23rd International Conference
ENGINEERING MECHANICS 2017
Svratka, Czech Republic, 15 – 18 May 2017

UNMANNED AIRCRAFT VECHICLE DESIGN FOR TEMPERATURE FIELD ANALYSIS

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Abstract: *This paper presents the design and implementation of device for remote and automatic monitoring of temperature field of large objects like pipes, PV fields and building complexes. With the help of originally designed system based on commercial low cost unmanned aircraft vehicle equipped with anopen source software and commercially available infrared camera, thermal imaging was performed. Research was made on the temperature field of working district heating system during winter in Poland. The system is based on open source PixHawk automatic pilot device and implementation of FLIR-One thermal micro camera under the Android environment.*

Keywords: **UAV, Aerial Robotics, Remote Sensing, Infrared Camera, Thermal Imaging, District Heating.**

1. Introduction

Unmanned Aerial Vehicles (UAVs) or more extensively Unmanned Aerial Systems (UAS) are platforms considered under the Remotely Piloted Aircraft (RPAs) paradigm. All of them are presently in continuous development at a rapid rate. Altogether, the development of sensors and instruments to be installed onboard UAV platforms is growing exponentially. These factors together have led to the increasing use of these platforms and sensors for remote sensing applications with new potential (Pajares, 2015).Recent advances in UAVs for civilian use make it possible to regularly monitor environments from the thermophysical point of view, at spatial and temporal scales that would be difficult to achieve using conventional methods. Previous aerial monitoring of thermophysical environments has been expensive and time consuming (Nishar et al., 2016).Thermal and visual image registration consist of different methods to improve the quality of interspectral registration for the purpose of real-time monitoring and mobile mapping. Images captured by low-altitude UAVs represent a very challenging scenario for interspectral registration due to the strong variations in overlap, scale, rotation, point of view and structure of such scenes (Yahyanejad and Rinner 2015). Drones are now routinely used for collecting aerial imagery and creating digital elevation models (DEM). Lightweight thermal sensors provide another payload option for generation of very high-resolution aerial thermal orthophotos. This technology allows for the rapid and safe survey of thermal areas (Harvey et al., 2016). For example, as reported by (Tsanakas et al., 2016) standard Electro-Luminescence imaging method for large Photo-Voltaic fields gives no information on the thermal impact of a potential fault and, thus, no estimation on the result and power output loss can be done for the impacted PV module, It is purely qualitative rather than quantitative diagnosis. This approach is suitable not only for PV fields but also for solar thermal fields (Carlson et al., 2014).

This paper validates the use of cost effective and small (< 2 kg) quadcopter UAV to safely and precisely map the physical characteristics of industrial and urban thermal locations. Thermal infrared imaging and photogrammetry are used to capture complete information of thermal exterior features. The general objective of this paper is to deliver device for distant recognizing applications based on unmanned aerial platforms, equipped with a set of specific sensors and onboard instruments specifically intended to easily

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capture thermal data. Applications in several areas are proposed, where the combination of unmanned platforms and sensors, together with methods, algorithms, and procedures provide complex thermal imaging.

In the era of reducing energy consumption in the industrial processes, an important issue is good thermal insulation of devices. This problem applies to pipelines from industrial heat networks as well as district heating (DH) networks and finally in the whole area of municipal structure. The effect of thermal bridge previously well recognized in the range of building insulation aims the fact that even a small point leakage or line leakage can cause significant heat loss. With regard to industrial facilities thermal bridges resulting from the structural design are difficult to avoid and much more difficult to locate. Usually, when the object is not big hand infrared camera is enough. Considering the long pipes or heating networks, or clusters of residential houses one should have an automated device that will allow to complete the imaging task in reasonable time. Assembling such a device for solving the interdisciplinary problem – from knowledge of the mechanisms of heat transport through the construction or adaptation of flying device with supply of infrared camera and appropriate software is essential and specific to mechanical engineering, energy, mechatronics, automation and control and finally sustainable development of urban and suburban areas.

2. Methods

Rising fuel prices are forcing to look for savings. One way to search for such savings is constant or cyclical verifying the thermal insulation of industrial pipelines, heat distribution networks from internal and hot water pipes: both of low and high temperature. These issues are problematic for the large areas and the use of manned survey cost will certainly exceed the benefits of the potential savings as manual network monitoring by trained staff can be very tedious and take a lot of time. The use of unmanned aircraft instead of traditional heat loss surveillance methods reduces network maintenance costs by precise indication of the problematic spots. The tests may be carried out in an fully automatic way.

The project aimed to create a quadcopter flying platform equipped with a thermal imaging camera. For this commercially available UAV model was used – 3DR-Iris+ (Fig. 1). The model is capable of 20 minutes flight on a single battery and perform autonomous flight along the pre-programmed route. The platform is equipped with advanced flight control – Pixhawk which allows for further. Successful use of this model in the research, was possible thanks to custom equipment with a set of devices such as – Raspberry-Pi-3 microcomputer, infrared micro camera FlirOne and AV transmitter that transmits real-time image to the ground. Image stabilization during the flight is provided by gimbal device – Tarot-2D (Fig. 1).

The Pixhawk flight controller contains sensors like accelerometer, gyroscope and barometer. Barometer allows to fly at a constant height and hovering. Taking pictures at a constant height is a prerequisite for the subsequent processing of visual data. The sensor also allows the imposition of the platform of the upper limit of the amount to which the model can soar. This is a very important aspect in the conduct of research in the active area of flight. The presence of GPS module allows to fly the programmed route, the ability to lock the area over which the platform cannot find and track the position of the model in real time. (Anweiler and Piwowarski, 2016). Iris+ platform is not waterproof, but it is designed to allow the usage in areas with high humidity, during fog, low temperature (below 0 °C) and during fine rain. The maximum wind speed in the course of research is approx. 20 km/h. Iris+ power source is a lithium-polymer 3S 5000 mAh, 11.1 V battery. Reserve power model allowed to mount on the camera Flir-One along with the necessary equipment without affecting the stability of the flight. In summary, the UAV platform 3DR-Iris+ looks very promising as a carrier of measuring devices. It meets all the requirements while offering additional options and possibilities. This is an easy development platform that allows further modifications and improvements to provide valuable information about the test object or area.

Thermal images are made using the Infrared camera FlirOne (Fig. 1). The camera is characterized by the possibility of carrying out the measurement temperature in the range of from -20 °C to 120 °C, with the resolution of 160 x 120 pix and a low weight of 30 grams. This camera works in the Android software environment. To equip the camera to the UAV platform the use of microcomputer Raspberry Pi 3 is recommended (Fig. 1). This micro device includes Broadcom 1.2 GHz quad-core processor, 1 GB of RAM and HDMI connector. These features enabled the installation and commissioning of required applications and proved to be sufficient. Android environment is installed on a micro SD card affixed later in the Raspberry Pi.

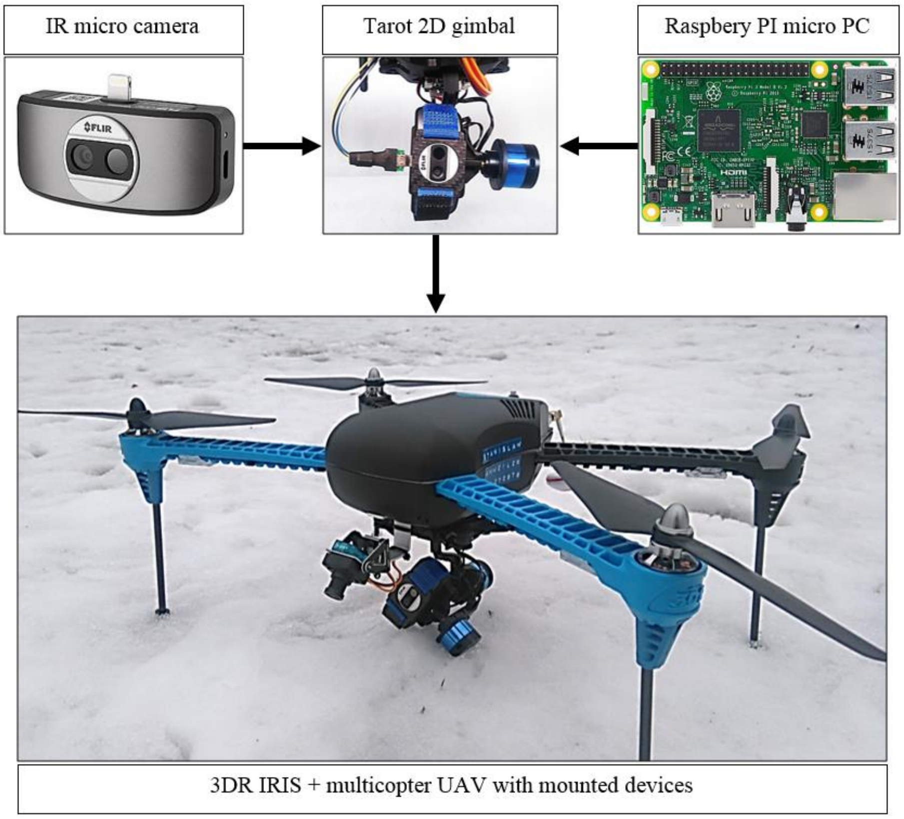

Fig. 1: Multicopter UAV – imaging aerial platform 3DR Iris+ and mounted devices: IR FLIR micro camera, Tarot 2D gimbal, Raspberry Pi 3 microcomputer and visual recording camera.

3. Results

A fragment of Opole municipal district heating network with the part of a high temperature pipeline (design values 126/68^{o}C) under study is presented in Fig. 2. Thermally imaged heat pipe line lays underground and is constructed as twin preinsulated system that consists of two pipes with a diameter equal to 125 mm. During the thermal imaging the temperature of water in a supply pipe was equal to 91 ^{o}C, while the temperature of water in a return pipe was equal to 50 ^{o}C.

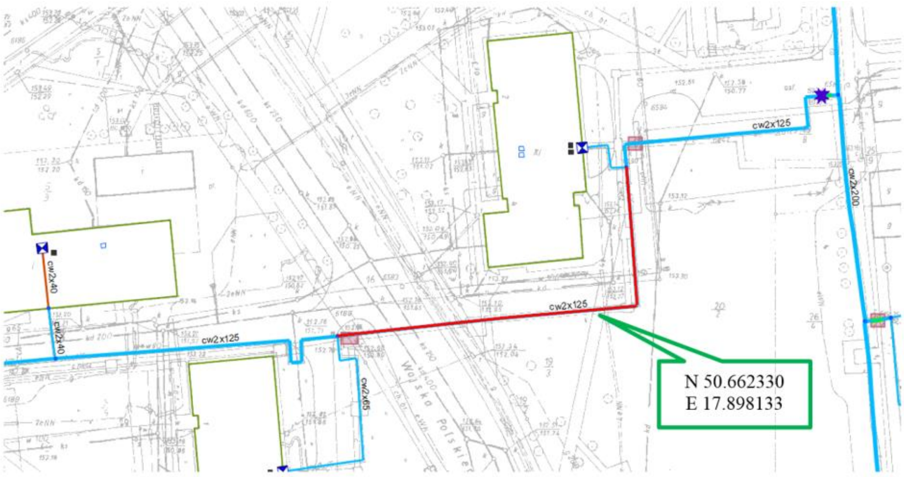

Fig. 2: GIS map of district heating system network. Analyzed section of the heat pipeline is marked with red color. Corresponding geographical coordinates marked in green. (1:1000 scale).

Fig. 3 presents the images that have been made with visual and IR FlirONE camera. It was made on 5/2/2017 at 12:30 hours. Outside temperature was –1 ^{o}C and atmospheric pressure 1020 hPa. The geographical coordinates of the photographed location: N50.662330, E17.898133. Despite the low resolution of the camera underground pipeline is clearly visible.

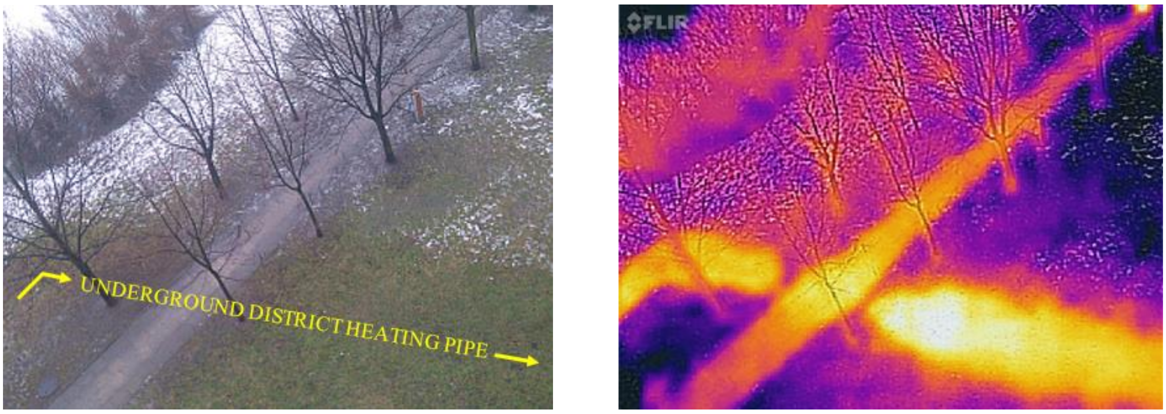

Fig. 3: Visual and infrared capture of the location with underground district heating pipe.

4. Conclusions

The development of the energy and heating industry, requires the use of new technologies for energy production, as well as the monitoring of industrial processes. This reveals a whole new area where the unmanned aircrafts can be used successfully. This article describes how to visualize the temperature field using the multicopter platform Iris + equipped with a thermal imaging camera FlirONE. It proved to be an excellent tool for locating underground heating lines. This is a very good alternative to currently used methods. It allows quick and precise determination the course of the pipeline and an indication of a possible leaks in case of failure. The used method also enables visualization and determination the size of the heat loss in the individual sections of the heating network. Presented example, studies thermal imaging has proven effective in the location of the preinsulated pipeline with reduced heat losses. It must therefore be assumed that the proposed method can be a good tool to diagnose the traditional networks, with a much larger heat losses, commonly used in Poland. Low assembly cost of the platform (below 1000 $) and low maintenance cost allows frequent measurements. By comparing the data collected in time the wear of pipeline can be detected in advance, and plan their earlier exchange or establish the maintenance schedule to the network. All these aspects lead to a reduction in the risk of failure, reduce network maintenance costs of transmission and thus, by reducing the loss of heating medium and heat loss, reducing the impact on the environment. UAVs used in monitoring temperature field reveal only a portion of their capabilities. Fast growing market of the multicopter platforms still provides new solutions and improvements.

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