Development of a Control System for an Autonomous Seaplane

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1 Introduction

Self-driving vehicles, also named as: driverless vehicles; autonomous vehicles; or robotic vehicles, are these transport systems that can operate with a limited human input or even with no human impact at all. In their fully autonomous forms these vehicles are in command for all the driving activities, including observing and interpreting the situation, monitoring accuracy of work of all the sub-systems, predicting the future changes. What is more, they are supervising the actual state parameters and they are planning the future, including its navigating. Despite of numerous similarities, there are many differences in the designs of their control systems. *Design Domain of Operation* also branded as *Operational Design Domain* (ODD) is a term used to definite a specific operational context for the vehicle. The ODD is defined by a set of circumstances, including: geographical positioning; period of the day; environmental situation; presence of co-traveling objects, and others. For example, if the autonomous cars are reflected, roadway and traffic characteristics are included in the ODD. The present paper is restricted to four types of the potential applications: Unmanned Surface Vehicles (USVs); Autonomous Underwater Vehicles (AUVs); Unmanned Aerial Vehicles (UAVs); and Autonomous Seaplanes (ASs).

In recent time, topics of USVs, and AUVs has been extensively studied. Mainly, according to the unmissable benefits coming from: far-ocean; undersea; and deep-ocean explorations [1]. Recalled features stimulate investigations and accelerate developments of understanding and controlling of aspects related to the USVs and AUVs in such areas as: scientific studies; commercial uses; risk supervisions. But also in many military aspects. USVs and AUVs are used extensively to perform operations such as: free navigation [2]; discovering and monitoring of undersea life; and environment [3]; assembling; inspections of pipelining [4]; underwater cables; and underwater constructions [5]; conservation; repairing [6], surveillance; and patrolling [7]. Therefore, USVs and AUVs are recognized as the most forthcoming tools for surface or under-water developments and researches that are expected in the adjacent future.

Analogous aspects we can find in studies of Unmanned Aerial Vehicles (UAV). The UAV are presently being documented as accessible, low-priced and efficient substitutes to the classical human-controlled aerial vehicles. They are used for several tasks, in civil and military requests as: precision agriculture; and foresting; border and critical infrastructure monitoring; monitoring of wild life; and wild environment; support in disaster areas; and in unsafe zones; etc. Focusing on agriculture, their uses range from recognitions of the possible plantation illnesses to topography mapping; precise fertilization; and herd supervision. In the military domain, their applications focus on such actions as: patrolling; reconnaissance; combat tasks; and missions, but also on finding and transporting people out of the combat area. In local administration, they offer additional larger mapping and detailing possibilities, comparing with other imaging techniques such as satellite imaging.

Potentially effective, the USVs and AUVs, AS, and UAVs still have various questions that should be resolved, such as: motion control; acquisition; ordering; identification; and analysis of sensors' information; skill of selection of environment-dependent behavioural decisions; unnegotiable priorities in the machine/human contacts; collision-free navigation; self-localization; and other subsequent aspects. In order to find the potentially valuable and practical vehicle that can operate in the ocean or in the air, planned construction shall be able to identify and judge the altering environmentally-dependent conditions from their own instruments, and it shall be required to control their behaviour with limited efforts of the human control. Because of the impacts sourced in the working environment the USVs and AUVs and UAVs shall be autonomous as much as possible and should have adaptive ability to fit their behaviours to their environments.

2 List of aspects decisive during the design processes

The following list of aspects has to be taken account during the design processes:

- **Mapping; Active; and Hybrid navigation**, i.e., each rational navigation needs information about obstacles to sketch the optimal path from the origin to the destination. Thus, presence of a stored database of maps is critical. Different design of such systems was proposed. Some of them operate with simple, maps supplemented with elaborated perception systems devoted to detection of the obstacles. Other are based on highly detailed maps that can describe all the standard and accidental obstacles, with an ability of their on-time actualization.
- **Perception**, i.e., USVs, AUVs and UAVs shall be able to collect information about the neighbour area. Associate tools include fusion of video streams (in the infrared and visible bands); LiDAR; radar; audio; and ultrasound microphones; GPS, and other [8, 9]. The raw inputs from the sensors shall be analysed to extract the useful data. Typically, the related systems combine and contrast data from multiple sensors. It delivers a more complete overview of the surrounding and offers an ability of a potential cross-verification useful to detect errors [10] We can operate with various algorithms to identify and

to locate the static and moving objects and to evaluate probability of their trajectories. Landmarks or other ground-based real-time locating system may help during localization of the vehicles;

- **Path planning**, i.e., proposing a sequence of segments that the vehicles shall follow to move from the origin to the destination. Typical systems operate with graph-based search algorithms or with variational-based optimizations.
- **Drive by virtual or physical wire**, i.e., the capacity to decrease the driving autonomy and ability of initiation of electrical or electro-mechanical systems for performing the basic vehicle functions such as steering; or speed control. An ability to be driven by a human located inside or outside of the vehicle (e.g., in the control centre).
- **Driver-monitoring**, i.e., an additional ability useful, if the drive-by-a-wire mode is activated. We can employ the existing autonomous control system to assist the driver, or to estimate its alertness and attention. It helps to evaluate the actual status of the driver and detect all its potentially-dangerous behaviours. Typically, it focuses on eye monitoring, and on verifications of driver’s manual activates, e.g., on values of forces applied on the steering elements of its console.
- **Vehicular communication systems**, the control can benefit from communications with the other vehicles, or we can use the system to share information about obstacles, to receive new map and software updates.
- **Software update**, i.e., available over-the-air updates can distribute upgrades; codes of the auxiliary situation-requested algorithm; case-useful maps; and/or bug fixes. We can deliver the required information by the on-air internet or by others communication techniques. Information send by the vehicles can schedule the necessary visits in the service centres.
- **A safety model and the safety control block**, i.e., a software that control and formalize rules that confirm that vehicle operate the user-set level of safety.
- **Security control, espionage prevention and privacy**, i.e., since the autonomous systems require a radio or satellite or internet connection to operate, it opens the possibility that hackers might gain access to the system. It is suggested to have a system that decreases exposure to cyberattacks and data stealing, e.g., private information such as destinations; courses; camera recordings; behavioural patterns [11, 12]. Pointed-out systems shall detect any potential hacking operation, but also it shall prevent against activation of any unauthorised external control commends.
- **Human/machine communications**, i.e., the control system shall answer to human expectations of ability to communicate with peoples that it meets, e.g., traditional signals such as verbal comments or hand signals
- **Prediction of behaviour of surrounding objects**, i.e., the ability to predict the behaviour of other moving objects. Such prediction shall be done in real time to guarantee safety of the motion. The task is additionally challenging. It has to deal the capability of fast revision of the raw calculated estimates to operate with unpredictable or panicky behaviours. Potential answer is the over-all re-computation of positions and courses of any object at any request, or many times per second. The alternative is to stock the earlier predictions and to work with case-dependent corrections.
- **Handover**, i.e., the ability to securely switch control from-and-back to the human located outside of the vehicle. We shall extend it with safe alterations of modes of control and/or alternation of their parameters, taking under consideration the necessity of estimates and planning of intermediate operations needed during the transfers.
- **Minimization of ineliminable harms**, i.e., a block focused on the on-line prediction, estimation and balance of results of potential collisions and risky operations. It shall combine economical and ethics recommendations, e.g., has to balance probability of a safe landing but with a potential risk of an accident with a suddenly-noted pedestrian who steps in its way versus effects of collisions with a wall of a building resulting in the total destruction of the vehicle, destruction of the building and with a risk of potential injures of persons staying in the building. Possible contexts of final decisions shall embrace formal rules (deontological ethics) and damage reduction (utilitarianism).

3 Seaplanes and ground-effect vehicle

Seaplanes establish themselves an independent subcategory of vehicles. They shall be located intermediate between airplanes and boats. They are defined as powered, fixed-wing aircrafts able of taking off and landing on water. Seaplanes are standardly divided into two sub-classes: floatplanes and flying boats. Floatplanes are defined by an existence of slender floats that are fixed under the fuselage. Standardly, only the floats contact with water. Fuselage remains above. This idea is addressed to small aircrafts. Flying boats are generally larger. The source of their buoyancy is the fuselage, which works like a ship's hull. Many of the flying boats are additionally equipped with small floats mounted on their wings.

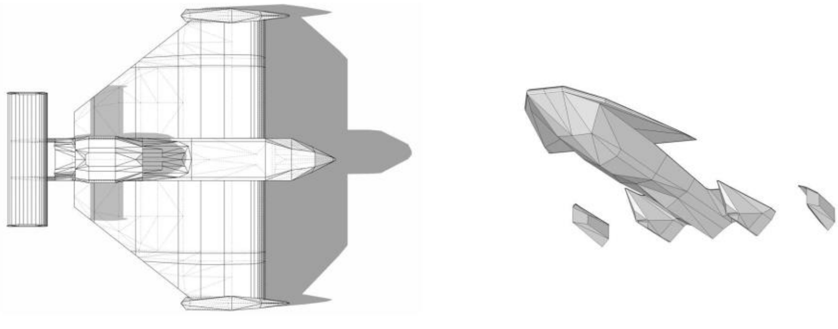

Figure 1: Visualizations of analysed concepts of the aerodynamic part of the USV-UAV-WIG and the shape of the hydrodynamic part according to the multi-hull concept [13-15]

Commercial use of seaplanes is low for numerous reasons. The capability to land on water became less important since the

number of land-based runways increases considerable, moreover the speed and range of land-based aircraft amplified to the regions inaccessible for the seaplanes. Additionally, seaplanes can only land and take off on water with no or tiny wave action. It makes them sensitive to weather conditions. However, focusing on small islands; limited infrastructure of the island’s ports; and roads; offers an ability of connections of the islands themselves and also with the mainland. Seaplanes can deliver supports at rivers and lakes locations. They can deliver supports for offshore installations and sea-bases.
Focusing one aircrafts, there is a separate subcategory constituted by the ones that able to use the near-surface effect. They alternative names are screenplanes, wingship, Bodeneffektfahrzeug, flarecraft or ekranoplan. So far, majority of their projects are related to ground-effect, and they remain in the design or experimental phase. Only a few have been used. In the former USSR, the Alexeyev design bureau has worked on ground-effect aircrafts. They designed over 40 different versions of ground-effect airplanes, of which over 30 were built. In the 1960s, an example was recognized on satellite photos of the Caspian Sea area. It was probably a 550-tonne military ground-effect aircraft of 92 m length. The aircraft was called the Caspian Sea Monster. The most successful ground-effect aircraft of this bureau is the 140-tonne A-90 Orlyonok. Three of the A-90 Orlionok crafts was built and send to exploitations. Their take-off weight was 140 tons. Selected elements of knowledge related to the research and design of the USSR screenplanes are presented in the literature [16, 17]. In1963, in Germany, Lippisch developed the X-112. It was a design of an aircraft with reversed delta wing and T-tail [18]. Associated patents have been sold to Rhein Flugzeugbau company, which extended them and developed the X-113 and the six-seat X-114. Next, Hanno Fischer continued these works in his own company, called Fischer Flugmechanik, and possibly finalised two models: Airfisch 3 and FS-8. Günther Jörg is a man that worked on first designs of Alexeyev. He developed a ground-effect airplane with two wings set in a tandem configuration. It was called Jörg-II. In September 2010, Iran presented Bavar 2, a two-seat version of ground-effect airplane. In Singapore, Wigetworks demanded and gained certification from Lloyd's Register. In 2011, its AirFish 8-001 became one of the first ground-effect airplanes labelled in the Singapore Registry of Ships. In Korea, Wing Ship Technology Corp. developed and inspected a 50-seat ground-effect airplane called WSH-500.

4 Investigated object

The paper-investigated object is a demonstrator of a technology of an unmanned surface-air vehicle of the USV/UAV/UGEV type (Unmanned Surface Vehicle/Unmanned Arial Vehicle/Unmanned Ground Effect Vehicle). The constructive tasks for this vehicle include: carrying out tasks over water zones and over lands but close to the coastline; carrying cargo and other on-board equipment of considerable mass; the possibility of taking off and landing on water; the capability to fly at low altitudes to rise the carrying ability thanks to the near-surface effect [13]. Definition of geometry of the screenplane in its on-air/above-water part was inspired by shape of the airplane made by Lipisch's, a reverse-slanted airfoil (in order to ensure the appropriate Wing in Ground Effect) [13, 14]. Definition of hull geometry in the underwater (hydrodynamic) part was based on the shape of a hull, according to the multihull concept. It ensures appropriate sea properties during the taking off and landing [13-15].

Figure 2: Visualizations of selected concepts of the USV-UAV-WIG platform [13, 15]

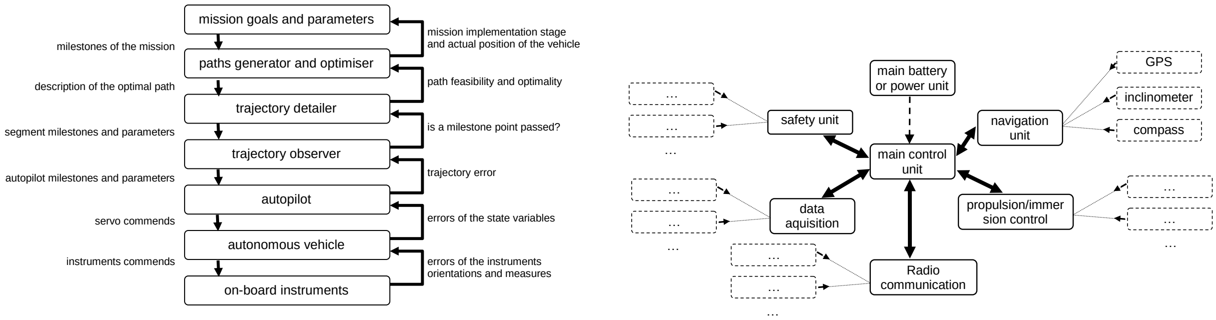

Figure 3: Block diagram of the designed structure: linear structure of sequential control system/algorithm (a); grid structure of distributed control system (b)

5 Control systems of Autonomous Underwater Vehicles

Focusing on simple controllers, we can apply a linear structure of the successive control (Fig. 3a). A case of such control is disused in [19]. Operational blocks can be arranged in a linear order and initiated sequentially, and often the sequence of these succeeding activities can be implemented in a single programmable computer module. If more-elaborated control system is required, it shall be design in a modular way, i.e., in a distributed grid structure (Fig. 3b). Such system has to be assembled from different independent subsystems and managed by its supervising central unit (e.g. managed by a PC104 embedded computer [20]). Each subsystem is capable to make their measurements and tasks separately. Exchange of information (formerly processed, segregated and aggregated) is supervised by the main unit. Usually [20], five subsystems shall be linked for: the navigation; the propulsion/immersion; the safety control; communication; and data acquisition.

5.1 Navigation system

Presently, to detect the actual position of the vehicle, we provide it with a GPS navigation system. It offers comparatively good precision. It interprets signals of Satellite Based Augmentation Systems and permits a real-time navigation at user-required level of precision. To acquire the signal from the satellites, a passive antenna is needed [20]. The GPS signal has many benefits in case of USVs navigations, but in case of AUVs it is useful for low immersions only (since water blocks the GPS radio signal). What is more, water acts on the signal like a mirror (mainly because sea water is a conductive medium). Resulting reflections of the GPS signal, affect the accuracy of the positioning. Alternate systems can operates with low-frequency radio signal (i.e., long waves), on sonar/ultrasound signals or partially on detection of polarization of the sun light. Online diagramming of the seabed can be beneficial for recognition of the actual location of the AUV in some of the cases. What is more, to control direction of the future motion of the AUVs, classical navigation system shall be equipped with a 3-axis attitude sensor (a gyrocompass). To reduce effects of accumulation of numerical errors, the GPS system can be used occasionally to correct the estimated position. It involves emerging of the AUV, or the use of an antenna installed on an emerged buoy. Existing navigation systems offers high resolution; accuracy; low consumption of electrical power. In case of AUVs, a supplementary subsystem controls its actual immersion. Most of them is based on measuring the hydrostatic pressure. Their precision may be reduced due to sea waves and due to the lack of data about the above-water atmospheric pressure. In addition, the navigation system shall be equipped in a block that measures speed of the vehicle. Classically it determines the speed by measuring the difference between static and total pressure (i.e., a dynamic pressure). To decrease the effect of sea currents, it is vital to have an accurate map of the currents occurring in the area.

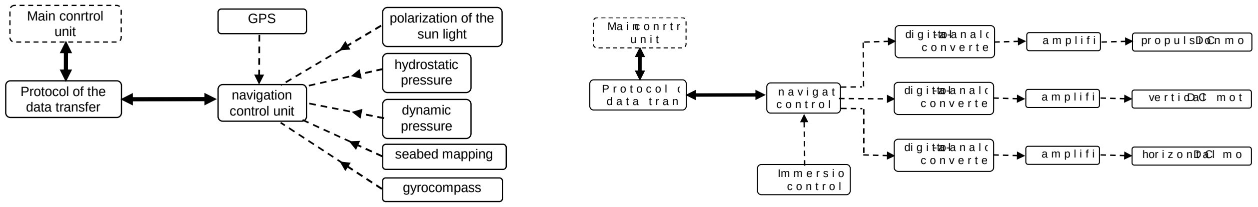

Figure 4: Block diagram of the designed sub-structure: navigation control unit (a); propulsion/immersion control unit (b)

5.2 Propulsion/immersion system

Propulsion/immersion control drives and engines. This system covers: control system of the main engine (delivering the propulsion), control system of the side engines (changing direction of motion) or rudders engines with their position controllers. In case of USVs, a single system of the side engines (or a single rudder controller) is sufficient. In case of AUVs, these systems are doubled (one is oriented for the horizontal, another for vertical direction). In the predominant number of constructions, they control rotations (positions and speeds) of combustion engines or they control electrical currents that flows to the controlled electrical engines. In case of AUVs, the immersion/emersion block is usually equipped with water pumps or with pneumatic cylinders. Their rotations/positions has to be measured and controlled by the immersion/emersion block. A significant/additional aspect in projects of the propulsion control is the unavoidable partition of the tasks between the main block, the navigation block and the propulsion block, since a number of the initial unprocessed raw input signals (e.g., information about the actual immersion) shall be used in all these block. Different strategies can be employed for gathering (parallel or associated), processing (parallel or associated) and transferring the signals (direct inter-block transfer or a transfer via the main block of the control system). Type of the controlled physical quantities may also be divided and made in different blocks, e.g., the propulsion block can control a dedicated speed or simple the driving torque, letting the control of the resulting velocity to the navigation block (with the open question about the parallel or associated processing).

5.3 Safety system

To increase the safety of operations, we shall install a block that monitor all these parameters of the vehicle that can be critical to its operational accuracy. Some examples of the possible sub-blocks shall control: state of the charge and the charging current of the batteries; depth of immersion, selected temperatures (sensors shall be located in critical points of the vehicle to verify work of the subsystems), humidity control (essential for the correct work of all electronic and electric systems). It is useful to extend the main safety sub-systems with additional dedicated travel recorders which can record and store all the principal parameters and commends of the block

5.4 Radio connecting system

Usually, the vehicles are communicating with their bases via radio link. It permit to receive and send the real-time data about the environment as well as the main parameters of the vehicle. It offers an ability of additional monitoring and is allows a manual control in some circumstances. In most of the cases the radio offers bidirectional communication.

5.5 Data acquisition system

In case of patrolling or inspecting, the principal job of the mission is to gather and collect information about the situation at the patrolled area. Optimal configuration of the subsystem is difficult to generalise, since it depends considerably to the tasks of the missions.

6 Control systems of Unmanned Aerial Vehicles

Contrary to AUV, the Unmanned Aerial Vehicles require in more developed/complex data-gathering systems to collect data, monitor sensors, as well as to telemeter their information to the ground stations. In most of the cases, aircrafts are better instrumented. We install more sensors, they are smaller, their acquisition times are shorter, and their precision is higher. Accordingly, the data collection and the flight control shall be driven by similar, but smaller and more capable, platforms. We can find an example of such system in [21]. The standard UAV Autonomous Control System consists of sensors cooperating with their associated microcontrollers or with a grid of microcontrollers. Typically, their set of sensors contains: *gyroscopes* (measuring angular accelerations); *accelerometers* (measuring linear accelerations); *relative altitude sensors* (measuring the attitude relative to the reference/starting point); and *absolute altitude sensors* (typically - barometric sensors measuring the altitude relative to the level of the inputted reference pressure); *ultrasonic sensors* (measuring the distance from the sound-reflecting point); *infrared sensors* (measuring the distance from obstacles or from the ground); *LIDAR*; *cameras of the anti-collision vision system*, a *reference magnetometer* (determining the actual orientation of the coordinate system associated with the vehicle relative to the global/stationary coordinate system); and a *GPS* receiver. The typical barometric sensor works according to the linear drop of the atmospheric pressure of 12 hPa at each 100 m of the attitude.
Not all UAVs have the same level of autonomy. Readers can found a standard example of categorisation of such levels (together with possible trends of their expected evolutions) in U.S. Unmanned Aircraft Systems Roadmap 2005-2030 [22]. It recapitulates strategies/algorithms of the control, starting from Level 1 devoted to very basic remote control systems, and finishing with Level 10 devoted to system capable cooperate with the neighbouring control systems and leading to totally autonomous flays of formations of vehicles. Following an opinion expressed in [21], the current level of the AUV developments corresponds to Levels 4 or 5 (ability of autonomous in-flight re-planning of their paths, basing the decisions on data from the on-board cameras and/or visual sensors). Accordingly, these systems are close to the level when the autonomous avoidance of potential obstacles can be accessible.

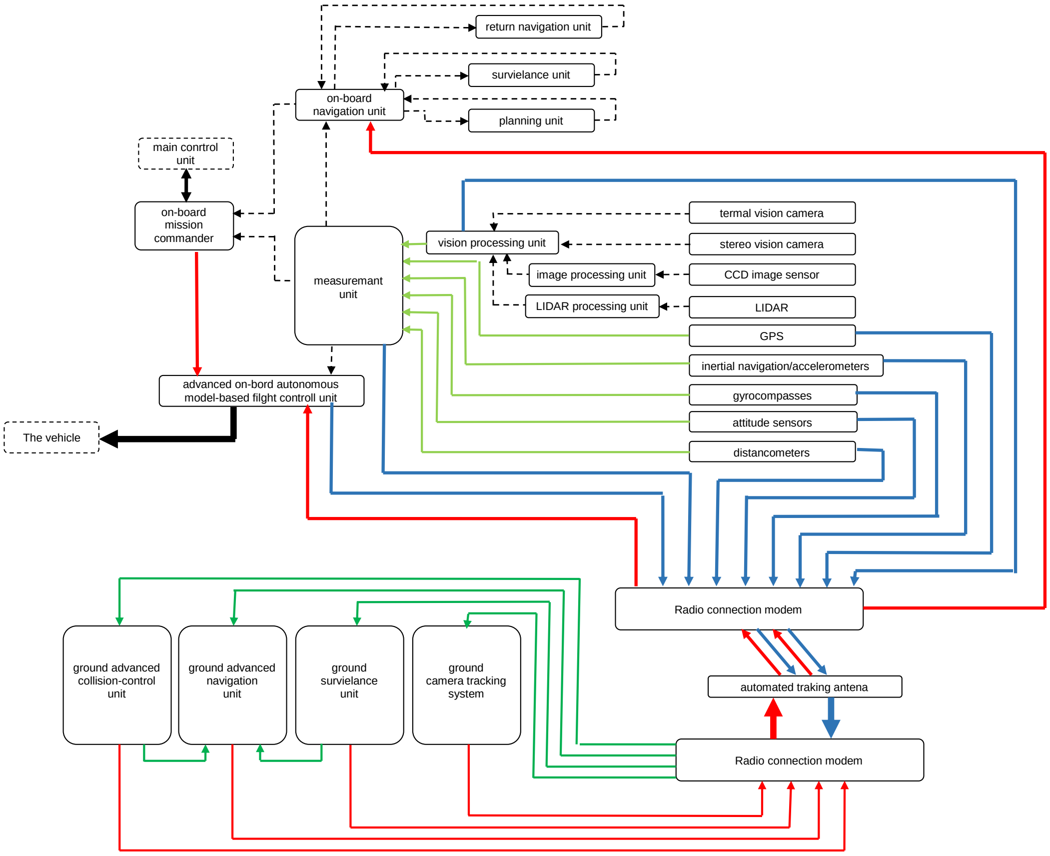

Figure 5: Block diagram of the exemplary structure of the air navigation control unit

However, majority of actual on-board embedded computers does not have the necessary and sufficient numerical power to real-time operate with the necessary amount of data. Thus supplementary calculations often are distributed to the computers of the ground control. Therefore it is fundamental to have an access to highly-reliable and highly-efficient radio links for data transmission (Fig. 7). Additional requirements shall be fulfilled, if all weather flights are accepted for the vehicle, as the changing weather conditions can disturb work of the typical sensors and communication systems on-board.

7 Control systems of Autonomous Seaplanes

As configurations of the UAVs and USVs are analogous, we can express a suggestion of their adoption/implementation in the control systems of autonomous seaplanes (ASs). However few significant remarks has to be pointed-out:

- If focusing on their opposite work situations, corresponding operational situations differ considerably (e.g., reaction forces of the environment, or operational speeds). Accordingly, physical phenomena that are grave in the first state can be negligible/absent in the second state;
- In intermediate work situations, both phenomena can be important and shall be considered in the control systems;
- Selected sensor/measuring-instruments shall operate in the first work situation and shall be switched-off or replaced by other ones in the second work situation, (e.g., flight-attitude barometric sensors are useless during water navigation, seabed ultrasonic sensors are useless during flight, sensors of dynamic pressure used during flight may not be used to measure the dynamic pressure of water during its water navigation, i.e., the physical nature of the measurements is this same but the measurements device shall be differently constructed).

Accordingly, three optional natural solutions can be used to deal with these variable work situations: parallelization (a); morphing (b); parallelization with an ability of eventual morphing (c).

In the parallelization idea, two or even three independent/case-devoted control units shall be installed. As a result, one shall extend the group of the parallel control systems with an additional supervising unit that can switch activities from one to another, depending on the actual operational situation. Accordingly, one of the systems operates in the flight situations. The second is for the water navigation. The eventual third is in charge to operate for landing and starting/taking-off. Each of these systems is operates with its own set of sensors and with its own set of communication lines. Contrary, in the morphing method, there is a single control unit that can operate in all the distant work situations. It can be obtained thanks to serious reprograming done at every instant when the work situation changes. The morphing can be restricted to the numerical units or it can be extended to redefinitions of input/output lines. In order to reduce the total mas of the AS, it is useless to keep transmission ports with no information transferred, and thus, we can shift its associated transmission line to connect the control unit with other actually-active sensors. Finally, in the parallelization extended to eventual ability of morphing, if the usual/safe work situation are controlled, the system operates as the standard parallelized one. But, in the eventual emergency situation (hard weather or in case of partial failure) some elements of the non-activated/non-used units can be reprogramed and added to the actually-operating components as a supporting elements or they can replace the defective ones.

The pointed-out morphing method looks as attractive, as it offers a possibility to reduce the complexity and weight of the developed control unit. However, a critical disadvantage of this configuration is the time delay needed to reprogram the unit. As it is unreasonable to let the vehicle move with no control (during reprogramming), we shall equipped it with a transient control unit, and we shall set this transient unit according to idea of the parallel configuration. Since time of its activity is a short and its activations are seldom, it need not to offer all spectrum of the accessible operations, and thus, its structure can be reduced/simpler in compare to the main system. However, it leads us closely to the initial idea of parallelization with an ability of eventual morphing.

Let us focus on the case when the costs, size and significance of the mission is substantial. Eventual loss of the vehicle becomes inacceptable. In the pointed-out situation, an additional emergency control unit is recommended in case of malfunctioning of the main unit. To cases can be considered: continuation of the mission and safe return for reparation. In the second case, the main task is not to continue the mission, but it is to move the vehicle to a safe landing zone. In the case of malfunctioning, critical sensors or communication lines can be damaged, and thus considered return trajectory shall be simplified, but in parallel it shall guaranty low probability of collisions. Since the main anti-collision instruments can be inaccessible, trajectories with lower number of obstacles are preferred. What is more, since the most probable organ of the malfunctioning is the loss of the electrical power (or a damage of one of the main electrical components) reasonable data from the sensor can be inaccessible. Therefore, an open-loop blind-man control unit shall be the most recommended option. Unused/non-powered flight instruments shall be self-moved to their neutral/natural positions, but these natural positions shall be previously on-line real-time calculated by the control unit and on-line real-time pre-adjusted by the main control unit to guaranty that the natural/neutral flight direction will lead the vehicle to the save landing area. Elementary, clock-working mechanical time-measuring devices can be added to activate of the landing procedures or activate of the trajectory changes at a given instant of time. Operating with such emergency unit and such strategy should help the rescue team to find the plane safer and faster and also, it helps to minimize the risk of collision during landing in non-prepared area.

Comparing to the ground based UAVs, the ASs request in significantly altered landing algorithms. Foremost differences are related to selections of the landing zone. Technically, any part of the sea is acceptable for landing, but probability of collision is higher, since sea is not protected against eventual presence of objects and people (as guaranteed in ground airports). Selected landing zone shall be pre-controlled by cameras or other vison systems and eventually relocated if the inspection indicates risk of a collision. The other problems relates to the seafloor obstacles, hard to identify by the typical vision systems. The subsequent difference is the absence of aid from airport supervisors. As a result, de-icing, or turning the plane to orient it in the correct take-off direction shall be done by the AS on its own. And therefore, corresponding protocols/algorithms shall be implemented in the AS control units.

8 Control systems of Autonomous Seaplanes

Except of the ideal situation, in the practical ones, the AS control unit has to trust to data received from the sensors, but in fact, in case of highly possible malfunction of these sensors, their data can be fouls. Resulting response of the control unit may be inappropriate and may lead to a disaster. The control system shall be able to detect and to eliminate data from the malfunctioning sensors. To deal with it, the most popular concept is the idea of tripling the sensors (if one intends operate with data from a duplicate system of sensor, it may help us to identify a failure, but it will not inform us which of the sensors is sending the incorrect data). Thanks of it, data that is significantly different from the two others is excluded and the sensor is stored on the list of units scheduled for technical inspection. Presented parallelization technique shall be extended to other units of the designed system.

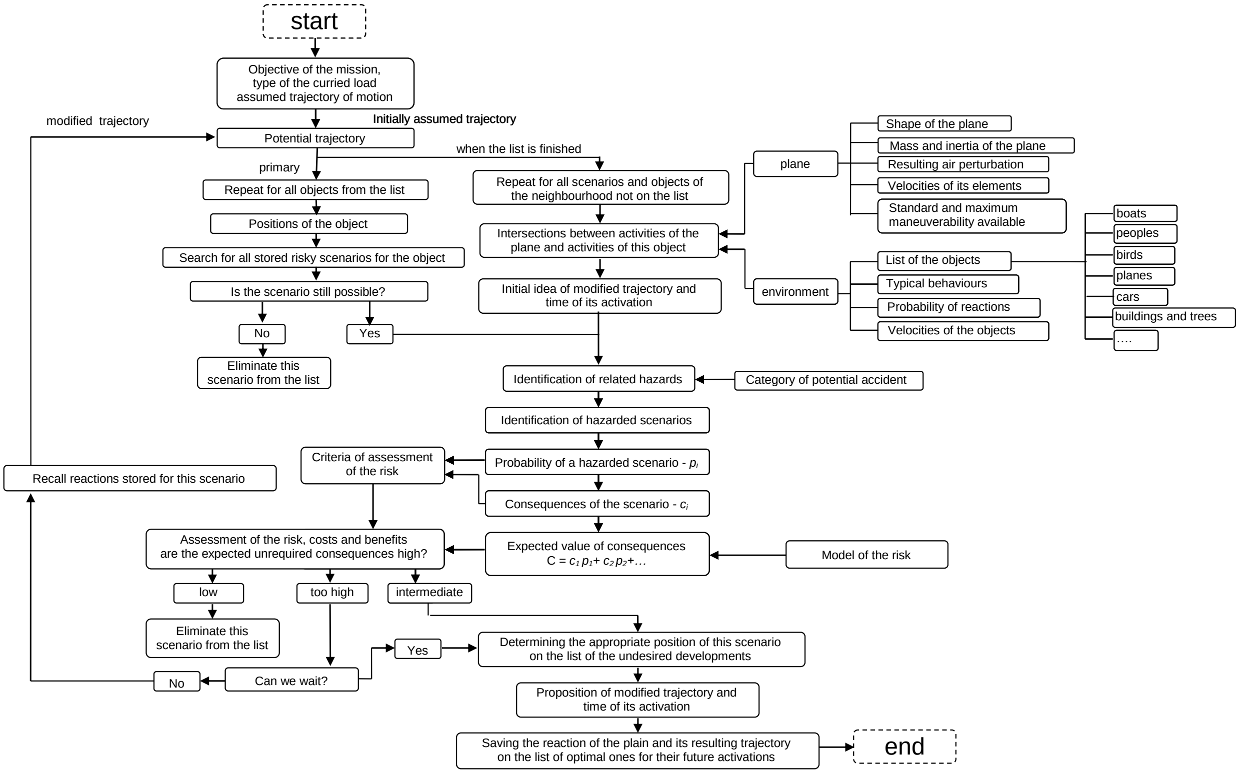

Figure 6: Block diagram of the investigated process of prediction of reactions on potentially dangerous situations

According to the general experience, when a potentially danger situation occurs, we detect it late and thus the accessible response time is short. Accessible time for analysis and finding optimal responses and reprograming the trajectories is insufficient. If comparing it to our natural/human activities, our natural tendency is to observe the neighbourhood, select obstacles, imagine most-often-met potentially dangerous developments of the actual situation, and anticipate our potential responses before any scenario occurs. Similar ability shall be implemented in the developed control unit (Fig. 8). All the elements in the neighbourhood of the plane shall be observed (together with the work parameters of the plane on-board systems). Probability of their unrequired behaviour shall be estimated together with the probability of collisions or unwonted consequences. All the considered scenarios shall be classified according to the expected values of their adverse effects, and a potentially optimal responses of the system should be determined starting from the highest classified scenarios (from the one with the most unwanted expected value of consequences). The list of scenarios and the list of their optimal responses should be actualized permanently in real-time, based on situational changes observed by the vision system. If the collision probability exceeds the emergency level set by the owner, the already-prepared optimal response shall be started to avoid the unwanted consequences. Required prediction should be based on work of numerically efficient numerical units according to a well-organized computational algorithm. The unit-available memory should be big enough to stock all the potential evolutions. To correctly predict the probability of potentially-dangerous developments, an extensive knowledge base shall be installed.

9 Conclusions

Purely autonomous operation of plans, seaplanes, AUVs, USVs, ASs and other vehicles shall be recognized as the unavoidable future, especially in case of automatic inspections an operations in risky environment. Appropriate abilities and properties of such vehicles are critical in realization of their tasks, but also, developed control unit are required. Denoting the most-sophisticated potentially-expected designs of these control unit as referring to Level 10, the present level of developments refers to Levels 4 or 5. It refers to the ability of autonomous in-flight re-planting of travel-paths basing it on data obtained from the on-board visual systems and cameras. The actual main limitations come from the limitations in the numerical power of the used computational units. But the numerical power of such unit is growing. The CPU exponentially growths in their processing speed over last decades. We may suppose that autonomous control of vehicles will grow is similar way in close correlation with the growths of the CPU speed.

Arising new abilities of quicker calculations give as the chance to perform more tests, to control more parameters and to predict better both reactions of the vehicles and reaction of the neighbour objects. Larger grids of processors can help us to parallelize computations, analyses and observations done by the control units. But in parallel, it requests in a need of new algorithms and better arrangements of the structures of the grid of the processors. Permanently increasing importance of the safety factors forces us to modify the earlier algorithms and forced to focus on better prediction and avoidance of the potentially unsafe situations.

Seaplanes will never be classified as the most fundamental vehicles, but they are beneficial and will exist in future, as they combine together many of the unique/useful properties. In their autonomous versions, their control units shall differ from these used in boats and in ground-landing planes. The seaplanes control units should be considered as unions of the individual units used in the planes and in boats. Algorithms of their collaborations and/or successions are critical for the paper investigated accurate autonomous control of seaplanes.

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