise in collecting and analyzing location data using AI and IoT technologies.

These are some of the questions that need to be answered to better understand the privacy implications involved in the usage of AI and IoT technologies. Therefore, this study attempts to answer the questions asked above and paint a clearer picture of the potential role of these advanced technologies in location data and the privacy implications that come with them as after conducting the initial literature research, there appears to be a lack of publicly available research to answer these questions.

## 1.6 Research objectives and questions

In order to get the desired results, research will have to be conducted on the technical side of these new technologies in order to find out what impact they can have on location data and location privacy. An essential part of this is understanding how traditional ways of the location data process work from a technical perspective. Also, more research will have to be conducted to determine the privacy implications of these technologies. To collect this information, research will be conducted online to use prior research on both subjects. Whether this study succeeds at answering these questions and ascertaining the impact of AI and IoT on location privacy will determine whether it was a success. This includes the goal of the study to create awareness among users and a strong knowledge basis for governments, companies, and institutions to create a trustworthy regulatory framework.

This all results in the following leading questions to be answered:

### **Leading research question**

*What are the privacy implications of AI and IoT in location data?*

This research aims to address the sub-questions presented below, which collectively contribute to answering the primary research question highlighted above.

1. *What are the current methods and technologies used for location data?*
2. *How would AI and IoT fit into the process of location data?*
3. *What insights can be obtained from an individual's location data by utilizing publicly available AI?*

The final product is this research report answering all the questions laid out above. This report will be made public to everyone by publishing it online. Through this, it should be available to both consumers as well as governments, companies, and organizations to work with. This report could also be offered to governments and technology companies as a knowledge basis for privacy protection and a regulatory framework regarding the usage of AI and IoT.

This final report also carries significance for the GIS (Geo Information sciences) work field as it is crucial for GIS specialists working at commercial companies or governments to understand the value of location data and the privacy implications that the collection, analysis, and usage of this data can have on the user or individual whose data is being collected. This report should provide meaningful insight into these subjects and support GIS developers working with the data to approach their work ethically and decrease privacy implications when using these new and advanced technologies. Again, the goal of this research is not to come up with potential solutions to privacy implications, but to create awareness around these implications among governments, technology companies, consumers, and professionals in the GIS work field as these will work with the data most frequently.

## 2. Materials and Methods

This chapter addresses each sub-question separately, utilizing specific methods of data collection or literature research for each. By comprehensively researching each sub-question, this research aimed to provide a complete answer to the main research question. The gathered data and results, obtained through both desk and field research, were analyzed and presented in a descriptive manner, primarily through written text rather than graphs.

As for data and information reliability and validity, most of the data and information that is collected through desk research, as explained for each research question, was derived from peer-reviewed sources to ensure the good reliability of the provided information and research. Additional facts derived from non-peer-reviewed sources were backed up by additional sources making the same or similar claims to ensure the higher reliability of these facts and information. To ensure a similar sort of information reliability and validity for the field research conducted, the trial that was set up to answer sub-question three was conducted among a diverse research group with all sorts of backgrounds, and 15 participants were used to ensure high research quality.

### 2.1 Sub question 1: What are the current methods and technologies used for location data?

In order to answer this question, information was collected on the traditional methods in which location data is collected, analyzed, used, and processed nowadays, and how this has been working in the past, in order to get a better understanding of how these technologies work. This was a crucial question to answer in order to be able to determine the way in which IoT and AI can be used to enhance these methods and what difference this makes from a privacy perspective.

To address this research question, a form of qualitative research was used through desk research. Desk research was used by analyzing previous research reports on the collection and analysis of location data with a technical focus to find out how this works. In addition, similar research reports were used to precisely determine which organizations, companies, governments, or institutions collect this form of location data, to supply a solid basis for privacy concerns. There are a number of research reports on Google Scholar, ResearchGate, and Springer that discuss the technical requirements and systems of location data, as well as the parties involved in these processes. In order to improve the relevance of the used literature, the prioritized literature used for this research question was ideally no older than 5 years. This is why research by Boshell (2019) and Valentino-DeVries et al. (2019) were among the most frequently used references.

In addition to scientific research reports, large social media companies, telecom companies, government organizations, and market research firms also offer research reports on this subject that will be used to answer this question and gather information. These companies and organizations are known for their technical knowledge, making their research very useful. This is why, for example, research by Google was used, as this is a leading stakeholder in location data. Gathering this information through literature research allowed for a knowledge basis to be built to work from. The search queries in Table 1 were used to find useful literature.

*Table 1 Used search queries*

Location data	Data collection	Big tech data
+ Collection	+ By governments	+ Collecting
+ Collecting	+ By companies	+ Processing
+ Technical		+ Using
+ Privacy		
+ Techniques		
+ Analysis		
+ Usage		
+ Social Media		
+ Technology		
+ Risks		

## 2.2 Sub question 2: How would AI and IoT fit into the process of location data?

In order to answer this question, information was collected on both the technical capabilities and systems of AI and IoT and potential privacy implications. In order to find out whether they could make a difference and the potential privacy implications of using these technologies, it was important to first understand the technical capabilities.

To address this research question, a form of qualitative research was used through desk research. Desk research was used by analyzing previous research reports on the use of these technologies and the privacy issues connected to them. There are a number of research reports on Google Scholar, ResearchGate, and Springer that discuss the technical qualities and capabilities of these advanced technologies, in which privacy threats, concerns, or issues are also discussed regarding the technological capabilities. The search queries in Table 2 and Table 3 will be used to find useful literature.

Literature that was no older than 5 to a maximum of 7 years was prioritized to ensure relevant technical information. This is why most sources are no older than 5 years. In addition, the references used for this research question appear to be more non-scientific literature due to the little research performed in relation to the integration of AI and IoT technologies in location data. Therefore, non-scientific literature was often needed to gather the needed information. As explained before, all information gathered through non-scientific literature research was only used when backed up by multiple articles or reports. Through this desk research, the goal was to get a better understanding of the technical qualities and capabilities of AI and IoT technologies, in order to find out how these can be implemented in location data, and the privacy implications that come with leveraging these technologies.

*Table 2 Search Queries*

AI/IoT	
+ Defining	+ location privacy
+ Definition	+ Data collecting
+ Technical	+ Data analysis
+ Privacy	+ Threats
+ Techniques	+ Machine learning
+ Analysis	+ Cloud computing
+ Usage	
+ Social Media	
+ Technology	
+ Risks	

*Table 3 Search Queries*

AI/IoT
+ Privacy Implications
+ Problems
+ Threats
+ Risks
+ Privacy issues
+ Automation
+ Liability

### 2.3 Sub question 3: What insights can be obtained from an individual's location data by utilizing publicly available AI?

Publicly available AI is making large steps with the availability of programs like ChatGPT, that offer meaningful functionality. Yet, the availability of these AI programs to the general public also allows individuals with bad intentions to leverage the abilities of the AI to de-anonymize or analyze user location data, creating serious privacy implications. Therefore, this research question aims to find out what insights can be derived from location data by using publicly available AI programs, to point out the privacy risks.

In order to answer this question, a form of field research was used as a trial or test was run to explore the real capabilities of publicly available AI in particular. This trial was run with a group of 15 individuals, of which the identity is unknown. A group of 15 individuals was chosen to ensure a diverse user base and to build a buffer to account for possible technical issues that could cause the loss of data. These 15 people were tracked for a period of either one or two full weeks to collect location data on these individuals. The collection of location data from each individual was then put into an AI language model to form a profile based on this individual's location data, focused on gender, age, home location, work location, hobbies, etc. The AI was also asked to come up with targeted advertising suggestions based on this profile, to visualize how AI can use the user profile insights to create commercial value. The following input question was used in the AI to get these results:

"Can you sketch a detailed profile by using the given visited locations of an individual? Focus on gender, age, home location, work location, hobbies, school, preferred form of transport, and other possible conclusions that can be derived from the data. Please also include a personality estimate and targeted advertising suggestions. This is the data:"

Through this field test, the research aimed to show just how well AI can create a profile on an individual's location data alone in just a matter of seconds, pointing out both the sensitivity of location data and the ability of AI to work out complex workloads in a short period. This data was collected using Google Maps tracking capabilities as through this method every individual still controlled his own data, decreasing privacy worries among the test group. Also, through the Google Maps platform, the data was accessible and easy to download, as well as to delete. This, again, with the aim of ensuring optimal privacy and control. An explanation file for installing the tracking mechanism was created to support the participants. This can be found in the attachments (attachment 3) of this report and explains how to install the Google Maps tracking system. Also, before the data is inserted into the AI model, this first had to be sorted and made into text as the language models can only process text at this point in time. In order to check the correctness of the AI output, participants were asked to judge the profile created by the AI to see to what extent this matched reality.

In this report, the identity of each individual will be unknown and only limited data will be available. The research group included people from all racial backgrounds, ages, and occupational backgrounds to create a diverse user base. For AI language models, ChatGPT and Perplexity AI were used, with the goal of creating the most accurate results by using two different language models. The results include the best takeaways from both of these AI models.

## 3. Research Results

This chapter presents the research results obtained from a comprehensive investigation into the utilization of location data, with a particular focus on the integration of Artificial Intelligence (AI) and the Internet of Things (IoT) technologies in location data. The data collection for this study primarily involved an extensive review of relevant literature for two of the sub-questions. In addition, a trial was conducted involving a group of 15 individuals to examine whether AI could generate a sufficient profile sketch based solely on location data, answering the final sub-question.

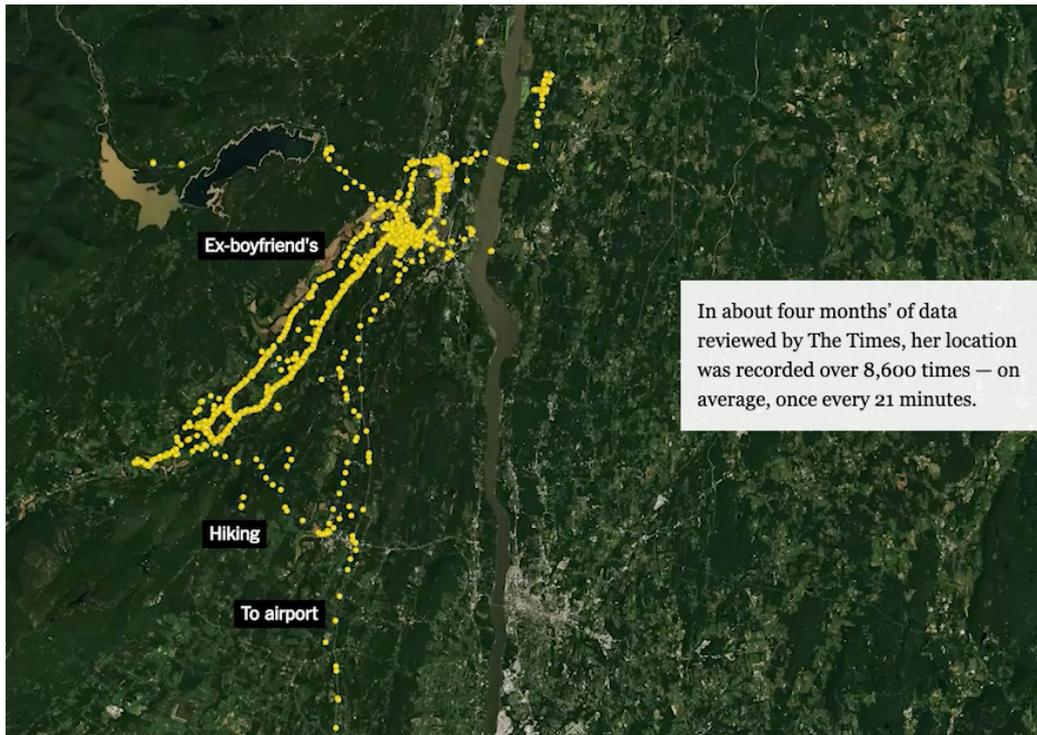
Overall, this chapter serves as a pivotal point in the research report, consolidating the knowledge acquired through extensive literature research and trials. The subsequent sections will delve into each of the sub-questions in chronological order as laid out earlier in this report, presenting the outcomes and implications discovered, thus contributing to a deeper understanding of the research domain. First, the current methods and technologies used for location data and the motives and drivers behind this will be discussed, followed by the results derived from literature research with the goal to find out how AI and IoT technologies can be used in location data collection and analysis. Finally, the third part of this chapter will show the trial results in order to get a better understanding of the abilities of publicly available AI in combination with location data.

### 3.1 Current methods and technologies used for location data.

#### 3.1.1 The foundation of location data collection and motives.

How location data is used, collected, and analyzed is closely correlated with the rate of innovation in this space and the fast developments in tracking technologies and data analytics methodologies, as shown by the literature research results which will be discussed below. Playing a role in this is the amount of consumer data available as the available volume today requires new ways of collecting and processing (Boshell, 2019). Research by Valentino-DeVries et al. (2019) shows that many apps and operating systems track up to 200 million mobile devices in the U.S. alone. The data that is collected by these companies and apps is most often accurate within a few yards and in some cases updated more than 14,000 times a day, which results in Figure 6 seen below, created from the data of an individual by Valentino-DeVries et al. (2019).

Valentino-DeVries et al. (2019) also showed that apps often collect a user's location data every 2 seconds, according to a database of more than a million phones in the New York area that was reviewed. And while this data was anonymous and did not show the identity of the user in question, Valentino-DeVries et al. (2019) could easily connect the user to the dots by using multiple reference points. Elkhodr et al. (2012) give another example of this as they refer to a study published by The Wall Street Journal, which analyzed 101 of the most popular smartphone applications across different mobile operating systems. This study showed that out of these applications, 47 transmitted location data to third parties without the users' permission.



*Figure 6 A visualization of location data collected from a single user over a period of 4 months (Valentino-DeVries et al., 2019)*

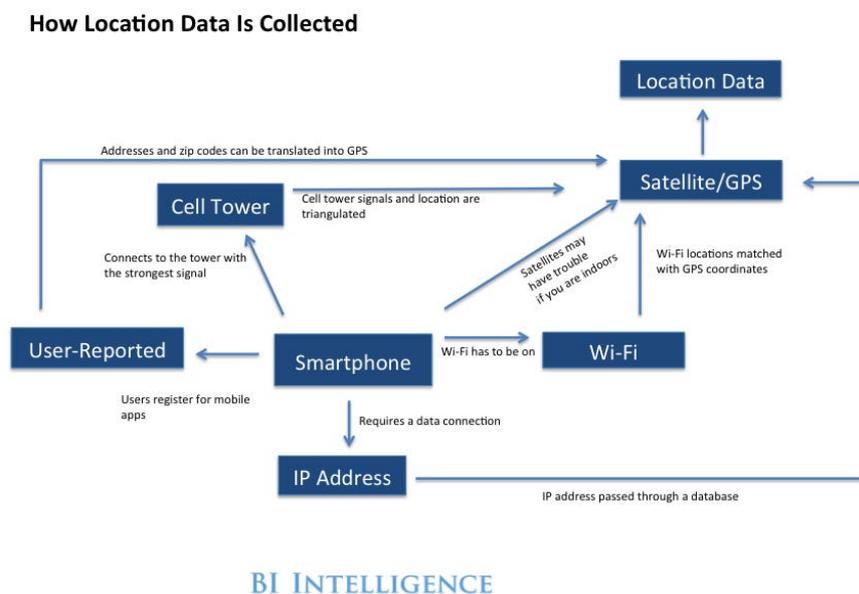
These third parties can then leverage the data for commercial purposes like targeted advertising (Valentino-DeVries et al., 2019). Research by Valentino-DeVries et al. (2019) showed that out of the 20 apps they tested, 17 of those sent exact latitude and longitude data to 70 third-party businesses, showing that location data used for commercial purposes is most often collected by daily used applications, and this has had a meaningful impact on the approach technology companies are taking nowadays to collect user location data. In the past, the issue of location privacy received limited attention as location information was not widely and consistently accessible (Minch, 2015).

However, according to Minch (2015), with the significant advancements in technology like smartphones and applications, the availability of location data has dramatically increased. Today, systems of Google employ monitoring mechanisms that analyze various aspects of a user's online activities, including email, social media, location data, and travel reservations in real-time (Minch, 2015). Research by Gravy Analytics (2023) shows targeted advertising is the most common use of this data. Companies have the opportunity to acquire customized "advertising audiences" with specific characteristics, leveraging insights obtained from location intelligence. This approach enables targeted marketing strategies based on location data analysis (Gravy Analytics, 2023).

For instance, a health food brand could purchase an advertising audience consisting of individuals who have recently visited health food stores, allowing them to deliver highly relevant advertisements to consumers interested in healthy food choices (Gravy Analytics, 2023). Additionally, the same brand could utilize an advertising audience composed of individuals who frequent gyms, as location analytics has revealed that these individuals often have an interest in maintaining a healthy diet. By leveraging an audience with overlapping interests, the health food brand can effectively target a new customer base (Gravy Analytics, 2023). Yet, all this data still needs to be collected and what technologies can be leveraged to do this will be discussed next.

### 3.1.2 Technologies supporting location data processes

The collection of technologies that can be used for location data is broad and diverse but the most common is GPS, which relies on satellites to determine location coordinates (Tsai et al., 2009). Smartphones, tablets, and GPS trackers can collect and transmit location data through GPS (Martin & Nissenbaum, 2019). Yet, most often, different systems and techniques are used. Google, for example, uses a service known as Google Location Services (GLS) on Android devices, which is provided by Google as the network location provider (Google, n.d.). This service is designed to enhance device location accuracy and overall location services. While mobile phones typically rely on GPS signals from satellites to determine location, Google Location Services utilizes additional data from nearby Wi-Fi, mobile networks, and device sensors to make location data even more precise (Google, n.d.). So, what Google does is leverage multiple technologies to better enable itself to collect precise location data, as is shown in Figure 7.



*Figure 7 The process of location data collection from multiple sources (Business Insider, 2013)*

As explained above, these additional sources and technologies include Wi-Fi and Bluetooth tracking, as companies can collect location data by monitoring Wi-Fi and Bluetooth signals emitted by devices (Martin & Nissenbaum, 2019). Wi-Fi tracking is done by scanning for Wi-Fi signals which can be identified by IP address or through large databases of wireless routers of which the location is known (Martin & Nissenbaum, 2019). Companies like Mozilla and Comban are reported to hold databases with millions of unique Wi-Fi networks and all valuable data connected to these (Gray, 2020). If a mobile device scans for these Wi-Fi networks and links the results to these databases, it can determine an approximate location.

Bluetooth tracking uses a similar system as it leverages the location of Bluetooth beacons (Gray, 2020). These are small transmitters that can be installed at specific locations, like in front of a store or display to monitor store traffic or display popularity (Gray, 2020). In these cases, when a user grants permission for an app to access Bluetooth functionality, it becomes possible for the app to deduce the device's location or transmit alerts and other content based on proximity (Gray, 2020). Gray (2020) continues by explaining this means the operating system or app can then pinpoint a user's location by knowing the user is near a certain Bluetooth beacon.

By using multiple location tracking techniques, companies can improve tracking capabilities (Gray, 2020). Also, this allows certain apps to work around legal consent issues. Martin & Nissenbaum (2019) discussed this by pointing to an app called “Accuweather.” This app would request access from users to track their location in order to provide the best weather forecast for their location. When users answered “no” to location tracking, the app would disable the GPS tracking function. Yet, as the company behind the app still wanted the user’s location data, it started using these other technologies like Wi-Fi and Bluetooth tracking, which did not require consent from the user. This is why these apps often leverage multiple tracking methods besides GPS or IP addresses, which is the most used tracking method besides GPS, according to Tsai et al. (2009).

An IP address, commonly known as an Internet address, is assigned to a device by the Internet Service Provider (ISP) and is essential for accessing the internet (Google, n.d.). It serves as a vital link connecting the device to the websites and services the user wants to utilize. IP addresses have a geographical component, which implies that websites you visit, such as google.com, might gather certain general location details related to your area or exact location (Google, n.d.). Companies and governments can use this information to estimate the general geographic location of the device (Gray, 2020). However, IP addresses can only provide an approximate location and may not be accurate for mobile devices using cellular networks (Google, n.d.).

Finally, while the above-discussed technologies are excellent for location tracking, operating systems and Social Media are making the use of these technologies much easier and often unnecessary, according to Martin and Nissenbaum (2019), as a result of the many smartphones carried by individuals worldwide. Various smartphone apps and services and operating systems like Apple’s IOS and Google’s Android request access to location data for features like mapping, navigation, and personalized recommendations (Cohen, 2022). These apps collect and use the location data to provide tailored experiences to users, after which this data gets sent into the “secondary market,” which will be explained further in the next paragraph (Boshell, 2019). In addition, many social media platforms and online services collect location data when users voluntarily share their whereabouts in posts, check-ins, or by enabling location-sharing features, making the process of location data collection even easier for technology companies (Tsai et al., 2009). Contributing to this as well is the increase in digital activity driven by the increase in smartphone usage, as pointed out by Ahmed (2020).

### 3.1.3 Platforms and applications as location data generators

The main sources of location data collected by technology companies nowadays are platforms and apps, as highlighted by Boshell (2019). The fact that almost every single person nowadays carries a smartphone with them is the primary driver of this, as individuals can now be tracked everywhere after giving consent to the OS or app provider, often unconsciously (Boshell, 2019). With 85% of Americans carrying a smartphone in 2021, according to research by Pew, this is the best source of location data (“Mobile Fact Sheet,” 2023). For apps, this works as follows. An individual downloads an app for navigation, but in order to use this app, the user has to give consent to the app to track his location (Boshell, 2019). The smartphone hardware and app software then allow the app to follow the individual's location and guide this person in the right direction by using the techniques explained earlier (Boshell, 2019).

But, according to Boshell (2019), these apps also regularly send real-time locations of their users to third-party data companies, which can then use this data to make conclusions and predictions about the tracked individual. This is called the secondary market for location data, whereas the service offered to the tracked individual is the initial market (Boshell, 2019). This secondary market involves leveraging location data to generate revenue through means unrelated to its original intent, according to Boshell (2019). This may include facilitating the creation of a comprehensive individual profile, which can then be sold to interested parties for access. Most of the time, this profiling is done for the purpose

of targeted advertising of which examples were given earlier in this research report (Martin & Nissenbaum, 2019)

Operating systems like Apple’s IOS and Google’s Android are doing a similar thing. When you boot up a new smartphone, this one asks you to agree with the general terms of the company behind the brand. Within these terms, you also allow the OS to track your location (Sharma, 2022). Google, for example, explains on its website that it uses user location data to support its services, collecting it on Android devices that use the Google Location Services technology (Google, n.d.). On its website, Google states that it “uses your location for making sure your search results include things near you, to showing you when a restaurant is typically busy,” which indicates that Google saves and uses data from its users to predict when a location is busy and when not (Google, n.d.).

Considering everything discussed so far, it is no surprise that Google is the leading company in location data collection and targeted advertising, as also highlighted in Figure 8 (Sharma, 2022). Through Android and Google Location Services technology, it is able to track every single Android smartphone from the moment a user agrees to its terms (Google, n.d.). In addition, Google also owns the largest search engine on the planet through which it tracks locations based on search queries and IP addresses (Gaubys, n.d.).

Social Media is another very well-known primary source for data privacy breaches as the amount of data people release about themselves on these media platforms is “incredible” and holds meaningful value for technology companies and governments alike (Loebel, 2012). Technology leaders in the social media space allow users to enrich their posts with GPS coordinates in a way of sharing their whereabouts with their friends and family (Loebel, 2012). Over the years, we have seen this way of voluntary location sharing increase in popularity across social media. Therefore, 82% of all digital data generated in 2017 contained some sort of geotagging (Newgrove, 2017).

And it is social media in particular that relies heavily on geotagging (Ajayakumar & Ghazinour, 2017). For example, a location is generated every time a status is updated or a post is placed (Loebel, 2012). To put this into perspective, the Instagram platform registers 95 million photos and videos posted daily (Flynn, 2023). This means that parent company Meta receives 95 million voluntary locational pings daily, creating free info for Meta for which no permission needs to be asked as the user agreed with

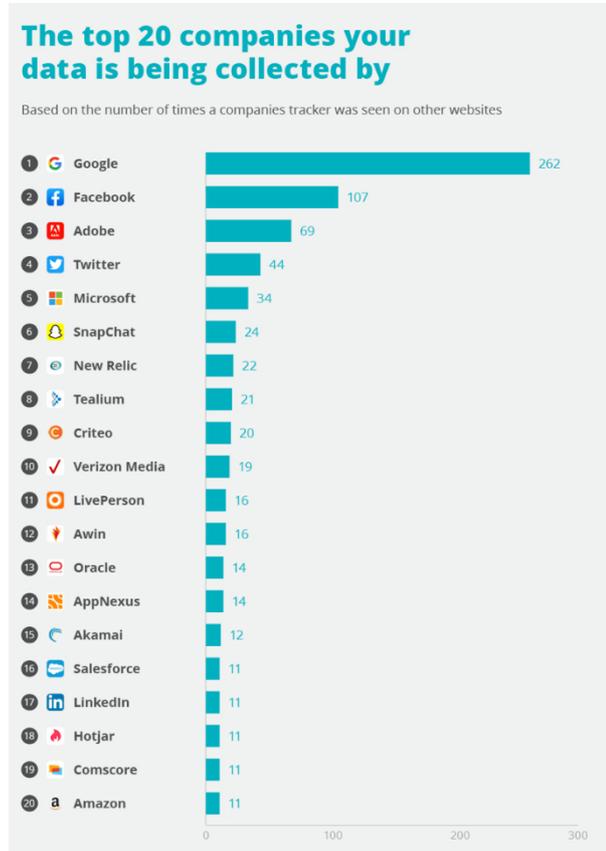


Figure 8 The leading technology companies in user data collection (Price, 2021)

the terms of the application (Ajayakumar & Ghazinour, 2017). And Meta is not hiding the fact that it uses the location of your post, as Figure 9 shows how users of Instagram can search for a location and see all the pictures posted in this location by all public users.

Overall, the increasing digital activity, high smartphone penetration, and increasing activity on social media platforms cause an increase in location data generation for which the collector often does not even need to ask permission (Boshell, 2019). Using this information and research, the following paragraphs will attempt to discover how these techniques and platforms can be complemented and improved by using new and advanced technologies like AI and IoT devices but also discover the downsides and privacy implications of using these technologies.

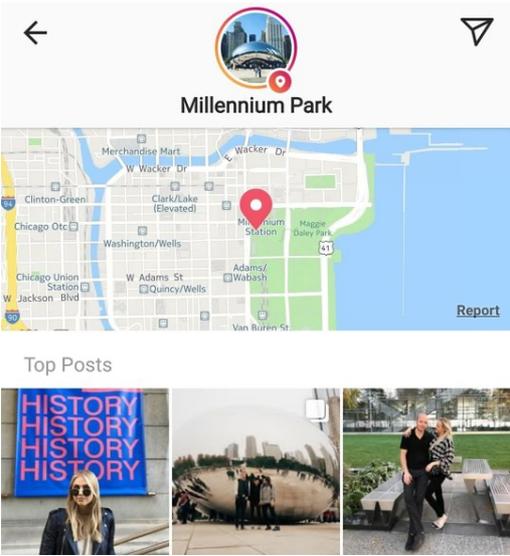


Figure 9 Instagram posts location tagging (Flynn, 2023)

### 3.2 How AI and IoT fit into the process of location data

#### 3.2.1 Artificial Intelligence (AI) or Machine Learning (ML)

Manheim & Kaplan (2018) see AI as the most disruptive technology of the modern era, powering new developments like the Internet of Things and big data analytics. Research by Ergen (2019) points to this being driven by the sheer amount of data available today to train machine learning (ML) algorithms. Ergen (2019) continues by explaining that ML algorithms are statistical tools used to identify patterns in large amounts of data, which are then used to make predictions. Manheim & Kaplan (2018) believe the general improvement in computing power has allowed AI and ML to rapidly develop, now showing capabilities beyond humans in areas like pattern recognition, data processing, voice/image/text recognition, and content recommendation.

Despite this rapid development, ML is still an unknown term for most people (Atscke, 2022). Machine learning is often used under the banner of AI as an overarching term (Atscke, 2022). This is not a wrong approach, though, as machine learning, in reality, is a more advanced form of AI that depends less on human programming as the algorithm has the ability to use data to learn (Manheim & Kaplan, 2018). In contrast, basic AI needs to be programmed by humans, as indicated by Manheim and Kaplan (2018). Therefore, ML is often referred to as advanced AI. The relationship between the technologies and terms is visualized in Figure 10.

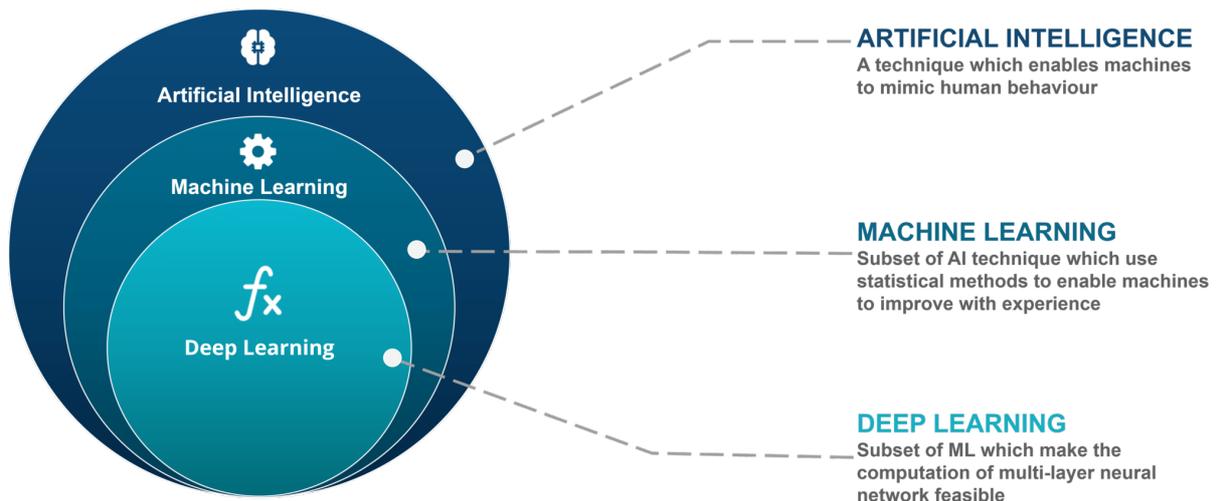


Figure 10 The relationship and differences between AI and ML (Atul, 2023)

According to research by Manheim and Kaplan (2018), the power of advanced AI lies in its ability to crunch data, deliver insight from it, and learn from it for improved future performance. They then describe this as the goal of AI being to “filter the noise, find meaning, and act upon it, ultimately with greater precision and better outcomes than humans can achieve on their own.” Therefore, using advanced AI in daily or business processes can achieve greater milestones and results as advanced AI allows for complete automation and better data analytics capabilities (AI Business, 2022).

As a result of these qualities, Manheim and Kaplan (2018) believe advanced AI is well-equipped to improve data insights by using a process known as “data fusion,” which merges, organizes, and correlates large data sets that only provide little insight on their own. After executing this process, third parties can use the improved data to create sophisticated profiles of their data subjects (Manheim & Kaplan, 2018). AI has been the engine behind this process for many years already, so the use of AI on this front in itself is nothing new (Manheim & Kaplan, 2018). What is more groundbreaking is the use of advanced AI to improve data fusion capabilities beyond human programming abilities as the algorithms are able to improve their skills over time and learn from the data (Manheim & Kaplan, 2018). Ergen (2019) builds on this by pointing out that advanced AI can then also be used to make predictions based on patterns, increasing data value to third parties.

Wang et al. (2020) point to data optimization as another way in which AI can play a role in location data. According to their research, AI algorithms can refine location data by correcting inaccuracies caused by factors like signal interference or multi-path reflections in GPS (Wang et al., 2020). Also, advanced AI can leverage other location-tracking techniques like Wi-Fi or Bluetooth tracking in real-time in locations where the GPS signal is insufficient. These indoor localization techniques allow for accurate and reliable location tracking within buildings where GPS signals are often weak or unavailable, according to Naser et al. (2023). By using advanced AI in these instances, location data becomes more precise while not requiring human interference as advanced AI techniques can analyze historical data patterns to improve accuracy and provide more precise location information, as shown by research from Li and Hsu (2022).

Besides the ability to process massive datasets in a matter of seconds and the complete automation of advanced AI, its ability for image, voice, and text recognition can also be applied in various ways for location data (Youhui, 2020). Over the last decade, the boom in smartphone usage has led to an explosion in social media activity, bringing a meaningful increase in image information (Y. Li & Xie, 2020). Research by Youhui (2020) shows that image information can hold meaningful data for all sorts of purposes and location information is one of those.

How social media can be used to acquire location information through geotagging has already been discussed previously in this report. Still, for those images that do not hold a geographical component, the picture itself can release information about the location, for example, by looking at the background (Youhui, 2020). Yet, in the past, it was impossible to retrieve or process the information expressed in the pictures on a large scale as talked about by Youhui (2020). Today though, advanced AI can be trained to recognize image content and patterns and gather location data from just an image (Manheim & Kaplan, 2018).

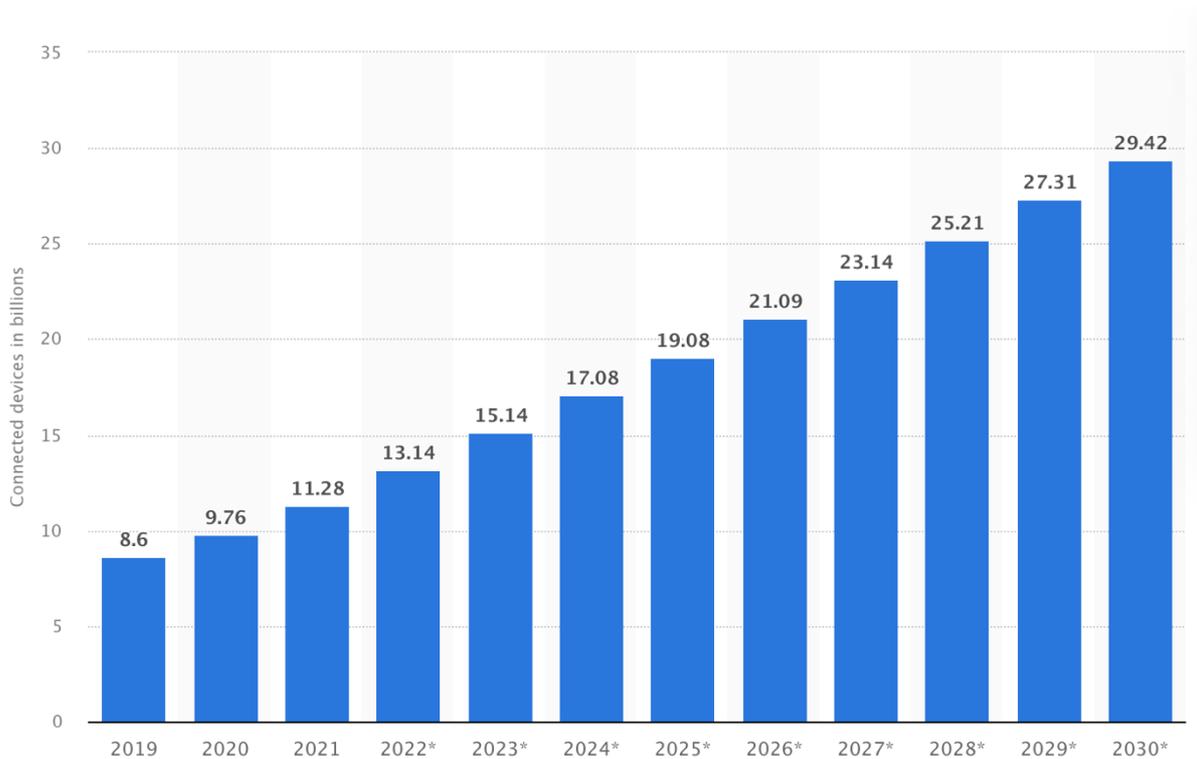
These same advanced AI algorithms can recognize and process text using Natural Language Processing (NLP) technologies that enable AI to communicate more conveniently with humans (Lutkevich & Burns, 2023). The best-advanced examples of this are Amazon's Alexa and smartphone assistants, including Siri and Google Assistant (Ai.nl, 2022). The rapid development in this field allows technology companies to use NLP technologies for text classification and improved data analysis (Juhn & Liu, 2020). Through this, the AI can scan through all sorts of texts like messages, social media posts, and other text sources to, for example, collect location information (Ai.nl, 2022). Yet, the most reliable and useful location data is still transmitted by personal devices and IoT technologies can play a crucial role in this. Therefore, the abilities of IoT technologies and the role of IoT devices in location data will be discussed next.

### 3.2.2 The Internet of Things

Martin and Nissenbaum (2019) rightfully point out that nowadays location tracking is not just limited to an individual's mobile phone, applications, and social media. Today, most people carry multiple smart devices, like fitness trackers and smartwatches. These devices collect all sorts of information about the user, like health data measured by the device, incoming messages, and location data (Martin & Nissenbaum, 2019). These devices get access to your location by connecting them with your phone and granting them permission (Martin & Nissenbaum, 2019). Simply put, IoT technology makes location data continuously available, particularly as sensors and smart tags can track an individual's movements and habits on a perpetual basis, as shown by research from Maras (2015)

All these new and connected devices, like the above-mentioned smartwatch and fitness tracker, are part of the IoT network. With the penetration of these devices increasing, the Internet of Things is doing so as well, offering a massive source of new data for technology companies, as pointed out by Perera et al. (2015). Manheim and Kaplan (2018) refer to IoT as the human body collecting the sensor information while AI is the human brain processing and analyzing the information, forming a location-tracking body. IoT devices constantly collect raw data on the physical actions carried out by individuals and the communication they have with others (Manheim & Kaplan, 2018). Minch (2015) gives an example of this in relation to location data as he points out that Apple's iOS and HomeKit can "take advantage of geofencing to set a thermostat to "home" mode when a homeowner is within a certain perimeter of the home, and "away" when outside that perimeter."

With the number of active IoT devices expected to keep growing significantly, as shown in Figure 11, the amount of data generated by these devices will also be meaningful. This is why Perera et al. (2015) believe that in the IoT era, the amount of data collected by technology companies will be higher than we have seen in the past, allowing them to create more detailed profiles on each individual with a higher value to third parties. Research by Perera et al. (2015) also shows that the data coming from IoT devices is more contextually enriched information as these wearable technologies "can collect sensitive information about users ranging from their health conditions to financial status by observing or recording their daily activities." Maras (2015) confirms this by stating that "these data can easily be used to provide real-time information about a person, his/her health and finances, locations, contacts, habits, behaviors, and activities."



**Figure 11** The number of IoT connected devices worldwide, with forecasts from 2022 to 2030. (Statista, 2022)

Contributing to the large number of data generated by IoT devices is the fact that connected devices continuously emit identifying information through which the location of these can be tracked (Gray, 2020). According to research by Abdur et al. (2017), these digital devices “can effectively communicate with each other using Internet Protocol (IP) addresses.” This includes mobile phones, fitness trackers, and vehicles. Most of the time, the signals transmitted by these devices are used in a privacy-friendly way, like supermarkets which track these signals to understand when their busiest hours are (Abdur et al., 2017). According to Elkhodr et al. (2012), this should be seen as the interconnected network of everyday objects that communicate with backend systems to seek out patterns that can help businesses better serve their customers. Yet, as a result of this data collection, IoT devices create an environment where individuals are constantly monitored and analyzed (Elkhodr et al., 2012). And given the vast quantities of information being talked about here, detailed profiles of the private lives of millions of users of these devices can be created (Gray, 2020). To put this into perspective, the Apple Watch alone already has over 100 million active users, creating 100 million additional sources of enriched data information (B, 2022).

Whereas IoT and AI can have a meaningful impact on different processes as discussed above, the integration of these technologies and systems into different location data processes also brings with them privacy implications. The next section of the research report will get into these possible privacy implications.

### 3.2.3 Privacy implications that come with the use of AI and IoT technologies

In the past, the significance of location privacy was relatively limited since location information was not extensively and consistently accessible (Minch, 2015). However, with the significant advancements in technology, the availability of information has undergone a radical transformation (Minch, 2015). Consequently, location data privacy has become closely intertwined with the ability to regulate access to this information, with individuals expressing a strong desire to control its availability, according to research by Maras (2015). This is particularly evident as sensors and smart tags have the capability to



And while these datasets individually may only provide limited insight, AI can then be used to merge these datasets and create more useful data for third parties (Manheim & Kaplan, 2018). In their research, Manheim and Kaplan (2018) make the case that AI can process vast amounts of data with the potential to undermine privacy in many forms. Elkhodr et al. (2012) give the example of an individual visiting a medical clinic regularly, which could indicate illness or regular visits to activist organizations that could hint at a political opinion. Both of these are incredibly sensitive but could be derived from just location data. The role of AI in this has been shown in previous paragraphs of this report, where it was discussed how AI could be used to improve data insights by using a process known as “data fusion” or the cross-correlation of data, which has the ability to de-anonymize data by using multiple different sets of data and connecting the dots in a way that humans are unable to (Manheim & Kaplan, 2018). Manheim and Kaplan (2018) describe this ability of advanced AI as it being “great at re-identifying (or de-identified) data by extracting relationships from seemingly unrelated data.”

Third parties can then use this improved data to create “sophisticated profiles of their data subjects,” according to Manheim and Kaplan (2018). The engine behind these insights is advanced AI, whereas IoT technologies are boosting the collection of data, together enabling predictive decision-making based on consumers’ financial, demographic, ethnic, racial, health, social, and location data, as shown by research from Manheim and Kaplan (2018). They continue by saying that this raises concerns about potential manipulation, discrimination, or invasive marketing practices.

On another note, research by Boshell (2019) showed that the technical progress being made today on the front of both IoT devices and AI is causing lines to blur between “identified and identifiable, and identifiable and not identified or anonymized,” which results in a complicated situation for regulators. Simply put, regulators have trouble keeping up with technological progress being made on the front of these technologies that offer new ways of data collection and analysis, which blurs the lines between identifiable and anonymous data (Boshell, 2019).

An example of this, which was discussed earlier in this report, but fits this issue perfectly, was the one from Martin and Nissenbaum (2019), who discussed how an app called “Accuweather” bypassed regulation and user approval by being clever with its terms. When users choose not to be tracked, this app would disable the GPS but use other technologies to track the user anyways. The app would ask for access to the Bluetooth and Wi-Fi network in its general terms of use and, through this, was still able to track users who opted out of location tracking, illustrating how companies always try to find new ways to bypass regulations using new technologies.

Another privacy issue with regard to AI technologies and data analysis is the training of advanced AI or machine learning models. These are often trained with datasets containing sensitive information, as shown by research from Manheim and Kaplan (2018). Zhang et al. (2020) confirm this theory by explaining that advanced AI algorithms often contain sensitive personal information, giving these models high commercial value. In addition, these training models most of the time, do not have similar cybersecurity protection compared to operational AI algorithms, which opens up the opportunity for malicious users to recover the data used to train the models, which creates serious information leakage potential, according to research by De Cristofaro (2020).

On top of this, flaws in the data can also create unfair biases that can insult entire racial groups as they might be offered the wrong personalized advertisements or product recommendations (Myers, 2021). According to research by Elkhodr et al. (2012), “literature shows that if an effective public record of people’s locations is created through automation, discriminations based on race and religions, for example, are most likely to occur.” As a result, advanced AI algorithms trained on historical data are highly likely to reflect existing biases present in society, as shown in Figure 13 (Smith, 2020). This makes AI models highly sensitive to amplifying those biases, which can lead to skewed results and reinforce existing inequalities, especially when used for targeted advertising (Elkhodr et al., 2012). An example

of how AI can mimic existing human biases is the Islamophobia problem of the GPT-3 AI language model on which ChatGPT is built (Myers, 2021). Through the historical data with which this AI was trained, it adopted the human bias which connects the Islam religion to violence. As a result, research by Stanford University showed that 66% of all prompts that mentioned Muslims received a response regarding violence (Myers, 2021).

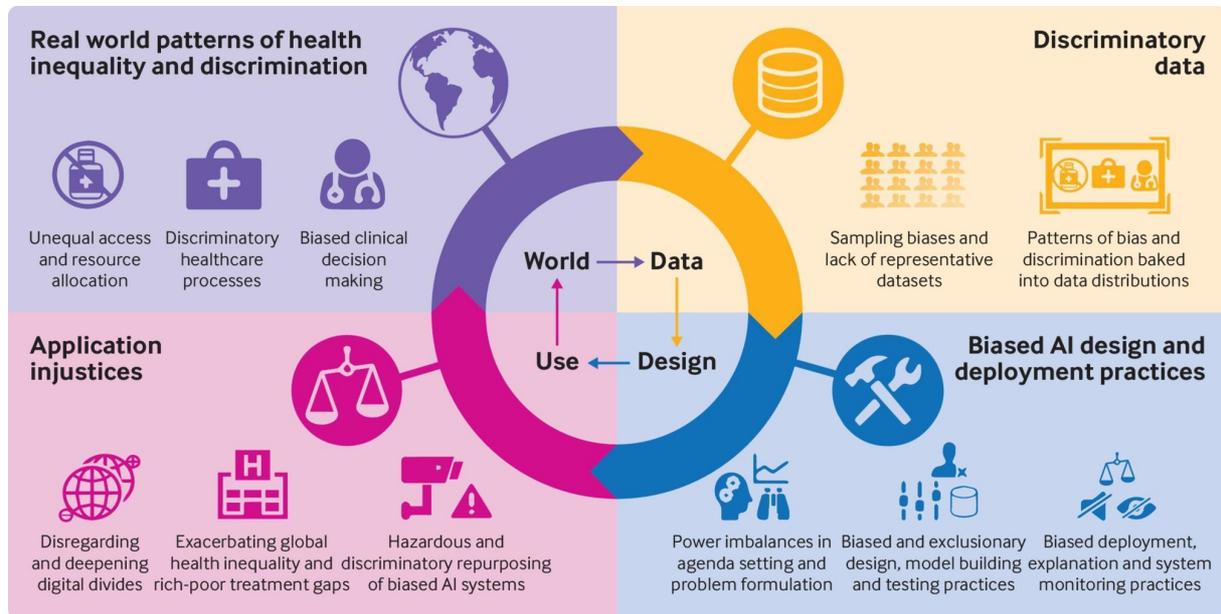


Figure 13 A visualization and examples of AI discrimination and biases risks (Dilmegani, 2022)

In conclusion, IoT technologies and advanced AI seem to have a number of qualities or abilities that could prove useful when integrated into location data collection and analysis. Yet, with the integration of these technologies into these processes also emerge serious privacy implications for the user to which the data belongs. Furthermore, with these technologies developing rapidly and these getting accessible to the general public like we have seen with ChatGPT for example, privacy risks will most likely increase (Van Rijmenam, 2023). Following the results presented so far in this chapter, the next part will lay out the results of the performed trial in order to determine the capabilities of publicly available AI when combined with location data.

### 3.3 The abilities of public AI in location data analysis

The results discussed below are collected with the goal of discovering what insights can be obtained from an individual's location data by utilizing publicly available AI. To achieve the results, a trial was set up with a group of 15 individuals including people from all racial backgrounds, ages, and occupational backgrounds to create a diverse user base. Please note that as a result of technical issues, only the data of 9 individuals were used as these technical issues caused some invalid or lost data, and some data was too little to create a profile. This was already expected prior to the research execution and therefore caused no further issues. Furthermore, six of these will be presented in this chapter, whereas the other three can be found in the attachments (attachment 2) at the end of this report.

The collected data, visualized in Figure 14 was placed into two different AI language models (ChatGPT and Perplexity AI) and the AI was then asked to create a detailed profile of the individual using the location data, to write a personality assessment, and come up with targeted advertising suggestions. The following input question was used in the AI system:

“Can you sketch a detailed profile by using the given visited locations of an individual? Focus on gender, age, home location, work location, hobbies, school, preferred form of transport, and other possible conclusions that can be derived from the data. Please also include a personality estimate and targeted advertising suggestions. This is the data:”

The further details and design of this trial were laid out in a previous chapter and will be discussed in the discussion again. In addition, to ensure optimal privacy for the participants, the collected data and the direct AI output cannot be displayed in this report. Therefore, only the AI results built on the data will be included in the results after personal information had been filtered out. This is also why no further data visualizations or images can be used apart from Figure 14. The rest of this paragraph will now discuss the trial results per individual, based on the collected data and AI input question, in which the privacy-corrected information will be highlighted in red, while still representing the AI answer. All other text is unedited and originates from the AI language models. Results will be presented in the following order for each participant:

1. Profile sketch
2. Personality estimate
3. Targeted advertising suggestions
4. The participant review of the AI results

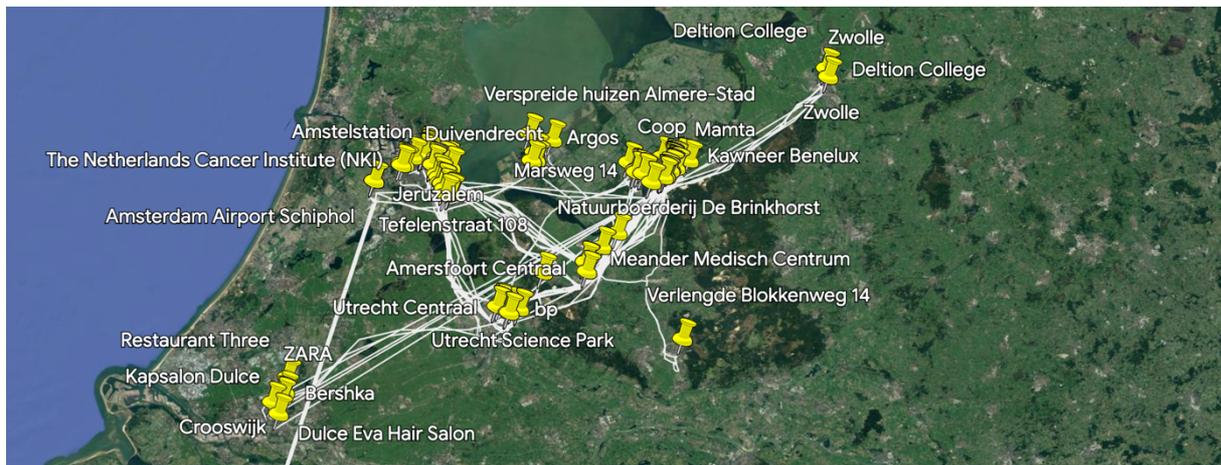


Figure 14 The complete dataset of all participants visualized in Google Earth

### 3.3.1 Trial results

#### Participant 1

##### AI profile results:

- **Gender:** Female
- **Age:** Some assumptions can be made based on typical patterns. Given their visits to a school, it is reasonable to assume that the individual is likely to be a student, possibly in their teenage years or early adulthood.
- **Home Location:** AI was able to pinpoint the exact home address, meaning it was able to identify an exact street name and house number from the data.
- **School:** The participant's school name was correctly identified from the data
- **Preferred Form of Transport:** The individual's preferred forms of transport include cycling, driving, and taking the train.

#### Additional Observations:

- The individual seems to be physically active, as they visited a playground and engaged in walking multiple times.
- They have a preference for fast food, as indicated by their visits to McDonald's.
- The individual visited the Kok Experience in Harderwijk, suggesting an interest in recreational activities or entertainment.

#### Personality estimate:

1. **Outgoing and Social:** The individual's visits to community parks, playgrounds, and local events suggest a social and outgoing nature. They may enjoy interacting with others and participating in community activities.
2. **Family-Oriented:** The visits to family-friendly locations like the playground and the local school indicate a focus on family and potentially having children.
3. **Active and Health-Conscious:** The individual's engagement in cycling and walking, as well as visits to fitness centers and wellness resorts, suggests a preference for an active and health-conscious lifestyle.

#### AI-targeted advertising suggestions based on this profile:

1. **Local Advertising:** Since the individual's home location is in **\*location\***, local advertising campaigns targeting that specific area could be effective. This could include advertisements in local newspapers, community notice boards, or targeted online advertising specific to the region.
2. **Student-Focused Offers:** As the individual is a student, advertising promotions or discounts targeting students could be effective. This could involve partnerships with local businesses offering student discounts or special offers on products and services relevant to students' needs and interests.
3. **Active Lifestyle and Recreation:** Considering the individual's visits to a playground and their engagement in cycling and walking, advertising campaigns that promote an active lifestyle and outdoor activities could resonate with their interests. This could include advertisements for sports equipment, outdoor gear, or local events related to cycling, walking, or other recreational activities.
4. **Fast Food and Dining Offers:** Given the individual's visits to McDonald's, targeted advertising for fast food or dining options in the **\*location\*** area could be effective. This could include promoting special deals, new menu items, or local restaurants that align with their fast-food preferences.
5. **Travel and Hospitality:** Considering the individual's visits to Hotel Casa Amsterdam and trips to Amsterdam, targeted advertising for travel services, accommodation options, or tourist attractions in Amsterdam could be relevant. This could involve advertisements for hotel bookings, city tours, or transportation services catering to individuals traveling to Amsterdam.

#### Participant review:

"The AI results are surprisingly accurate as the profile was spot on. I am indeed a female in my teenage years (13). Also, my personality estimate sounded very much like me, although I am not very active apart from my daily commute. This was possibly influenced by the fact that I have to cycle to school every day. The targeted advertising suggestions are roughly what I see on social media every day and seem like a good match with reality." *Participant 1*

## Participant 2

### AI profile results:

- **Gender:** The provided information does not explicitly indicate the gender of the individual. Therefore, we cannot determine the gender based solely on the visited locations.
- **Age:** It is reasonable to speculate that the individual could be in their late teens to early thirties.
- **Home Location:** AI was able to pinpoint the exact home address, meaning it was able to identify an exact street name and house number from the data.
- **Work Location:** AI was able to correctly conclude a work location from the data by naming the correct employer.
- **Hobbies:** They frequently cycled and walked, suggesting an interest in outdoor activities and exercise. The visits to restaurants and bars imply a preference for socializing or enjoying meals at local establishments. The visit to "Estadio Mestalla" suggests an interest in sports, particularly football.
- **School:** The individual visited *\*school\** indicating that they may be a student or have some affiliation with the college.
- **Preferred Form of Transport:** The individual frequently drives and walks. They also used a bicycle, indicating a preference for cycling as a mode of transport. The mention of a boat suggests the occasional use of water transport.
- **Other Locations:** The individual has made multiple trips to Amsterdam Airport Schiphol and Airport Valencia, indicating a tendency to travel by air. The visit to "McDonald's" suggests a preference for fast food. The mention of "Casa Mon" and "Sweet Hotel Renasa" indicates visits to Valencia, Spain, potentially for leisure or tourism purposes. The visit to "Place de la verge" suggests an interest in historical or cultural sites.

### Personality estimate:

1. **Active and Outgoing:** The individual's frequent visits to various locations, such as cycling, walking, visiting city centers, bars, and restaurants, suggest an active and outgoing nature. They seem to enjoy engaging in physical activities, socializing, and exploring different environments.
2. **Adventurous:** The visits to multiple airports, flying, and the mention of a boat trip indicate a sense of adventure and a willingness to travel. This suggests a certain level of openness to new experiences and a desire for exploration.
3. **Sociable:** The visits to bars, restaurants, and the mention of social establishments imply a social inclination. The individual may enjoy spending time with friends, meeting new people, and engaging in social activities.
4. **Sports Enthusiast:** The visit to "Estadio Mestalla" suggests an interest in sports, particularly football. This implies a potential passion for sports and possibly enjoyment of the team atmosphere.

### AI-targeted advertising suggestions based on this profile:

1. **Outdoor Activities and Sports Gear:** Since the individual frequently cycles and walks, it suggests an interest in outdoor activities. Targeted advertising could focus on promoting sports gear, bicycles, fitness accessories, and outdoor adventure equipment.
2. **Local Establishments and Dining:** The individual visited restaurants and bars multiple times, indicating an affinity for local establishments and dining experiences. Targeted advertising could highlight promotions, special offers, or new menu items at local restaurants, bars, or cafes in the *\*location\** area.
3. **Travel and Leisure:** The visits to Amsterdam Airport Schiphol and Valencia Airport, as well as the mentions of "Casa Mon," "Sweet hotel Renasa," and "Estadio Mestalla," suggest an interest in travel and leisure. Targeted advertising could focus on travel deals, flight promotions, vacation packages, and accommodations in popular travel destinations.

4. **Fast Food and Quick Service Restaurants:** The mention of "McDonald's" indicates a visit to a fast-food restaurant. Targeted advertising could feature offers, new menu items, or loyalty programs from fast-food chains and quick-service restaurants in the individual's vicinity.
5. **Cultural and Historical Sites:** The visit to "Place de la verge" implies an interest in cultural and historical sites. Targeted advertising could promote local museums, historical landmarks, guided tours, or cultural events in the region.

**Participant review:**

"There are some correct and incorrect results to be found in the AI results. For example, it was roughly correct on age, work and home location, and school. Yet, while football is a hobby of mine, I am not especially social or a fan of going out for dinner. This could be influenced by a visit to Valencia, Spain. The personality estimate is showing similar mistakes as, apart from a sports enthusiast, the other personality points are incorrect. Also, the targeted advertising suggestions do not match with my personality." *Participant 2*

*Participant 3:*

**AI profile results:**

- **Gender:** Male
- **Age:** Assumed to be a young adult in the early to mid-20s.
- **Home Location:** AI was able to pinpoint the exact home address, meaning it was able to identify an exact street name and house number from the data.
- **Preferred Form of Transport:** Driving seems to be the preferred mode of transport, as indicated by the frequent visits to the home location and the driving occurrences.
- **Work/Study Location:** The specific work or study location is not mentioned in the provided data. The individual is possibly unemployed.
- **Hobbies and Interests:** While specific hobbies are not explicitly mentioned, the individual has visited a hair salon and a cinema, suggesting an interest in personal grooming and recreational activities.
- **Shopping Preferences:** The individual has made multiple visits to De Bijenkort in Utrecht, indicating a preference for shopping at this department store.
- **Travel:** The individual frequently visits train stations, indicating regular travel by train. The visit to World Trade Center Rotterdam suggests potential business-related travel.
- **Dining:** The individual has visited Restaurants, indicating an interest in dining out or trying new restaurants.
- **Socializing and Entertainment:** The visits to Crooswijk, Kok Experience Harderwijk, and the various train stations suggest an inclination towards socializing, exploring different locations, and engaging in recreational activities.

**Personality estimate:**

1. **Adventurous and Social:** The visits to different recreational venues, restaurants, and bars indicate a desire for new experiences and socializing with friends.
2. **Independent and Goal-Oriented:** The preference for driving as the primary mode of transportation suggests independence and self-reliance. The individual may have a focus on personal goals and achieving them.
3. **Fashion-Conscious:** The visits to hair salons and various clothing stores indicate an interest in personal style and grooming, suggesting a fashion-conscious personality.

### AI-targeted advertising suggestions based on this profile:

1. **Automotive-related Ads:** Since driving is the preferred mode of transport, targeted advertising for automotive products, services, or accessories could be effective. This might include promotions for car dealerships, car accessories, auto maintenance services, or even advertising campaigns for specific car models aimed at young adults.
2. **Personal Grooming and Beauty:** The visit to a hairdresser suggests an interest in personal grooming. Advertising campaigns for barbershops, hair salons, grooming products, or skincare routines targeting young men could resonate with the assumed profile.
3. **Recreational Activities:** Given the visit to Kok Experience Harderwijk, targeted advertising for recreational activities, amusement parks, escape rooms, or entertainment venues could be relevant. Promoting discounted offers, group packages, or new attractions may appeal to the assumed interests of the individual.
4. **Fashion and Shopping:** The multiple visits to De Bijenkort in Utrecht indicate a preference for shopping at this department store. Advertising campaigns that highlight fashion trends, clothing discounts, or special promotions in the Utrecht area might attract the attention of the assumed profile.
5. **Travel and Dining:** With frequent visits to various train stations and a visit to Restaurants, advertising campaigns for travel services, restaurant deals, or food delivery services could be effective. Promoting travel packages, train discounts, or local dining options in the assumed profile's areas of interest could generate engagement.
6. **Social Media Engagement:** Given the assumed age group, targeting advertising efforts through social media platforms such as Instagram, Snapchat, or TikTok could be effective. Utilizing influencer marketing or engaging content that aligns with the profile's assumed interests may help drive brand engagement and awareness.

### Participant review:

"The first thing that jumps out to me is the fact that it is completely wrong for both gender and age as I am a woman in my fifties. At the same time, on transport, work, and hobbies it is entirely correct. The targeted advertising suggestions are a great match for my personality. Overall, I find the AI surprisingly correct." *Participant 3*

### Participant 4

#### AI profile results:

- **Gender:** Assuming no specific indications, it is difficult to determine the individual's gender.
- **Age:** Young adult to adult (early to mid-20s to early 30s)
- **Home Location:** AI was able to pinpoint the exact home address, meaning it was able to identify an exact street name and house number from the data.
- **Preferred Form of Transport:** The individual utilizes various modes of transportation, including walking, driving, bus, subway, and train, depending on the context and location.
- **School:** The participant's school was correctly identified from the data.
- **Hobbies and Interests:** The individual visits a variety of places, including restaurants, cafes, bars, a cinema, and shopping outlets. This indicates an interest in socializing, dining out, shopping, and entertainment.
- **Fitness and Wellness:** Visits to sports centers and Wellnesresorts suggest a focus on fitness, sports, and wellness activities.

#### Additional Observations:

- The individual frequently visits Amsterdam. This indicates a strong connection to Amsterdam and potentially residing there or having regular business or personal commitments in the city.

### Personality estimate:

1. **Ambitious and Academically Inclined:** The visits to a University and a research institute suggest an individual who values education and may have an ambitious mindset towards personal and professional growth.
2. **Sociable and Enjoyable of City Life:** The frequent visits to various social venues like restaurants, cafes, bars, and entertainment locations indicate a sociable personality who enjoys the vibrant city life, dining out, and exploring different environments.
3. **Well-Rounded and Health-Conscious:** The engagement in fitness activities, visits to wellness centers, and interest in personal grooming suggest a well-rounded individual who values both physical and mental well-being.

### AI-targeted advertising suggestions based on this profile:

1. **Student-focused Offers:** Advertising promotions or discounts targeting students at the University of Amsterdam could be effective, such as student discounts, study-related products, or services catering to the student lifestyle.
2. **Fitness and Wellness Services:** Promote fitness classes, wellness retreats, gym memberships, and spa services.
3. **Transportation Services:** Advertising campaigns for public transportation services, car rentals, or bike-sharing options might appeal to the individual's varied modes of transport.
4. **Dining and Socializing:** Promote restaurant deals, happy hour specials, and events at venues visited by the individual.
5. **Local Cinema and Shopping Promotions:** Advertise movie releases, special screenings, promotions, and shopping discounts or new collections at Bershka, Zara, and other stores frequented by the individual.

### Participant review:

"The profile results are somewhat correct. I am a female in my early 20s, whereas it states that I am mid-20s to early 30s. This is surprising to me as I am still studying. Also my gender was not determined. When looking at my hobbies it concludes socializing, which is not necessarily a term I would use when talking about myself. This, however, really depends on my activities in these weeks. For instance, I've only visited the wellness center once in my life, which just happens to be that week. Therefore, some things are very accurate, whilst other points are only based upon those weeks. Nevertheless, based on only 2 weeks it has a somewhat accurate profile on me. Especially the focus on my academic mindset. The AI-targeted advertising is on point as the advertisement it mentions are also the advertisement I mostly receive." Participant 4

### Participant 5:

#### AI profile results:

- **Gender:** Unknown.
- **Age:** Assuming an adult in the 30s to 50s range.
- **Home Location:** AI was able to pinpoint the exact home address, meaning it was able to identify an exact street name and house number from the data.
- **Preferred Form of Transport:** Driving, as indicated by the high frequency of driving and visits to Shell and TotalEnergies.
- **Shopping Habits:** Multiple visits to specific locations indicates shopping preferences for bakery items, home improvement supplies, groceries, fashion, cosmetics, and more.
- **Active Lifestyle:** The visits to Harderwijk City Center, walking, cycling, and occasional boat trips suggest an active lifestyle and a preference for outdoor activities.
- **Dining Preferences:** Visits to restaurants suggest an appreciation for dining out and experiencing different culinary offerings.

### Personality Estimate:

1. **Practical and Responsible:** The high frequency of driving and visits to home improvement stores like Gamma Bouwmarkt suggests a practical and responsible nature, focused on maintaining and improving the living environment.
2. **Active and Outdoorsy:** The frequent walking, occasional cycling, and boat trips indicate an active and outdoorsy personality. The individual likely enjoys exploring their surroundings and engaging in physical activities.
3. **Appreciation for Gastronomy:** The visits to various restaurants and culinary establishments suggest an interest in experiencing diverse cuisines and appreciating the dining experience. This implies a discerning taste and a willingness to explore different culinary offerings.
4. **Value-Conscious Shopper:** The visits to supermarkets and discount stores like Vomar Voordeelmarkt and Albert Heijn indicate a preference for value-conscious shopping and seeking out deals or promotions.

### AI-targeted advertising suggestions based on this profile:

1. **Home Improvement and DIY:** Promote home improvement products, DIY tools, or services to cater to the individual's practical nature. Highlight durability, quality, and affordability to capture their attention.
2. **Outdoor Recreation and Activities:** Advertise outdoor recreational activities, such as walking tours, cycling trails, or boat trips, to appeal to their active and outdoorsy personality. Highlight scenic locations, adventure, and relaxation.
3. **Culinary Experiences and Restaurants:** Targeted advertising for local restaurants, gastronomic events, or culinary tours can capture the individual's interest. Emphasize unique dining experiences, diverse cuisines, and quality food.
4. **Grocery Store Promotions:** Advertise exclusive discounts, loyalty programs, or new product launches at supermarkets like Vomar Voordeelmarkt and Albert Heijn. Highlight convenience, affordability, and a wide range of product choices.
5. **Fashion and Cosmetics:** Promote fashion products, cosmetics, or beauty services through targeted advertising. Emphasize quality, style, and personalized recommendations to appeal to their fashion-conscious nature.

### Participant review:

"The results are close to a perfect match with my personality. It's right in all aspects as far as I can tell, and I find it highly impressive. I am indeed in my late 40s with a preference for using the car. In addition, I am indeed very outdoorsy and active. Really every single aspect is a match. Also, the targeted advertising would be suited to me. Whether this is what I would receive in reality I do not know since I do not use any form of social media. Yet, I believe these advertising suggestions could work for me."

*Participant 5*

### *Participant 6:*

#### AI profile results:

- **Gender:** Unknown.
- **Age:** Assuming an adult in the late 20s to early 40s.
- **Home Location:** AI was able to pinpoint the exact home address, meaning it was able to identify an exact street name and house number from the data.
- **Preferred Form of Transport:** Driving, as indicated by the frequency of driving.
- **Commuting Habits:** The visits to Station Harderwijk, Utrecht Central, Amstel Station, and Amsterdam Central indicate frequent use of train transportation, suggesting a need for commuting or traveling between cities.

- **Hotel Stays:** The repeated visits to Hotel Casa Amsterdam and Sweet Hotel Renasa suggest a preference for staying in hotels, possibly for business, long-term stays, or leisure purposes.
- **Shopping Preferences:** Visits to Vomar Voordeelmarkt and McDonald's indicate shopping for groceries and occasional fast-food choices.
- **Active Lifestyle:** The high frequency of walking and occasional running suggests an active lifestyle and a preference for physical exercise.

**Personality Estimate:**

1. **Independent and Adventurous:** The frequent driving, train travel, and visits to multiple cities like Utrecht, Amsterdam, and Valencia (Estadio Mestalla) suggest a sense of independence and a desire for exploring new places.
2. **Time-Conscious and Efficient:** The use of train transportation for commuting suggests a preference for efficient travel methods to manage time effectively.
3. **Health-Conscious:** The high frequency of walking, occasional running, and visits to subway restaurants indicate a focus on health-conscious choices and maintaining an active lifestyle.
4. **Convenience-Oriented:** The visits to McDonald's and Vomar Voordeelmarkt suggest a preference for convenience and practicality in daily routines.

**AI-targeted advertising suggestions based on this profile:**

1. **Hotel and Travel Offers:** Advertising promotions, discounts, or loyalty programs for hotels and travel services could target the individual's frequent hotel stays. Highlighting convenience, comfort, and unique experiences may be appealing.
2. **Commuter Services and Travel Apps:** Targeted advertising for travel apps, public transportation services, or commuter solutions could focus on simplifying the individual's train travel experience. Emphasize features like real-time updates, ticket booking, and travel planning tools.
3. **Fitness and Sports Products:** Targeted advertising for fitness apparel, running shoes, or sports accessories could appeal to the individual's active lifestyle. Highlight quality, performance, and the benefits of staying fit.
4. **Healthy Food Options:** Promote healthy food choices, including fresh ingredients, pre-made salads, or nutritious meal options, that align with the individual's health-conscious preferences. Emphasize convenience, taste, and nutritional value.
5. **Convenience Stores and Quick Meals:** Targeted advertising for convenience stores or quick meal options could focus on offering practical solutions for the individual's busy lifestyle. Promote ready-to-eat meals, grab-and-go snacks, or exclusive deals.

**Participant review:**

“The results are largely correct. Driving is indeed my preferred way of transport and commute a lot between cities. Though I rarely stay at a hotel, it just happened to be twice this week. The personality estimate and targeted advertising are very much in line with what I am seeing in reality and look very good. Remarkable that it has been able to generate these results from only a single week of data.”

*Participant 6*

## 4. Discussion

This research aims to explore the utilization of AI and IoT technologies across the various processes of location data and their implications on an individual's location privacy. By gaining insight into the impact of these technologies, users, regulators, and developers can work towards establishing a more robust regulatory framework. This deeper understanding can influence the behavior of internet and service users, as well as encourage developers, technology companies, and governments to prioritize safety measures and enact new laws and regulations.

Following the research results laid out in the previous chapter, this chapter will discuss the chosen approach and the most important research results. First, this chapter will shortly summarize the most important takeaways from the previous chapter, followed by a critical discussion of the chosen approach and the difficulties of the chosen methods. These aspects will be discussed for each of the sub-questions.

### 4.1 What Are the Current Methods and Technologies Used for Location Data?

#### 4.1.1 The most important research results takeaways

The research results show a broad and diverse collection of technologies technology companies leverage to collect and analyze location information. These include GPS, Bluetooth, Wi-Fi, and IP addresses. Each of these technologies has its own up and downsides, which will be shortly discussed below.

- GPS is the most used tracking method and has great accessibility due to the fact that most mobile devices are equipped with GPS tracking hardware. Yet, GPS signals get useless when the individual is indoors or out of satellite range. Also, GPS has to be turned off when the user chooses to opt out of location tracking functionality.
- IP addresses can be used to track users through their internet activity, but these signals are not very precise and are less useful when the user is on a cellular network.
- Bluetooth and Wi-Fi tracking are great alternatives to the above-mentioned most-used technologies as these scan for nearby Wi-Fi signals and Bluetooth beacons, making these very useful in urban areas. Also, these do not fall under the permission of location tracking functionality as these fall under the general terms of use. At the same time, the data collected through these technologies tends to be less precise than GPS data and is dependent on nearby Wi-Fi and Bluetooth networks, limiting the use potential in rural areas.

Most of the time, technology companies leverage multiple of these tracking technologies to gather the most precise and real-time data. Also, using multiple of these technologies allow for location tracking even when users answered "no" to location tracking, as this forces the application to only disable one of the tracking technologies, allowing them to bypass regulatory permission.

In addition to the above-mentioned techniques used for location tracking and data collection, mobile phone operating systems and applications like social media are becoming more popular as a source of location data due to the easy accessibility of the data. Users are likely to give permission to their mobile phone's operating system or important applications for all tracking methods. In addition, many social media platforms and online services collect location data when users voluntarily share their whereabouts in posts, check-ins, or by enabling location-sharing features. This happens as every time a status is updated or a post is placed, a location tag is generated, producing a large amount of data for application developers like Meta and Google.

#### 4.1.2 Discussing the research results

The research results presented above match with the expectation previous to conducting the literature research, based on the findings in the introduction and theoretical framework as the results indicate targeted advertising and commercial benefits as primary drivers of technological progress and location data collection. Results confirmed that commercial interest and the value of the data are worth more than user privacy to these technology companies, which is in line with the general public's perception when discussing the data privacy offered by these technology companies as this is a much-discussed subject. Results show that this is no different for location data privacy.

Also, the use of generally well-known technologies for digital mapping and tracking technologies in location data collection like IP addresses and GPS matches previous expectations. This does not come as a surprise as these technologies are well-known in the use of digital location services. Finally, the importance of applications and social media, of which privacy implications were introduced in the introduction of this report, was reflected in the research results as important contributors to location data collection practices, matching previous expectations. The largest surprises in these results were the impressive tracking accuracy and tracking recurrence as these showed that a remarkable amount of precise location data is collected on most smartphone users, even more than anticipated, further contributing to location privacy worries. The primary reason for this surprise is most likely the little information released about this data by technology companies as the use of location data is not a public process.

Overall, as the results largely match previous expectations and offer great insight, the results are believed to carry meaningful value in understanding the processes, technologies, platforms, and motives behind the collection of location data, contributing to the understanding of location privacy implications. This understanding could allow regulators to be better able to build a reliable regulatory framework to avoid location privacy implications. Also, the knowledge basis laid out in these research results can be used as a technical foundation for further research. Finally, the research results could very well improve user understanding of how their location data is collected and how to avoid this.

#### 4.1.3 Discussing the research method and process

In order to answer this research question and gain greater insight into the technologies and methods used for location data and the motives behind it, literature research was performed and found sufficient to answer the research question as all required information was collected. The literature used for the research consisted of both scientific research reports and non-scientific sources. These non-scientific sources were required as the scientific research available was insufficient to answer the research question due to the fast technological progress being made in tracking technologies. As a result, research tends to be quickly outdated which was a difficulty in this research as it focuses on advanced technologies. Therefore, sources no older than 5-7 years were preferred, limiting the available literature.

The used non-scientific sources include reports from technology companies, research firms, and other technology-related websites. Yet, this does not endanger information reliability as all information collected from non-scientific sources was confirmed by multiple sources. Therefore, the results can be viewed as very reliable.

The research process was completed without critical issues as all information could be collected without any issues, apart from the little available acceptable literature. This means no further problems emerged and collecting the information was completed as planned. As all information was available in the literature, no further or additional research was required to collect all necessary information.

## 4.2 How would AI and IoT fit into the process of location data?

### 4.2.1 The most important research results takeaways

Advanced AI has surpassed human capabilities in pattern recognition, data processing, and content recommendation. Advanced AI's ability to process data, derive insights, and learn from it enables greater automation and improved data analytics, leading to better outcomes than humans can achieve alone. Advanced AI is particularly effective in improving insights through "data fusion," which merges and organizes large data sets to extract meaningful information. By analyzing patterns, advanced AI can make predictions and enhance data value for third parties. In addition to advanced AI's analysis capabilities, Internet of Things (IoT) devices and networks play a significant role in generating location data through various connected devices like smartphones, fitness trackers, and smartwatches. IoT technology connects these devices and enables continuous data collection. The growing penetration of IoT devices generates substantial data for technology companies, allowing them to create detailed profiles of individuals. This data includes sensitive information about users' health, finances, locations, contacts, habits, behaviors, and activities.

However, the integration of AI and IoT technologies provides enough reason for privacy concerns. Technological advancements have transformed the availability of location information, leading to a growing emphasis on regulating access to location data. IoT devices, such as sensors and smart tags, continuously track users' movements, habits, and preferences, contributing to the collection of large-scale data. Security vulnerabilities in IoT devices and the potential for mass surveillance raise concerns as well. In addition, AI's ability to process vast amounts of data can undermine privacy, as it can merge datasets and de-anonymize information. Regulators face difficulties in keeping pace with technological advancements and distinguishing between identifiable and anonymous data. The insights generated by advanced AI and extensive data collection by IoT technologies enable predictive decision-making based on various personal data categories. Concerns arise regarding potential manipulation, discrimination, and infringement on individual privacy.

### 4.2.2 Discussing the research results

The research results largely match the expectations previous to conducting the literature research, based on the theoretical framework and the general understanding of AI and IoT, while also showing surprising results. As discussed in the theoretical framework, AI and IoT technologies are complex and offer many functions and possible integrations that surpass the ability of humans, allowing for new ways of data processing and collection. Also, the results reflect the previous expectation of IoT devices playing a role in data collection, whereas results show AI can be used for data analysis, as also discussed in the introduction of this report. In addition to these roles of both technologies, a surprising fact that emerged from the results was the link between AI and IoT technologies as the results describe these as complementary, while these were not chosen in this research for that particular reason.

The expectation of AI and IoT technologies to bring with them both upsides and downsides were also reflected in the results, as well as the multiple possible general privacy implications emerging from the use of these technologies. These are important findings as these are key to answering the research question, and it is, therefore, essential that these match the expectations prior to the literature research. Overall, as the results largely match previous expectations and offer great insight, the results are believed to carry meaningful value in understanding the value of AI and IoT technologies and their capabilities, as well as the privacy implications coming with the use of these technologies. Understanding the capabilities of the technologies and the privacy implications as shown in the results, could allow regulators and technology companies to be better able to build a reliable regulatory framework to avoid privacy implications and implement the technologies with a more ethical approach. In addition, the results can be used as a foundation for further research on solving these privacy implications as the results on the abilities of both AI and IoT devices can be easily used to find possible solutions.

### 4.2.3 Discussing the research method and process

In order to answer this research question and gain greater insight into the capabilities of AI and IoT technologies in location data and the privacy implications of these technologies, literature research was performed and found sufficient to answer the research question as all required information was collected. Just as explained for the previous research question, both scientific research reports and non-scientific sources were used for collecting these results due to the fast technological progress being made in both AI and IoT technologies. As a result, research tends to be quickly outdated which was a difficulty in this research focusing on the newest technologies and advancements in these technologies. Due to the fast technological progress, relevant scientific data and reports are often unavailable.

In addition, technology companies working on and developing the technologies often offer the most relevant and detailed information, which is why reports and webpages of relevant companies were used in multiple instances for AI and IoT technologies. In general, sources no older than 5-7 years were preferred, limiting the available literature. In some instances, older scientific sources were used as these gave insight into user preferences or general privacy issues. The use of these non-scientific sources does not endanger information reliability as all information collected from non-scientific sources was confirmed by using multiple sources. Therefore, the results can be viewed as highly reliable and all required information has been collected.

Besides the limitation of available literature, technical knowledge upfront on AI and IoT technologies also emerged as a difficulty. As a result of this limited technical knowledge, it is beyond the scope of this study to examine the technical capabilities of location data collection techniques and AI and IoT technologies in greater detail, which could have possibly been a meaningful theoretical addition to the research. Yet, the reader should bear in mind that the study is focused on the privacy implications of integrating AI and IoT technologies in location data processes, and not on the technical details of AI and IoT technologies. Still, exploring these technologies in combination with location data processes further to explore better and safer integrations or technical ways to ensure higher data privacy could be a possible direction for further research.

The research process was completed without critical issues as all information could be collected without issues, apart from the little available acceptable literature and limited technical knowledge upfront. This means no further problems emerged and collecting the information was completed as planned. As all information was available in the literature, no further or additional research was required to collect all necessary information.

## 4.3 What insights can be obtained from an individual's location data by utilizing publicly available AI?

### 4.3.1 The most important research results takeaways

The research/trial results show a good outcome from the AI language model as this one was able to create a profile from the input data and questions. The results show each participant's profile, personality estimate, and targeted advertising suggestions, excluding any sensitive information. Apart from privacy-sensitive results, the results are unedited and come straight from the AI model.

### 4.3.2 Discussing the research results

The trial results have surpassed previous hopes and expectations as the results were much more valuable than anticipated. The trial results show a correct interpretation of the provided location data by the AI and the AI outcomes are sufficient to answer the research question. The results give a better understanding of how the publicly available used AI systems process the data and the results that can

be derived from it by asking a single question, making the results valuable. The results also illustrate the positives and negatives of using AI with location data from a functionality and privacy perspective. As illustrated by the participant reviews, the AI results were fairly correct, surpassing previous expectations, primarily due to the usability of the AI and the impressive results. Prior to the trial, the expectation was for the AI to make many mistakes or refuse to use the data from a privacy perspective. Both these expectations were wrong.

Through the trial results, the qualities of the AI can be highlighted, in addition to the sensitivity of data when used in an AI language model. These results could carry meaningful value in understanding the ability of public AI models when used with personal location data. This could, for example, enable individuals with bad intentions to be better able to track individuals or pick out patterns from the data to predict their movement, which can be used for a multitude of malicious intentions like stalking. Therefore, the trial results could alert regulators of these privacy-threatening AI capabilities, pushing them to build a more reliable regulatory framework to stop the abuse of AI. Yet, by using these research results, the most important is that the technology companies behind the public AI software realize the dangers of these software programs when leveraged by individuals with malicious intentions as described above. This realization could drive these companies to build in more safety systems and block the AI from analyzing data at this point in time, to avoid possible privacy implications. Overall, the results of this research trial should be able to create awareness among stakeholders and drive the creation of privacy-preserving measures and actions.

#### 4.3.3 Discussing the research method and process

In order to answer this research question and gain greater insight into the capabilities of publicly available AI in combination with location data, a trial was run with 15 participants to collect location data and let an AI language model create a profile, personality estimate, and targeted advertising suggestions based on the data. This approach has been found sufficient to answer the research question as the collected data and AI process delivered outstanding results that were above expectations in correctness and answer quality, partly driven by the unbiased approach that was needed due to the data sensitivity and fast developments in the technologies.

Yet, the major downside of this unbiased and privacy-preserving approach was that much data had to be left out of the results and only limited information could be included in this research report. The integration of privacy-sensitive details could lead to privacy implications. Even if the data was not connected to the name of the individual, thorough research would still be able to connect the dots to the individual, which is why is chosen only to release minimal data in this report, and a participant review approach was used to check the quality of the AI results. In this situation, this was the best workaround.

In addition to privacy preservation challenges, there were a number of challenges and difficulties with using AI models. For example, as brought up by multiple participants, the AI answer was sensitive to special one-time occurrences like a hotel visit, vacation, or visit to a spa. As the data was collected for a single week, these one-time special occurrences greatly impacted the AI answer and caused some wrong results. This problem could have been solved by collecting location data for a more extended period, recommended to be over one month, as this would make these one-time occurrences stand out less. Unfortunately, this was a flaw in the trial method.

Another challenge with the AI programs was the inconsistency of the answers. As can be seen from the trial results, the AI was unable to use the same answer format for every single participant, causing irregularities in the answers as some are more extensive than others. Using publicly available AI, this could not be changed in the AI and caused messy and inconsistent result formats. Yet, the results itself were consistent which means it did not hurt the ability of the results to answer the research question.

The AI created a valuable answer for all participants, apart from the ones that gathered too little data. This was another flaw in the one-week collection approach as some participants did not go to a lot of places in this particular week, resulting in too little data for the AI to create a personalized profile. As a result, the data from some participants has been found insufficient.

Another cause for data collection problems were technical issues with Google, which were calculated to happen as technical issues are often hard to avoid. Therefore, more individuals than required were asked to participate to keep a buffer. Despite some participants handing in insufficient datasets, enough data was collected to answer the research question. Overall, the number of participants was sufficient to get a better idea of the AI capabilities and provided enough room for error.

Finally, the programs and apps used for data collection and analysis were excellent choices. The way of data collection was successful and gave participants a feeling of privacy preservation which boosted the morale of participants, driving better research results and a higher number of participants. The Google Maps platform caused few technical issues and was easy to use for the participants by using the explanation file found in the attachments (attachment 3) of this report. ChatGPT and Perplexity AI were used for the AI data analysis, and both were able to create sufficient profiles based on the data.

Overall, the trial results are sufficient to answer the research question as the results were above expectations despite a number of challenges. Further research by using a larger collection of location data could possibly result in even more detailed and matching results, resulting in more interesting results for further research.

## 5. Conclusion & Recommendations

### 5.1 Conclusions

This research aimed to investigate the manner in which fast-growing technologies, namely AI and IoT technologies/devices, are utilized in location data processes, like collection, analysis, and utilization, and the subsequent effects on an individual's location privacy. The results for this research have been gathered by using literature research and a trial in which the abilities of publicly available AI were tested with location data after this was collected from 15 individuals. In order to establish a more effective regulatory framework, users, regulators, and developers must comprehend how these technologies can impact privacy. A deeper understanding could potentially influence the behavior of internet and service users and spur developers, technology companies, and governments to implement safety measures and enact new laws and regulations. As such, this study carries significance for a wide range of stakeholders.

In the remainder of this chapter, each research sub-question will be answered, followed by the answering of the leading research question.

#### **Leading research question**

*What are the privacy implications of AI and IoT in location data?*

#### **5.1.1 Answering sub-question 1: *What are the current methods and technologies used for location data?***

The current methods and technologies used for location data include GPS, Wi-Fi tracking, Bluetooth tracking, IP addresses, and data collected from platforms and applications. Here is a summary of these methods and technologies:

1. **GPS (Global Positioning System):** GPS is the most common method used for location tracking. It relies on satellites to determine precise location coordinates. Smartphones, tablets, and GPS trackers can collect and transmit location data through GPS.
2. **Wi-Fi Tracking:** Companies can collect location data by monitoring Wi-Fi signals emitted by devices. By scanning for Wi-Fi networks and linking the results to databases of known wireless routers, approximate location information can be determined.
3. **Bluetooth Tracking:** Bluetooth tracking involves installing small transmitters, called Bluetooth beacons, at specific locations. When a user grants permission for an app to access Bluetooth functionality, the app can deduce the device's location or transmit alerts and content based on proximity to the Bluetooth beacon.
4. **IP Addresses:** IP addresses have a geographical component that can be used to estimate the general geographic location of a device. Websites and services can gather certain location details based on IP addresses, although they may only provide an approximate location and may not be accurate for mobile devices using cellular networks.
5. **Platforms and Applications:** Platforms and applications, such as smartphones, operating systems, and social media platforms, are major sources of location data. Many apps and services request access to location data for features like mapping, navigation, and personalized recommendations. Location data collected by these platforms and apps can be sent to third-party data companies, contributing to the secondary market for location data.

#### **5.1.2 Answering sub-question 2: *How would AI and IoT fit into the process of location data?***

AI and IoT play significant roles in the process of location data by enabling data collection, analysis, and integration. The combination of AI and IoT has several positive implications, including improved data insights, data fusion, data optimization, and enhanced image, voice, and text recognition. AI, particularly in the form of machine learning (ML) algorithms, can process large amounts of data and

identify patterns, allowing for better data analytics and predictions. ML algorithms can analyze location data to refine it, correct inaccuracies, and improve accuracy using historical data patterns. This can result in more precise location information, especially in indoor environments where GPS signals may be weak or unavailable.

Furthermore, AI algorithms can be trained to recognize image content and patterns, extracting location data from images. They can also process text using natural language processing (NLP) technologies, enabling the extraction of location information from various text sources such as messages and social media posts. IoT devices, on the other hand, continuously collect raw data on users' movements, habits, and preferences, providing a massive source of data for technology companies. These devices, such as smartphones, fitness trackers, and smartwatches, generate contextually enriched information that can be used to create detailed profiles of individuals, including their location, health, finances, contacts, and activities.

However, integrating AI and IoT into location data processes also raises privacy implications. The continuous collection of location data by IoT devices and the interconnected network they create can lead to constant monitoring and analysis of individuals. This can result in the creation of detailed profiles of users' private lives, raising concerns about data privacy and control. Additionally, IoT devices connected to personal location data and networks may pose security risks, as they can be vulnerable to hacking and unauthorized access. The autonomous nature of IoT devices, which track users without their awareness or control, further complicates privacy and security issues.

While offering numerous benefits in data analytics and automation, the combination of AI and IoT technologies requires careful consideration of privacy protection measures. Safeguards should be implemented to ensure user control over their location data, secure IoT devices against unauthorized access, and address the potential risks of mass surveillance and data de-anonymization. Overall, AI and IoT have the potential to revolutionize the process of location data by enabling advanced analytics, data fusion, and enriched insights. However, privacy considerations should be at the forefront to ensure the responsible and ethical use of these technologies.

### 5.1.3 Answering sub-question 3: *What insights can be obtained from an individual's location data by utilizing publicly available AI?*

Utilizing publicly available AI to analyze an individual's location data can provide valuable insights and make reasonably accurate inferences about certain aspects of their profile, preferences, and interests. However, there are also limitations and potential inaccuracies in the AI's conclusions.

In terms of the information that AI is able to identify successfully, it often accurately determines the participant's home location, preferred forms of transport, and frequently visited locations such as schools, restaurants, bars, and shopping outlets. The AI is also able to make reasonable assumptions about the age range of the individuals based on their visited locations and activities. The AI's profiling is more successful in capturing certain characteristics and interests strongly represented in the location data. For example, it can correctly identify individuals with an active and health-conscious lifestyle based on their visits to fitness centers, wellness resorts and engagement in cycling and walking activities. Similarly, it can accurately identify individuals with an interest in sports based on visits to sports venues or stadiums.

However, the AI's accuracy varies across different aspects. In some cases, it can struggle to determine the gender of individuals solely based on location data. The AI also faces challenges in accurately determining the work or study location of the individuals, as well as their specific hobbies or interests beyond the activities indicated by visited locations. The AI's personality estimates are not

always accurate and occasionally make incorrect assumptions about social inclinations, dining preferences, or other personality traits. Yet, these inaccuracies are often the result of too little data input and one-time special occurrences that greatly impact the AI answer and can cause some wrong results. Using a greater supply of location data would probably largely remove these inaccuracies. Despite these limitations, the targeted advertising suggestions based on the AI profiles generally align well with the individuals' feedback. Many participants of the trial from which the data was collected found the advertising suggestions relevant and matching their interests or preferences.

#### 5.1.4 Answering the leading research question: *What are the privacy implications of AI and IoT in location data?*

The combination of Artificial Intelligence (AI) and the Internet of Things (IoT) can and has revolutionized the process of collecting and analyzing location data. Various methods and technologies, such as GPS, Wi-Fi tracking, Bluetooth tracking, IP addresses, and data collected from platforms and applications, contribute to the vast amount of location data available today. AI algorithms, particularly machine learning (ML) algorithms, play a significant role in processing and analyzing this data to extract valuable insights and make predictions. However, integrating Artificial Intelligence (AI) and the Internet of Things (IoT) in location data processes, complementing or improving existing technologies, raises important privacy implications that must be carefully considered. While the collection and analysis of location data through the use of AI and IoT can provide valuable insights and personalized experiences, it also introduces potential risks to individuals' privacy and autonomy.

One of the primary concerns is the constant monitoring and tracking of individuals through IoT devices. These devices continuously collect location data, creating a network that enables the real-time monitoring of users' movements and activities. The continuous nature of this tracking can lead to the creation of highly detailed profiles outlining individuals' daily routines, habits, and preferences. This level of surveillance raises significant questions about personal freedom and the right to privacy. Individuals may feel a loss of control over their own movements and a sense of constant observation.

Another privacy concern stems from the potential for data breaches and unauthorized access to IoT devices and networks. As IoT devices become more interconnected, they create an expansive attack surface that can be exploited by malicious actors. A security breach could expose individuals' location data, leading to various risks, including stalking, identity theft, or targeted crimes. Additionally, unauthorized access to location data collected by IoT devices raises questions about who has control over this information and how it is being used.

Furthermore, the integration of AI in location data analysis allows for the improved extraction of personal information compared to more traditional ways, as well as complete automation of this process. By analyzing patterns and trends in location data, AI algorithms can infer sensitive details about individuals, such as their home addresses, workplaces, frequented locations, and even their social connections, without human interference and oversight. The conducted trial shows that even publicly available AI models can derive these conclusions from only a week's worth of location data, creating a dangerous situation. Publicly available AI can provide valuable insights and reasonably accurate inferences about certain aspects of an individual's profile, preferences, and interests. It can accurately determine home locations, preferred forms of transport, frequently visited locations, and certain characteristics and interests strongly represented in the location data. These insights could, for example, enable individuals with bad intentions to be better able to track individuals or pick out patterns from the data to predict their movement, which can be used for a multitude of bad intentions like stalking. Moreover, when combined with other datasets through data fusion, this

information can enable the identification of individuals and the potential disclosure of their private lives.

The anonymization of location data is challenging, as even seemingly anonymized data can be re-identified or de-anonymized when combined with other datasets. This presents a significant risk to individuals' privacy, as their identities can be revealed, and their sensitive information can be exposed. The potential for data aggregation and correlation across different sources further exacerbates these privacy risks, as seemingly innocuous location data can be linked to other personal attributes or behaviors.

In conclusion, the integration of AI and IoT in location data processes brings both benefits and privacy implications. While AI and IoT enable valuable insights, personalized experiences, and advanced data analytics, they also raise concerns about constant monitoring, potential data breaches, and the extraction of sensitive personal information. The fine balance between utilizing location data for beneficial purposes and safeguarding an individual's privacy is a critical challenge that requires careful consideration and ethical decision-making. As the use of AI and IoT continues to expand, it is essential for stakeholders to prioritize privacy protection, implement robust security measures, and ensure transparent data practices. Especially with the rapid development in advanced AI capabilities and increasing value of location data-driven insights today, these results on the privacy implications of combining advanced AI, IoT devices, and location data are more relevant than ever before. Therefore, regulators and technology companies must consider the above-discussed privacy implications as much as the opportunities of these advanced technologies.

## 5.2 Recommendations

While offering numerous benefits in data analytics and automation, the combination of AI and IoT technologies requires careful consideration of privacy protection measures. Safeguards should be implemented to ensure user control over their location data, secure IoT devices against unauthorized access, and address the potential risks of mass surveillance and data de-anonymization.

To address some of the discussed privacy implications, it is crucial to adopt privacy protection measures. These can include implementing privacy by design principles, ensuring transparent data collection practices, obtaining informed consent from users, providing clear information on how location data is used, and giving users control over their data. Robust security measures should also be implemented to safeguard IoT devices and networks from unauthorized access. Moreover, data anonymization techniques should be employed to protect individuals' identities and prevent re-identification. It is vital for organizations and policymakers to prioritize privacy and enact regulations that safeguard individuals' rights in the context of AI and IoT-enabled location data collection and analysis.

Therefore, it would be recommended to perform further research into possible concrete and practical privacy-preserving measures, either regulatory or ethical, that can resolve these privacy implications stemming from the integration of new and advanced technologies, building on the findings discussed in this research report. For conducting this research, a team of AI and IoT specialists is recommended to ensure better technical knowledge, as well as individuals with upfront knowledge of technology regulation. This research could further support the building of a regulatory framework, as well as drive a more ethical approach by technology companies and user awareness.

In addition, further research into the privacy implications stemming from publicly available AI in particular could be valuable to tackling certain privacy and safety implications. AI programs such as ChatGPT already possess the ability to de-anonymize data and, as shown by the results from this research, are already capable of finding patterns in the data that could threaten users after a data leak. The recommendation for follow-up research in this direction is to use user data from a time period of over one month to drive more meaningful results that are not impacted by one-time events. Also, the use of popular AI programs will be better able to catch user attention. In conclusion, further research in this direction could, again, raise more user awareness and force regulators to build a stronger, much-needed regulatory framework.

# Attachments

## Attachment 1: References

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## Attachment 2: Trial results participants 6-9

### Participant 7:

#### AI profile results:

- **Gender:** Unknown.
- **Age:** Assuming an adult in the late 20s to early 40s.
- **Home location:** AI was able to pinpoint the exact home address, meaning it was able to identify an exact street name and house number from the data.
- **Preferred Form of Transport:** Driving, as indicated by visits to car dealerships and occurrence.
- **Medical Services:** Frequent visits to Meander Medisch Centrum and Chiropractic locations suggest a focus on healthcare and well-being.
- **Shopping Preferences:** Visits to Lidl, Bloemenhof, Argos, Coop, and the Action indicate shopping preferences for groceries, household items, and general merchandise.
- **Fitness and Wellness:** Visits to health clubs suggest an interest in fitness and maintaining a healthy lifestyle.
- **Dining:** Visits to certain restaurants indicate a preference for exploring different restaurants and cuisines.

#### Personality Estimate:

1. **Practical and Self-Sufficient:** The individual's preference for driving, visits to car-related locations, and practical shopping choices (Lidl, Coop, and Action) suggest a practical and self-sufficient personality.
2. **Value-Conscious:** The choice of shopping at discount supermarkets like Lidl and Coop suggests a value-conscious personality, seeking cost-effective options.
3. **Open to Exploring:** Visits to different restaurants suggest a willingness to explore and try different dining experiences.

#### AI-targeted advertising suggestions based on this profile:

1. **Local Automotive Services:** As the individual demonstrates a high frequency of driving, targeted advertising for local automotive services, such as car maintenance, repairs, or accessories, could be effective. Promotions, discounts, or service packages tailored to car owners in the area may capture their attention.
2. **Health and Wellness Offerings:** Targeted advertising for health and wellness services may be relevant. This could include promoting preventive health check-ups, chiropractic services, fitness programs, or wellness events in the local area. Emphasizing convenience, quality, and personalized care could resonate with their health-conscious lifestyle.
3. **Local Grocery and Retail Promotions:** Since the individual visits supermarkets like Lidl and Coop, targeted advertising can focus on local grocery promotions, exclusive discounts, or loyalty programs. Additionally, promotions or new product launches at the Action and Bloemenhof could capture their interest. Highlighting affordability, variety, and convenience may be appealing.
4. **Fitness and Lifestyle Offers:** Given the visits to Health clubs, targeted advertising can include gym membership offers, fitness classes, personal training sessions, or wellness programs. Emphasize the benefits of a healthy and active lifestyle, such as stress reduction, improved fitness, and overall well-being.
5. **Restaurant and Dining Promotions:** With visits to restaurants, targeted advertising can focus on local dining promotions, special menus, or discounts. Highlighting diverse cuisines, unique dining experiences, or special events can attract their attention. Collaborations with local eateries or offers for new culinary experiences may be effective.

## Participant 8:

### Profile Estimate:

- **Gender:** Unknown.
- **Age:** Assuming an adult in the 30s to 50s range.
- **Home Location:** AI was able to pinpoint the exact home address, meaning it was able to identify an exact street name and house number from the data.
- **Preferred Form of Transport:** Driving
- **Travel Destinations:** Visits to Amsterdam Schiphol Airport, Curacao International Airport, and various resorts in Curacao (Curacao Marriott Beach Resort, Lionsdive Beach Resort) indicate a fondness for travel and exploring different destinations.
- **Dining and Entertainment:** Visits to De Buren Curacao, Jaanchie Restaurant, Bali Curacao, El Patron B.V., and Zanzibar Beach & Restaurant suggest a preference for dining out and experiencing different culinary offerings and entertainment venues.
- **Outdoor Activities:** Visits to Boka Ascension, Boka Pistol, Shete Boka National Park, Playa Lagun, Relaxed Guided Dives, Flamingos, Parasasa Beach, and Walking indicate an interest in outdoor activities, exploring beaches, and nature.

### Personality Estimate:

1. **Adventurous and Travel Enthusiast:** The visits to multiple airports and different resorts in Curacao suggest an adventurous and travel-loving personality. The individual appears to enjoy exploring new destinations and experiencing diverse cultures.
2. **Food and Entertainment Enthusiast:** The visits to various restaurants and entertainment venues indicate an appreciation for culinary experiences and entertainment. This suggests a desire to indulge in local cuisine and enjoy social gatherings or events.
3. **Nature Lover:** The visits to outdoor locations like Boka Ascension, Boka Pistol, Shete Boka National Park, Playa Lagun, Flamingos, and Parasasa Beach highlight an affinity for nature and outdoor activities. The individual likely enjoys serene environments, beach activities, and wildlife encounters.

### AI-targeted advertising suggestions based on this profile:

1. **Travel and Vacation Packages:** Promote travel agencies, flight deals, and vacation packages to attract the individual's interest in exploring new destinations. Highlight unique experiences, luxury accommodations, and adventure activities to capture their attention.
2. **Culinary Experiences:** Advertise restaurants, food festivals, or culinary tours to cater to their love for diverse cuisine. Emphasize authentic flavors, local specialties, and dining experiences that reflect the destination's culture.
3. **Outdoor Activities and Adventure Sports:** Targeted advertising for outdoor activities such as guided dives, beach excursions, wildlife encounters, or water sports can resonate with their adventurous personality. Highlight the beauty of nature, adrenaline-filled experiences, and the chance to create unforgettable memories.
4. **Beach Resorts and Leisure:** Promote beachfront resorts, leisure facilities, and relaxation packages to appeal to their affinity for beach destinations. Highlight stunning views, luxurious amenities, and opportunities for relaxation and rejuvenation.
5. **Travel Gear and Accessories:** Advertise travel gear, luggage, and accessories to cater to their travel needs. Emphasize durability, convenience, and innovative features to capture their interest.
6. **Nature Conservation and Wildlife Preservation:** Support eco-friendly initiatives, nature conservation organizations, or wildlife preservation projects to resonate with their love for nature. Highlight the importance of preserving natural habitats and offer opportunities to contribute to these causes.

## Participant 9:

### Profile Estimate:

- **Gender:** Unknown.
- **Age:** Assuming a young adult to adult in the 20s to 40s range.
- **Home Location:** AI was able to pinpoint the exact home address, meaning it was able to identify an exact street name and house number from the data.
- **Preferred Form of Transport:** Driving
- **Work and Education:** Visits to Universiteit van Amsterdam, Science park, and Albert Heijn (assuming it is related to the university) indicate involvement in education or work in Amsterdam.
- **Commuting Habits:** Frequent use of trains and visits to train stations like Barneveld Noord station and Amersfoort central suggest a regular commuting routine, possibly between the residential area and work or educational institutions.
- **Retail and Dining:** Visits to various stores like Albert Heijn, Kruidvat, Jumbo, and Action, as well as dining establishments such as McDonald's, Chinees Indisch restaurant Mei-Wah, and Grandcafe Wijntje, indicate regular shopping and dining habits.

### Personality Estimate:

1. **Academically or Professionally Driven:** The visits to Universiteit van Amsterdam, Science park, and regular commuting to work or educational institutions suggest a focus on personal growth, education, or career development. The individual appears driven and motivated to pursue academic or professional success.
2. **Convenience-Oriented:** The frequent use of personal transportation (driving) and visits to nearby retail stores like Albert Heijn, Kruidvat, Jumbo, and Action indicate a preference for convenience and efficiency in daily activities. The individual values time-saving options and accessibility.
3. **Social and Food Enthusiast:** The visits to various dining establishments, including Chinees Indisch restaurant Mei-Wah and Grandcafe Wijntje, suggest a social and food enthusiast personality. The individual likely enjoys exploring different cuisines and spending time with friends or family in social settings.

### AI-targeted advertising suggestions based on this profile:

1. **Education and Professional Development:** Advertise educational programs, courses, or workshops that align with the individual's interest in academia or professional growth. Highlight the benefits of advancing skills, career opportunities, or specialized knowledge.
2. **Commuting Services and Products:** Promote transportation-related services like car rentals, car-sharing platforms, or public transportation apps to enhance the individual's commuting experience. Emphasize convenience, time-saving, and cost-efficiency.
3. **Convenience Stores and Supermarkets:** Advertise local convenience stores and supermarkets to attract the individual's attention for regular shopping needs. Highlight product variety, competitive prices, and special offers.
4. **Dining and Socializing Venues:** Promote restaurants, cafes, and socializing venues in Amsterdam to cater to the individual's interest in dining out and social experiences. Emphasize unique menus, ambiance, and special events or promotions.
5. **Health and Wellness Services:** Advertise fitness centers, sports clubs, or wellness programs to cater to the individual's interest in maintaining a healthy lifestyle. Highlight amenities, personalized training options, or relaxation services.
6. **Student or Young Professional Offers:** Tailor advertising to suit the needs of students or young professionals, such as discounted student memberships, affordable housing options, or career-related events. Focus on affordability, convenience, and opportunities for personal and professional growth.

## Attachment 3: Data collection participant explanation file (Dutch)

Fijn dat u mee wilt doen aan dit onderzoek welke loopt van 22 tot 28 Mei.

Dit onderzoek is ter ondersteuning van een scriptie welke in gaat op de privacy omtrent locatie data en de eventuele rol van AI in deze kwestie.

Voor dit onderzoek zal de data van 20+ individuen worden verzameld voor een week lang om na te gaan of met enkel deze data, een publieke AI-software een goed profiel kan schetsen van de gebruiker. Denk hierbij aan geslacht, leeftijd, hobby's, werk, seksualiteit, etc.

De verzamelde data bestaat enkel uit alle bezochte plekken in deze week en het voertuig welke gebruikt is op hier te komen. Alle verzamelde locatie data is volledig anoniem in het onderzoek en door middel van de onderstaande uitleg volledig onder de controle van uzelf. De data kan handmatig (hieronder uitgelegd) verwijderd worden om garantie te hebben op privacy.

Om de data te verzamelen zal hieronder een uitleg worden gegeven van hoe u de app instelt om uw locatie op te slaan. Hiervoor zal Google Maps gebruikt worden omdat deze het makkelijk maakt om data te downloaden, goede privacy voorwaarden heeft, en het makkelijk maakt om de data handmatig ook weer te verwijderen.

Kort samengevat:

- U wordt gevraagd om een week lang Google toegang te geven om uw locatie te volgen
- De uitleg hieronder zal stap voor stap doornemen hoe u deze functionaliteit inschakelt.
- U dient dit te doen voor 22 mei en dit zal niet langer dan 15 min duren
- U wordt verzocht om de volgende dag te controleren of de functionaliteit werkt. Ook hiervoor is een uitleg aanwezig.
- Op 28 of 29 Mei kunt u, idealiter via een laptop of computer, inloggen op google maps en hier uw data vinden.
- De uitleg hieronder zal aangeven hoe u de data downloadt naar een zogenaamd "XML" bestand. Dit doet u dan voor iedere dag van deze week. Dit zal ongeveer 15 minuten duren.
- De data kunt u vervolgens mailen naar het volgende mailadres door alle 7 bestanden (voor iedere dag 1) toe te voegen aan de bijlagen
- Email: [daanrijnberk@gmail.com](mailto:daanrijnberk@gmail.com)
- Vervolgens zal de uitleg hieronder aangeven hoe u uw data verwijderd zodat deze niet meer in bezit is van google en hoe u het volgen van uw locatie uitzet.

Ter verduidelijking: De enige met toegang tot deze data bent u en de data is dus aan het eind ook weer te verwijderen om privacy problemen te voorkomen. Zodra de data bij mij terecht komt gaat deze anoniem een geo-systeem in.

Nogmaals bedankt!

U kunt nu de onderstaande stappen volgen om de locatie tracking van Google aan te zetten. Tijdens het proces kunnen alle eventuele vragen gestuurd worden via whatsapp naar: 0637166475

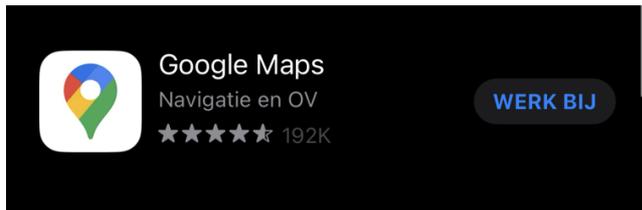
## Stap 1.

U kunt allereerst de Google Maps app downloaden in de App Store of Play store, indien u deze nog niet heeft.

Let op! Deze dient gedownload te worden op uw smartphone.

**Als u de app gedownload heeft en opent, zal deze vragen om toegang tot uw locatie. Hier kunt u antwoorden “Ja” of “Altijd”. Dit zal schelen in volgende stappen.**

**Vervolgens klikt u op het icoontje recht bovenin, naast het microfoonje. Hier kunt u inloggen met een Google-account of er één aanmaken.**



## Stap 2.

Nu gaan we de gedownloade app toegang geven tot uw locatievoorzieningen.

Op **Android** zijn dit de volgende stappen: Het gaat hier dan om de Google Maps app

1. Zoek het app-icoon op het startscherm van je telefoon.
2. Tik op het app-icoon en houd dit vast.
3. Tik op App-info ⓘ.
4. Tik op **Rechten** > **Locatie**.
5. Selecteer een optie:
  - **Altijd**: De app kan je locatie altijd gebruiken.

Selecteer dus de optie “altijd”

Op **Apple** kunt u het volgende doen:

1. Ga naar uw instellingen
2. Zoek naar het kopje “Privacy en beveiliging” en klik deze aan
3. Bovenaan staat hier “locatievoorzieningen”, klik deze aan
4. Zoek in de lijst naar de Google Maps app. Dit is alfabetisch ingedeeld
5. Klik Google Maps aan en selecteer hier “altijd” en vink “exacte locatie” **aan**

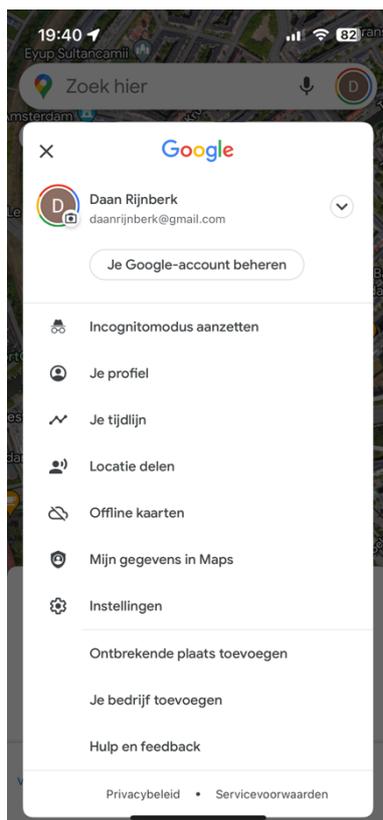
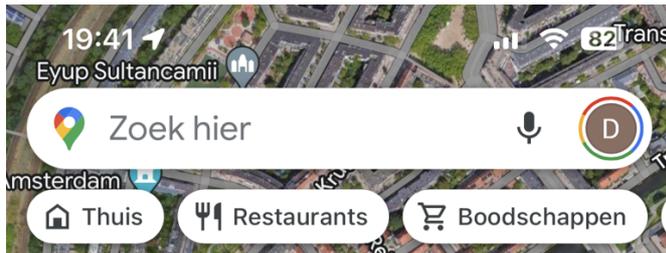
Google maps heeft nu toegang tot uw locatie.

### Stap 3.

We gaan nu uw tijdlijn, oftewel het volgen inschakelen.

U kunt naar de app van Google Maps gaan welke u als het goed is nu al hebt ingelogd met een Google account, ook wel een Gmail account.

U kunt nu opnieuw op het icoontje rechtsboven (hieronder een "D") klikken en dan springt een menu in het scherm zoals hieronder zichtbaar.



U kunt hier vervolgens klikken op "je tijdlijn", waarop het onderstaande beeld zichtbaar zal worden.



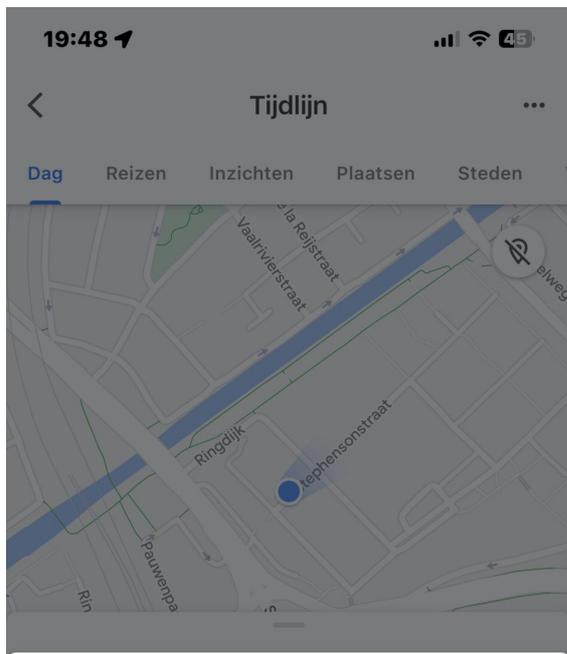
Hier kunt u klikken op "instellingen checken" tenzij hier staat "geen bezoeken voor deze dag" of een Lijst met waar u geweest bent. In dit Geval heeft google al toegang tot uw Gegevens en bent u klaar voor het onderzoek.

Bezoeken en routes worden niet opgeslagen

[Instellingen checken](#)



U zal dit scherm te zien krijgen na het aanklikken van “instellingen checken”. Hierop staan 2 onderwerpen nu aangevinkt en een enkele niet. (mochten er meer niet aangevinkt staan, klik deze dan aan en volg de nodige stappen welke aangegeven worden.



U kunt de blauwe letters onder het eerste kopje aanklikken en dat zal u naar de volgende foto brengen.

Nieuwe bezoeken worden niet opgeslagen ✕  
Als je nieuwe bezochte plaatsen en routes in je tijlijn en locatiegeschiedenis wilt bekijken, check je deze instellingen. [Meer informatie](#)

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⚠ **Locatiegeschiedenis moet aanstaan**  
Status: **Uit** · [Dit apparaat kan geen gegevens toevoegen aan Locatiegeschiedenis](#)

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✓ **Apparaatlocatie moet aanstaan**  
Status: **Aan**

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✓ **Locatietoegang voor Maps moet zijn ingesteld op Altijd**  
Status: **Altijd**

Op deze pagina kunt u klikken op “aanzetten”

Er sprint een niet scherm op met een hoop tekst. U kunt iets naar beneden scrollen en dan klikken op “Aanzetten”. Hij zal vervolgens terugspringen naar de vorige pagina waar nu “uitzetten” staat zoals op de volgende afbeelding

22:23 📶 📶 🔋 33%

✕ **Google-account** J

### Activiteitsopties

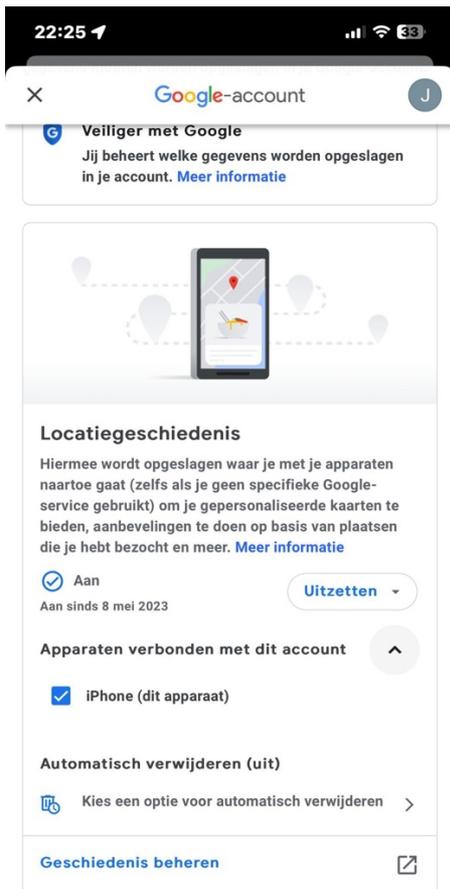
Aan de hand van de gegevens die worden opgeslagen in je account, kunnen we je meer gepersonaliseerde functies bieden in alle Google-services. Kies de instellingen waarvoor gegevens moeten worden opgeslagen in je Google-account.

G **Veiliger met Google**  
Jij beheert welke gegevens worden opgeslagen in je account. [Meer informatie](#)

 **Locatiegeschiedenis**  
Hiermee wordt opgeslagen waar je met je apparaten naartoe gaat (zelfs als je geen specifieke Google-service gebruikt) om je gepersonaliseerde kaarten te bieden, aanbevelingen te doen op basis van plaatsen die je hebt bezocht en meer. [Meer informatie](#)

⊖ **Uit** Aanzetten  
Uit sinds 8 mei 2023

**Automatisch verwijderen (niet van toepassing)**  
Je hebt geen activiteit om te verwijderen. Zet Locatiegeschiedenis aan om een optie te kiezen voor automatisch verwijderen. >



+ [Alle activiteitenopties tonen](#)

U kunt hier nu op het pijltje klikken naast “apparaten verbonden met dit account”. Hier kiest u vervolgens uw telefoon zoals hierboven ook gedaan is.

Ten slotte klikt u nog op de optie daaronder met als titel “automatisch” verwijderen. Dit leidt tot het volgende scherm.

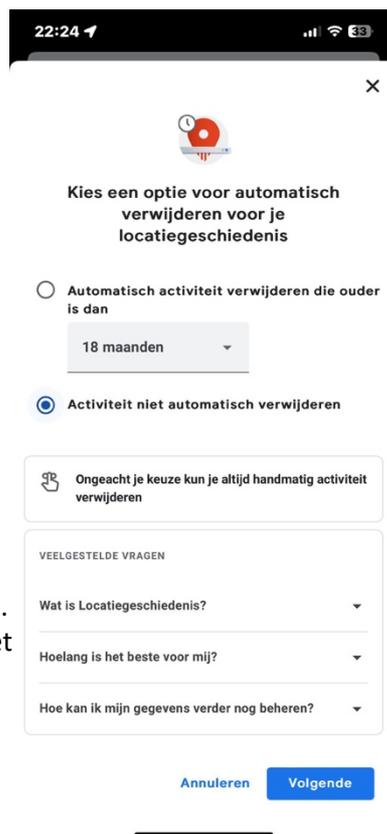
Hier kiest u vervolgens voor de optie “activiteit niet automatisch verwijderen”. Dan volgende en afronden.

U kunt nu de Google maps app volledig afsluiten en deze opnieuw opstarten. Als u dan opnieuw naar uw tijdlijn gaat zal er staan: “geen bezoeken voor deze dag”

Dit betekent dat alles staat ingesteld en Google nu uw locaties Opslaat in de tijdlijn.

Als dit allemaal gelukt is, wordt u verzocht de volgende dag te Controleren of Google inderdaad een tijdlijn vormt.

U zal dan een tijdlijn zien zodra u dit heeft aangeklikt in de app. Mocht dit niet het geval zijn, dan ontvang ik graag een mail met Met het probleem of een bericht op: 0637166475 (whatsapp)

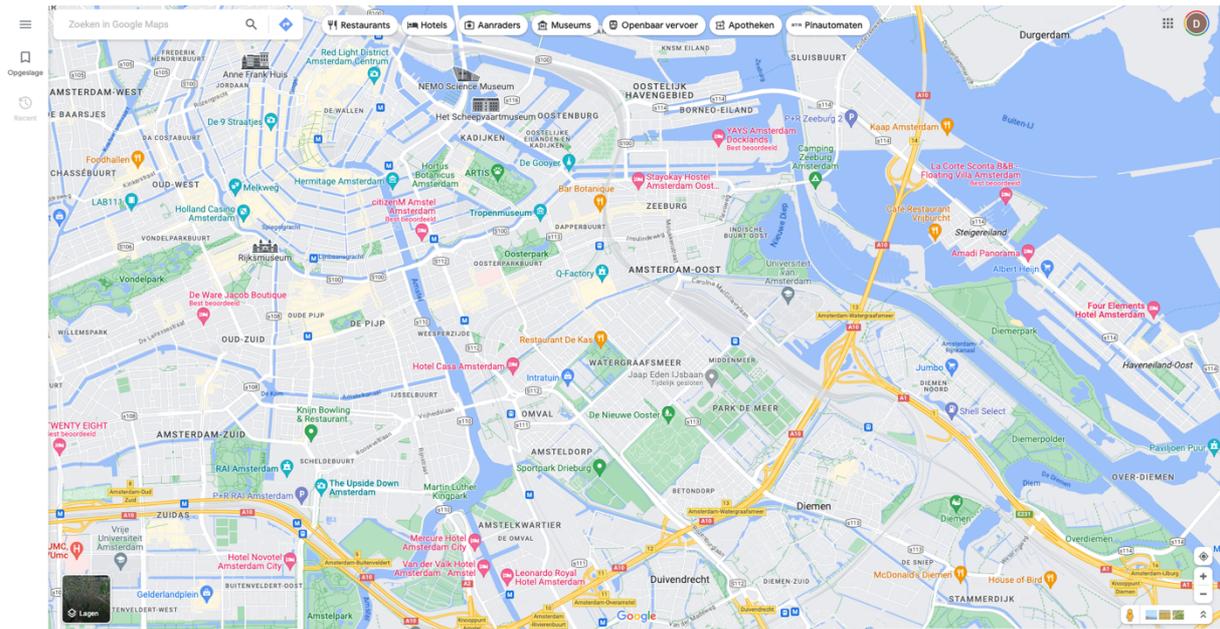


## Stap 4 (pas aan het eind van de week)

Aan het eind van de hiervoor bestemde week kunt u de data voor iedere dag gaan downloaden en mailen.

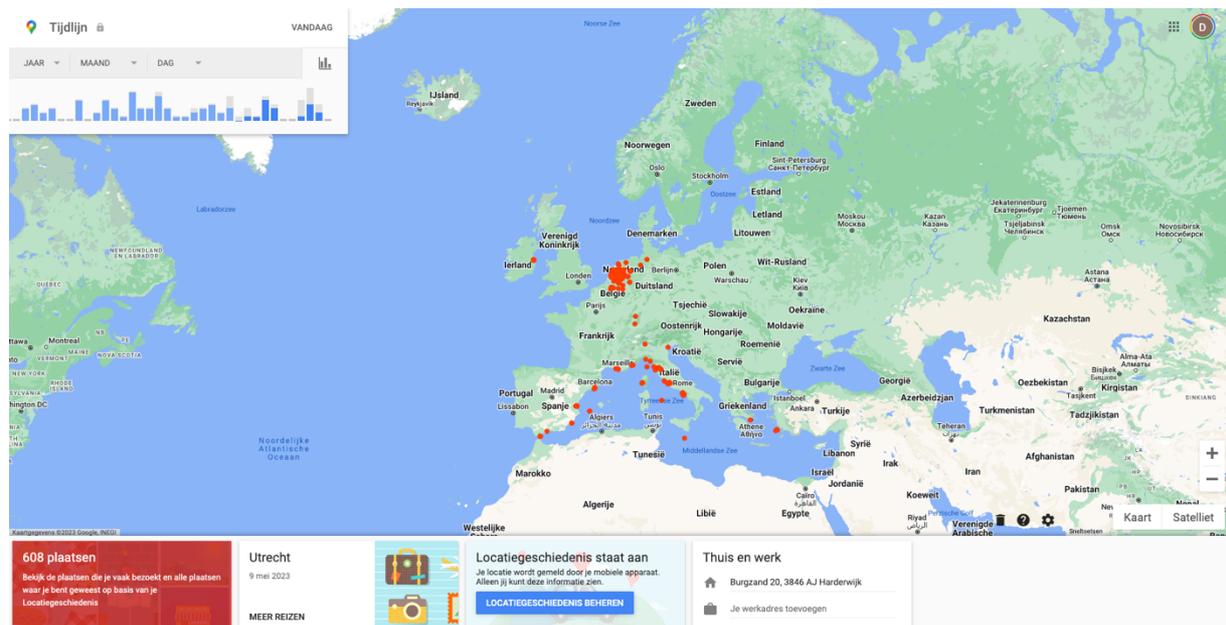
Hiervoor dient u in te loggen op een laptop of computer en op Google naar “Google Maps” te zoeken. Zodra u hier bent moet u eventueel inloggen. **Let op! Doe dit met hetzelfde Google-account als op uw telefoon.**

Zodra dit gelukt is beland u op het scherm van google maps zoals hieronder



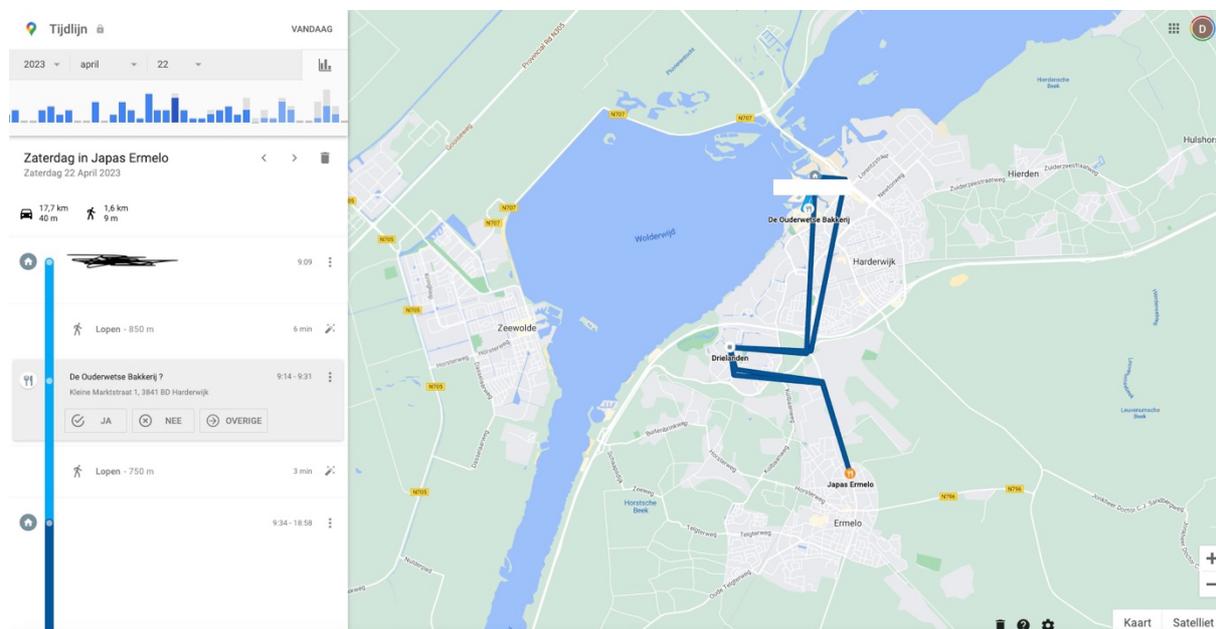
U kunt hier de drie streepjes helemaal **LINKS** in het scherm aanklikken en een menu zal openklappen

In dit menu kiest u “tijdlijn” en hij zal u dan doorsturen naar een nieuwe pagina zoals hieronder.



Bovenin de hoek bevindt zich een menu met blauwe balkjes. Dit zijn alle dagen. U kunt hier met de muis overheen gaan en dan maandag 22 Mei aanklikken.

Een nieuw scherm zal openklappen met de activiteiten en locaties welke bezocht zijn op deze dagen.



Hier kunt u in de tijdlijn eventueel dingen met ja beantwoorden om te bevestigen of onduidelijke locaties verbeteren. Dit is niet perse nodig.

Vervolgens vindt u onderin het scherm aan de rechterkant drie zwarte icoontjes. Als u hier klikt op het instellingen icoontje springt er een menu op.

Hier kiest u dan voor de tweede van boven, welke zegt "deze dag exporteren naar KML"

Zodra u hier op klikt wordt er een bestand gedownload en deze komt in uw downloads of onderin het scherm terecht.

U kunt dit herhalen voor alle 6/7 dagen welke u nog steeds in de bovenste balk met blauwe balkjes kunt selecteren.

U zal dan 6 of 7 bestanden hebben.

Deze kunt u allen mailen naar [daanrijnberk@gmail.com](mailto:daanrijnberk@gmail.com)

## Stap 5.

We gaan nu alle data verwijderen. ***Let op! Verwijder de data niet voordat de mail is gestuurd en u een bevestiging van mij terug hebt dat deze ontvangen is!***

Dit kunt u doen door weer op het instellingen icoontje te klikken en dan te kiezen voor “volledige locatiegeschiedenis verwijderen”

Door hiervoor te kiezen wordt u volledige locatiegeschiedenis verwijderd.

U kunt vervolgens aan de hand van dezelfde stappen voor het instellen van het tracken ook uw locatiegegevens weer uitzetten door op uitzetten te klikken in de app en tevens in uw telefooninstellingen te kiezen om de locatie niet te delen zoals eerder exact andersom gedaan.

Hiermee is het onderzoek afgerond.