The Parkinson's disease and its challenges: a solution for smart monitoring

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Parkinson's disease

- Neurodegenerative disease
- Affects 1% of population over the age of 65
- Motor and non-motor symptoms
- No existing cure
- Some medication can alleviate the symptoms

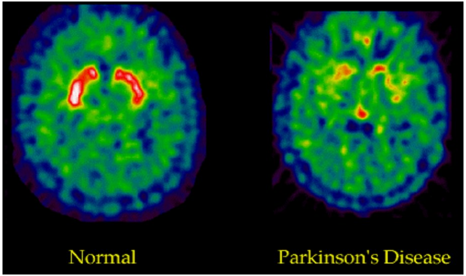

Figure 1: Parkinson's disease affected brain shows lower levels of dopamine in PET scan, in red.
(photo by Marc Savasta, INSERM Grenoble)

The Kuranos Parkinson Project

Founded at CERN, supported by the CERN Knowledge Transfer (KT) group
Aims to provide effective monitoring of Parkinson Symptoms

- Evolution of symptoms typically tracked twice a year by a neurologist
- The sensors in smart watches makes continuous monitoring of symptoms possible
- Improved quality and quantity of data may lead to better understanding of the disease

Figure 2: An example of a smart watch (the Apple Watch).
source:
https://pixabay.com/photos/apple-watch-fashion-time-indoor-2561475/

My summer project (CERN Openlab Summer Studentship)

Developer for the Kuranos Parkinson Project at CERN, which aims to provide effective monitoring of Parkinson Symptoms.

Achieve a proof-of-concept through four main goals:

- Create an Apple Watch application to acquire motion and health data
- Store the centralized data using the CERN EOS disk storage system
- Create a dashboard where symptoms can be monitored
- Perform preliminary analysis using existing datasets

Architecture and technologies

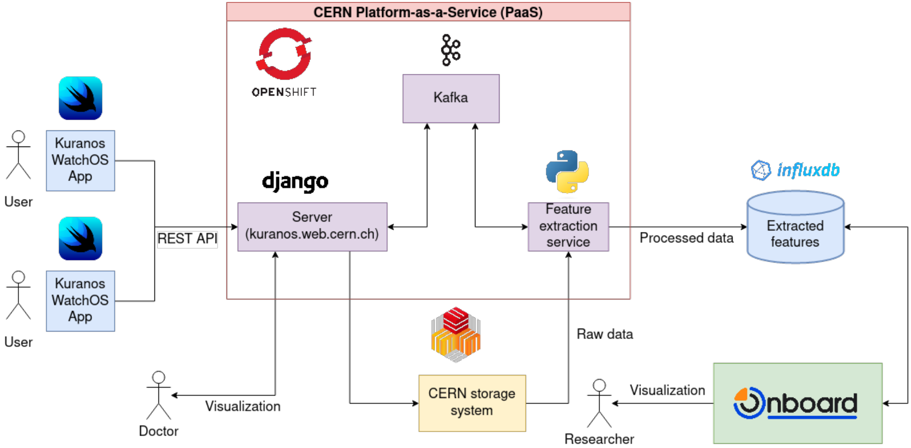

Figure 3: The designed architecture and used technologies

Data acquisition (1/4)

Developed an Apple Watch application using SwiftUI

Collected data include:

- Acceleration, orientation of the watch;
- Heart rate, heart rate variability, blood oxygen level, etc.
- Step count, walking speed, walking asymmetry percentage, stair ascent speed, etc.
- User-entered information: medicine intake, tremor rating, etc.

Figure 4: The symptom rating page of the Apple Watch application

Programming with Swift

Interact with users through *views*. Collect data through *frameworks* (CoreMotion, HealthKit...)
Example of view:

```swift
struct MultipleChoiceView: View {
    let measurementManager: MeasurementManager
    var body: some View {
        VStack {
            Text("Rate tremor intensity")
            HStack {
                Button("0") { measurementManager.rate(intensity: 0) }
                Button("1") { measurementManager.rate(intensity: 1) }
                Button("2") { measurementManager.rate(intensity: 2) }
                Button("3") { measurementManager.rate(intensity: 3) }
            }
        }
    }
}
```

Data acquisition (2/3)

Figure 5: The main page of the iPhone companion application

Figure 6: Dynamic notifications on the Apple Watch to remind users to take their medicine

Data acquisition (3/3)

Developed a Django server to receive collected data and store it on EOS in HDF5 (Hierarchical Data Format) files.

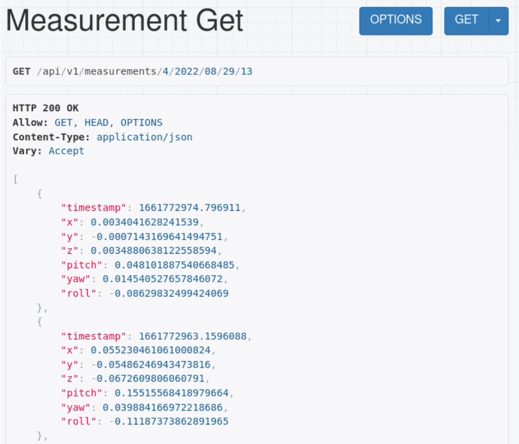

Figure 7: Example of a REST API endpoint of the web server

EOS (EOS Open Storage) (1/2)

- CERN storage technology used for storing large amounts of physics data
- Manages over 700 PB
- Highly scalable and adaptable

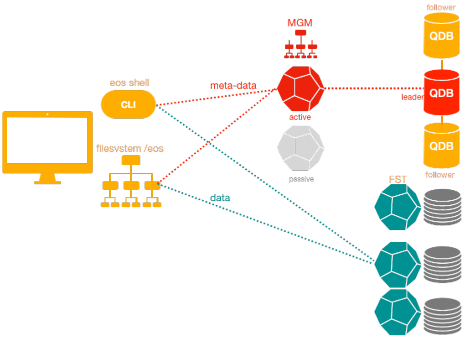

Figure 8: The EOS Client-Server Architecture [1]

[1] https://eos-web.web.cern.ch/eos-web/

EOS (EOS Open Storage) (2/2)

```
/eos/project-k/kuranos
├── data
│   ├── production
│   │   └── persons
│   │       ├── person_000001
│   │       │   └── 2022
│   │       │       └── 08
│   │       │           ├── 10
│   │       │           │   ├── measurements_14.h5
│   │       │           │   ├── motions_12.h5
│   │       └── person_000002
│   │           └── 2022
│   │               └── 08
│   │                   └── 21
│   │                       └── measurements_8.h5
│   └── research
├── public
└── www
```

Figure 9: The EOS storage hierarchy tree for our data

CERN PaaS (Platform As A Service) (1/2)

- Web hosting service for small applications
- Deployed in an OpenShift OKD cluster using Docker containers
- Automation of build and deployment (CI/CD)
- Offers scalability, reproducibility, portability

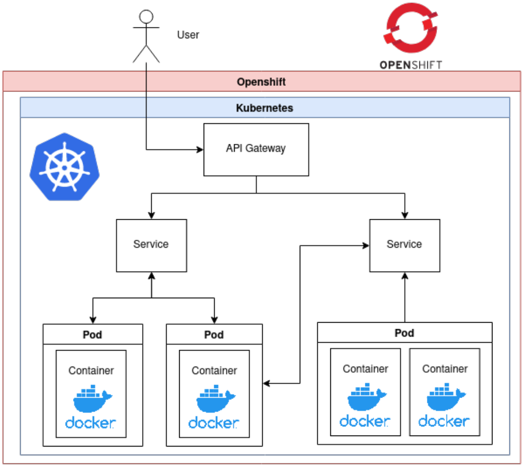

Figure 10: Openshift orchestration

CERN PaaS (Platform As A Service) (2/2)

- Configured Kubernetes Objects through YAML configuration files
- Deployed Apache Kafka using Bitnami Helm charts

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: feature-extraction
spec:
  replicas: 1
  selector:
    matchLabels:
      app: feature-extraction
  template:
    metadata:
      labels:
        app: feature-extraction
    spec:
      containers:
      - name: feature-extraction
        image: ...
        ports:
        - containerPort: 80
        env:
        - name: ENV_VAR
            value: ...
```

Figure 11: Example of a YAML configuration file

Results - Data visualisation (1/3)

Developed a Django website for data monitoring and visualisation by doctors.

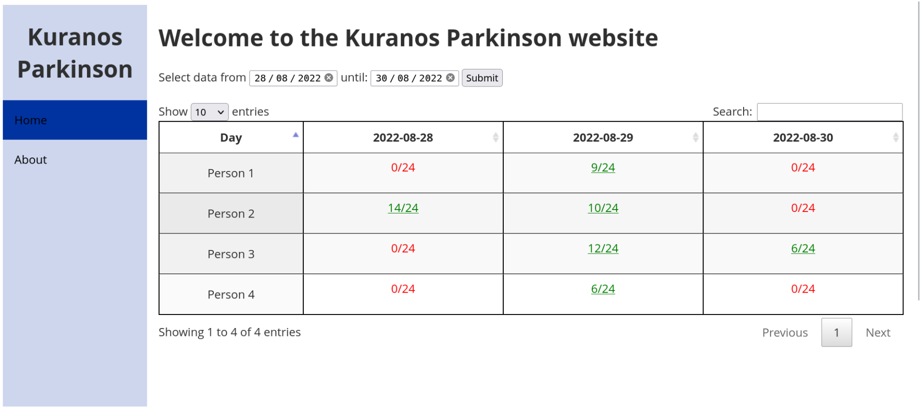

Figure 12: The main page of the Kuranos Parkinson dashboard

Results - Data visualisation (2/3)

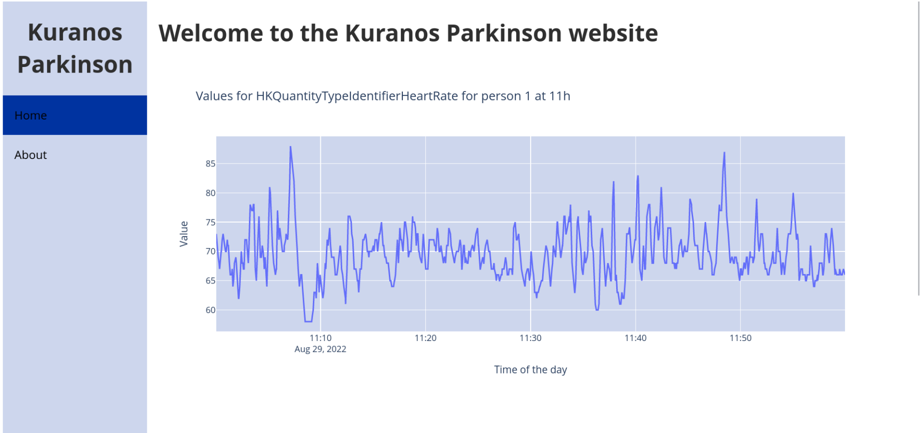

Figure 13: Example of collected heart rate from a test subject (in beats per minute)

Results - Data visualisation (3/3)

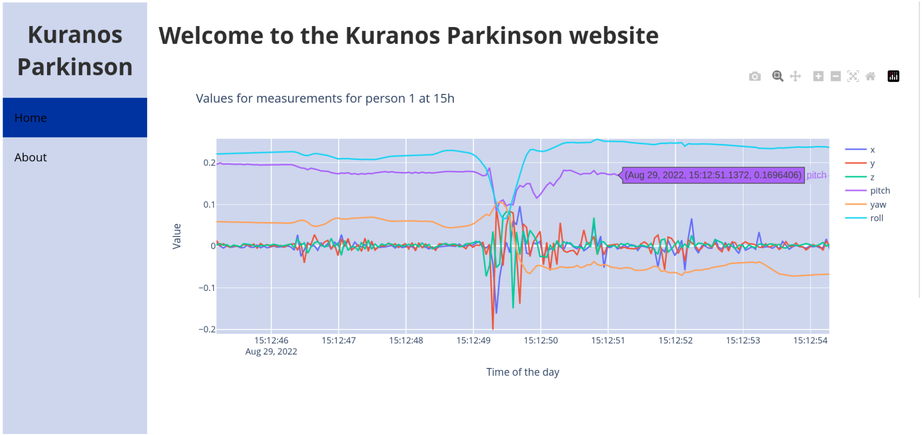

Figure 14: Example of collected accelerometer data from a test subject

Results - Data analysis

Created notebooks and pipelines for data analysis.

- Fourier-based band pass filtering
- Time series feature extraction using *tsfresh*
- Random Forest Classifiers using *scikit-learn*
- Deep Neural Networks using *PyTorch*

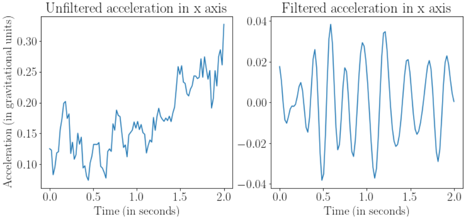

Figure 15: The effect of band pass filtering, used to keep frequencies associated with the rest tremor

Next Steps

- Transform the proof-of-concept to an alpha version
- Continue data analysis
- Further patient tests
- Tighter collaboration with doctors

Conclusions

- The Kuranos Parkinson Project aims to provide a solution to monitor symptoms of Parkinson's disease using wearable devices
- Built full chain from data acquisition though upload and storage to visualization and analysis
- Provides a proof-of-concept version for further development towards wider patient tests

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