Sensor Data Fusion of Multi-Sensor Drone Detection Systems

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DIDIT stands for **Di**stributed **D**etection, **I**dentification and **T**racking of small drones. The solution relies on a mix of radio sensors, electro-optical sensors-and radar. Each sensor type contributes to the functionality of the system with its strengths complementing the other ones. The data of the various sensors are fused in a central processing unit. Fusion of the data of the same type of sensors provides redundancy of measurements, increases the accuracy and allows identification of broken sensors. Applying triangulation algorithms allows determination of the position of detected drones. Fusion of the data of different types of sensors expands detection capabilities at all weather conditions and to all types of drones. Fusion of sensor data is also essential to exclude ambiguities and to ensure that a drone detected by more than one sensor is treated and displayed as one single object only. This article provides an overview of the sensor data fusion approach implemented in DIDIT and of its impact on system performance.

FUSION OF SENSOR DATA – WHY?

The tentacles of Drone Detection systems are sensors like radio sensors, electro-optical cameras, radar. They have to reliably detect, classify, localize and track all types of drones at all weather conditions. The observers need to get information like drone model, location of first detection, position of drones and pilots, carried payload, trajectory and speed.

Figure 1 – Drone over non-flight zone

Isolated sensors can only provide a fraction of this information. For instance, an isolated radio sensor is only able to give the direction from which RF signals are received but not the distance. A camera has reduced performance at night or at harsh weather conditions. A radar is able to detect non-transmitting drones but not the pilot of a controlled drone. All kind of sensors have their limitations.

Fusion of the data by a central processing unit using intelligent algorithms and artificial intelligence allows to derive indirect parameters like the position of a drone or its pilot from the direct parameters provided from single sensors. Data fusion Examples:

An isolated radio sensor is only capable to determine the direction from which RF signals are transmitted.

A camera visualizes the model of a drone and the carried payload. Fused data from two radio sensors provide the position of a drone but with low accuracy.

Fused data from more than two radio sensors give the position with high accuracy. Fusion of data from radio sensors and radar results in position and speed.

Because various types of sensors have different detection ranges the position derived from fusion of data from long range sensors can be forwarded to sensors with short range and the latter are able to lock immediately on the approaching drone.

Capability of Sensor / Type of Sensor	Radar	Radio Sensor	Rotatable Camera (PTZ)	Static Camera
Detection	✓	✓	✓	✓
Localisation of Drone	✓	✓	✓	✓
Localisation of Pilot		✓		
Tracking	✓	✓	✓	✓
Visualisation			✓	✓
24 / 7	✓	✓	(✓)	(✓)
Non-transmitting Drone	✓		✓	✓

(✓) camera specific

Figure 2 – Capabilities of sensors

FUSION OF DATA FROM SENSORS OF THE SAME TYPE

Measuring the Same Object

Measuring the same object with a number of identical sensors offers significant benefit. Comparison of the sensor data allows to detect deficiency of one of the sensors. The redundant sensors will execute continuous measurements without noticeable degradation of the service. Fusion of the sensor data ends up in increased accuracy of the measured parameter. Last but not least: Multiple sensors of low quality are often cheaper than one high-end sensor but produce identical results by means of intelligent data fusion.

Measuring the Same Object Aiming at Determination of Indirect Parameters

Example 1: Sensors of the same type measure the distance to an object. A central processing unit fuses the data and includes the position of the various sensors into the calculation. As a result, the position of the object is determined.
Example 2: Sensors of the same type measure the direction to an object. Fusion of the data from the sensors determines by means of triangulation the position of the object as an indirect parameter.

FUSION OF DATA FROM DIFFERENT TYPES OF SENSORS

Measuring the Same Object

Using different sensor technologies for measuring the same object and fusing the gathered data eliminates the weak points of the various technologies whilst their strengths complement each other. For instance, the longest detection range can be combined with the ability to detect the pilot as well as with the best performance under harsh environmental conditions to achieve the highest possible detection rate.

Measuring the Same Object Aiming at Determination of Indirect Parameters

Example: The data of radar, radio sensors and electro-optical sensors are fused to determine the position, the direction of movement and the model of a drone as indirect parameters. These data are displayed to the observer together with the visualisation of the drone and its payload.

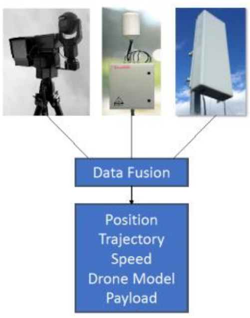

Figure 3 – Data fusion - different types of sensors

METHODS OF SENSOR DATA FUSION

Method A: Two Sensors

A network of only two sensors ends up in a closed system of equations. Direct and definitive results can be calculated.

Method B: More than Two Sensors

Fusion of data of more than two sensors ends up in an overdetermined system of equations. Approximation procedures have to be applied.

Method C: Different Types of Sensors

Various types of sensors generate a non-linear system of equations. For data fusion appropriate iterative procedures shall be used.

Method D: Implication of Sensor Characteristics

For most robust results known characteristics of the sensors like accuracy of measurements have to be implied. In these cases matched filters come into the game. From Kalman-Bucy-filters over Unscented Kalman filters for non-linear estimation up to highly specific filtering methods plenty of estimation procedures can be chosen from.
Complexity of the methods increases continuously from method A to method D.

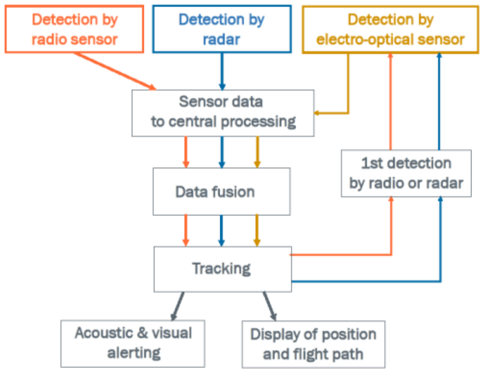

Figure 4 – Fusion data flow

DRONE DETECTION SOLUTION DIDIT

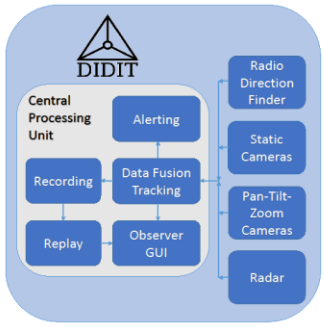

Figure 5 – Components of DIDIT

DIDIT is the Drone Detection Solution of Telespazio Germany. Radio sensors, electro-optical sensors and radar are integrated into the system. The sensor-mix empowers DIDIT to protect against both controlled and autonomously flying drones in all topographic positions and under all weather conditions. But the sensors are not the 'brain' of the solution, this is the central processing unit.
By applying intelligent algorithms and artificial intelligence the central processing unit fuses the data received from the sensors according to the methods explained above. Multiple types and formats of sensor data are analysed and put together to generate a comprising outline of the scenery out of the limited views of each single sensors. The result is transmitted

to - and displayed at - the observer station. Position and trajectory of the drones and their pilots are graphically overlaid on a configurable local map. In this process the central processing unit also ensures that a single drone that has been detected by several sensors is treated as one object only and displayed to the operator as one object only.

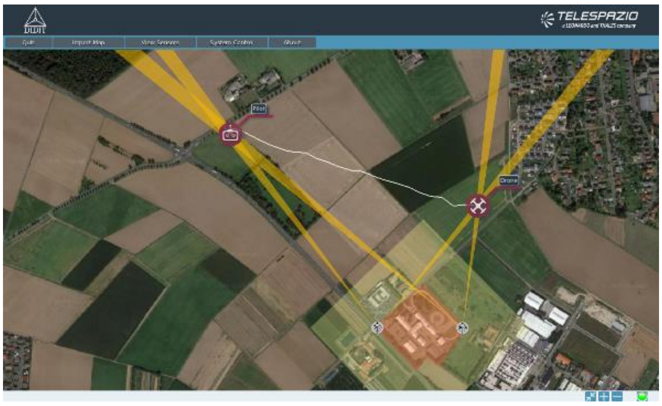

Figure 6 – Observer display – Output of sensor data fusion

Alarm zones which can be flexibly defined by the customer run into the fusion algorithms, too. As soon as the algorithms indicate that a drone penetrates the alarm zone an optical and acoustic alert is generated to draw attention of the security staff who can quickly gain awareness of the scenario and initiate appropriate measures in good time. Different levels of alerts are possible depending on the distance of the penetrating drone. The position coordinates as well as the trajectory can also made available to counter-drone technologies and UTM if connected. All relevant events are recorded and can be replayed at any time.

DIDIT is configurable according to customer requirements and can be tailored to the environmental conditions (topography, buildings etc.). Its modular design allows scalability and integration of each type of sensors. Thus we are not only able to react to modified customer-specific requirements but also to respond to new technological trends and to keep pace with state of the art technology. Currently the interfaces between the sensors and the central processing unit are proprietary ones. But first initiatives were started to standardise the interfaces of drone detection systems between the sensors and the central processing unit. This will lower the cost and the users will be able to easily combine sensors of different manufacturers or to replace the sensor of one manufacturer by the product of another one.

Activities were launched in Leonardo, Electronics Division to define a larger end-to-end C-UAS solution composed of the assets of different parts of the Group. DIDIT and/or single components of DIDIT are prepared to contribute to end-to-end solutions targeting at civil customers.

More details about DIDIT are available at:
www.telespazio-vega.de/en/solutions-services/drone-detection

CONCLUSIONS

For effective drone detection a mix of sensors is essential. Only drone detection systems comprising different types of sensor technology are able to detect, localize and track all categories of drones. But all kinds of sensor-mix are toothless without intelligent fusion of the sensor data. Sensor data fusion is the brain of each drone detection solution. Only sophisticated processing of these data combined with specific customer requirements like alarm zones can provide all the information in real time which is needed to gain awareness of a threat scenario and to achieve best possible protection against drones.

New sensor technologies which are to be expected in the future will challenge fusion of sensor data even more. To survive in the business of drone detection companies have to master this challenge.

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