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From Physical to Virtual Sensors (PVS)

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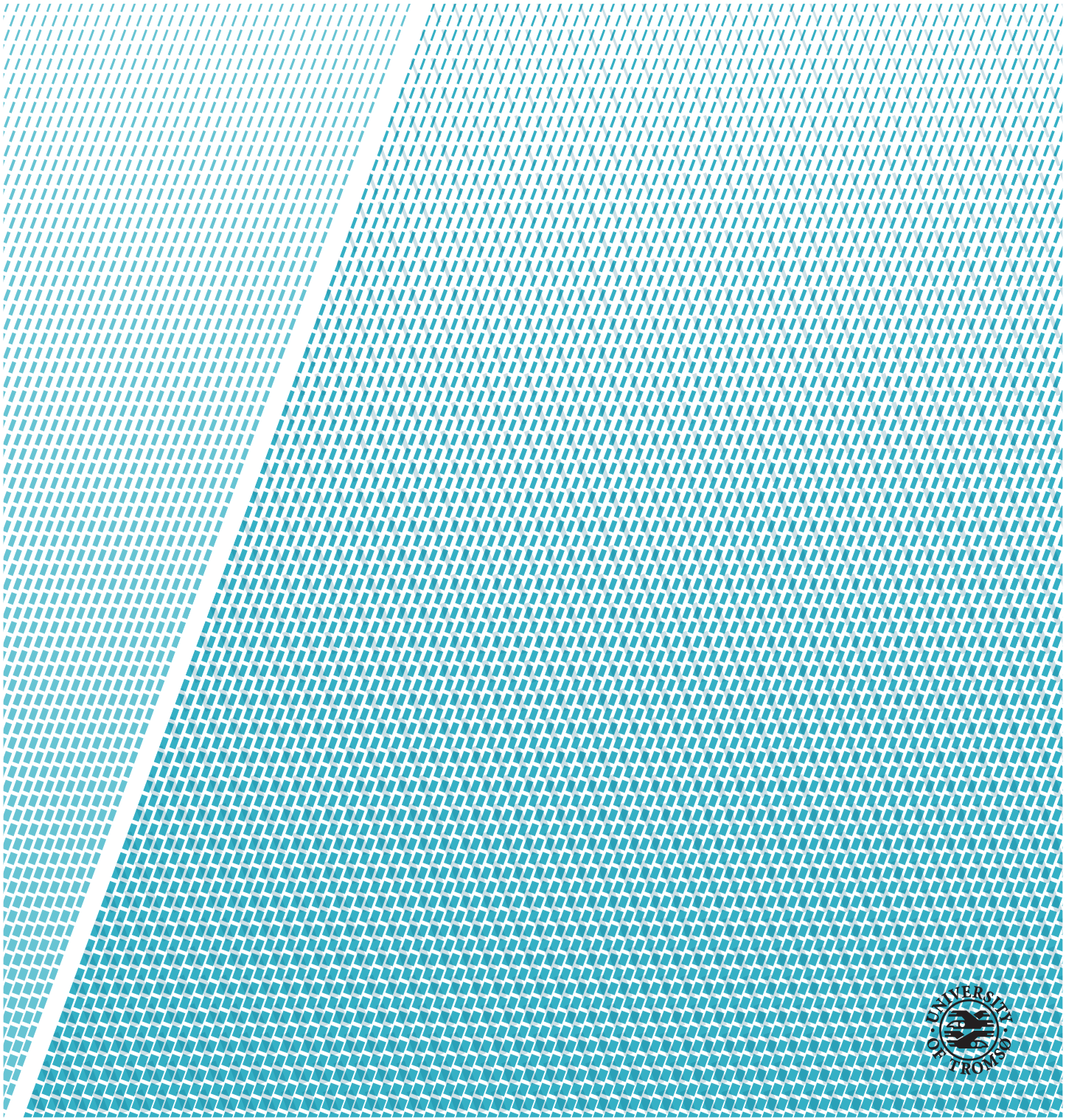

Abstract

W3 Whats wrong with the world? / motivation 1-3 setninger

Architecture - 1-3 setninger

Design- 1-3 setninger

Implementation - 1-3 setninger

Experiments - 1-3 setninger

Results - 1-3 setninger

Lessons learned/main conclusion - 1-3 setninger

Kutt heller etterpaa

This dissertation present/describe ...

Contents

List of Figures

1 Introduction

- Mention focus on camera-sensors/data, and not other sensors?! *John M.: Hvorfor fokus på bilder - forenkle, begrense, starte et sted*
- Talk a little bit about COAT in general?

This project will develop an abstraction for virtual sensors, and do a prototype of the abstraction on a set of computers with physical sensors.

The purpose is to provide for a more powerful and flexible sensor in the COAT monitoring of the arctic tundra. As such, a fox feeding station is the usage domain to be used for the prototype.

1.1 Motivation

The motivation!

- W3
- Problem definition: This project investigated ... x, with the purpose of y.

The motivation behind this project is that no single sensor may cover the sensing needs, and that sensing needs can change rapidly over time. Consequently,

there is a need for sensor fusion, and allow for combining sensors at different computers.

1.2 Contributions

What was the contribution?

1.3 Assumptions

AVGRENSE, VIKTIG!! Something about motivation and stuff

1.4 Limitations

AVGRENSE, VIKTIG!!

- Mention focus on camera-sensors/data, and not other sensors?!

2

Related Work

2.1 Virtual Sensors

A virtual sensor is a constructed sensor in contrary to a physical sensor [1]. They are used in place of the real sensors where they read real physical sensor data and calculate the outputs by using some processing models.

Previous research have focused on simple in-network data aggregation techniques and the sensor networks are often represented as a database. Two examples of such approaches are TinyDB [6] and Cougar [7], which enable applications to have a central point (base station) and create routing trees to funnel replies back to this root. The main focus on these approaches are operating intelligent in-network aggregation and routing to reduce the overall energy cost while still keep the semantic value of data high. In both examples, the data aggregation is specified using an SQL-like language. However, queries cannot be used to merge different data types, only homogeneous data aggregation is achievable. Their virtual sensors approach is offering a simple interface and heterogeneous in-network data aggregation. Yet, our virtual sensors have no SQL-like language or a database to store the aggregated data. Our work also relies on physical sensor data which is already in a data storage, and not directly from the physical sensors.

A virtual node[2] is a set of physical sensors that a programmer can interact with as a single sensor. Their virtual nodes are implemented using TinyOS [3] and their physical nodes are abstracted and specified using logical neighborhoods

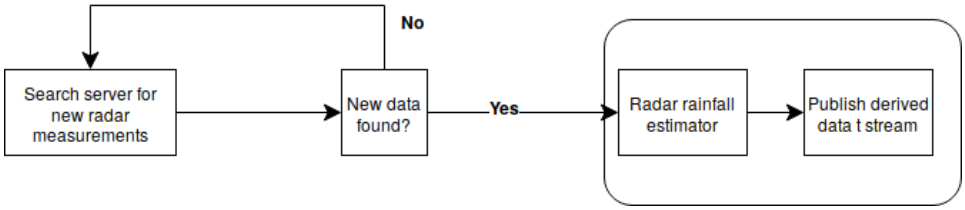

Figure 2.1: Figure illustrating the virtual rainfall sensor.

[4][5]. The nodes are combined in a logical neighborhood that are specified based on their characteristics by the programmer.

It is a prototype of a virtual sensor system for environmental observation with real-time customization of physical sensor data. The system can provide point-averaged radar-rainfall products at either temporal resolution of the radar or as a temporal average of a fixed time period, which is illustrated in Figure 2.1 In contrast, our virtual sensors system is running on-demand, not in real-time. **OGSÅ ANDRE ULIKHETER**

3

The Dataset

HVORDAN DE ER SAMLET, HVORDAN DE ER ORGANISERT?

The dataset is provided by COAT and contains over 1.6 millions of pictures taken from 2011 to 2015 by their camera traps stationed in the Arctic Tundra in Finnmark, Norway. The camera traps are placed at six different areas in the Arctic Tundra: Nordkynn, Ifjord, Komag, Nyborg, Stjernevann and Gaissene. The dataset contains pictures during night- and daytime. The cameras have infrared flash so the cameras can take pictures at nighttime. These pictures are without color while the pictures taken at daytime are with color, as shown in Figure 3.1.

3.1 Dataset Directory Structure

The pictures in the dataset is structured in directories and folders. The dataset is first divided into different years going from 2011 to 2015. Each of these folders are then again divided into the area of the 5 camera traps in the Arctic Tundra. Inside each of these folders specified by the area, they contain folders from each site inside the specific area. Figure 3.2 shows a cropped screenshot of the directories.

COAT also provided excel-sheets with information about all of the images in the dataset. The dataset contains the images metadata and animal classification,

(a) Picture of ravens at daytime. **(b)** Picture of an arctic fox at nighttime.

Figure 3.1: Images from the COAT dataset showing how a picture can contain colors or greyscale.

but did not contain any filenames or a filepath. We then had to find a method to find out which images correspond to the metadata in the excel-sheets. Fortunately, each image had metadata stored in Exchangeable Image File Format (EXIF). We recursively traverse the directories where images are located and read date-time from the metadata and store it in a dictionary with date-time as key and image-path as value. This was quite a time-consuming task because of the number of images to process.

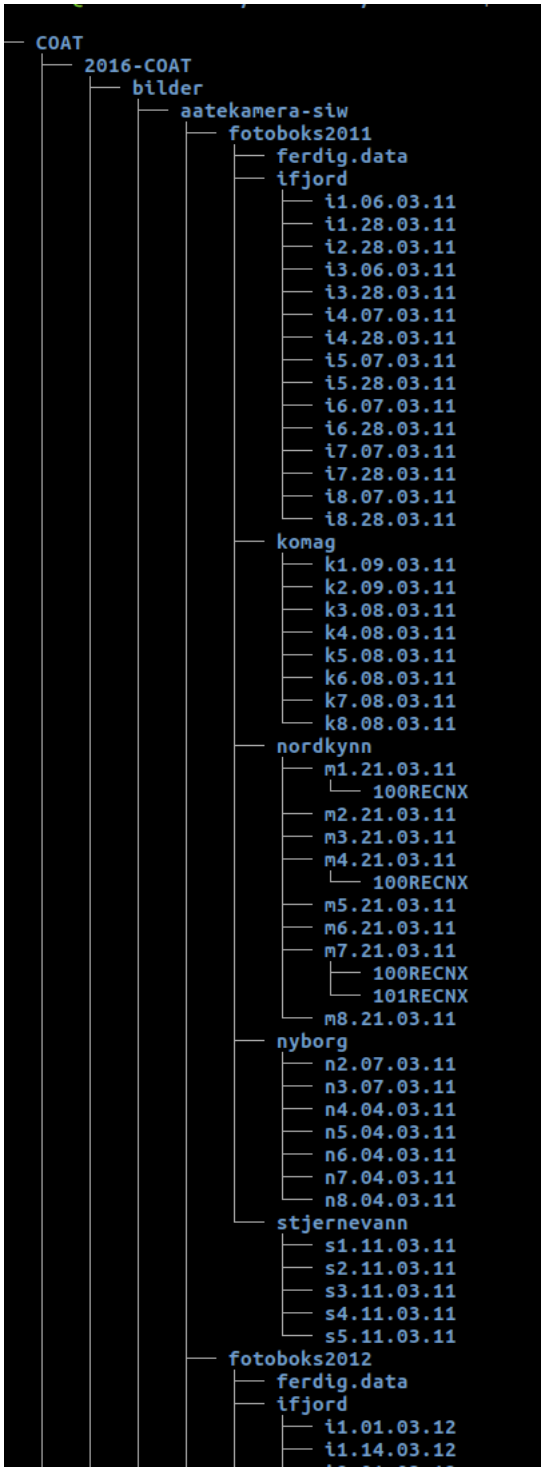

Figure 3.2: Figure showing a cropped screenshot of the structure of the directories.

4

Architecture

This chapter describes the architecture of the system. There are 6 components in the system: physical sensors, *raw data, anaytics and classified data* storage, fusion of data, fused data, virtual sensors and the user interface.

The architecture of the system is presented in Figure 4.1. **The arrows indicates the communication lines.... eller flyten av data/dataflow eller hvem som er aktiv i å gjøre akses/sende - NOE SÅNT HER OGSÅ I NY FIGUR**

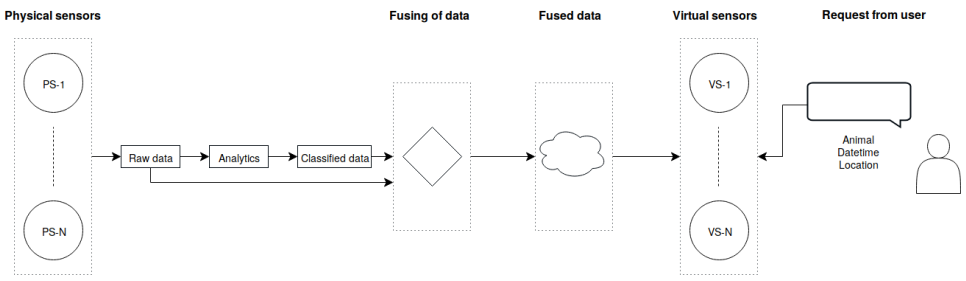

Figure 4.1: Figure showing the system architecture.

4.1 Physical Sensors

The physical sensors produce raw data. The raw data consists of images from different bait-camera sensors. The data also contains metadata about each image, as described in Chapter 3.

(More on the metadata!) — ha det i Chapter 3 med dataset???

4.2 Raw Data

Raw data from physical sensors..

4.3 Analytics and Classified Data

Biologist have detected animals in each picture and made excel-files containing metadata about each picture.

4.4 Fusing of data and Fused Data

4.4.1 Fusing of data

4.4.2 Fused Data

The fused data retrieves it's data and on demand. The fused data is the physical sensors location combined with necessary metadata such as date-time, location, site, year, what kind of animal there as in the image and also how many animals there was/**and animal classification**.

4.5 Virtual Sensors

The virtual sensors are divided into multiple sensors representing different animals that scientists are interested in, e.g. one raven-sensor, one red fox-sensor and one golden eagle-sensor. The user types in what animal he/she wants to see, where it is and the date-time and the search is redirected to the sensor related to that specific animal. The virtual sensor retrieves its result from the fused data.

OLD *The virtual sensors are divided into multiple sensors representing different animals that scientists are interested in, e.g. one raven-sensor, one red fox-sensor and one golden eagle-sensor. The user types in what animal it wants to see, where it is and the date-time and the search is redirected to the sensor related to that specific animal. The virtual sensor receive its result from the fused data from the CSV-file.*

4.5.1 Raven Sensor

Eller ha disse som eget kapittel "My virtual sensors"..

4.5.2 Red Fox Sensor

4.5.3 Golden Eagle Sensor

4.5.4 Result from Virtual Sensor to User (Eller egen section??)

A user wants to retrieve fused data about animals. The user interacts with a virtual sensor user interface. This takes care of the interaction with the virtual sensor. When a user gives a command, the responsible(?) virtual sensor retrieve data from the fused data as described in the section above, and presents the result back to the user.

OLD *A user wants to retrieve images from the data store. The user interacts with a user application. This application takes care of the communication to the virtual sensors. When a user gives a command, the user application sends it to one of the virtual sensors, the virtual sensor retrieve data from the fused data as described in the section above, and deliver the response back to the user. The image(s) are displayed through an image-vision.*

5

Design

Client/Server, p2p, put/get, pub/sub, protokoller, FTP etc.. BESKRIV INTERAKSJONEN MELLOM ENHETENE!!

Virtual sensors probably uavhengige prosesser, ikke threads ettersom man evt vil addere flere sensorer og unnga a starte alle sensorer på nytt igjen.. Er de virtuelle sensorene servere eller client/publisher?

In this chapter we will look at the design of the system and present the design of each component of the architecture. Figure 5.1 shows the design of the system. The arrows indicates the communication lines. The dotted arrows show how the data storage is structured with files and pictures. **Få med direction of arrows/active side?**

OLD *In this chapter we will look at the design of the environment. We will present the design of the data storage, the fused data the virtual sensors and the user application. Figure 5.1 shows the design of the system. The arrows indicates the communication lines. The dotted arrows show how the data storage is structured with files and pictures.*

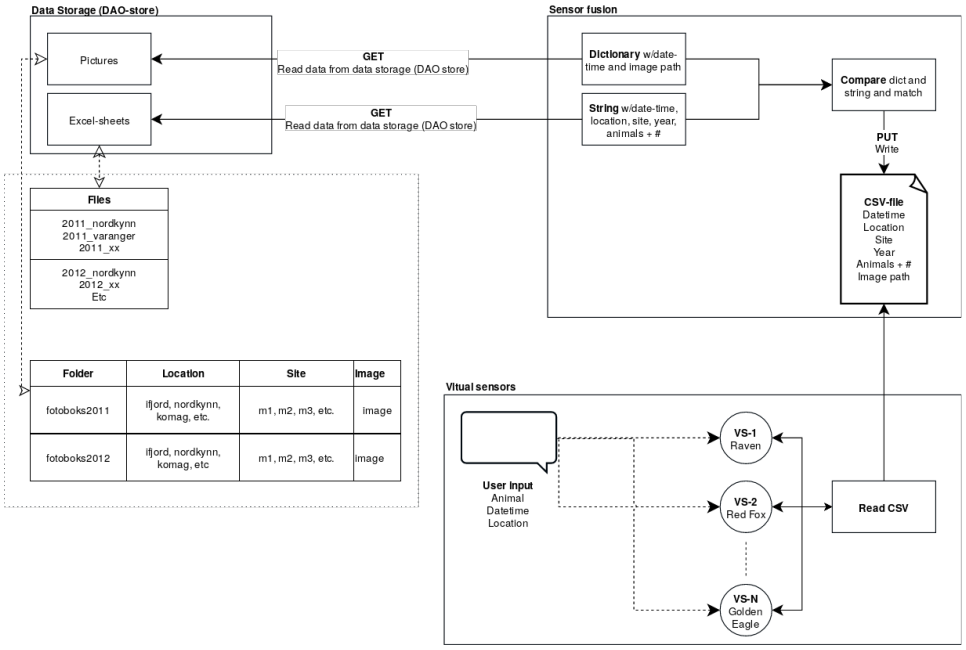

Figure 5.1: Figure showing the system design.

5.1 Data Storage

The excel-sheet in the data storage contains a pictures location, date-time, site, year and animal classification, but it did not contain any filename or a filepath. We then had to find a method to find out which images correspond to which field/row in the excel-sheet. Fortunately, each image had metadata stored in Exchangeable Image File Format (EXIF). We recursively traverse the directories where pictures are located and read date and time for each picture and store it in a Python dictionary, like a key-value store, with date and time as key and image-path as value. This was quite a time-consuming task because of the numbers of images to process.

... described in Chapter 3...

5.2 Virtual Sensors TIL Sensor Fusion

The respective virtual sensor must handle events from the user. Assume a user wants to find pictures of a red fox at a specific time. The user interface makes the respective virtual sensor aware of the task. The virtual sensor will then go to a list of all red foxes that are located from the fused data and search for the specific request. If the virtual sensor find pictures that are similar to

the request from the user, one and one picture is visualized on the computer screen to the user.

respective/corresponding

John M.: Kan du ha flere identeiske virtuelel sensorer for å prosesere i parelll? Og Er det sensorene som visualiserer, eller returnerer de data som kan visualiseres av klienten= ut fra 4.3 høres det ut som siste

5.3 User Application TIL Virtual Sensors

Otto: I design: The image(s) are displayed through an image-vision.

The user-application is the connection between the user and the virtual sensors. It gets input from the user and sends a request to the virtual sensor based on its input. The user-applications goal is to make an interface that is easy to use and to show images that the user want to see. The main menu is shown in Listing 5.1. The user only need to specify the following 3 parameters for the virtual sensor:

- **Animal:** The user can choose to see 3 different animals; raven, red fox and the golden eagle. The user can also chose to see pictures with no animals in it. The reason that the user only can chose between these 4 categories is that these are the only virtual sensors that are implemented in this version of the system.

- **Date-time:** If the user wants a specific date-time the picture(s) was taken, he/she can specify the date and time in this section. If the user leave this field blank, all dates **count/will be** "**processed**" when the system search for pictures.

- **Location:** At last, the user can chose if he/she wants the picture to be located anywhere specific. The only valid arguments in this field is Nordkynn, Komag, Nyborg or Stjernevann since these are the only names in the CSV-file in the fused data.

Listing 5.1: Main menu

```
**** WELCOME! ****
**********************

Write what you want to see
```

```
(Raven, RedFox, GoldenEagle):

Write when you want to see (blank is all dates):
E.g: 2011:03:24 or 2011:04:24 10:10:00

Where do you want the animal to be located
(nordkynn, varanger: komag, nyborg, stjernevann):
```

6 Implementation

6.1 Overview

This chapter will elaborate on how we implemented the system, **general implementation requirements, issues and choices??**.

The system is implemented and written in the high-level programming language Python 2.7[1]. **This was a practical ... reason 1, reason 2, reason 3...** We made this choice because Python is object oriented and it offers different frameworks that are relevant for this implementation.

In the rest of this chapter we will first look at the data storage in Section 6.2, then we will take a look at the sensor fusion in Section 6.3, and at last we will describe the virtual sensors in Section 6.4.

Threads, data structures, language ...

1. https://www.python.org/

6.2 Data Storage

6.2.1 Data Storage and Fused Data

The data storage contains folders with labeled animals, but these images have no metadata so we don't know when the picture is taken. Therefore, the solution is to traverse the whole data storage and find the original images with metadata and compare these to the excel-sheets containing date, time, location and site. **HOW DID I TRAVERSE?!?!?!**

6.2.2 Exchangeable Image File Format - EXIF

To read the metadata, as mentioned in Section 5.1, we used a Python module called EXIF 2.1.2[2], to extract the metadata from the jpg-files.

6.2.3 Pandas

Pandas[3] is an open source Python Data Analysis Library which provides high-performance and easy-to-use data structures. It is a NUMFocus[4] sponsored project which will help ensure success of the development of pandas as a open-source project in world class. A dataframe[5] is a two-dimensional, dynamic tabluar data structure with labeled axes (rows and columns), just like an excel-sheet.

We use Pandas dataframe to extract relevant data from the excel-sheets in the data storage. **HVORDAN EXTRACTED JEG DATA FRA EN DATAFRAME?!**

2. https://pypi.python.org/pypi/ExifRead
3. http://pandas.pydata.org/
4. https://www.numfocus.org/open-source-projects/
5. https://pandas.pydata.org/pandas-docs/stable/generated/pandas.DataFrame.html

6.3 Sensor Fusion

6.3.1 Comparing, CSV-file

6.4 Virtual Sensors

6.4.1 Virtual Sensors

ikke threads ettersom man evt vil addere flere sensorer og unnga a starte alle sensorer på nytt igjen.. Er de virtuelle sensorene servere eller client/publisher? The virtual sensors are *constructed/implemented* as functions/definitions, not threads or subprocesses (uavhengige prosesser - independent processes)... *Discussed in discussion Section....*

The OpenCV[6] library is used to visualize/show pictures to the user in the user application. The library read the pictures it is given and display these on the screen to the user.

John M.: lesere vil kanskje tenke at dette er overkill. Kanskje bare gjøre et poeng at dette bare ble valgt på grunn av kjennskap til det / bruk i andre prosjekter og at nøyaktig hvilket verktøy som brukes til visualisering ikke var fokus.

6.4.2 User application

The user application is implemented as a ... There is currently no logging of a user's action. Nor is it possible for more than one user to be connected (in the same application) at a time. Because of lack of time, we have not thought about implementing this...*(One user - one application, another user run another new application)*

Write about that you don't have all animals, only the ones who is most of in csv-file, not every animal is presented in the dataset..

6. `https://opencv-python-tutroals.readthedocs.io/en/latest/`

7

Evaluation

This chapter describes the experimental setup...

metrics, define (CPU, memory, latency.), benchmarks (micro, kernel... How to measure, where done, PSEUDOCODE

NOTATER:

- Time: Finding folders and metadata takes: 1:43:13.488799 (103,2167 minutes), Reading excel file takes: 0:00:17.413845 (0.2833 minutes), Comparing takes: 4:43:30.705587 (283.5 minutes), Overall time is 6:27:01.608355 (387.0167 minutes). Med alle bilder m/metadata og hele fotoboks2011_nordkynn_nordkynn.2011.xlsx.

- New time: Finding folders and metadata takes: 1:46:17.406581 (= 106.2833 minutes) Reading excel file takes: 0:01:07.686779 (= 1.1167 minutes) Comparing takes: 19:03:11.177869 (= 1143.1833 minutes) Overall time is 20:50:36.271415 (= 1250.6 minutes) Med alle bilder m/mETADATA og hele nordkynn og varanger

- "Concurrent" python find_folder_ok_concurrent.py Finding folders and metadata takes: 1:30:50.250732 (= 90.8333 minutes) Reading excel file takes: 0:00:18.127597 (= 0.3 minutes) Comparing takes: 4:18:33.368199 (= 258.55 minutes) Overall time is 5:49:41.746759 (= 349.6833 minutes) – Pool(processes=4) FRA fotoboks2011_nordkynn_nordkynn.2011.xlsx

- "Concurrent" igjen Finding folders and metadata takes: 1:44:18.788013 (= 104.3 minutes) Reading excel file takes: 0:00:17.269817 (= 0.2833 minutes) Comparing takes: 3:54:23.483186 (= 234.3833 minutes) Overall time is 5:38:59.541248 (= 338.9833 minutes) – Pool(processes=100) FRA fotoboks2011_nordkynn_nordkynn.2011.xlsx

  This chapter describes the experimental setup and metrics used to evaluate the implemented system.

7.1 Experimental Setup

All experiements were done on a Lenovo ThinkCenter with an Intel® Core™ i5-6400T CPU @ 2.20GHz × 4, Intel® HD Graphics 530 (Skylake GT2), 15,6 GiB memory and 503 GB disk. It ran on Ubuntu 17.04 64-bit.

7.2 Experimental Design

7.3 Results

In this section we will discuss the results of the testing described in the sections above...

What does the result say? Each experiment, result, meaning

8 Discussion

8.1 Architecture

8.1.1 Other solutions

- Virtual sensors probably uavhengige prosesser, ikke threads ettersom man evt vil addere flere sensorer og unnga a starte alle sensorer på nytt igjen..
- Updates of "database" in background, not on demand -> future work?

8.2 Design

8.2.1 Other solutions

- hash-map instead of multiple lists with different animals. hash on animal and/or place
- parallel/concurrent program when doing metadata-collecting and reading from excel-sheet and writing to csv. Python - bad experience with threads/subprocess, golang probably better?

9

Contributions

Combine with conclusion??

10

Conclusion

10.1 Contributions?

11

Future Work?

12

Appendix?

readme, source code, dataset measurement RAW

Bibliography

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