A HELICOPTER PILOT ASSITANT SYSTEM FOR INFLIGHT MISSION PLANNING

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Abstract

The presented assistant system will support the helicopter pilot by inflight mission planning and execution to enhance safety and to improve the mission effectiveness using a new approach in the design of the Man Machine System (MMS).

In the future, helicopter pilots will be supported by partly complex systems which are only taking a certain task into account. This kind of support limits the information flow between the systems. To get to an appropriate picture of the actual situation the pilot has to overcome these limits. He has to merge and prioritise the displayed information to find out the most important and most urgent action. This causes a high workload in usual and an excessive in unusual situations.

Our assistant system integrates extended, new support functions into one system with a consistent Human Machine Interface (HMI). Therefore, the obtainable onboard data are collected in a data pool. A merge of the data pool with an onboard database forms the central information system which provides the information for the modules of the assistant system. Using this information extended, new planning functions are introduced to support the pilot in a mission specific manner. The design of assistant system is based on the human behaviour with solving guidance and control tasks. To allow an intuitive input, a graphical user interface is integrated into the new designed HMI.

1 Introduction

Helicopters are used for a wide variety of missions. Therefore pilots are faced with a large amount of different mission profiles. This leads to exceedingly multifaceted and complex tasks resulting in an unacceptably high pilot workload. For future helicopters demands exist to operate in extended conditions and to enhance the mission efficiency which demands:

- reduced visibility ranges and noise levels
- enhanced performance
- improved safety and
- flexible adaptation to special missions.

These demands can only be satisfied if the pilots are being supported in an effective manner.

Up to now pilot assistance mainly consists of uniquely automating certain tasks. This traditional way of task centred automation reaches its limits when it comes to complex tasks requiring the co-ordination of many such unique automation systems. The unique systems put an additional load on the pilot, since he must collect information about the situation from several individual systems and merge it to an overall picture. Further the pilot must frequently move some data from one system to the other "by hand".

In this paper, a new approach to pilot assistance based on human centered automation is presented (chapter 2.1). Human centered automation could be reached by structuring the support functions in a way that resembles human behavior. One general structure in this regard is the recognize act cycle. An important point in the system design based on this approach is a well balanced support for the different subtasks (chapter 2.2).

To form the basis of the assistant system, the separately, developed planning, monitoring and control systems will be integrated with a new HMI. A generic assistant system architecture provides the necessary framework for this integration [1]. Then new functions based on recent advances in the avionic equipment will be developed and integrated (chapter 3.). The following functions will be provided by the assistant system.

The assistant system is connected via a data link to external sites. This provides a support for the external co-ordination by automatically exchanging and preprocessing information with the mate. The internal co-ordination between the system and the pilot is sup-

ported by a map display, which shows the external situation and allows system inputs (see chapter 3.2.1).

A Route Planner (RP) generates a list of waypoints and constraints based on the information from the pilot, external sources and an onboard knowledge base. The knowledge base includes information about landmarks, navigation aids etc. The RP provides the functions "avoid", "evade", "follow features" and integrates pre-computed trajectories into the flight plan. The list of waypoints generated by the RP serves as input for a trajectory generator which produces a flyable 4D-trajectory (see chapter 3.2.4).

A guidance function and a flight control system (FCS) are provided to automatically fly the helicopter along the planned trajectory (see 3.2.5). The redundant full authority FCS is combined with an online monitoring and diagnosis function to identifies faults in the FCS and assesses their impact on the functionality and redundancy of the system (see 3.2.3).

2 Concept of the Assistant System

2.1 Human Centered Automation

The definition of automation stated in the German Industry Norm DIN 19 233 is: "Automate matters to use artificial means, thus a process automatically runs. With regard to a plant this means, to equip it in such a way with machines, that it operates automatically, where a machine is an artificial system, which obeys a self-acting program." This definition counts until today, because there's no functional description for the artificial means and no definition of the interaction between the artificial means and the environment.

The reasons to automate systems are just the same since the first regulator at Watt's steam engine to control the rotary speed. The technicians in this time wants to substitute the children that have done this job before, to streamline the production and to improve the quality. The new regulator was cheaper, faster, better (with controlling speed) and more reliable. But they quickly noticed that the regulator was also bind, deaf, inflexible and unadaptable. So the factory owners reemploy the children to shut down the engine if damages or accidents at the engine or the looms occurred.

One industrial revolution later and after a leap in the complexity of the systems, the view on automation has changed from task centered automation to human centered automation. In the 80' Wiener and Curry stated that "the question is not whether a function can be automated, but whether it should be, due to various human factors questions that are raised."[2].

More than 200 years before, there were extremely less possibilities to make systems see, to gave them ears (sensors), a memory and to process this information. So the technicians have to automate what they are able to automate. The remaining difficult subtasks were still allocated to the human operator.

The problem thereby occurs, is that some subtasks are completely quarried out of the cohesion of the work process. Controlling the engine, the children recognise whether it runs "badly". This change in the behaviour of the engine usually points to increasing technical problems, which are not detectable for the children if the regulator is engaged. If the children don't control the steam valve by hand, they are not able to compare the engine response on a known input with the expected response because they are not actively involved. With the implementation of the regulator, the control mean of the children was changed. As a result, the children are not adequately informed to perform tasks like the assessment of the efficiency of the steam engine. This examples describes the situation if there is only one task to perform. But in aeronautics the pilots have to perform a lot more than only one task.

The task expertise a pilot must have, are in flight control, navigation, communication and system management. In all these areas the pilot is forced to perform partly concurrent tasks where he often is not fully aware of what the support systems will do for him, if he is only passively involved in the work process and the assistance is unpredictable for him. Are there more than one task, the pilot has further the problem to schedule the tasks and to select the support system he will use to perform the task. For example, he has the choice between entering a new waypoint in the FMS or use the autopilot to change the flight path.

According to these problems with the task centered automation, the question on design criteria for a human centered automation are raised. Answers to this

question are provided by Billings [3] and are restated by Onken [4] in two basic functional requirements:

(1) "Within the presentation of the full picture of the flight situation it must be ensured that the attention of the cockpit crew is guided towards the objectively most urgent task of that situation."

(2) "If basic requirement (1) is met, and if there still comes up a situation with overcharge of the cockpit crew (in planning and execution), then this situation has to be transfered – by use of technical means – into a situation which can be handled by the crew in normal manner."

In some situations, the pilots, by default, are overloaded, e.g. flying an extremely unstable aircraft. So, beside the functional requirements the goals of the classical, task centered automation still remains especially when the particular capabilities of machines

- objectivity,
- long term monitoring,
- broadband reception,
- complex planning,
- detailed information retrieval,

are necessary to perform this tasks. The share of such tasks will increase in the future because of the growing machine capabilities. In opposite to the humans, the machine capabilities increases in a partly exponential way due to the rapid development in computer science.

2.2 Act Recognise Cycle

If the design requirements on human centered automation are defined, the next question is which approach will be used to fulfil these requirements.

Back to Watt's steam engine. The first attempt to substitute a human by automation failed, because the machine was not in the position, to be aware of the total situation of the environment it influences. This weakness of the system, based primarily on the lack of sufficient sensors and of typical human capabilities like:

- instinct, creativity
- problem reduction and generalisation
- pattern recognition
- ability to adapt, learn and abstract

In fact, the regulator has improved the total system so it was an engineering progress. The engineering progress of the modern computer and software technologies provides permanently growing possibilities to extend the human capabilities with typical machine capabilities and, recently, to imitate human behaviour.

The first design requirement for the human centered automation demands, that the system must be able to direct the attention of the crew towards the most urgent task. Hence, this system has to comprehend the situation.

The conformity of the situational picture of the pilot with the real worlds state is one of the most important topics. A good situation awareness enables him to recognise arising problems in an early state. If so he has enough time to classify the problem regarding whose importance and to develop strategies to solve this problem, before it becomes urgent. Under these circumstances the pilot is able to use the means of the classical support systems in a proper manner. Deficiencies in the situation awareness conducts to recognise a problem late or to mistake a problem, so the pilot is taken by surprise and the problem becomes immediately important and urgent, even if it is neither important nor urgent. To confuse relevant problems with nonrelevant problems could lead to mistake the situation. If so the task centered automation helps to solve the wrong problem.

A look on the second design requirement for human centered automation shows that there is an overlapping in the tasks which can be performed either by the pilot or by the support system. Particularly by the overlapping division of work, the question, how behave a human operator, plays an outstanding role, since the provided support must take this behaviour into account. The lesson learned with Watt's steam engine and the design requirements of human centered automation demands that the cockpit computer system have to act human like. This implies to interact with the crew in a similar way to how humans interact among each other. That can be performed considering the goal-directed interaction of man with the surrounding world, which can be decomposed into the functional elements of the act recognise cycle [5]:

1. Recognise the actual state of the world and compare it with the desired,

2. Analyse the deviations of actual and desired state.
3. Think about actions to modify the actual state.
4. Decide about the action to reach the desired state.
5. Take this action to change the state of the world.

The points one and two can be described as Situation Analysis, the points three, four and five as Plan Generation, -Selection and -Execution. To perform these functions, an exchange of information between the systems due to the internal information processing is necessary. This function is described as Coordination.

2.3 Goals and Resources

To implement a goal-directed interaction of man with the surrounding world the definition of the goal plays an important role. Therefore following definition is suggested: "The goal of a work system is to fulfil a certain task while saving all resources." In aviation this certain tasks are missions like:

- SAR, CSAR
- transportation of patients, VIP's, offshore, troops
- supervision operations (police, maintenance, environment, reconnaissance, disaster control...)
- aerial work, load transportation
- combat mission air-to-air, -to-surface, over water

The task of these missions are the transportation of persons and materials from point to point or along specially constrained flight paths. The persons and materials can either only be transported or fulfil a special task on board. The shape of the specially constrained flight paths depends on the actual situation.

To obtain the claimed goal of the work system, pilot/helicopter, (to fulfil a certain mission) a high mission effectiveness is necessary, so it has to be maximised. For a assistant system this means that the capabilities of the crew have to be extended by information processing and by a optimally adjustment with the capabilities of the helicopter. For the implementation a detailed mission task and a precise helicopter description is necessary. Because many missions are assembled out of the same mission parts, a task description of separate mission parts is more useful than a task description of total missions.

According to the goal description of a work system, a task should be fulfilled taking care of all resources. Thus, the consumption of the resources has to be minimised. A minimisation of the consumption of the resources human life and equipment can be referred as flight safety. So, this minimisation is a premise to reach the goal, fulfil a certain mission. Among others, the important resources their consumption have to be minimised are human life, equipment, human capacity, environment and comfort. Considering the importance of the resources a hierarchy of this resources has to be introduced. For this hierarchy of importance of the resources the sequence of appearance as mentioned above is suggested. The first three resources are on the top because they are related to flight safety. Environmental compatibility is another important resource, primarily concerning the public acceptance of the helicopter employment. The comfort has to be taken into account due to the fact that this is a relevant quality criterion for the helicopter customers.

Most of the tasks performed by the pilot can be associated with the minimisation of one of these resources. Hence, this hierarchy gives a possibility to decide how urgent a task is. This information is needed to fulfil the first design requirement for the human centered automation. Beside the importance of the resource, the urgency of a task depends also on the size of the deviation between the real worlds and the desired state. To determine the deviation and its importance a criterion regarding the consumption of resources can be used. The difference between the minimal consumption of resources related to a certain mission and the predicted consumption of resources based on the actual real worlds state gives a measure for the urgency and importance of the tasks and a way to sort those.

If for example the pilot is busy because of an engine failure at a twin turbine helicopter during a cruise flight and he also flies towards a power line a sequencing of the caution has to be made. The biggest possible deviation between the desired and the real worlds state can be expressed by the total loss cost for a helicopter. The likelihood of a total loss by an engine failure can estimated as low as 10%. The likelihood of an total loss by a collision with a power line can be estimate with 100%. The total loss likelihood for the collision depends on distance. By a long distance to the power line the assistant system gives a caution referring to the turbine to the pilot. Below a certain distance to the power line the system then clears the turbine caution and releases a collision caution.

3 Helicopter Pilot Assistant System

3.1 Central Information System

The first step to build up a pilot assistant system is to integrate the already, independent developed components for planning, monitoring and flight control into a generic architecture for assistant systems. Same applies to the man-machine interface which must provide an overall impression of the situation onboard and in the environment of the aircraft in a uniform way.
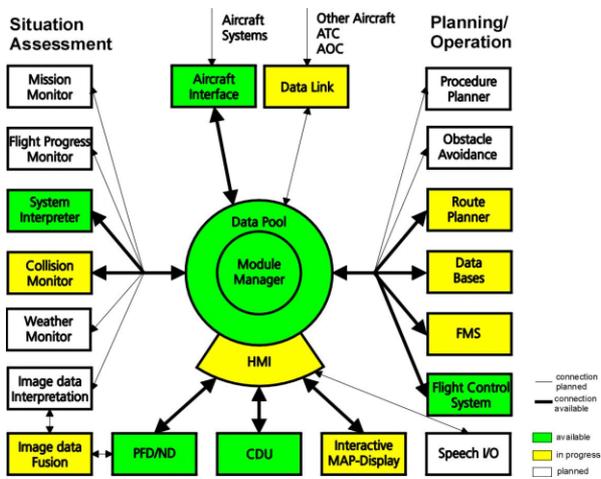

Figure 1: Generic Assistant System Architecture.

As a precondition a central recording, administration and distribution of the onboard information is needed. The developed generic architecture enables to merge the dynamic onboard data in the data pool. Dynamic data are so-called, since they are changing during a flight, like sensor signals, data provided by the pilot, by transmission, by the planning systems or the situation analysis. A further element of the generic architecture, the module manager, takes care of a co-ordinated and safe access of the function modules to these data. One function module is a data base, which contains the necessary onboard data. Among these static called data there are e.g. maps, a helicopter performance model, landmarks, aviation obstacles, navigation aids, information about landing sites, take-off and landing procedures and communication possibilities.

The data pool and the data base module together represents the knowledge base of the pilot assistant system, the central information system. The access to the knowledge base is provided by the module manager.

3.2 Mission support

Out of the huge account of thinkable support functions, it is necessary to identify which are important ones for many missions. Each flight contains the mission parts takeoff/landing as well as en-route, influenced by the specific mission. So we decided to develop first a mission-specific pilot assistant system for takeoff and landing and afterwards extent this system about frequently used functions in en-route flight.

The most important task of a helicopter pilot is to ensure flight safety. One part of this task is to avoid collisions. Out of the technical point of view there are two different avoiding functions. The task of the first function "evade" is to evade an unknown obstacle on the basis of sensor signals. The second function "avoid" shall avoid known restricted areas like a stored obstacle or a threat area. Beside these functions, the functions "follow a feature" or "keep a 4D-waypoint" are important in the en-route flight. The function "follow a feature" supports the pilot to follow a certain terrain feature such as a street or a pipe line. For a military mission keeping of 4D-waypoints is substantial, e.g. for a rendezvous manoeuvre, to flyover the own air defence or to define the point of time for a evacuation.

According to the preceding section and as shown in fig. 2, it is necessary to provide a continues support from the co-ordination over the situation analysis up to planning and execution for the considered mission.
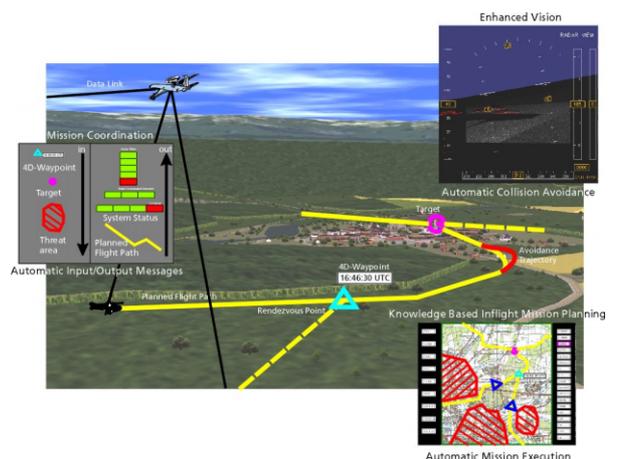

Figure 2: Support Functions of a Mission.

3.2.1 Co-ordination

The co-ordination module relieves the pilot from the task of a bare exchange of information, e.g. from ATC,

Command and Control Center (CCC) or ATIS (Air Traffic Information Service), to the onboard systems. To perform this task a data link is introduced which exchanges digital data automatically. The pre-processed digital information are passed in to the data pool where the information are available for the other modules as well as for the HMI.

If a digital information have been received from e.g. ground, the pilot is informed about the incoming information. Accepts the pilot this information, the co-ordination module processes it and files it in the data pool. Arrived in the data pool, the module manager informs the modules which are registered as readers for this kind of information. These modules execute a situation analysis and, if necessary, perform actions like planning or displaying. From the pilots point of view, the new information appears directly on the map display with the proposed actions according to this situation. If the pilot approves these procedures or plans, may be after some changes, a appropriate response is transfered automatically back to the ground station or an other aircraft.

The transferred information can be directly used e.g. as input for a flight path calculation. The information consists, in the case of take off and landing, depending on the infrastructure of the landing site, of actual weather information and/or status information of the landing site, start-up clearance and so on. Beside technical data, information like "hospital is ready to pickup the patient" or "the point in time to pick up a VIP" can be transferred.

3.2.2 External Situation Analysis

For a flight in the vicinity of obstacles a good visibility is indispensable. Although, the assistant system is able to take known obstacles into account, it's not sure that all obstacles are included in the information system. With decreasing visibility ranges, flights are only possible with an appropriate support of the pilot by a sensor based Enhanced Vision System (EVS). To improve the external view, we will use the results of a group at our institute working in the field of Enhanced Vision.

For a high performance of EVS, different imaging sensors, supported by a terrain data base, are fused. This sensors cover a wide range of wavelengths, starting with a MMW radar system up to the visible

light. The different sensors possess different characteristics concerning their scope under different weather conditions and their image quality. In general it could be stated that an increasing wavelength leads to a decreasing picture quality and an increasing range of the sensor under adverse weather conditions.
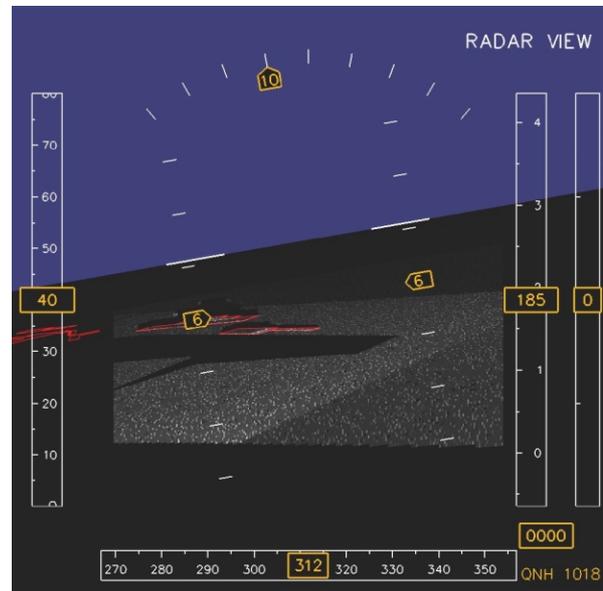
Figure 3: Enhanced Vision Display.

By fusing different sensor , the pilot is informed prematurely about a faraway located obstacle by the radar whereas the sensors with a shorter wavelength, detect the obstacle significant later, e.g. in the case of fog. The early, but inaccurately known obstacle enables the pilot to comprehend the situation and to perform precautionary measures, like reducing the forward speed.

The EVS provides only a visual assistance to the pilot, as shown in fig. 3. For a comprehensive support in adverse weather conditions the fused picture has to be processed to obtain a 3D-model of the external environment. So, the external situation is represented by the external environment model and the situational information received by the data link.

3.2.3 Internal Situation Analysis

If unexpected situations occur by failures of components of the helicopter, the pilot must be aware of the remaining capabilities of its aircraft. This knowledge of the internal situation is decisive, in order to perform the correct decisions. The presented assistant system supports the pilot by failures at the flight control system with the determination of the causes, i.e. the failed

components and with the evaluation of the effects on functionality and the remaining redundancy.

To perform this task we developed a online monitoring, diagnosis and assessment module. This module is applied to our fault tolerant Flight Control System (FCS) which enables different levels of redundancy for different control functions. The backbone of the FCS is a quad redundant 1:1 fly by wire steering and the core system is a triplex redundant rate command controller (RCC) on which the autopilot and the guidance functions are based. The redundancy level of the specific autopilot functions depends only on the receptive sensor configuration of the helicopter and is configurable from a simplex up to a triplex system.

Figure 4 shows two selectable display formats for the diagnosis results. The left section shows the architecture of the fault-tolerant FbW system. The red marked components were as faulty detected by the diagnosis. The right section displays the effects of the faulty components on the functionality and the redundancy of the FCS. The horizontal rectangles show the available redundancy of the 1:1 FbW, resp. of the RCC. The simplex autopilot functions are shown by the vertical rectangles. The red rectangles refer to a drops of the redundancy and to a loss of the autopilot functions.
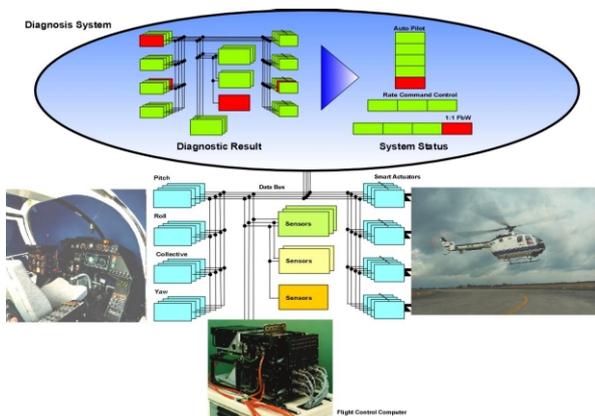
Figure 4: Example for the internal Situation Analysis.

The diagnostic results are used to disengage faulty functions and components of the flight control system. Based on this function a immediate control input of the pilot by a failure in a simplex component is avoided, since the last valid measured value is maintained. So, the pilot can wait for proposals from the planning modules to react to the failure.

3.2.4 Planning

Based on the external/internal situation analysis the planning modules determine suitable procedures which are unsolicited suggested to the pilot to proceed the mission by unexpected events. If the pilot e.g. inserting a waypoint with the graphical interface of the map display, the mission-specific planning modules instantly modify the flight path in a desired way.
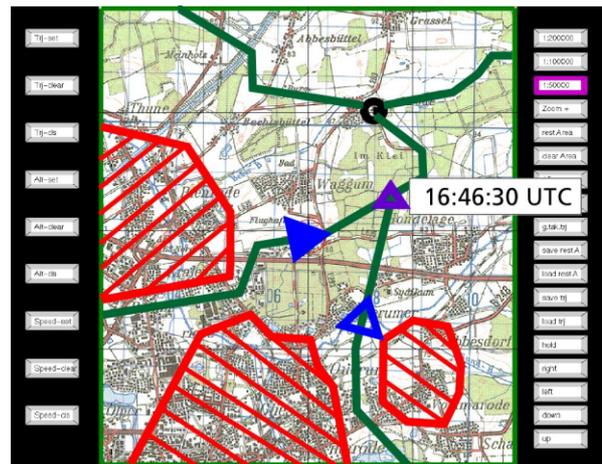
Figure 5: Map Display for En-route Flight.

The flight path created with the route planner contains the waypoints, flight altitudes, airspeeds and arrival times at the waypoints. These information are used to compute a precise trajectory on the basis of a helicopter performance model, atmosphere, weather data and so on. The overlay of the flight path data with additional information, e.g. obstacles, sports fields, terrain data etc. on the map display, increases substantially the situation awareness of the pilot. In this way long paging and looking up of information about the flight path is avoided. During the flight the displayed current position of the helicopter can be compared with the calculated trajectory on the map display.

3.2.4.1 By take-off and Landing

An assistant system for take-off and landing improves the situational awareness of the pilot and relieves him by the planning and execution of todays and future take-off and landing procedures. The support functions for take-off and landing are described using the example of a transport flight from one helipad to another.

Based on the exactly known position the assistant system recognises that the helicopter is located on a

helipad. Based on this knowledge, the central information system provides specific data about that helipad.

Figure 6: Helipad Display for the Approach Planning.

The simplest way for the pilot to create a complete flight path is to enter a destination city. According to this information the assistant system gives a list of landing sites in the vicinity of this city out. To chose one of these landing sites the pilot clicks on its identifier. The information system now provides the same data as for the takeoff site. Depending upon availability, the knowledge base contains different approach and departure routes for the certain helipads. This approach and departure routes consider standard, emergency, as well as performance and noise abatement optimised trajectories. Based on this information, the trajectory planner calculates the take-off and landing trajectories and displays it on the helipad display.

The graphical user interface is used by the pilot to modify the flight path if necessary. The needed flexibility is provided by inserting, deleting and shifting waypoints. At each waypoint the altitude and the airspeed can be modified by the pilot on the vertical and speed profile display. Subsequently the route planner compiles a first suggestion for a flight path. For this purpose the last waypoint from the departure trajectory is linked directly with the first waypoint of the arrival trajectory. The terrain and the obstacles according to the planned trajectory are displayed in the vertical display as well as the planned altitude. If changes in the flight path, as a result of the situation analysis appears, a new flight path is suggested by the planning modules and displayed on the HMI, including the reason why.

3.2.4.2 By Supervision Missions

Supervision missions often refer to tracking an infrastructure at the ground, e.g. railways, power lines. Not only real terrain features, but also "invisible" administrative features, like national or country borders, are offend supervised with helicopters, e.g. by the Federal Border Police. The function of the crew during these missions are to collect relevant information concerning the observed infrastructure. The developed support function relieves the pilot from the navigation and the guidance of the helicopter along this structure.
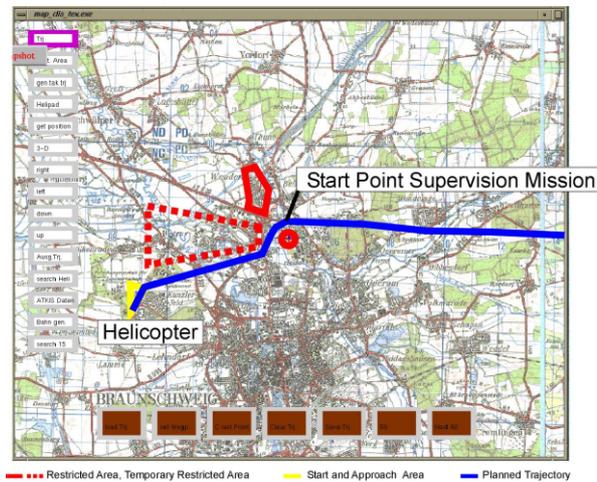
Figure 7: Supervision Mission.

To follow a certain structure on the ground, the pilot selects this structure, e.g. a road by entering the name of the road using the HMI. The assistant system looks up the coordinates of this road in the terrain feature data base (a part of the information system) and display it emphasised on the map display (see fig. 7).

To intercept to the road the pilot only has interactively to set a waypoint on the high lighted road. To leave the road the pilot sets an exit waypoint. Thereupon, the route planner integrates the course of the structure into the en-route flight path. To perform this, the route planner must transform the coordinates of the structure into suitable waypoints. For example, to integrate a part of the highway A2, the interchanges and the ramps of the highway have to be removed from the course of the A2. Further the large number of coordinates have to be reduced to significant waypoints. The waypoints and the constrains are the input to the trajectory planner to calculate a flyable trajectory which will be used to guide the helicopter along the road.

3.2.4.3 By Avoidance of Restricted Areas

In aviation, safety is of highest importance. The presented assistant system supports the pilot in this context by takeoff and landing. The support within the supervision mission has more a relieving character. To close the gap of the safety-relevant support in en-route flight, we developed the function "avoidance". This function calculates the shortest distance between two waypoints around an area which has to be avoided. These areas can be defined either as a circle or as any closed polygon. As output the function "avoidance" delivers a set of waypoints which is transferred by the trajectory planner into a flyable 4D-trajektorie.

Sources for such areas are the data pool, the information system or the pilot. To enter such areas, two interactive possibilities are given. First the pilot can draw a circle and second a polygon anywhere at the map display. The interactively entered areas can be stored in the information system. The restricted areas, which are transfered e.g. from a ground station are added to the data pool as well. The third source for restricted areas is the information system where closed airspace and aviation obstacles, etc. are stored. To mark an aviation obstacle, the avoidance module places a restricted area shaped as a circle at the coordinates of the obstacle.

If the pilot creates a flight plan, the avoidance function looks up the stored restricted areas along this route which will be displayed on the map display. Unrequested the route planner calculates a new route around these areas and suggests it to the pilot. The pilot can assume the route or change it, by inserting, shifting or deleting of waypoints and restricted areas.
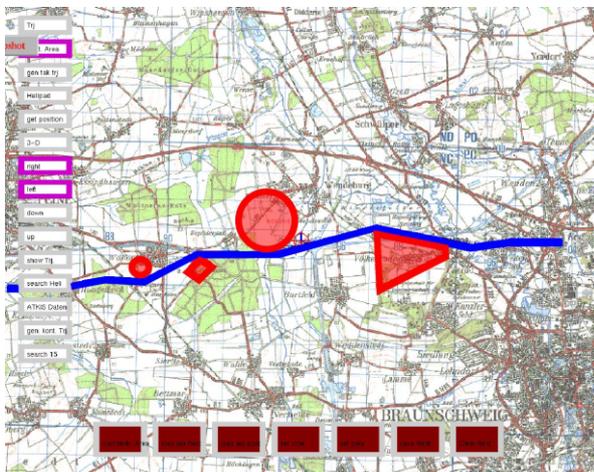

Figure 8: Avoidance of Restricted Areas.

So far, the restricted areas always refers to "hard" restricted areas, which have to be avoided for safety reasons. The public acceptance of helicopters is closely related with the term noise. That's why the helicopter noise has to be minimised. In the en-route there are also noise-sensitive areas, like villages, which should be avoided in the case of flight altitudes lower than 2000 ft. Since, the information system knows the village limits and the function "avoidance" is already available, "yield" restricted areas are introduced. Flying into "yields" restricted area is possible in opposite to the "hard" restricted areas to reach a landing site within city limits. For a low noise flight, the pilot enters the attribute "quiet" whereby the assistant system selects low-noise procedures for T/O and landing and avoid to fly over, e.g. villages.

3.2.4.4 By Evasion of Obstacles

For a planning support on the basis of the external situation analysis, the function "evade" will be introduced. This function enables an update of the flight path regarding a threatening collision with an unknown obstacle. With this function, the presented pilot assistant system provides a complete support considering the safety aspect collision avoidance.
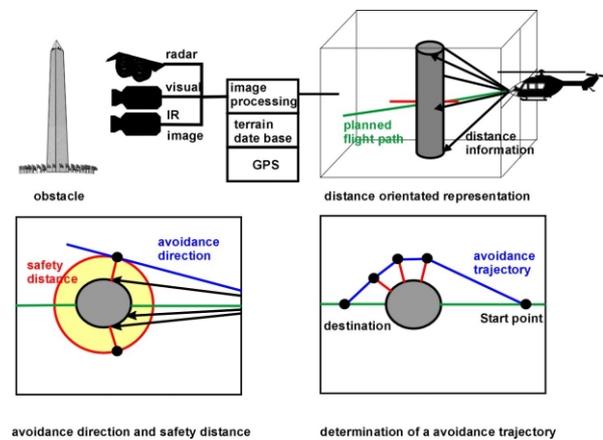

Figure 9: Evade Obstacle.

In flight planning all previously available information are used to plan a obstacle-free flight path. Because no one can guarantee in advance, that no unknown obstacles emerges, a sensor based solution has to be introduced to evade these obstacles. Using EV a 3D environment model will be created. With the flight path, either predicted or planned, inserted into the environment model it can be checked if the helicopter is on a

collision course or not. Is the helicopter on such a course, an alternative flight path must be calculated.

To calculate such a flight path, further information like safety margin to the obstacle, the avoidance direction and the start point of the trajectory has to be considered additionally to the obstacle data. These information depend on the specific mission, the terrain or weather situation, the flight dynamics etc.. With this information and the shape of the obstacle a first part of a avoidance trajectory can be determined. The onwardly detection of the obstacle shape enables the calculation of further waypoints. The trajectory planner uses these waypoints to calculate a flyable trajectory, which afterwards serves to guide the helicopter. If the obstacle is overcome, the helicopter returns to the original planned trajectory.

3.2.5 Plan execution

In the actual configuration of the assistant system, the execution is limited on guide the helicopter along the trajectory. In the future the execution of mission-specific procedures is taken into account.

To guide the helicopter along the trajectory there are two possibilities: manual or automatic. For manual flying a flight director is set up to the pilot in the primary flight display. If the pilot is overloaded this function can be performed by the FCS. The design of the FCS allows the pilot to incur the controls any time. If the pilot flies with the stick, the rate command control mode of the FCS is engaged. This is provided by the shell-shaped structured design of the controller of the FCS. The 1:1 FbW steering, the rate command control, the autopilot and the guidance mode composes at each case as a self-contained control system with interfaces to the next higher and deeper system part. This design provides a flexible and smooth division of the execution task between the assistant system and the pilot.

4   Perspective

The assistance system is developed in three levels. The first level comprises the generic software architecture, the baseline displays and the FCS. These modules, (green in the fig. 1) are the core of the existing assistant systems. With the module system interpreter, a first module for the situation analysis is available.

The emphasis of the second stage, which is currently under development, lies on the HMI and the knowledge-based flight path and trajectory planning. For the flight planning, the modules route, trajectory planner (FMS) and the data base, shown yellow, are developed. The interactive map display provides the interface between the planning modules and the pilot. The substantial development of the EVS (block image data fusion), also takes place at this stage. The white blocks display functions which are planned for the third stage. This stage primarily contemplates the situation analysis and the corresponding planning modules. The emphasis of the work will be the obstacle evasion on the basis of EV. The planned speech in- and output contributes an important redundant possibility to enter data into the assistant system.

The development of the pilot assistant system takes place in our helicopter test environment. This contains a cockpit with appropriate displays, a simulation of our helicopter, a redundant FCS and computers for the pilot assistant system. The individual components are linked with a redundantly implemented bus system. After each stage, flight tests with our research helicopter ACT/FHS are planned. This EC 135 helicopter is equipped with a FbW/Light control system and permits the individual user to install a mission computer. The equipment further contains a data link and a sophisticated sensor site so that the whole spectrum of the CNS-technologies is available or can be emulated.

5   References

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