

## **From Physical to Virtual Sensors (PVS)**

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# **Abstract**

**W3** Whats wrong with the word? / 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 ...



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## Introduction

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

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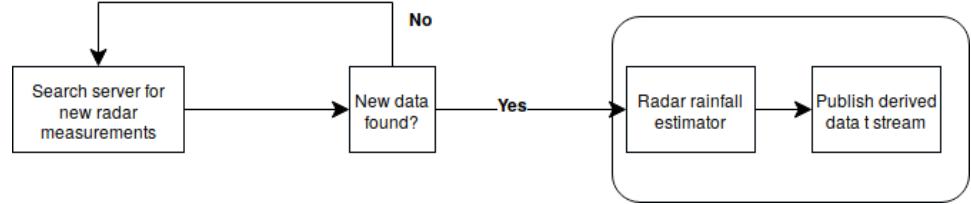
## Related Work

### 2.1 Virtual Sensors

A virtual sensor is a constructed sensor in contrary to a physical sensor as described by S. Kabadai et. al.[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 physical sensors.

In this project the biologists want to search for pictures of a specific animal from different locations in the Arctic Tundra. A virtual sensor would collect data



**Figure 2.1:** Figure illustrating the virtual rainfall sensor.

from the physical sensors and then return those images that are equivalent to the biologists input.

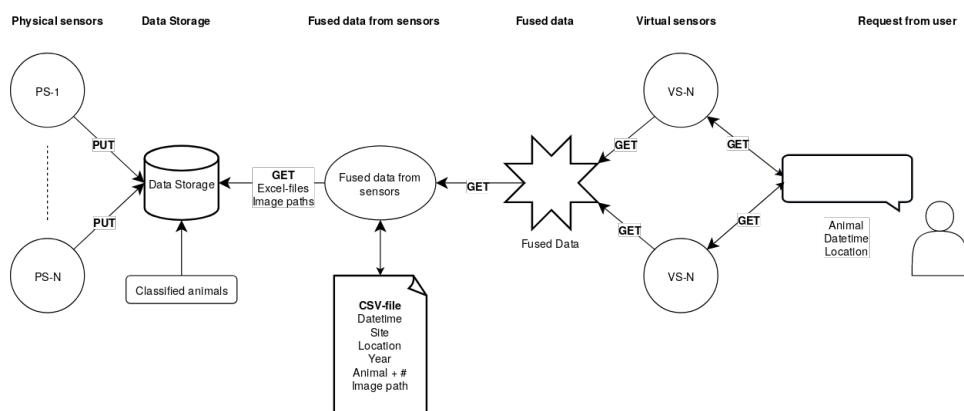
Cicirillo et. al.[2] describes virtual nodes which are programming abstractions that should simplify the development of decentralized wireless sensor network (WSN) applications. Their system enable access to the data by a given set of sensors and making it into one virtual sensor that a programmer can interact with. Their virtual nodes are implemented using TinyOS [3] and their physical nodes are abstracted and specified using logical neighborhoods [4][5]. The nodes are combined in a logical neighborhood that are specified based on their characteristics by the programmer.

Hill et. al. [8] present a prototype of a virtual sensor system for environmental observation with real-time customization of physical sensor data. The virtual rainfall sensor is illustrated in Figure 2.1. It is created by linking data-processing modules together in a workflow that is triggered by a data fetcher provided by the streaming data toolkit. In contrast, our virtual sensors system is running on-demand, not in real-time.

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## Architecture

This chapter describes the architecture of the system. There are 6 components in the system: physical sensors, data storage, fused data, virtual sensors and the user. However, the main components in the system are the data storage, the fused data, the virtual sensors and the user. The architecture of the system is presented in Figure 3.1.



**Figure 3.1:** Figure showing the system architecture.

### 3.1 Physical Sensors and Data Storage

The physical sensors transmit their data to the data storage, so the data storage consists of several set of images from the different bait-camera sensors. These pictures are organized by the year they where taken and also where the camera was placed in the Arctic Tundra in Finnmark, Norway. The data store also contains several excel-sheets containing information about each picture structured by the location of the physical bait-camera sensor position.

### 3.2 Fused Data

The fused data retrieves it's data from the data storage and store the fused data into a Comma-Separated Value (CSV) file on demand. The fused data is the image-path from all the directories in the data storage combined with necessary information from the excel-sheet such as date-time, location, site, year, what kind of animal was in the image and also how many animals there was.

### 3.3 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 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.

### 3.4 Result from Virtual Sensor to User

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.

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## Design

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

Virtual sensors probably uavhengige prosesser, ikke threads ettersom man evt vil addere flere sensorer og unngå å 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 environment. We will present the design of the data storage, the fused data the virtual sensors and the user application. Figure 4.1 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.

### 4.1 Data Storage and Fused Data from Sensors

The dataset from the physical sensors contains over 1.6 millions of pictures from 2011 to 2016 taken from the Arctic Tundra in Finnmark, Norway. The physical sensors are placed at different areas in the Arctic Tundra such as Nordkynn, Komag, Nyborg, Stjernevann and Gaissene. The excel-sheets contains from 17 000 to 70 000 rows with information about each picture taken.

The excel-sheet in the data storage contains a pictures location, date-time,

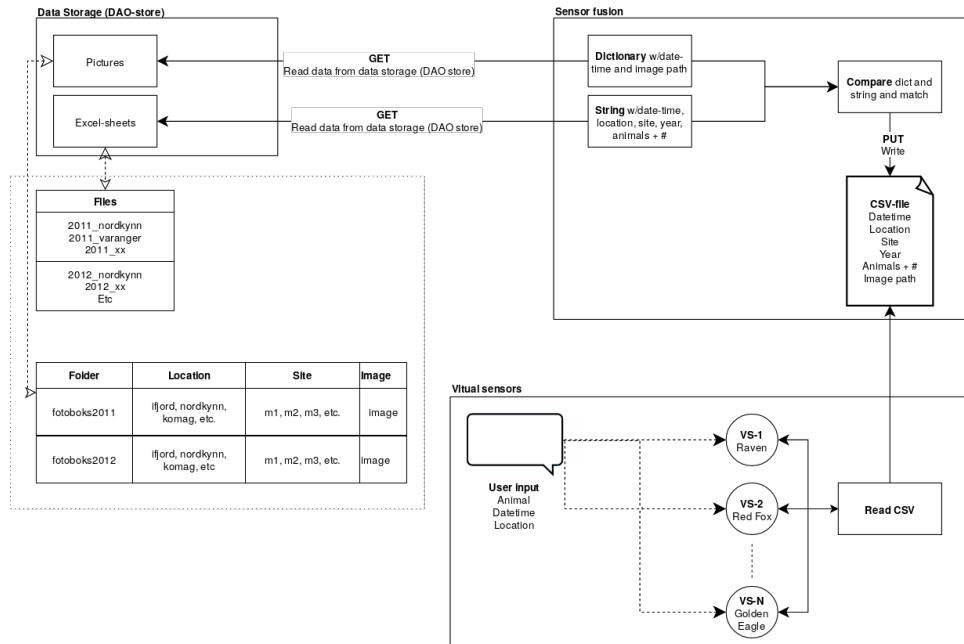


Figure 4.1: Figure showing the system design.

site and year, 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 traversing the directories where pictures are located and read date and time for each picture which is stored in a Python dictionary, like a key-value store, with date and time as key and image-path as value.

Date and time from each image is extracted and stored in a dictionary together with the necessary information from the excel-sheet.

## 4.2 Fused Data from Sensors

Rekursiv traversering av directories og leser metadata fra bildene (ca 1,6 mill bilder) - Lagres i en dictionary hvor datetime og sted er key og image pathen er value).

**FRA HÅVARDS MASTER:** The csv files did not contain any filenames, only image metadata and animal classifications, so we had to get creative to find out which images the annotations corresponded to. Fortunately, each image had metadata stored in Exchangeable Image File Format (exif). We created

a Python script to extract the date and time from each image, along with camera information, to match them with the annotations. This was quite a time-consuming task because of the number of images to process.

Disse sammenlignes og de som matcher blir skrevet til en CSV-fil.

### 4.3 Virtual Sensors

### 4.4 User

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 user only need to specify the following 3 parameters for the virtual sensor:

**Animal**

**Date-time**

**Location**

- Animal:
- Date-time:
- Location:



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## Implementation

### 5.1 Overview

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

The system is implemented and written in Python 2.7<sup>1</sup>. We made this choice because Python is highly portable among different platforms and there are also many frameworks available in this language that are relevant for this implementation.

In the rest of this chapter we will first look at the different frameworks used in this virtual sensor system in Section 5.2, 5.3 and 5.4. Then we will look at the data storage in Section 5.5, the fused data in Section 5.6, the virtual sensors in Section 5.7, and at last we will describe the user application in Section 5.8.

Threads, data structures, language ... testing (CPU, memory, time?)

<sup>1</sup>. <https://www.python.org/>

## 5.2 Pandas

Pandas<sup>2</sup> is an open source Python Data Analysis Library which provides high-performance and easy-to-use data structures. It is a NUMFocus<sup>3</sup> sponsored project which will help ensure success of the development of pandas as a open-source project in world class.

### 5.2.1 Dataframe

A dataframe<sup>4</sup> is a two-dimensional, dynamic tabluar data structure with labeled axes (rows and columns).

## 5.3 ExifRead

To read exif/metadata from pictures, we used a Python library called exifread 2.1.2<sup>5</sup>.

*"Easy to use Python module to extract Exif metadata from tiff and jpeg files."*

## 5.4 OpenCV

CV2 - show image To visualize/show pictures, a Python library called OpenCV<sup>6</sup> was implemented.

OpenCV was started at Intel in 1999 by Gary Bradsky and it was relsased in 2000.

*Currently OpenCV supports a wide variety of programming languages like C++, Python, Java etc and is available on different platforms including Windows, Linux, OS X, Android, iOS etc.*

OpenCV-Python combines the best qualities of OpenCV C++ API and Python language.

2. <http://pandas.pydata.org/>
3. <https://www.numfocus.org/open-source-projects/>
4. <https://pandas.pydata.org/pandas-docs/stable/generated/pandas.DataFrame.html>
5. <https://pypi.python.org/pypi/ExifRead>
6. <https://opencv-python-tutroals.readthedocs.io/en/latest/>

## 5.5 Data Storage

Contains folders with labeled animals, but images have no metadata so don't know when it is taken etc.. Therefore, traverse the whole storage and find "real" images w/metadata and compare to excel-sheet....

## 5.6 Fused Data

## 5.7 Virtual Sensors

## 5.8 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 ...



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## Evaluation

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

- Time: Finding folders and metadata takes: 1:43:13.488799, Reading excel file takes: 0:00:17.413845, Comparing takes: 4:43:30.705587, Overall time is 6:27:01.608355. Med alle bilder m/metadata og hele fotoboks2011\_nordkynn\_nordkynn.2011.xlsx.
- New time: Finding folders and metadata takes: 1:46:17.406581 Reading excel file takes: 0:01:07.686779 Comparing takes: 19:03:11.177869 Overall time is 20:50:36.271415 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 Reading excel file takes: 0:00:18.127597 Comparing takes: 4:18:33.368199 Overall time is 5:49:41.746759
  - Pool(processes=4) FRA fotoboks2011\_nordkynn\_nordkynn.2011.xlsx
- "Concurrent" igjen Finding folders and metadata takes: 1:44:18.788013 Reading excel file takes: 0:00:17.269817 Comparing takes: 3:54:23.483186 Overall time is 5:38:59.541248 – Pool(processes=100)  
FRA fotoboks2011\_nordkynn\_nordkynn.2011.xlsx

This chapter describes the experimental setup and metrics used to eval-

ate the implemented system.

## 6.1 Experimental Setup

All experiments was 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.

## 6.2 Something!?

## 6.3 Results

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

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## Discussion

### 7.1 Architecture

#### 7.1.1 Other solutions

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

### 7.2 Design

#### 7.2.1 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
- FRA HÅVARDS MASTER: The csv files did not contain any filenames, only image metadata and animal classifications, so we had to get creative to

find out which images the annotations corresponded to. Fortunately, each image had metadata stored in Exchangeable Image File Format ( exif ). We created a Python script to extract the date and time from each image, along with camera information, to match them with the annotations. This was quite a time-consuming task because of the number of images to process.

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## Contributions

Combine with conclusion??



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## Conclusion

**9.1 Contributions?**

**9.2 Future Work**





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## **Future Work?**



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## Appendix?

readme, source code, dataset measurement RAW



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