# The Applicability of ROS in the Use of Unmanned Combat Aerial Vehicles

János Sári
*Alba Regia Technical Faculty*
*Óbuda University*
Székesfehérvár, Hungary
sari.janos1999@gmail.com
ORCID: 0000-0001-8861-3300

Károly Széll
*Alba Regia Technical Faculty*
*Óbuda University*
Székesfehérvár, Hungary
szell.karoly@amk.uni-obuda.hu
ORCID: 0000-0001-7499-5643

***Abstract*— Thanks to the technological advancement in the past few years the Unmanned Arial Vehicles (UAVs) have developed immensely. It is inevitable to use UAVs for surveillance, reconnaissance and intelligence purposes in modern warfare. As a result of their high efficiency using more than one UAV in a mission has become incredibly widespread. Of course, drones required not only professionals on the field but also experts in the lab. Numerous algorithms are needed to enhance the UAV's intelligence in guidance, navigation, and control. One of the possibilities to upgrade drones in order to fulfil the requirements is the Robot Operating System (ROS). This paper introduces the possibilities of ROS based on its capabilities.**

***Keywords*— UAV, ROS, framework, military**

## I. Introduction

Unmanned Aerial Vehicles (UAVs) can be found in many industries and environments due to their versatility. Of course, for UAVs to operate properly, it is essential to use and operate devices that can meet the different criteria. The resulting complex system is known as UAS (Unmanned Aircraft System) which has adopted by the Federal Aviation Administration (FAA). UAS include not only the Ground Control Station (GCS) and the Unmanned Aircraft but also the Command and Control Link/Data Link. In 1998 NATO started a standardization process in order to unify the unmanned control systems and help enable UAS interoperability. As a result, STANAG 4568 has been created which clarifies the definition of data link interface, control interface and Human and Computer Interfaces within NATO (see Fig. 1.).[1][2][4]

In modern warfare using UAVs are not only inevitable but also essential in order to aid soldiers and protect human life. Drones can be controlled remotely or can fly autonomously (based on a pre-programmed flight plan); also, they are capable of operating individually and in swarms. Nowadays it can be risky to use one drone for a specified mission because of the new threats that have emerged in the recent years (EMP attacks, hijacking, Data link spoofing, jamming) [16]. Due to this, research in the field of swarm intelligence and artificial intelligence is becoming increasingly important.[9]

One way to enhance UAS while maintaining the efficient development is using software like ROS (Robot Operating Systems). ROS not only provides hardware abstraction and low-level device control but also message-passing between processes for system.[7]

In this paper the integrability of ROS in UAS is investigated. After a brief description about the possible ways of grouping drones and the UAVs used in military, the basics of ROS will be discussed connected to the topic. The following sections describe the vulnerabilities of Robot Operating Systems, the problems that might arise, the solutions, and the basic requirements of a ROS based UAV.

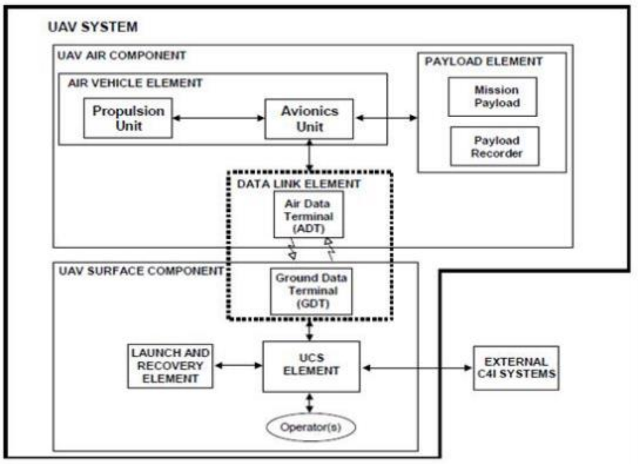


Fig. 1: Possible UAS Architecture (STANAG 4586) [3]

## II. Classification of UAVs

The classification of the Unmanned Aerial Vehicles can be done in several ways due to their universal use and diversity. There are differences in size (micro), design (VTOL, tilt-wing, HTOL) and also in the incorporated energy source (battery, fuel cells). Of course, as technology continues to evolve, new types will emerge, sometimes forming entirely new groups (see Fig. 2.). [6][8]

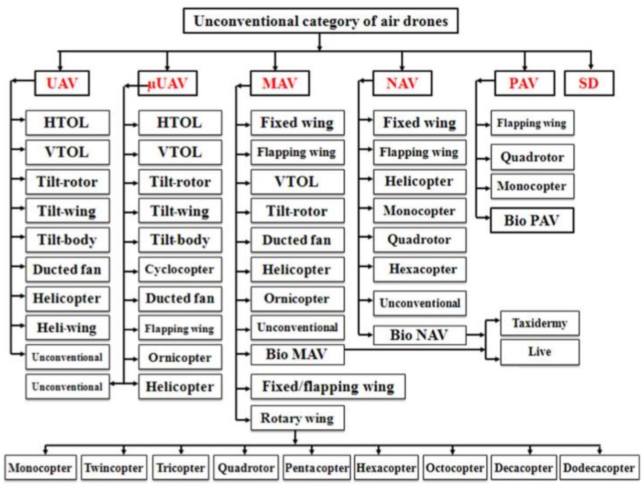


Fig. 2: Various types of UAVs [8]

## III. UAVS FOR MILITARY PURPOSES

As we mentioned UAVs can be used for different kind of military purposes: surveillance, reconnaissance, intelligence etc. They can also intervene on the battlefield either indirectly using precision guided munitions controlled by an operator or directly by dropping or firing these munitions autonomously.[14][15]

The history of the first military Unmanned Aerial Vehicle dates back to the Second World War. The result of the competition between France and the US was the Voisin BN3 biplane which was able to fly for about 100km. However, UAVs were not used for surveillance purposes until 1973, during the Vietnam War.[14][15]

Although a classification of unmanned aerial vehicles has been presented above, a classification as function is preferred for military use. On this basis we can distinguish:

- Target and Decoy UAVs
- Reconnaissance UAVs
- Combat UAVs
- Research and Development UAVs
- Civil and Commercial UAVs

The different classifications clearly define the difficulty or the risks of the mission and its purpose. Of course as technology evolves, these groups are also expanding. One such application – that has been explored by the authors as well – is the deployment and use of various UAVs to enhance the security and runway safety of military airfields. [14][15]

Using drones with thermal imaging camera can improve the accuracy of weather mapping. With the image analysis of images along the runway UAVs can help to detect the presence of foreign object debris (FOD) on the surface (runway), such as fallen parts of the aircraft or a flock of birds. Furthermore, changes in the condition of surfaces, cracks and icing can be detected (see Fig. 3.).[9]

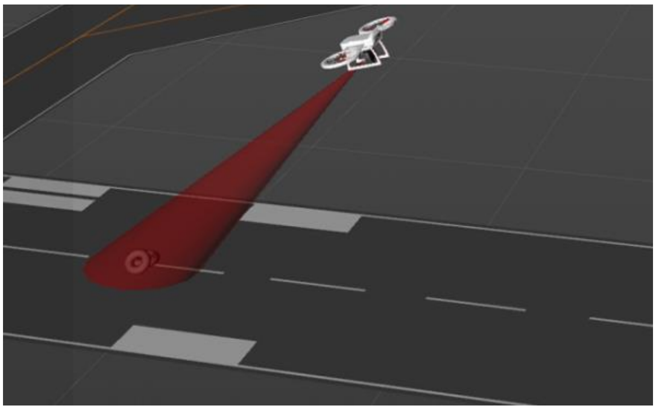

Fig. 3: Use of unmanned aerial vehicle as a FOD seeker

## IV. ROBOT OPERATING SYSTEM (ROS)

The Robot Operating System, or ROS, is a framework widely used in robotics. It is an open source; American-developed; meta-operating system that uses libraries to build, write and run codes across multiple computers. It has the advantage of having many pre-built features such as face recognition, motion tracking, robot control, route planning etc. ROS is mainly based on Linux, C++ and Python programming languages. The applications created in ROS are called nodes (see Fig. 4.) (master, publisher, and subscriber). The communication between nodes is implemented by the ROS system itself. [1][7]


Fig. 4: ROS structure

In case of asynchronous communication in ROS, the preferred model is the publisher-subscriber model. The advantages of this model are:

- Any code can publish a message to any topic.
- Any node can subscribe to any topic.
- Multiple nodes can publish to the same topic.
- Multiple nodes can subscribe to the same topic.
- A node can publish to multiple topics.
- A node can subscribe to multiple topics.

In order to support different kind of programming languages ROS include a client library. Of course for other purposes for example hardware control, transmission and reception, visual space controlling; ROS has its own relevant component: hardware interface, communication, simulation tools (see Fig. 5.).


Fig. 5: Components of ROS [7]

As we mentioned ROS is an open source, meta-operating system which allows us to use it in the field of unmanned aviation. In a structure where ROS is implemented into an UAV or UAS, the aforementioned pub-sub model is usuall adopted for communication. In this case the master node helps in the information exchange process between the two other nodes. [1]

To make the communication process easier between small drones a protocol so called MAVlink is used. It follows a modern hybrid publish-subscribe and point-to-point design pattern. Thanks to the diversity of ROS, the possibilities offered by MAVlink can be exploited by MAVROS (see Fig. 6.). In fact MAVROS is a MAVlink expandable communication node. [5]

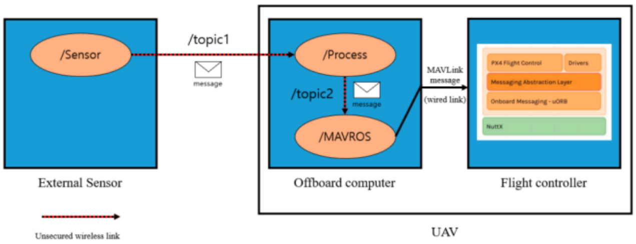


Fig. 6: A possible structure of a ROS-based UAV [1]

As we mentioned there are many disadvantages using ROS in UAVs. The weak points are the possibility of jamming, Data link spoofing and in extreme cases hijacking [16]. Of course software developers are aware of the risk factors. Due to this users are advised to create a restricted access to the network, and not disclosing the ROS master. It can be achieved by establishing isolated hosts, networks, or using firewalls. Additional problems can be caused by the formation of abnormal or infinite loops. For this reason a timer tool called Watchdog is implemented in ROS which monitors the CPU and intervene when loops may occur. [1][7]

Because of the vulnerability of the systems it is easy to break into the network. Attacks like false data injection can easily lead to total collapse. Unfortunately the weaknesses of the master node (for example the master node does not check whether the node making the request is a normal node or a malicious node) are the main reason why this can happen. [1]

## V. How To Secure ROS

Apart from the mentioned solutions there are many other options for securing our ROS system. In the following we would like to present two alternatives that have become quite popular in the recent days.

### *Encryption*

Many studies show that ROS-Encryption is not an idea to be rejected. Ciphered communications in ROS requires just a little more overhead of CPU performance but it provides a much more secure flow of information.

The number of algorithms which can be used for encryption has increased significantly in the past years. Nowadays cryptographic algorithms AES (Advanced Encryption Standard) are preferred over DES (Data Encryption Standard) due to their speed and reliability. Algorithms like AES converts data in plaintext to an uninterpretable form which is called the ciphertext.[20]

### *Secure-ROS*

Secure-ROS provides alternative versions of core ROS packages that enable secure communication between ROS nodes. Secure-ROS uses IPSec (Internet Protocol Security) in transport mode and modified versions of the ROS master (rospy, roscpp) to ensure secure communication. The user only can specify authorized subscribers and publishers to topics at run time.[19]

## VI. The Basic Requirements For ROS Based UAVs

The first and most important task is to check whether the integration of the drone into ROS is even possible. This step is crucially important because complete ROS systems can be very expensive, and due to this they are not always cost-efficient. Thankfully, the mentioned problem can be solved easily with ROS plugins. An additional solution is the use of ROSBRIDGE, which provides a JSON API to ROS functionality for non-ROS programs (the client does not have to install ROS).[12][13]

The second step is the correct choice of the frame and the propeller. The size, structure and the material of the frame have a significant influence on the flight characteristics. The properties of the propeller will mainly affect the lifting power. To study the behavior of the propeller and the frame, it is worth creating a simulation environment. This can be done with software like Ansys (see Fig. 7.) which is a numerical fluid dynamics software that discretises continuous operations in space and time. [11]

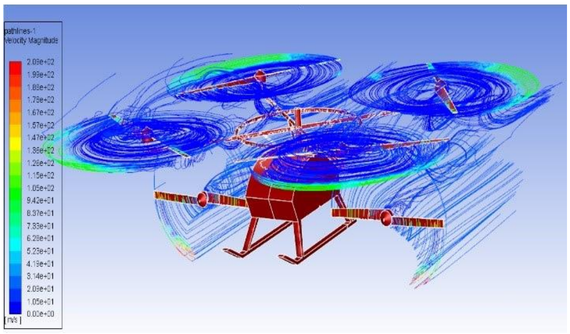

Fig. 7: A possibility of a UAV Ansys simulation [10]

As already mentioned, drones or UAVs can also be distinguished by the energy source they use. For small unmanned aircrafts, as shown in Figure 3, lithium polymer batteries are the preferred choice. Compared to lithium-ion, these types are more resistant to overcharging and less likely to leak electrolyte. Another feature is that they are much lighter than their predecessors, thanks to the special polymer.

A further necessary condition is the existence of engines. The number and the power of engines are mainly affected by the goal which we want to achieve. Of course, it is not enough to install the engines themselves, they also need to be synchronized. In case of small drones the brushless engines are more common due to their durability and performance.

Other essential components of drones are the various control elements such as Electronic Speed Controller, Flight Controller, Manual Control Unit etc. (see Fig. 8.) In the case of embedded system, the applications of fault-tolerant redundant solutions are recommended [17], [18].

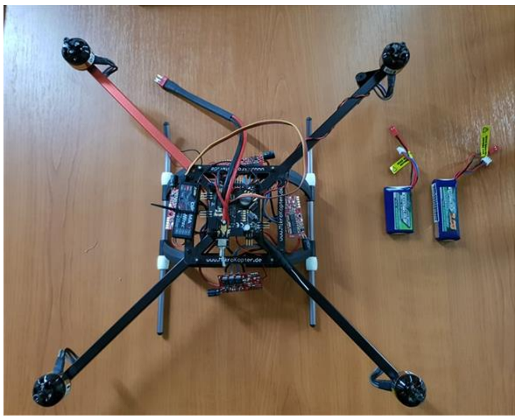

Fig. 8: Example of drone main parts

## VII. Conclusion

The experience of recent years suggests that unmanned aircraft will become more widespread in the coming years. Of course, this will influence many civilian and military areas as well. UAS will become more complicated, but hopefully the communication between drones becomes easier. But of course this requires a system that can effectively manage the parties involved in the communication process. According to the current state of technology, one such solution could be ROS.

The use of ROS in military drones is not always advantageous, as can be seen above, but it offers a very practical solution thanks to its ease of use and simplicity. It is easy to see that systems such as ROS would be able to innovate, this branch of warfare, but we assume that ROS itself will only be used by underdeveloped forces.

This study not only presents the classification of drones and their system architecture, but also takes a new look at the application of unmanned aerial vehicles using ROS.

## Acknowledgment

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# Acceleration Measurement Experiments in Dairy Cattle

Éva Hajnal
*Alba Regia Technical Faculty*
*Óbuda University*
Székesfehérvár, Hungary
hajnal.eva@amk.uni-obuda.hu

Gergely Vakulya
*Alba Regia Technical Faculty*
*Óbuda University*
Székesfehérvár, Hungary
vakulya.gergely@amk.uni-obuda.hu

Péter Udvardy
*Alba Regia Technical Faculty*
*Óbuda University*
Székesfehérvár, Hungary
udvardy.peter@amk.uni-obuda.hu

Levente Kovács
*Hungarian University of Agriculture and Life Sciences*
Gödöllő, Hungary
Kovacs.Levente@uni-mate.hu

***Abstract*— The great challenge of our time is monitoring of the condition of our farm animals, which is made possible by IoT technologies. This segment of agriculture is called IoF, Internet of Farms. This article presents the preliminary experiments in bolus sensor development. Many physiological and behavioral characteristics of cattle can be monitored by recording and analyzing data from an external three-axis accelerometer placed on the cattle's body.**

***Keywords—IoF, accelerometer, dairy cattle, data science***

## I. Introduction

Automation and digitalization are trends in animal husbandry today[1]. This process is often referred to as IoF, Internet of Farms [2]. This covers that animals are instrumented with different sensors, allowing them to be monitored continuously. This innovation not only helps livestock farms to manage their workforce, but also helps farms to keep their animal welfare in focus, including good health, housing conditions and the management of heat stress, which is increasingly affecting animals as a result of global warming. In the case of dairy cattle, we often speak of sensors placed on the legs, neck, tail, or rectum, or possibly combinations thereof [1]–[9]. External sensors placed on the animal are very problematic in animal husbandry because they are picked up by the animals or can be damaged during their daily movement. To prevent this, boluses placed in the rumen of cattle have also recently appeared. With the development of technology, the goal would be to develop tools that can accompany the life of an animal, perform complex measurements and often provide complex analysis of the condition of animals. In line with this trend, we performed experiments to investigate which physiological and behavioral characteristics of dairy cattle can be identified with a three-axis accelerometer. The ultimate goal is to develop a bolus that can perform complex measurements and complex analysis from the measured data, helping to detect estrus, heat shock, the onset of calving, and to assess overall animal welfare. One of the planned components of this complex measuring instrument is the three-axis accelerometer, which, together with the experimental device, would be introduced into the rumen of cattle. In the preliminary experiments, unfortunately, neglecting the movements of the rumen, the sensors were placed to the side of the cattle and tried to collect as many behaviors that could be identified with an accelerometer. Thus, our research question was what elementary behaviors and events can be collected using a bolus sensor, which can be the input data of a complex evaluation system, even including artificial intelligence solutions.

Figure 1. Sensor unit with 3 axes accelerometer

## II. Methods

The experiments were performed on the Etyek farm. The identifiers (ear numbers) of the cows used in the experimental set-up were recorded. In all cases, the experiment was performed with healthy dairy cows.

Experiment I.

Devices used for the first experiment: Sensor unit with Bosch BMA180 three-axis acceleration sensor, in which the sample rate can be adjusted between 20 Hz and 2400

Hz and sensitivity can be adjusted between 1 G and 16 G. Wireless communication was implemented the 802.15.4 protocol with 250 kbps in the 2.4 GHz band. The sampling frequency was 600 Hz. The unit was powered from an 18650 LiIon cell.

Figure 2 Dairy cow in the 1st experiment in a paddock. The sensor is attached to the side with a strap.

The receiving side: it was a 2.4 GHz data radio, the data was recorded with a laptop. Meanwhile, video was recorded with a GoPro Hero 3 camera, and video and accelerometer measurements were time-synchronized. The structure of the measured data set is shown in Figure 3.

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··1,···1618991182.550546449,··2464,··3947,···676,··1578
··1,···1618991182.550546449,··2465,··3949,···707,··1620
··1,···1618991182.550546449,··2466,··3955,···727,··1686
··1,···1618991182.550546449,··2467,··3946,···721,··1695
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··1,···1618991182.550546449,··2472,··3837,···727,··1940
··1,···1618991182.550546449,··2473,··3810,···697,··1983
··1,···1618991182.550546449,··2474,··3804,···669,··2037
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Figure 3: Data format: Sensor ID, Timestamp, Buffer serial number, Acceleration in X, Y and Z directions

In a group, 16 data have the same timestamp, the time distribution of measurements is uniform, but the data is congested and several packets are lost, so a subsequent correction was required, the steps of which

- Chronological backward timestamp correction according to the buffer sequence number
- Possible interpolation of missing data based on buffer sequence numbers
- Modify the timestamp with a constant value, align it with the video.

Unfortunately, the noise of the measurements was very large, so in each case it was necessary to correct this, which was solved by averaging the data of the 16-member data buffer sent in units. With this we were able to get a roughly smoothed baseline.

During the data processing, the time synchronization of video recording had to be solved. During recording, synchronization points were added to the video, then a visible timestamp is added to the frames.

During the statistical processing of the data, the timestamp of the data records had to be corrected based on the buffer number, as in several cases congestion developed on the receiving side and the storage of the data was delayed. In addition, several data packets were lost, which were replaced by linear interpolation based on the existing data if the statistical processing algorithm could only process a complete data set.

When processing the video, the video was manually annotated according to the observable behaviors. These are: standing, walking, rumination, stepping, other, Unobservable behaviors: lying, drinking, eating, extreme movements.

In the statistical processing, the resulting vector was calculated, from which - histograms were made

Block-by-block scattering and its evaluation is the blending of motion information and video.

Figure 4 Lying data logger with the cattle ID

Experiment II.

Animal: three cattle, identified by ID wearing on the ears that were in a stable within the Etyek farm during the experiment

Methodology: The experimental device was strapped to the animal and the data from the device were recorded for 2 days, in parallel, the lying position counter (HOBO Pendant G Data Logger unfiltered, Onset Computer

Corp., Bourne, MA) [9] attached to the legs of the animals recorded the lying position for all three animals.
Device: Measuring instrument is the same as described in the experiment $1_{st}$. Sampling frequency was 300Hz, data was recorded with a Raspberry Pi 3B computer with the settings and data format described in the experiment $1_{st}$.
During the processing, no video was made, but we were able to separate the time spent by each animal with lying with help of the recorded data series provided by the lying position counter. Thus, this series of measurements is suitable for separating the lying position from other movements.

## III. Results and discussion

As a result of the first experiment, a set of data with acceleration values and timestamps was available, as well as video recording for the same period, which was manually categorized by behavior, distinguishing between standing, walking, stepping, ruminant, and other categories. The streamed graph of the measured data set was copied to the video recording. Figure 5 shows the measurement result. The image of the current video corresponds to the value of 0s in the graph. The graph in Figure 5 shows the standard deviation within the data buffers containing 16 data. In the graphs, standing and walking behavior can be well separated. The area below the graph characterizes locomotor activity. Unfortunately, rumination cannot be identified with these studies. Feeding and drinking were not available for the cow in the paddock, so eating and drinking behavior patterns could not be observed.

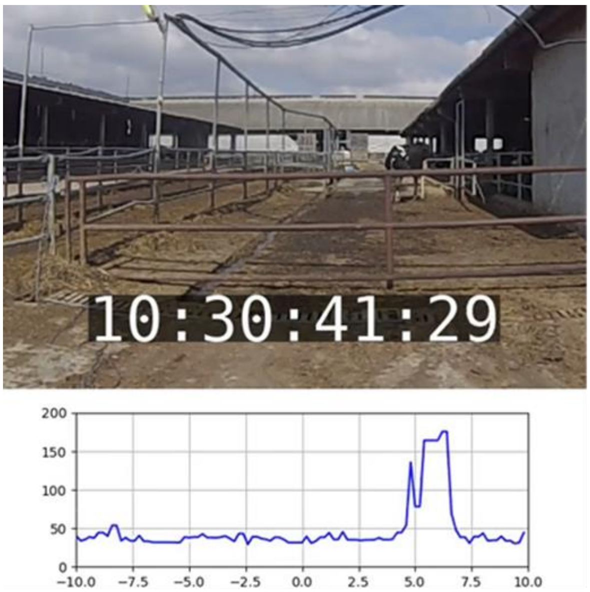

Figure 5 The timeline and the graph made from the sensor data stream were added to the video taken in the paddock.

As this paddock does not give the cow enough comfort, the cow remained standing throughout the study period. Thus, it was not possible to detect the lying position either.

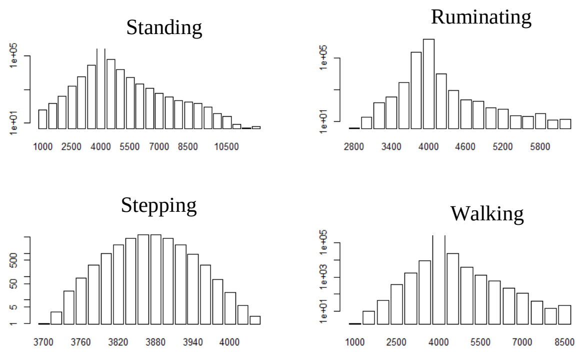

Figure 6 Histogram of the resultant acceleration values for four different modes of motion

The resultant acceleration from the acceleration values measured on the three axes was calculated. The resultant acceleration values were plotted on a histogram. Due to the setting of the device, the possible values of the resultant acceleration were in the range of 0-8000. Figure 6 shows that the histograms have also maximum for the three forms of motion at 4096, namely standing, ruminating and walking. The value of 4096 corresponds to a value of 1G of the ground gravity acceleration. Because the animals have a fairly large body weight, they perform the movements with relatively small relative accelerations. Only stepping as a behavior can be distinguished from other movements based on a histogram because the resulting acceleration averages 3850, which corresponds to 0.94G. From the histogram, it can be seen that the 2-fold standard deviation is within the intervals of 1000 and 7000. Thus, it will not be necessary to change this initial setting during the subsequent setting of the sensor.
Figure 7 shows the result of the second experiment. In this experiment, it was possible to observe the acceleration values measured in the lying position of the animal. The figure shows the acceleration values measured on the y and z axes. Acceleration values measured in lying position are indicated in green and those measured in other body positions are indicated in red. Besides a few outliers, red and green points, corresponding to the two categories, can be linearly separable. Unfortunately, as no additional sensors were available and no video capture was possible, it was no way to identify additional behavioral categories on the measured data set. The basis for position identification is that the angle of inclination of the sensor attached to the side of the animal is 20-30 ° when lying down.
Since the position of the sensor has changed at lying, this position could be separated from the other body positions. In the experiment, the sensor rotates when the cattle lying down.
Unfortunately, the sensor placed on the animal can be moved. In this case, the consecutive horizontal and non-horizontal positions can be distinguished because the angle of inclination of the sensor changes, but it is not possible to assign absolute acceleration values to the

lying position or the other positions. Unfortunately, in the case of a rumen bolus, a similar case must be occurring. In the rumen of the animal, the sensor can move easily. With proper techniques, the sensor can be mounted around roughly one axis, the vertical axis, but this can make it difficult to detect the position later on.

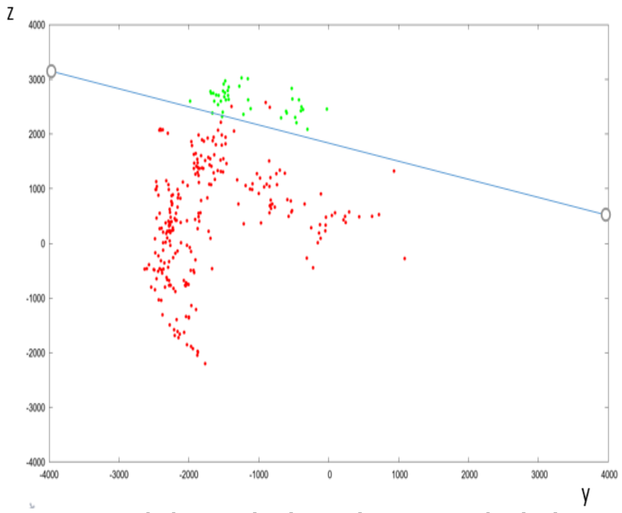


Figure 7 The horizontal and vertical positions can be clearly distinguished by considering the acceleration values measured along the y and z axes.

## IV. Conclusion

The article reviews and evaluates preliminary experiments of a rumen bolus accelerometer sensor. The sensor should make it possible to identify individual movements and behaviors. Based on this, the locomotor activity and activity of the experimented animals can be precisely determined and quantified. In subsequent experiments, some important health and animal husbandry characteristics of the animal can be identified on this basis. As well as on the basis of additional sensor data and other information collected about the animals, using data analysis methods that also use artificial intelligence. The primary goal is the accurate and rapid identification of health problems, estrus and parturition. In the presented experimental setup, the following forms of movement could be identified: standing, walking, stepping in a standing position, lying down. Eating, drinking, rumination, and increased locomotion activity indicating estrus were not detected in this experiment. The interpretation of the experiments was disturbed by the fact that the sensor was fixed to the side of the animal, so that the position of all three axes of the accelerometer relative to the animal was constant during the experiments. Later, it can be expected that the sensor can move freely in the rumen of the animal, with a maximum of one vertical axis that can be fixed in the absolute sense. In the next phase of the research, it is worth placing some bolus sensors in the cow's rumen and extracting native, measured data from it, as well as for a short time. A short time is a period of about 30 days because it contains at least one cycle of estrus of the cow. It is a good idea to follow the experiment with external validation tools. Ideally, this could mean making a video with a suitable camera system. Based on this, the behavior of the cow can be accurately categorized. Less valuable but usable results can be obtained by equipping the cow involved in the bolus experiment with bed counting, ruminant, and estrus sensors. In the first case, all important behaviors (standing, walking, lying, jumping, ruminating, eating, drinking) can be identified, while in the second case, only a reduced number of categories can be evaluated.

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# Photovoltaic Panel Failure Prediction Using a Thermal Imaging Camera

Bertalan Beszédes[1], György Györök[1]
[1] Óbuda University, Alba Regia Technical Faculty, Budai Str. 45, H-8000 Székesfehérvár
{beszedes.bertalan, gyorok.gyorgy}@uni-obuda.hu

***Abstract* — The aim of the study - based on domestic and foreign sources - is to show the inspection possibilities of thermal imaging cameras which used in industrial and civil areas. During the introduction of the topic, this paper will introduce the most important metrological requirements and practical knowledge of thermography. The paper focuses on photovoltaic panel inspection and failure detection. The paper will discuss the monitoring possibilities. Some common thermal camera operator errors, accuracy and credibility of the measurements are also presented.**

***Keywords* — thermal imager, heat camera, IR camera, PV inspection, photovoltaic panel inspection, PV error detection, photovoltaic panel error detection**

## I. INTRODUCTION

With the help of thermography, it is also possible to check the quality required during the production of photovoltaic cells and to check the solar panels during operation. This article discusses the condition assessment of solar panels in more detail. The advantage of this solution is that high-power solar parks can also be inspected in a short time, thus increasing operational reliability.

Examination of the electrical parameters (characteristic curve) of solar panels or strings shows a deterioration in efficiency, but the location of the fault and the type of fault cannot be determined. The thermal imaging test can be used to determine the location of the fault and to determine the type of fault.

Thermographic condition assessment helps in fault prediction, economical operation and maintenance. The thermographic examination also covers the electrical cables, connections and equipment, the rise of their temperature above the operating value indicates the location of the fault. For solar cells, however, more knowledge is needed to perform a more complex study.

## II. THEORETICAL BACKGROUND

Before inspecting and evaluating solar cells and panels, it is a good idea to review their operation in order to understand the causes of thermal effects that indicate fault phenomena.

The solar cell is a pn junction, the photons of the incoming solar radiation pass through the n-type layer, and then, giving off their energy in the depletion region, they generate free charge carriers. The charge carriers carry work as they pass through the load.

The internal photoelectric effect can be achieved with both thick-layer (single-crystal silicon, polycrystalline silicon) and thin-film (amorphous silicon) technology. The testing of compound semiconductor or electrolyte-based solar cells is not substantially different from the testing of silicon-based solar cells.

The voltage achievable with a solar cell is approximately 0.5V. By connecting the cells in series, the voltage of the module can be increased, thus increasing the efficiency of energy transmission. If one of the cells connected in a row fails or is shaded, the efficiency of the whole row is reduced. Within the solar panel, the solar cells connected in series are divided into substrings. The substrings are connected in parallel with a bypass diode. In the event of a substring failure, the solar panel will

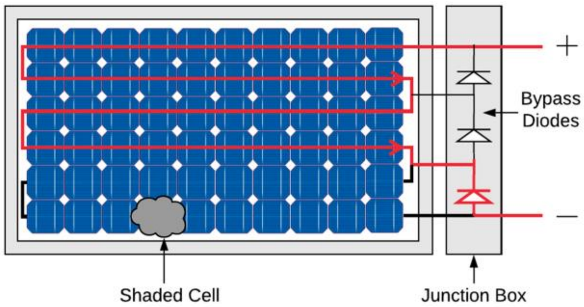


Figure 1: Solar panel bypass diode [1]

remain operational with reduced capabilities (Fig. 1).

Fig. 2 shows the different connection options between PV modules and PV inverters. Based on power output, location, reliability, cost and efficiency system properties, there are four main topologies.

The central topology connects several thousands of PV panels to one inverter. PV array has hundreds of PV strings connected in parallel, and each string has hundreds of PV panels connected in series. The string topology connects one PV string with one inverter. The multistring topology connects one PV string to a dc–dc converter, and then a few dc–dc converters are connected to one inverter. The module integrated topology connects one inverter to one PV panel.

## III. TYPICAL FAULTS AND ERRORS

Faults in solar systems lead to inefficiencies and other more serious faults. The causes of the fault can be traced back to the manufacturing, transport, installation, operation and environmental causes.