BD Lab Technical Report

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Context

Dementia is a cognitive disease that grows in the number of people it affects. What's even worse is that it tends to start earlier now than in the previous decades meaning the last years of a patient's life are getting worse. Our ambition is to ameliorate the patients' quality of life and delay the disease's progress.

Problem to tackle

Specifically, we aim at better monitoring the disease's evolution throughout time. Currently, cognitive abilities are tested punctually over a long period of time such as 6 months, 12 months. Punctual testing however is very sensitive to the context of the test. For example, cognitive abilities can be impacted not only by an underlying, undetected dementia, but also quotidian things like having a bad night's sleep, being in a bad mood, etc..

Solution

The aforementioned problem is what prompted us to develop a way of testing cognitive capabilities continuously throughout a long period of time such that random events like the ones described before are controlled for and do not impact the final result. A continuous evaluation will also provide the speed at which the disease progresses, thus allowing to prioritize patients in function of their needs.

Implementation

Coincidentally, people affected by dementia overwhelmingly wear glasses – we will use this fact to build a product on top of the glasses to monitor the patient's cognitive evolution. A series of sensors such as cameras and microphones are sufficient to collected relevant data from the patient. The data is to be analyzed by an artificial intelligence system that will output key metrics and indicators decided together with physicians dealing with dementia.

The AI will take the patient's POV and analyze the activities that they are doing. It will be able to detect anomalies in activities, such as dropping items or skipping steps in a sequence of actions. Microphones will be useful for the AI to perform speech analysis and detect anomalies such as talking nonsense, repeating words or sentences, struggling to speak etc..

AI video analysis as described before is feasible with tools such as Video AI by Google [1]. It is able to recognize objects, places, and actions in a video as well as extract rich metadata at video or frame level. Importantly, it provides real time insights with streaming video annotation and object-based event triggers – this could go beyond monitoring cognitive abilities, and help in monitoring the

patient's whereabouts and determining their safety. It is also able to create highlight reels, putting into spotlight important events from the patient's POV.

Mental health can also be analyzed by listening to the voice of the patient [2]. In particular, depression is detectable by analyzing how monotonous the speech is for example – a relevant fact because dementia and depression are correlated and have overlapping symptoms. This area of research can further be extended to detecting speech impairments often present in people with dementia.

Developing the AI

Python is a popular choice for AI development as it has lots of libraries developed for this purpose. For example, PyTorch [3] is an easy way to get started with deep learning in python while TensorFlow [4] is the more popular choice used in industry. Furthermore, Google and Microsoft offer virtual machines as computational platforms for machine learning. Alternatively, we may buy our own machines to develop locally.

After the service has been developed it needs to be deployed to a server to be accessible by the glasses for the purpose of retrieving data. For such purposes, Amazon Web Services are a great solution. We simply create an AWS instance where we upload our machine learning model wrapped in an online service created with Python libraries such as Requests and then the model will be able to receive data sent by the glasses, parse it, and store the results in a database.

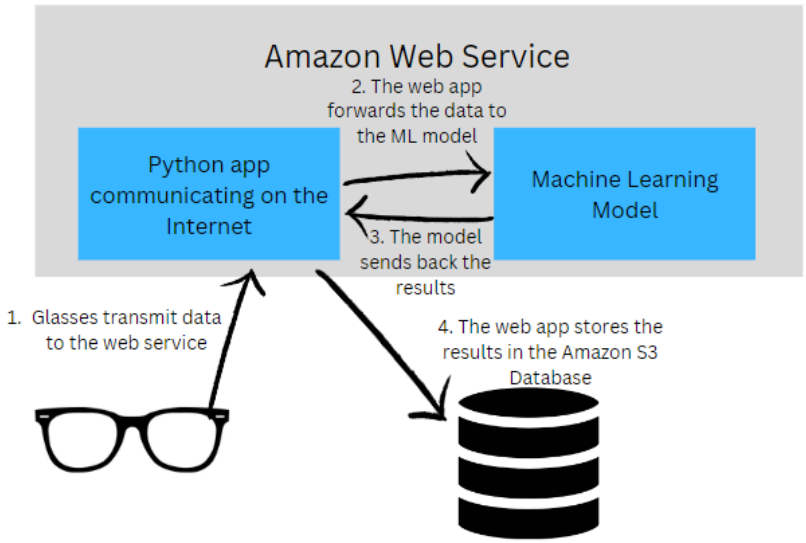
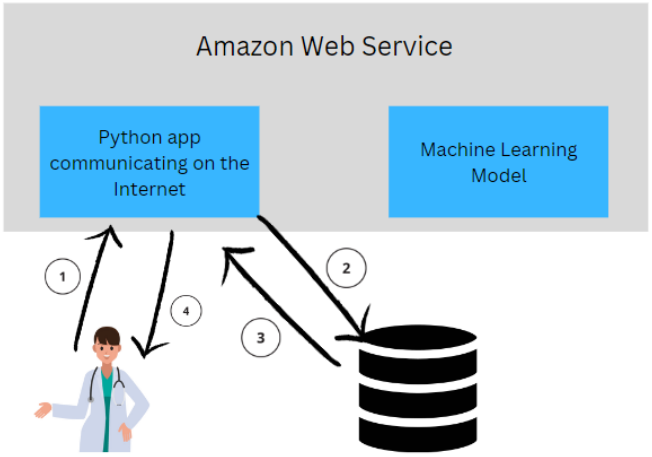


Illustration of communication between glasses, the service, and the S3 database.

The web app will also provide the doctors with the analytics they need as illustrated below.



Illustrated: the doctor asks the service for patient data (1), the service queries the database for it (2), the database replies with the data (3), the service returns the data to the doctor (4).

The resulting data can be stored on Amazon S3 for quite good prices. We could store 1 GB of data for 0.0004 euros. In the worst case scenario, a 720p video will require 650 GB per patient per month, translating to 0.26 euros spent to store a patient's data in a month, increasing cumulatively over time. Of course, storing the raw data forever doesn't serve a purpose, we shall only store the information given by the AI, so the storage cost tends to be negligible. Example of such a plan:

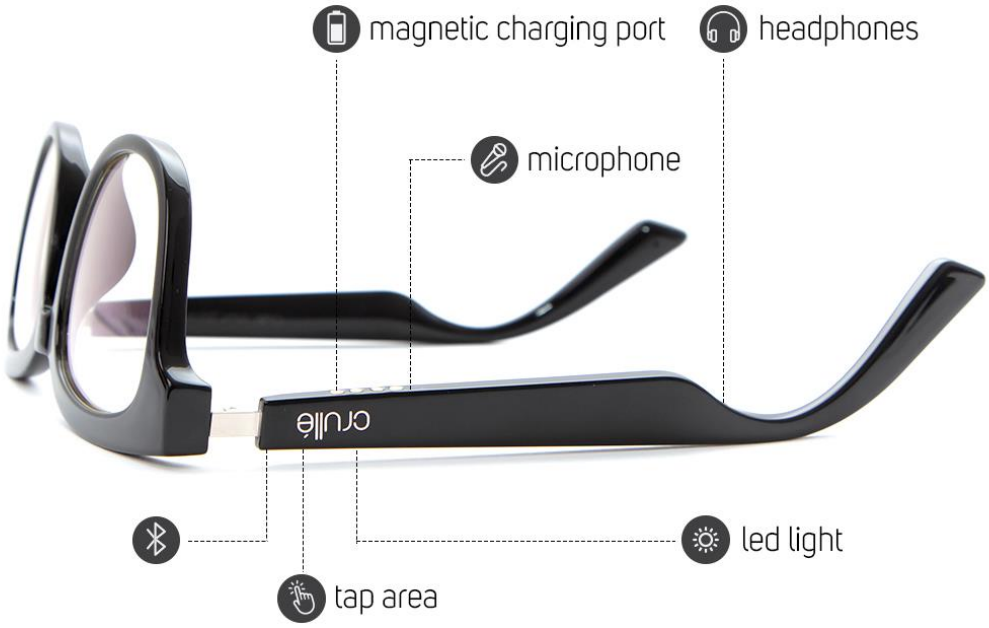
S3 Glacier Instant Retrieval*** - For long-lived archive data accessed once a quarter with instant retrieval in milliseconds

All Storage / Month	$0.004 per GB

[5]

"Smart glasses" incorporating various sensors are nothing new and there's plenty of manufacturers who could help us build our product. For example, the most popular are the Google Glasses, who failed to find a generic purpose in real-life, but we believe a similar concept with our specific goal would find success.

Illustration of a pair of glasses with 2 cameras. [6]



Example of smart glasses with microphone and other features. [7]

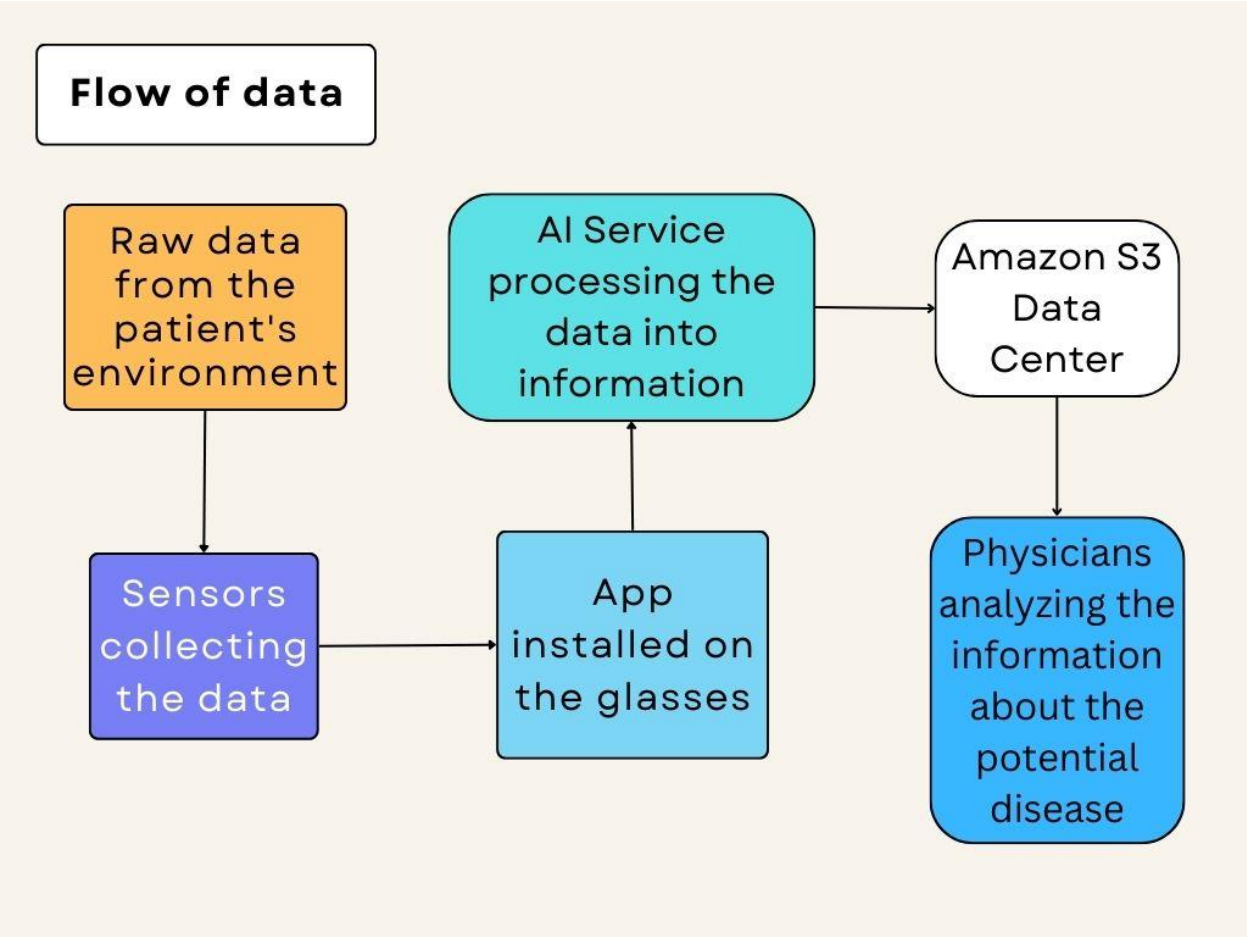
As one can see, they are lightweight and not too imposing, making them easy to wear even for a technophobe person, a trait with higher incidence in older people - a demographic with large overlap with the one affected by dementia.

A key feature of the glasses to have is internet connectivity. Either via the user's phone using Bluetooth either via a mobile sim card providing 3G or 4G internet access. The latter is more preferable as it has less requirements and dependencies and is less prone to failure.

After acquiring the properly equipped smart glasses, we need to install our software on it. Luckily, our software only acquires the data and sends it to the AI to be analyze, thus it should be small

in size and fast to install. Supposing our glasses run on Android (open source operating system), the installation of apps requires just connecting the device to a laptop and following the official steps provided by Google. [8]

It is not necessary that we manufacture the smart glasses, there are already plenty of companies [9] very good at this and partnering up with them will speed up our business' development. Our main selling point is essentially providing information about the cognitive health of a person by using an AI software. Our smart-glasses provider shall manufacture and deliver the glasses to us, and we shall install the software on them. The installation is to be done on our part to ensure protection of our application.



Pictured: a summary of how the data flows from the patient to the physician becoming useful information.

Challenges

Building the AI and navigating through the world of legal requirements for a medical device are the two greatest challenges we would face. Both will take a lot of time, money and effort to get done properly. Technically, the building blocks are all there, the innovation lies in putting them to proper use. The product will have to face the strict medical device regulations to be sellable to the national health systems of different countries. Thankfully, the EU countries have the same regulation, so once respected, the market is huge.

The expertise in machine learning is quintessential and will require lots of effort and studying white papers, learning from similar projects etc., we must be prepared to read an immense number of white papers and test various methods to get to the desired result. We shall attend machine learning events to keep ourselves updated and educated on the topic; falling behind is not an option.

Proper and continuous communication with the physicians must be ensured so that we deliver what they need.

Gathering the training data is going to require us to convince a lot of “test subjects” to wear our product and go on about their daily lives. People might not be so easy to convince due to concerns about privacy. GDPR compliance is of utmost importance, without which our business would cease to exist. We must be very careful in the way we process our data, make sure everything is end-to-end encrypted, so that a potential data leak would not reveal private information about the patients.

Glasses are a great means to an end because the patients are already familiar with them, but we must be careful not to deviate too much from their basic design and disrupt the familiarity. The various sensors we place of the glasses must be subtle and camouflage themselves. Thanks to recent advancements in technology, cameras and microphones are getting smaller and smaller while maintaining high quality output, so we are optimistic in this regard.

Another problem is due to the nature of the disease, the patient may simply forget to wear glasses. We may need a reminder system to prompt the patient to wear their glasses, however, due to the already established familiarity with the object, this is not a critical problem. Such a reminder system could be a subtle, impermeable bracelet that would know when the patient is awake and trigger an alarm on the glasses if the latter are not worn – doable with simple pressure sensors on the glasses frames.

Individual reflection on teamwork

I liked my teammates and working with them on the project. It was tough but a rewarding experience in the end. My teammates weren't all technical persons, only one of them studying something similar to me and someone else studying biology. It was an opportunity for me as a "technical" person to translate my language into the language of a "non-technical" person so that they could understand what I am talking about.

My teammates input from the domains of economics, law and biology proved very useful in better defining the technological capabilities and possibilities of our product. For example, the teammate studying law warned us about data privacy and consent issues that our product's monitoring features might cause, the economy students were careful to not make a too-expensive product that can't be purchased even if it's great at what it's doing, while the person studying biology talked to us about the human psychology, how it copes with dementia, how can we make our product friendly and what it should do.

My teammates who weren't so knowledgeable about technology and AI represented an opportunity for me to be a teacher of sorts and transfer my knowledge to them. It turns out I like explaining stuff to people and maybe I should consider teaching as a side-gig.

I think we all learned to cut corners from our ideas so that in the end we have a marketable product.

Bibliography

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