Technology and case study Pipeline monitoring

Objectives:

Monitoring leakage of uncovered and covered gas pipelines is done today by a wide variety of methods from ground inspections, inline sensors to airborne monitoring using Laser and infrared sensors. Especially the airborne technologies are giving the possibility to monitor pipelines fast also in remote areas, but methods are limited to very narrow corridors and specific conditions.

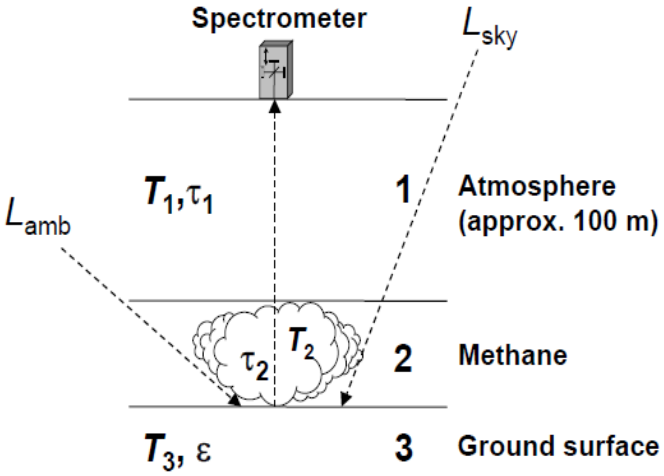
A modified newly available thermal hyperspectral sensor was used to test the reliable detection of Methane plums over a controlled output on a pipeline but also over pipeline segments with different outputs along the route of 60km.

The aim of the case study was also to optimize the processing so that a result is fast available but is also ready for management GIS systems and operational field PC's of maintenance crews.

Technical solution

Using a highly sensitive Fourier transform spectrometer installed in a helicopter allows detailed measurements in the range between 7700 and 11800nm covering also the range of some strong Methane absorption bands. The data collected in a flying height of 100 to 500m with up to 40 knts flying speed allowing coverage of more than 100km of pipelines (covered and uncovered) within one flying session per day. The collected swath width is between 30 and 200m. Same time as the spectral data are collected there is also RGB images as backdrop map for CAD and GIS systems.

The data processing is optimized for the fast detection of potential leakage areas. Therefor datacubes of each flight segment are processed directly in the air and identified areas of leakages are given out on landing of the helicopter or short after in their location and with the rectified datacube to send ground crews for further investigations there.



Practical test to identify sensitivity over a controlled gas release

To validate the methodology tests were flown over a known and managed gas release. Parameter as the flying height, the amount of released gas and the speed of flying were modified while meteorological data were recorded. This allowed the fine tuning of the methodology as well as definition of the optimal data collection parameters and limits of detection.

While the flying altitude was modified between 100 and 1000m above ground. The methane plum cloud could be detected in a flying height up to 300m above ground (and therefore also in a for flight operations over build up areas in a safe altitude), best results with high reliability were achieved in flying height between 100 and 200m.

Varying and averaging the amount of Methane gas from the controlled release and measuring in the same time the wind speed and direction allowed an estimation of the sensitivity of the method. For the flying altitudes of up to 200m even for the lowest release of under 70l/h the gas plume was detectable.

By increasing the spectral resolution of the measurements from 4cm-1 to 2.5cm-1 detectability of the gas plume increase also to altitudes above 200m while in the same time the flying scheme got more difficult due to lower flight speed.

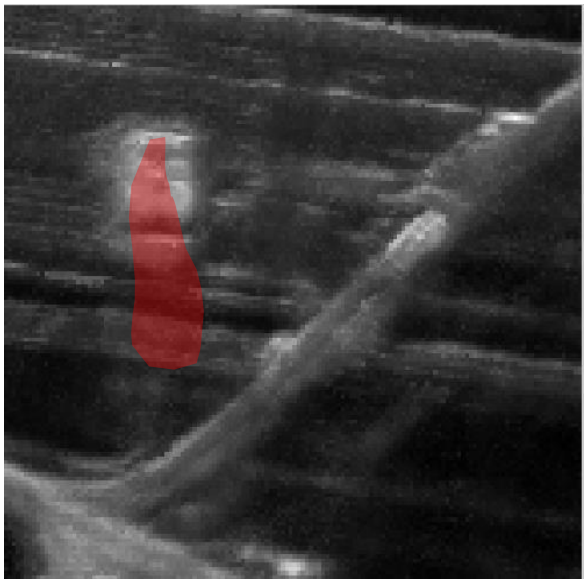


Image of the gas plume over the release with 125l/h based on multiple overlapping datacubes flown in 200m above ground

Summarizing the field tests in a controlled environment the method of using an infrared Fourier transform spectrometer in a helicopter proved valid for the detection of Methane leakages. The methodology allows the detection of methane plumes instead of the leakage place alone. That allows also the detection of underground leakages building small plumes direct over the surface.

The method can be used with variable background signatures as in urban and rural areas and also with light to middle wind. The detectability of leakages can be improved by flying not higher than

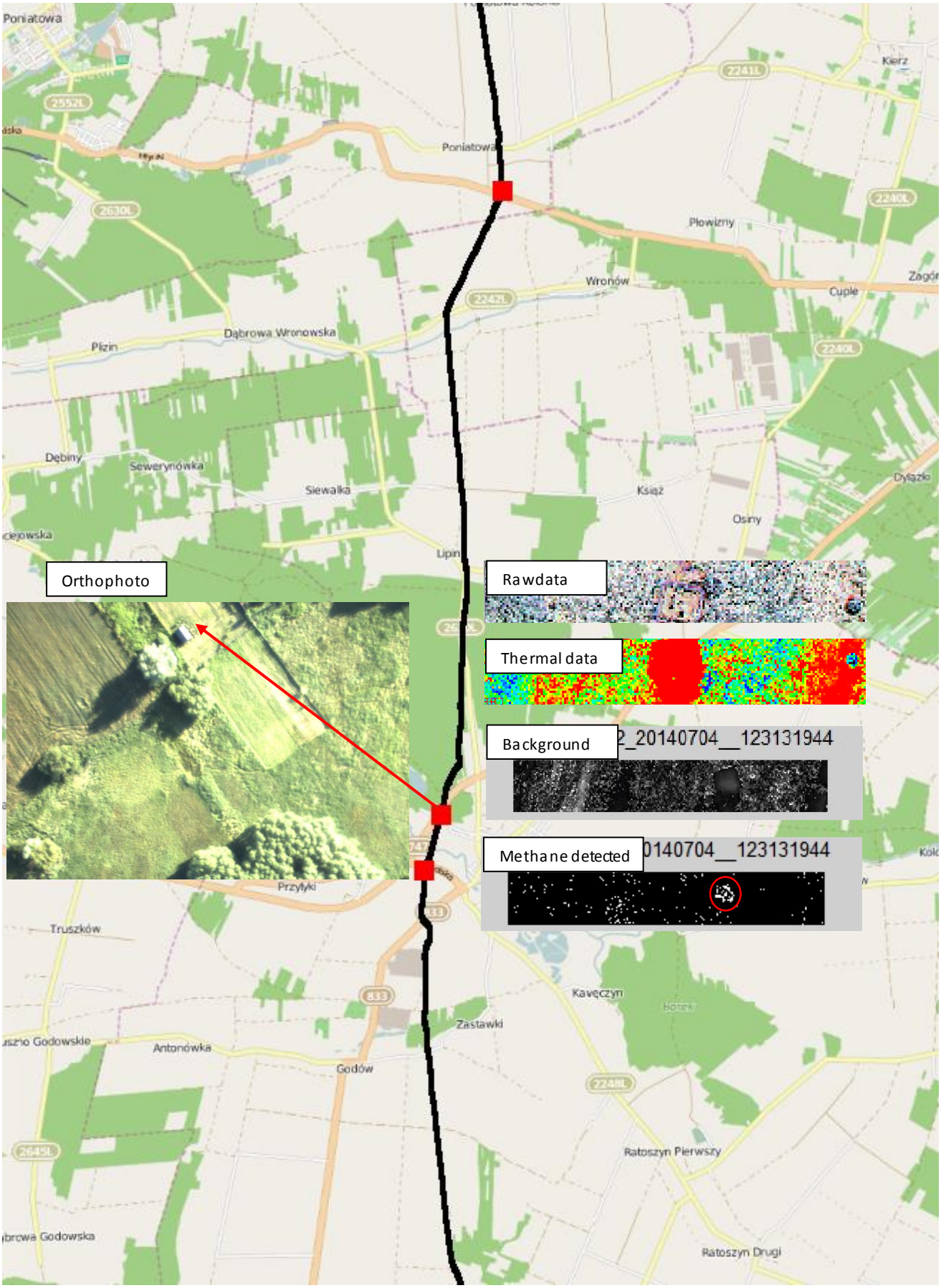
200m, using a high spectral resolution and having overlapping datacubes. Blue sky and good temperature differences are better suitable for the method, but in additional tests it was also possible to detect methane under closed cloud covers with high humidity and low temperature differences in the scene.

Mapping of a gas pipeline

In further operation pipeline segment of 60km was flown. On this segment were known leakages. For the first test the height was 300m above ground and the speed 40knts, the second test was based on preliminary results lower with 200 to 250m and 30knts speed. During both flights the system was recording data on the thermal sensor with a spectral resolution of 4cm-1 and image data for GIS backdrop with a resolution of 8cm.

The pipeline of 60km could be covered with a MI2 Helicopter within 30 minutes of data collection using the CAD drawing of the flight management to follow the pipeline within 20m accuracy. After collection of the data and download the data were processed for the research tasks based on following steps:

- Correction of the raw data using the camera intern black bodies to reduce the camera effects
- Atmospheric correction and temperature emissivity separation
- Definition of typical background scenarios and allocation of these scenarios to the datacubes
- Detection of possible methane leakages on each datacube
- Fast track rectification of datacubes with identified possible Methane leakages
- Cross check of the detected areas with the pipeline drawing to eliminate wrong detection outside of the direct pipeline corridor
- Final definition of datacubes with detected Methane over the pipeline
- Final coordinate list of detected leakages. In case earlier collected data from another flight are existing or a maintenance database includes information of earlier problems on the pipeline this data will included in the final listing


Poniatowa
Poniatowa
Płowizny
Wronów
Cuple
Dąbrowa Wronowska
Plizin
Dębiny
Sewerynówka
Siewalka
Książ
Osiny
Lipin
Przyłyki
Truszków
Kawęczyn
Zastawki
Antonówka
Godów
Ratoszyn Pierwszy
Ratoszyn Drugi
Orthophoto
Rawdata
Thermal data
Background
Methane detected

Output of the result data

The processed data will be provided in three packages:

1. The **ultrafast package** contains coordinates with the points where a highly likely leakage was detected, for this package no image data are transmitted. The package is provided for urgent action of maintenance crew. The absolute accuracy of this data is within 30m and only bigger leakage will be recorded. The data can be send via all electronic media and are available within hours after the flight.
2. The **fast package** provides coordinates of leakages within 3m accuracy, an image of the area with the leakage marked and detection parameters describing also semi quantitative values of the detection procedure. This data package is provided by email and requires no special software for visualization by maintenance crews. This data are delivered within 24 to 48h after the flight.
3. The **archive package** delivers compete orthorectified image data of the pipeline (which are suitable for the GIS as backdrop map to analyse encroachments and other issues), all original data of the Methane sensor and results of the detection with parameter tables. This data delivered within 2 weeks after flight allow the client the legal prove of the monitoring activities as well material for preventive maintenance of the pipelines.

Improvement

Based on the investigations on the known release and the developments on further flight operations and investigations on flights in the UK, Hong Kong and Israel following improvements for the operational application were adopted:

1. An increase of the spectral resolution based to 3 or weather permitting better 2cm-1 to increase the detectability of the gas plumes.
2. No flights under strong wind conditions or weather with low cloud coverage due to reduced thermal dynamics and the behaviour of the gas plume. But operation can be flown day or night.
3. Usage of a modified sensor with a more specific range of the data collection covering the Methane bands. This allows higher spectral resolution and better sensitivity.

Commercial considerations

Using this solution following performance can be achieved:

- Flight of approximately 50km per hour of operation of the helicopter
- Daily survey of up to 200km of pipeline with processing to the ultrafast package same day.

Comparing to others technologies the solution offers:

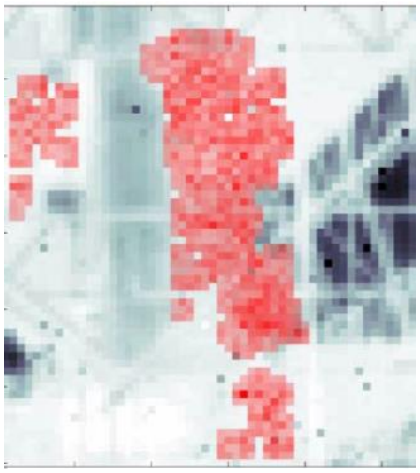
- It works on covered and uncovered pipelines and in limits also on subsea installations
- It covers a wider corridor of mapping and therefor monitors the whole scenario of leakages and includes also soil structures, vegetation components and other more complex parameters to evaluate and verify the leakages by the maintenance engineering
- It provides data which are directly usable in GIS and CAD systems

- Data are also usable for long term monitoring, official reporting and preventive maintenance planning based on multitemporal analysis and implementation of others sensors for vegegation analysis, Lidar and geophysics in the sensor set.

Adaptions of the technology

The technology is also adapted to:

- Monitor ground based installations in the petrochemical and chemical industry. This was tested from a place 150m away from the installation leakages in a refinery. For this tasks the sensor is setup on a tripod and collected data are processed near realtime for the detection of leakages.



- Estimate the output of Carbondioxid and other gases from chimneys to provide information for monitoring of environmental standards and calculations for Carbon sequestration.