Efficient Navigation System of Mobile Robot with Thermography Image Processing System and Mapping of Quadcopter

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***Abstract*—A generic approach for the real-time navigation and rescue of Mobile Robot through the control of the thermography mapping and image processing of Quadcopter. For navigation and position, mobile robot has to solve two problems: Initially it is essential to determine the current location, and build path of the upcoming journey, free from obstacles especially in bad weather (smoke, fog, covered area). According to the scenario of the mission, thermography mapping is the solution for these problems. Quadcopter takes off from Mobile Robot, surveys the path and transmits thermography image to robot. Mobile Robot processes thermography images, detecting dangerous area, matching moving targets in real time, calculating the optimum trajectory and allow automatic navigate through the outdoor environment based on the programmed route.**

***Keywords*—Thermography; Thermography System of Object and Area Detection; Mobile Robot; Quadcopter; Mapping; Heterogeneous group of robots; Navigation**

I. INTRODUCTION

The robot is an electromechanical machine intended to play out an assortment of undertakings in different parts of our lives. Clearly the customary machines have more note-worthy adaptability and capacity to adjust to different issues, including changes in environmental factors.

Service robots are mainly designed to serve people in the multilateral sectors of education, health, military, security, emergency, entertainment, research, and agriculture. Specific consideration is paid to the computerization of overwhelming, unsafe, repetitive and tedious work in an assortment of enterprises with the assistance of robotics [1], [2].

Presently designers of frameworks utilizing artificial intelligence can prepare their developments for the GPS-navigation systems, cameras, thermography images, as additionally numerous extra locators were expands the force of current robots.

The main objective is to reliably detect the static -dynamic people and vehicles in a variety of environments, both cluttered and uncluttered air views, regardless of weather conditions or terrain. Cameras with both mobile robot and Quadcopter used to detect obstacles [3]. Older image processing system has fair results in bad weather conditions (smoke, fog coated region) while displaying thermography is a solution to these problems.

Efficient navigation is important in any aircraft, especially in the night air IR operations. Turn on the path that Quadcopter system may be new to the region and outside the pale and global positioning system (GPS) is transformed into a need. GPS is used to detect the target, plan routes and during post-flight processing coded and showed data (latitude / longitude, altitude, date, time, speed, etc.) is essential.

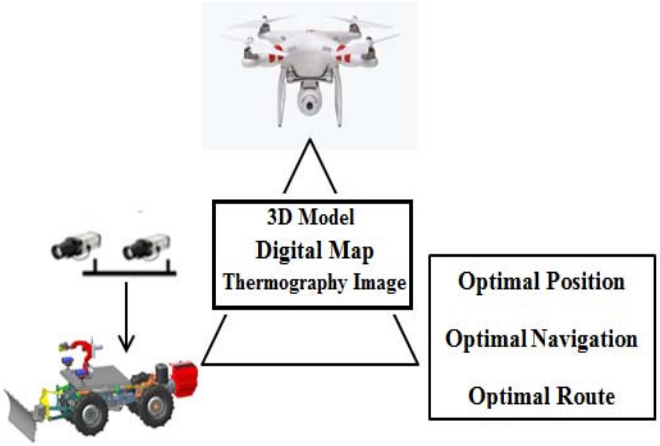

Fig.1. Navigation of Mobile Robot with Thermography Mapping

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A wide range of thermal imaging holds vast areas or divisions of emergency must be secured in order to detect or to characterize the thermal purpose, such as people, animals and objects. To distinguish and avoiding obstacles in their paths, the robots must be able to screen and adapt their environment by implementing an analysis of its kind and environment system [4].

As a result, thermography has many advantages, such as:

1) It shows a visual picture as temperatures over a large area can be compared to [5], [6].
2) Is able to catch moving objects in real-time maner [7].
3) It could be utilized in the field of medical sector, mainly in physiotherapy.
4) Is ready to discover disintegrates, i.e. higher temperature segments before disappointment.
5) It can be utilized for measuring or checking in regions that are blocked off or perilous for different strategies.
6) This is a non-dangerous test strategy.
7) It can be utilized to discover surrenders shafts, channels and other metal or plastic parts [8].
8) It can be utilized to distinguish objects and people in dim spots.

In regard to that, we are developing a system Robotic Quadcopter Mobile (QMRS), as shown in Fig.1 and Fig.3, which performs several operations, as a movement in the other direction, to avoid and detect obstacles, performing various tasks (fire and rescue people using thermography comparison).

To navigate and position the mobile robot has to solve two problems: to determine the current location, and build path of the upcoming trip, free of obstacles, especially in bad weather conditions (smoke, fog, covered area).

The first and second problems are solved by a system of visual display thermography image positioning of the robot and Quadcopter.

The purpose of the article is to demonstrate the simulation of air / ground-based robots [9] in the real world with the help of thermography mapping method, as shown in Fig.1 for optimal positioning and navigation of the mobile robot and rescue operation for the man.

Fig.2. Mobile Robot Belarus 132N

II. DIGITAL MAP

Digital Map is a procedure where the information gathering is prepared, arranged and organized in a digital image [10].

Maps depict natural and human-induced changes in the world in high-resolution for large areas and over long periods of time. In addition, Maps are the only source of information about the land as surveyed using geodetic methods. In order to preserve these unique documents that have been created, driven by advances in software and hardware technologies growing number of digital map files. Since the beginning of the 1980s, researchers from various disciplines, including computer science and geography, are working on computational methods for extraction and recognition of geographical features of the archival image maps (digital card processing).

A typical result of the card processing is geographic information that can be used in spatial and spatio-temporal analysis in the environment of a geographic information system, which benefits the many fields of research in spatial, social, environmental sciences, and health. However, the card processing literature is distributed in a wide range of disciplines in which maps are included in a special type of image.

Over the past 40 years, researchers have become increasing interest in methodological aspects of computing card processing (mainly scanned maps) for the purposes of search, retrieval and integration of geographic data. A similar increase in the results of the attention not only of the parallel advances in technology (e.g., digital image analysis, pattern recognition and geographic information systems [GIS]), but also, of course, may be due to the fact that the methods of processing computer card will enable the preservation of the unique (historical) cards and the use of geographic information in the modern analytical environments (e.g., GIS).

III. THERMOGRAPHY MAPPING

Thermal imaging cameras (developed by Hungarian physicist in the 1920s) is an advanced piece of technology that can detect the heat emitted by any object or living being.

Infrared thermography (IRT), thermal and thermal infrared video is cases of science show. Thermo-graphic cameras have a tendency to recognize radiation in the long wavelength infrared district of the electromagnetic range and imaging this radiation is called thermo-gram. Since infrared radiation is discharged by all items, thermography permits you to see your environment. Consequently, thermography permits us to see varieties in temperature. Accordingly, thermography is particularly helpful for military and different clients of reconnaissance cameras.

Thermography is likely a standout amongst the most underrated of new innovations of the most recent century; its utilization is by all accounts always showing signs of change and developing, as more businesses perceive the estimation of this innovation in their practice.

The technology uses a lens that focuses the waves of infrared light energy which can be detected in all objects on the infrared sensor device. The energy is converted into electrical signals, creating a video image. In relation to the object and its surroundings, an infrared camera produces thermal profile. The

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warmest areas appear white, creating a distinctive appearance that makes it easy to identify different objects.

Thermography has the ability to provide important information for quality assurance purposes. Even small temperature variations can result in serious loss of quality, i.e. in the plastics industry or automotive industry. By creating an infrared camera monitoring system, such errors can be recognized, documented and corrected immediately.

Scientists were adapting the use of thermography in a wide range of applications such as the field of security surveillance, law enforcement and defense, Quadcopter observation [11], monitoring the state, night vision and targets [12], thermal mapping, medical imaging; and chemical imaging.

IV. PROPOSED SYSTEM

QMRS (Quad-copter Mobile Robotic System) is a system of real-time calculation and avoidance of movable/stationary objects of mobile robot Belarus-132Nas shown in Fig.2 by the help of thermography image of quadcopter Phantom-4 Pro. One of the fundamental difficulties is here to build environment representations that coordinate aerial and ground information as shown in Fig.3.

A. Thermography System of Object and Area Detection of Quadcopter

1st Quadcopter takes off and moves over Mobile Robot at a stature of 15-20 meters and encompassed range, photographing it utilizing a camera and transmitting thermography picture information to Mobile Robot [13],[14]. 2nd Mobile Robot utilizes thermography mapping, and image handling and processing system to figure the ideal course to move. 3rd Mobile Robot utilizes the outcomes acquired in step 2 to travel through outdoor.

Phantom-4 Vision Quad-copter is a lightweight, multi-functional integrated rotor with a camera remote-control by DJI VISION APP as shown in Fig.4. Its range extender increases Wi-Fi distance to 5 km. Due to its reliability, Phantom-4 Pro Vision Quad-copter use anti-vibration camera platform with single axis stabilization. It operates at low-voltage protection with virtual radar aircraft locator on mobile device. The image processing uses HD Video Recording (H.264 and H.265) and save the sequence of image in JPEG and DNG picture formats and video in MP4/MOV (AVC/H.264; HEVC/H.265) formats.

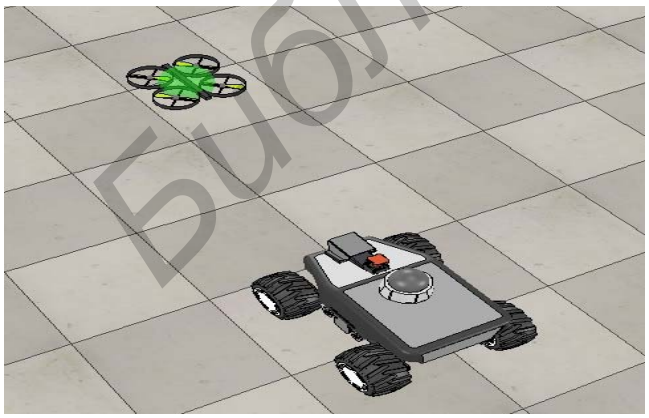

Fig.3. General view of Quadcopter Mobile Robotic System

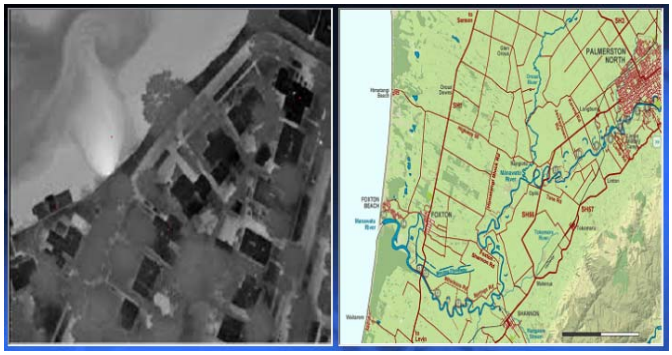

Fig.4. Thermography image mapping

Thermal image maps temperatures of the display area, and will be useful for applications such as the detection of structural damage to roads, to identify the source of groundwater discharge, spotting hidden archaeological ruins, and the discovery of roe deer, which may be affected by the cutting operation, as shown in Fig.4 and Fig.5.

Thermography system of object and Area detection is a hybrid system designed for temperatures from a given point in the thermal image and projects its location directly on the digital map, based on dynamic scales coordinates and colors set by the user that help mobile to freely navigate in unknown environment especially in bad weather conditions (smoke, fog coated region).

Thermography system consists of several parts:

1) The projection on the digital map: link between the system of heat detection and digital maps; allows the user preference for knowing about the selected input for destinations on the map, in addition to its coordinates. This feature helps speed access to the target location in the event of a forest fire, or in the case of foreign bodies marked by wide open spaces.

2) Dynamic display: By setting the initial coordinates of the image.

3) Control and monitoring: automatic scanning option is enabled in the system gives an important advantage to the central level, which would be on the other hand, the difference between the colors in the image to the user puts more attention to what he articulates. This function is inter-related directly in to the first two problems mentioned.

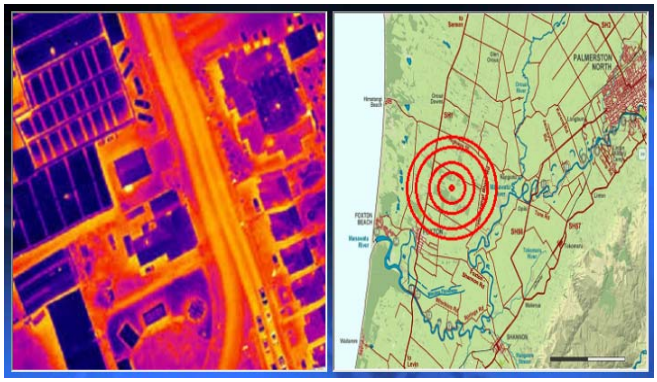

Fig.5. Thermography image selection location

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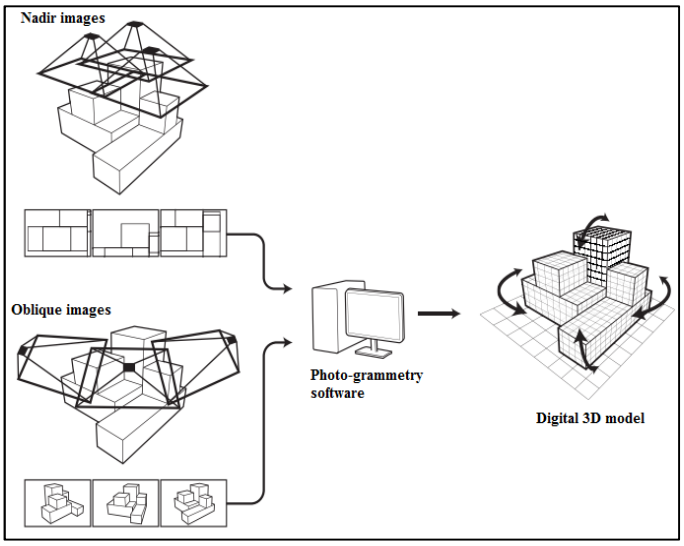

Fig.6. Thermography image 3D model processing

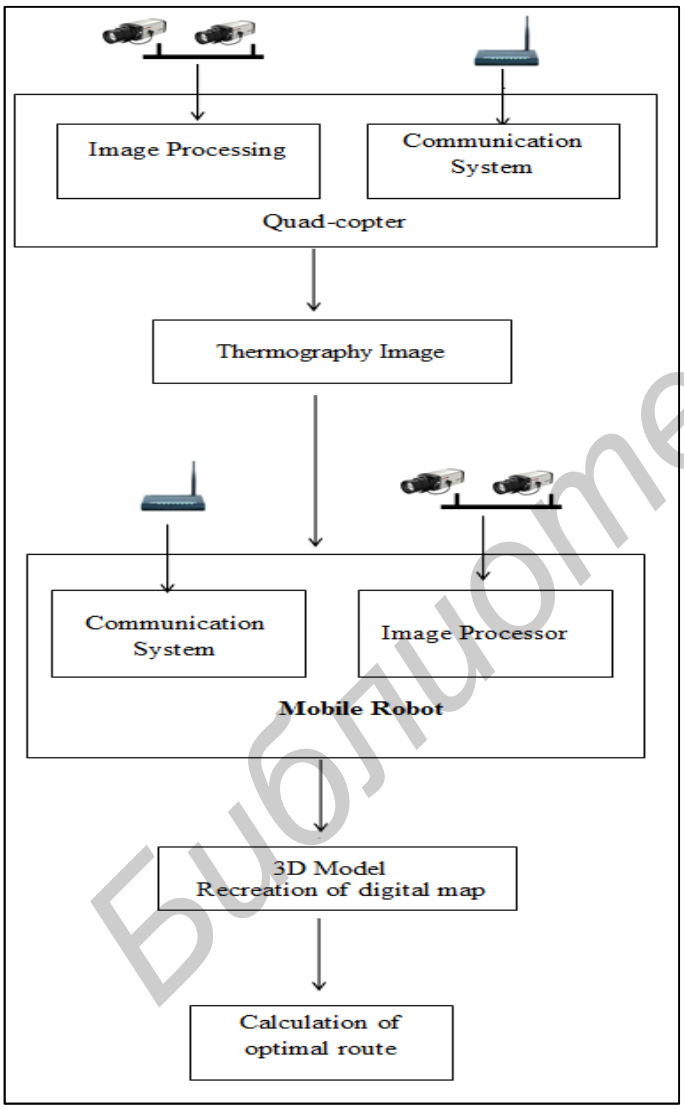

Fig.7. QMRS Position and Navigation algorithm to select optimal route

Fig.8. General View of Phantom-4Pro Vision Quadcopter

Quadcopter flight path or mapping projects should be designed to ensure a sufficient amount of a photographic overlapping forward and the side to be better to allow post-processing software to identify common points between each image.

B. Image Processing of Mobile Robot

Mobile robot Belarus-132N is outfitted with sensors and XY rotating imaging systems utilized for observation in open ground encompassing condition and control the development of movement. Image processing system gets information from different cameras to calculate the distance to the obstacle [15].

Image processing System of Mobile Robot includes three functional blocks:

- Electronic video stabilization unit;
- Video compression unit;
- Automatic tracking and service control unit.

As shown in Fig. 9, the image processing module is in a certain sense, the "intelligent". The level of intelligence of the video is determined by the machine the ability to isolate the informative features of the objects specified to accompany, to take low-level solutions (identified accompanied by objects) and to adapt to changing external and (or background) conditions. The video is not designed for high-level intellectual processing associated with scene recognition, high-level training, generating and testing hypotheses, the formation of problem-solving algorithms, and etc. Thick arrows in Fig. 9 display video transmission paths while thin arrows show the direction of transmission of commands and vector data.

With the help of image processing systems mobile robot show a point on a computerized digital map, which is to come, or the reference point in the video frame in the course you need to move.

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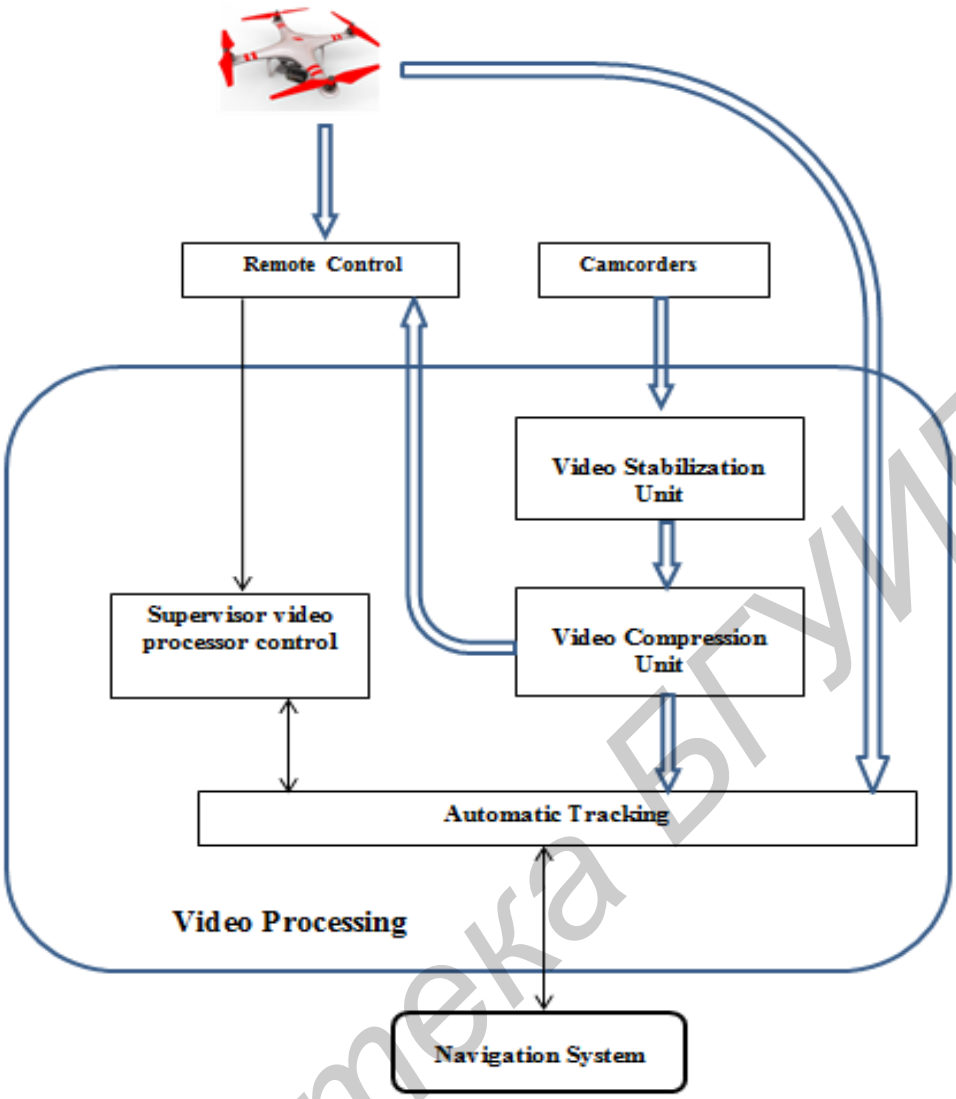

Fig.9. A generalized scheme of Image Processing System of Mobile Robot

Image processing of the mobile robot is going to use 3D-model, which can be created from any Nadir shots (shot in the vertically downward direction) or oblique image (with an angle to the side) Quadcopter and images from the mobile robot, but the most detailed models combine both in a single view. To create a 3D-map image processing system requires hundreds of overlapping images, as shown in Fig.6.

Next, the processing of the mobile robot image builds 3D polygon "mesh" on the basis of a dense cloud of points; representing the surface of the object, to think about the network, draped over the three-dimensional object. At the final stage, the software sets the texture taken from original photos of 3D-mesh, giving the original flat imagery a sense of depth and volume. The collected images must be processed on a computer to create a map.

C. Navigation and Object Detection

There are many ways for the positioning of the robot, which can be divided into two groups: the relative and absolute position measurement. QMRS (Quad-helicopter Mobile Robotic System) for positioning and navigation depends mainly on four factors: Quadcopter thermography image, the image of the mobile robot, 3D modeling of image processing, as well as the creation of a digital map based on thermo-graphic images delivered from Quadcopter.

The main problem is searching for missing persons or movable objects in particular zones or free navigation of the obstacle. Search of the missing in the open territory during the day, as a rule, is not risky, in spite of the fact that the conditions are not generally perfect; fog may show up or area can be intentionally invisible under cover of darkness.

There is a basic and compelling approach to see through fog, smoke, and even through the undergrowth and to "see" at night. All items or objects warmer than absolute zero transmit infrared radiation that can be identified by the thermal imaging system independently from the above impedance conditions. As living creatures (human, animal) quite often have distinctive

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body temperature than the environment, thermo-graphic images make great utilization of the light, during the evening and in bad/awful weather, such as rain, snow, and fog.

Human detection / vehicle from aerial photography is challenging mainly due to the small size of the body / vehicle as seen from an airborne platform. When properly installed and parameters read by a good device, object and humans of distinctive temperatures can be identified at a distance of several kilometers. It should be noted that the potentially dangerous "object" cannot just be a living entity, and may also be a car or other means of transport, or possibly in the center of the fire. Warm bodies usually are assigned thermo-grams contrasting colors, for example all higher temperature (35 ° C) is appeared in red.

In such cases, our proposed system offers elegant and accurate solution, as shown in Fig.7. It is simple and effective, in the sense that permits the controller to rapidly test any space inside a substantial region. The system can distinguish individuals crossing the land outskirts or to scan for individuals passing up a great opportunity for a substantial region. The proposed system can help to find a man trapped by fire and smoke.

Inputs of QMRS algorithm to find the optimal path are thermography image Quadcopter, mobile robot images, 3D modeling of image processing, as well as the creation of a digital map based on thermo-graphic images delivered from Quadcopter, as shown in Fig.4 and Fig.5.

V. Conclusion

The positioning and navigation system of mobile robot Belarus-132N was presented with a thermal imager images from Phantom-4 Pro Vision Quadcopter. QMRS reaches the following aspects:

i) Determination of 3D-model, involving the use of vision systems and image processing from both the robot and quad helicopter (thermography).

ii) By analyzing the way in real time and avoiding obstacles by recreating a digital map.

iii) Optimizing the efficiency and reliability of the whole system, particularly in robot navigation.

Our system consists of thermography Quadcopter image, the image of the mobile robot, 3D modeling of image processing, as well as the creation of a digital map based on thermo-graphic images delivered from Quadcopter.

References

[1] R. Siegwart, I. R. Nourbakhsh and D. Scaramuzza," Introduction to Autonomous Mobile Robots ",2nd Edition,2004, ISBN: 978-0-262-01535-6.

[2] J. Borenstein, H.R.Everett, L.Feng., "Where am I ? Sensors & Methods for Mobile Robot Positioning", 1996.

[3] I. Mezei, V. Malbasa, I. Stojmenovic, "Task Assignment in Wireless Sensor and Robot Networks", IEEE Trans. telecommunication forum, ISBN 978-1-4673-2984-2, January 2012.

[4] C. Karaoguz, T. Rodemann, B. Wrede, C. Goerick, "Learning Information Acquisition for Multitasking Scenarios in Dynamic Environments," IEEE Transactions on Autonomous Mental Development, vol. 5, No. 1, March 2013.

[5] J. Costello, C. McInerney, C. Bleakley, J. Selfe, A. Donnelly, "The use of thermal imaging in assessing skin temperature following cryotherapy: a review". Journal of Thermal Biology. 37 (2): 103–110. (2012-02-01).

[6] A. Bach, B. Stewart, G. Minett, J. Costello,"Does the technique employed for skin temperature assessment alter outcomes? A systematic review - IOPscience". Physiol Meas. 36: R27–51. (2015)

[7] A. Bach, I. Stewart, A. Disher, J. Costello,"A Comparison between Conductive and Infrared Devices for Measuring Mean Skin Temperature at Rest, during Exercise in the Heat, and Recovery". PLoS ONE. 10 (2): e0117907. (2015-02-06).

[8] Using Thermography to Find a Class of Latent Construction Defects. Globalspec.com. Retrieved on 2013-06-18.

[9] J. Choi and S. Kim, "Study on the Improved Target Tracking for the Collaborative Control of the UAV-UGV," Journal of Institute of Control, Robotics and Systems, Vol 19, No. 5, pp. 450-456, 2013.

[10] N. Mattern, N.Schubert, R.Wanielik, and G.Fac, "High-accurate vehicle localization using digital maps and coherency images," Int. Vehicles Symp., 2010.

[11] Infrared thermography (IRT) applications for building diagnostics: A review. Angeliki Kylili, Paris A. Fokaides, Petros Christou, Soteris A. Kalogirou. Applied Energy. Retrieved 30 October 2014.

[12] T. Breckon, A. Gaszczak, J. Han, Röning, Juha; Casasent, David P; Hall, Ernest L, eds. "Real-time People and Vehicle Detection from UAV Imagery". Proc. SPIE Conference Intelligent Robots and Computer Vision XXVIII: Algorithms and Techniques. Intelligent Robots and Computer Vision XXVIII: Algorithms and Techniques, (2011).

[13] C. Hui, C. Youcheng, L. Xiaokun, W. Shing, "Autonomous Takeoff, Tracking and Landing of a QUADCOPTER on a Moving MOBILE ROBOT Using Onboard Monocular Vision," Chinese Control Conference, pp 5895-5901, Jul. 2013.

[14] N. Michael, D. Mellinger, Q. Lindsey, V. Kumar, "The GRASP multiple micro UAV testbed", IEEE Robot. Automat. Mag., vol. 17, no. 3, pp. 56-65, 2010.

[15] G. Souza and A. Kak, "Vision for Mobile Robot Navigation: A Survey[J]", IEEE Trans on PAMI, vol. 24, no. 2, pp. 237-267, 2002

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