

A CONCEPTION OF VOICE GUIDED GENERAL AVIATION AIRCRAFT

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Abstract. The paper presents a conception of an airborne control system assisting the pilot, different than classical approaches present. There is a conception of voice commanded control system presented in this paper. The paper analyses possibilities of realization of aircraft control system with the voice recognition module for general aviation aircraft, at this moment. The author tries to define the main rules, which must be kept to project and operate such systems. The main functionality levels of such control system are defined and discussed too. The use of voice commands for the direct controlling the flight of the plane is also presented and analyzed in details. The paper discusses also types of voice commands pilot could use to control the plane. The main requirements voice commands must meet are defined and discussed. The last chapter contains the short description of the experimental control system, which can be the base for developing an experimental voice controlled general aviation aircraft.

Keywords. aircraft control systems, voice controlled aircraft, automatic flight.

1 Introduction

Still increasing air traffic of Small General Aviation Aircraft (SGAA) creates the problem of the numerous group of pilots using SGAA as air cars. They use SGAA as a mean of local transport for medium distances [1] From the second side they are just mostly not professional pilots and have not much aviation experience, often. They present different approach to aircraft control process [2] than professional pilots present. They also expect plane's features little different than professionals expect. So it seems to be purposeful to design an airplane equipped with avionics systems dedicated for that group of users. Such systems have been subjects of investigations at many both scientific and technical centers all over the world. All of them want to simplify the process of aircraft controlling. They contain a very wide range of technical solutions simplifying not only the aircraft control process but navigation, on-board system service, systems data interpretation, flight parameters identification and interpretation also [5, 4]. There are navigation devices, flight management systems, security systems, systems of automatic on-board installations supervising, displays and visualization systems among them.

The most of proposed solutions simplify piloting of plane but focus on the some kind of stick or control wheel as a control device, so they can be called as a "stick oriented" systems. Moreover, all of them have one the most important common feature, all of them engage pilot's hands to control the plane. There is a proposition of modification of our approach to aircraft's systems operation problem included in this paper. The author proposes to leave a conception of aircraft's systems controlled by hands. It is starting to be technically possible to prepare the avionic system, which can be voice controlled by the pilot, at this moment. The pilot could give voice commands to control aircraft's

systems and flights parameters. If we could speak to airplane just like to people (what we can see watching science-fiction movies), it would be the ideal situation probably. Unfortunately, we have to wait for such systems few years.

The paper tries to discuss the generic profile of the avionics system using a voice interface. Generic rules defining forms of commands are presented also. Some solutions allowing inputting voice recognition module into existing systems of autopilots are included in this paper also.

2 System functionality

When the discussion about Voice Controlled Aircraft (VCA) starts a few basic questions appear at once. There are following sample questions among them:

- What functions of on-board systems can be controlled by voice commands?
- Can the pilot “speak to the airplane” to control its flight?
- What level can the pilot control the plan by voice at?

This paper tries to answer both these and many other questions also.

The pilot controls lots of functions of on-board systems during the typical flight. There are functions having different priority levels and different influence aircraft safety, among them. Taking into consideration foregoing facts three levels the VCA works at can be defined. They differ from each other in serviced functions.

- Level I. Only supplementary function not directly influencing the flight are available e.g: *deicing on/off, taxi light on/off, pitot heater on/off* etc.
- Level II. Supplementary functions influencing the flight state are available: *gear down/up, flaps down/approach/up*. An autopilot can be engaged and disengaged and basic no critical navigation function can be activated also. It means *heading, altitude and airspeed stabilization functions* can be available if special safety mechanisms are implemented. The System must be equipped with functions protecting against both abnormal values of stabilized flight parameters and too dynamic maneuvers.
- Level III. Aircraft’s space attitude stabilization functions are available e.g. *pitch and roll stabilization functions*. Any *emergency functions recovering* the aircraft from dangerous and abnormal flight states should be implemented also.

The classification of VCA proposed earlier in this paper assumes, higher level include functions of lower one. Levels II and Level III include functions, which are strictly related to airplane’s flight control. It implies they have direct influence on flight safety. It is a reason why more attention is paid for them later in this paper.

3 Flight control

When the discussion about the voice commanded flight control system has been started it is necessary to make an attempt to define the way the aircraft can be controlled in. Following features of hand control decide that it is rather difficult to imagine the situation the pilot will directly steering control surfaces using voice commands.

1. Pilots move control surfaces continuously, by hand. It would be rather difficult to realize such kind of command processing if pilots gave voice command. The control can be only discrete one, even if pilot gives commands in one stream of words (Figure 1).

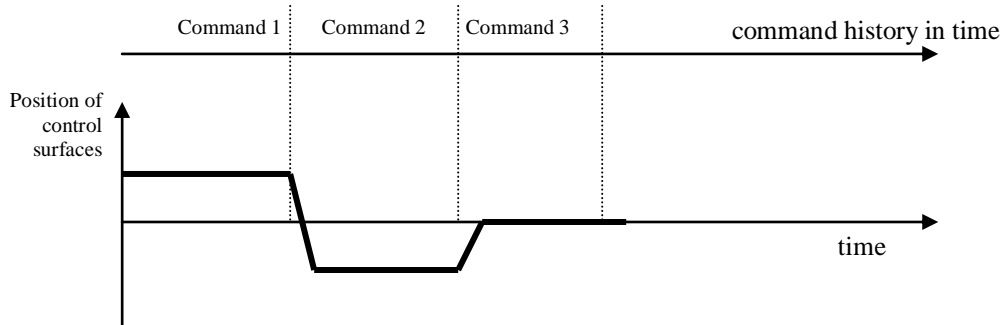


Figure 1: Control surfaces can go to new positions only at discrete time moments.

Moreover, it is impossible to correct any pilot's mistake immediately. Some time period is lost. The plane will be driven incorrectly until the new command is said and activated.

2. How the commands should be formulated - incrementally, as absolute positions of control surfaces or any mixed solution?
3. It is rather difficult to imagine the situation when just after the wind turbulence the pilot can say "aileron one degree right more" for instance. Such situation would mean the pilot could calculate new a position of ailerons in his mind. It is impossible especially that the system is intended not for professionals
4. Not only position of control device is important for the pilot but also the pattern of its displacement. It is important if movement of stick is dynamical or sluggish. Moreover, the control has an impulse character or other one sometimes.
5. The pilots often deflect more then one set of control surfaces simultaneously - ailerons and ruder for instance. The pilot controlling the plan by voice will not be able to generate movements more then one set of control surfaces at that same moment unless the special commands are implemented (Figure 2).

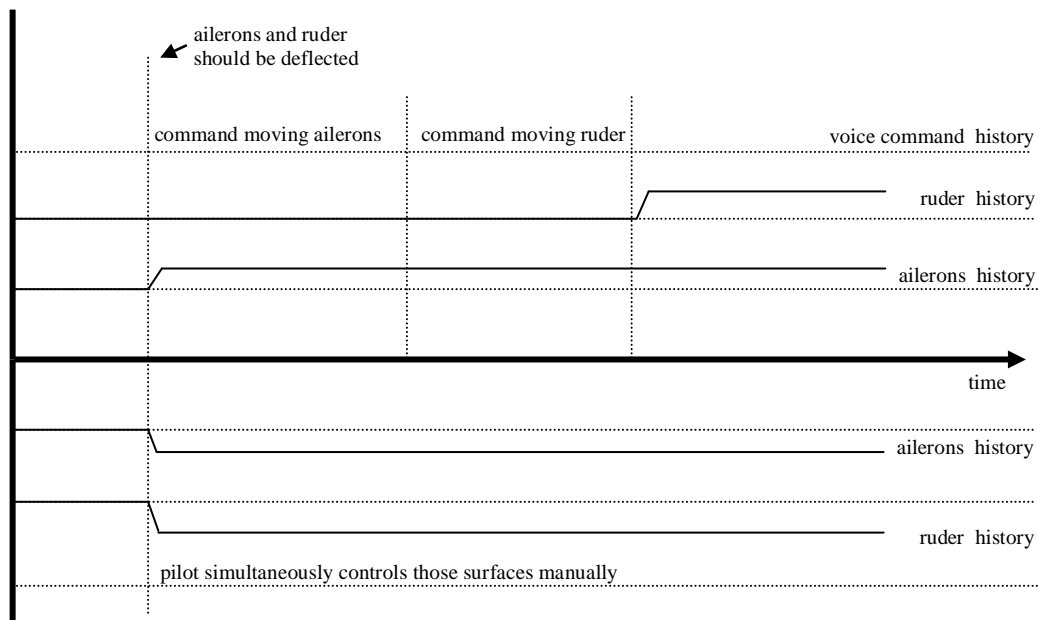


Figure 2: Sample histories of ruder and ailerons positions for both voice controlled and classical hand controlled systems.

Facts put at foregoing points probably decide that it is possible to control the plan indirectly only. The indirect control means control with the use of any system autonomously stabilizing selected flight parameters. So, projecting such system if is necessary to integrate the Voice Recognition Module (VRM) with any kind of autopilot (Figure 3).

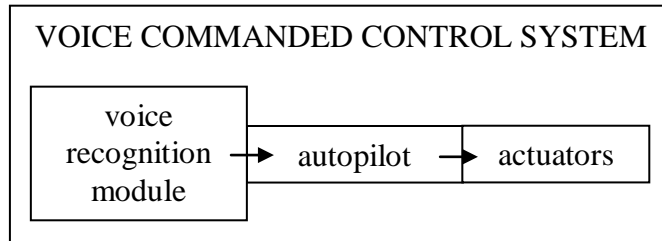


Figure 3: The VRM is integrated with autopilot's system.

It will realize basic functions of the aircraft flight parameter control activated by VRM. There are such sample function as space attitude controlling, altitude, heading and speed stabilization among them.

4 Possibility of realization

The voice commands can be used to control aircraft if voice-processing procedures enable fast and reliable command recognition only. The system must correctly recognize commands in the time period shorter then the pilot can indicate any delay. Taking into consideration human's perception possibilities it can be said that the time of system reaction T_{sr} can be defined by following formula (1)

$$T_{SR} = \frac{1}{2} T_{HR} \tag{1}$$

where:

T_{SR} - time system needs to recognize the command and to take the proper action,

T_{HR} - time human needs to indicate and recognize any event.

It is assumed that typical human's reaction time is about 0.15÷0.2[s]. So it can be said the system should take the action in time less then 0.1 [s].

Both algorithms of voice processing and hardware platform for this task have being separately developed for years. They have reached level, which enables using of voice recognition procedures at different areas currently. Mobile phones offer the voice dialing. Remote phone customer's service centers use voice commands to navigate the customer at voice menus. There are voice recognition instruments used in medicine also. All of those systems require rather strictly defined commands, which can be used, unfortunately. They can't recognize commands from continuous speech in general.

Commonly used systems don't recognize all commands correctly. The correct recognition depends on several conditions such us voice intonation, accents, speed of speaking, voice volume, speaking correctness for instance. The level of the recognition reaches about ninety percents of defined commands currently.

If system miss or misunderstand commands it can't be used to control any aircraft's systems critical function especially functions controlling the flight. Supplementary or basic navigation functions, which don't have any influence plane's safety directly, can be served only.

Taking into consideration limitation of capacities of the voice recognition systems. It can be stated that it is impossible to create fully voice commanded avionic system yet.

5 Commands

The intention of the voice command recognition system implemented into an avionic system for SGAA is to increase the pilot's comfort and decrease pilot's workload also. The situation, when the pilot must look for proper words to correctly constrain and say the command, can not exist. It implies that commands, pilot uses to control both on-board systems and flight of the aircraft must have pilot-friendly form. So, there are main requirements voice commands must meet to be identified as pilot friendly once, defined at following points:

- Must have the form of standard phrases used in aviation. – Each command consists of typical words the pilots use to express their expectations concerning flights parameters.
- Must be as short as possible. – Short phrases are easier to be remembered and it takes less time to say them.
- Both numeric and linguistic values are accepted. – It is more comfortable to say “*Heading little right*” for human, when the high accuracy is not necessary then to formulate the command precisely instructing the system about required correction of flight parameters: “*Heading three degrees right*” for instance. The second form is necessary when high accuracy of control is required of course.
- Linguistic values can change their meaning depending on flight conditions -
- More phrases can have, that same results if necessary – The pilot can not be obligated to strictly remember linguistic variables. So such words as “*little*”, “*bit*” should bring that same result, for example.
- Must be unique – Commands must be different from each other enough to protect against the situation when they could be mixed.

The voice recognition system should enable both operating with on-board systems and flight control, in assumptions. It results that available commands used to control plane's flight and to control on-board systems can be put into four basic sets of instructions as follow.

- **Switch on/off** type – “*gear down*” or “*gear up*” commands.
- Defining value of controlled parameter **directly** – “*roll ten right*”.
- Defining value of controlled parameter **incrementally** – “*roll ten more right*”.
- Special **emergency** commands – “*Recover*” command for instance, bringing the plane to the safe horizontal flight state.

There is the classification of available commands, taking into consideration the set of functions they realize presented at points early. Another classification takes into consideration the way parameters of commands are defined in. So parameters can be defined in two ways:

- with the strictly defined numerical value of the parameter – ten degrees, one hundred fifty knots for instance,
- with linguistic variable describing the value of the parameter – more, less, little, bigger for instance.

Commands interpretation process runs in a few following steps (Fig. 4)

The VPU recognizes the command and parameter's value. Its value is identified as numerical or linguistic one. The linguistic value is converted to numerical value depending on flight's conditions. If that process is complete the command and its parameters are transformed to the form the control system accepts and transmitted to it.

The algorithm of commands interpretation presented in figure 4 says, the value of the linguistic variable is transferred into, depends on flight conditions.

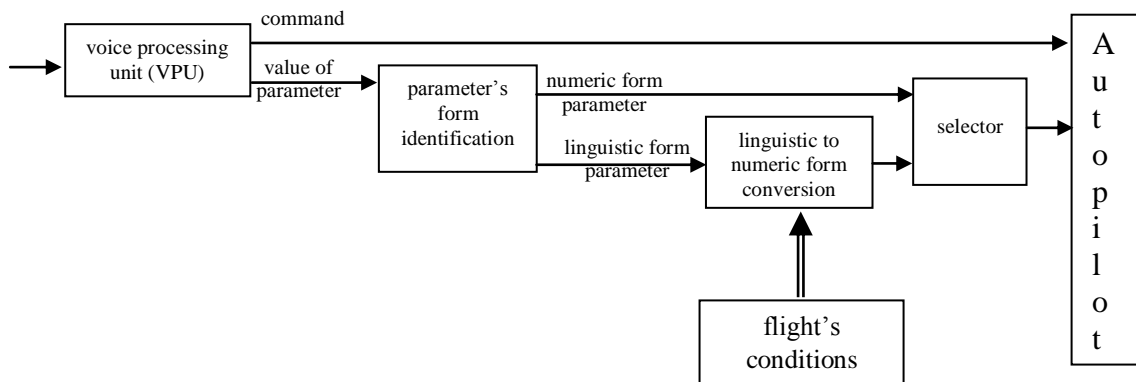


Figure 4: The command interpretation process.

What does it mean? Let's imagine the situation when the flight roll angle is not zero. The pilot wants to increase the roll saying the proper command "more roll" for instance. Then the system must decode the linguistic value "more". It is transformed to the proper numeric value the roll angle is modified in conjunction to the existing roll angle for instance. Then the "more" value can mean small increments for small roll angles and big increments for bigger ones.

There are few different methods used to decode linguistic values. There are following sample methods among them:

- The numeric value can be calculated from classical mathematical formulas taking into consideration the set of main parameters influencing on calculated value (2)

$$v = f(x_1, x_2, \dots, x_n) \quad (2)$$

where:

- v - calculated parameter,
- x_1, x_2, \dots, x_n - parameters deciding about numerical value.
- The fuzzy logic rules can be use to define correct numeric value.

6 The experimental control system

Department of avionics of Rzeszow University of Technology has worked with control systems for SGGa for years. Finally the experimental system SPS-1 has been created. SPS-1 system is prepared as a device enabling modifying of aircraft handling qualities [4, 5] Different control algorithms can be manually or automatically activated during flight depending on the program of the experiment. SPS-1 system is done in Fly-by-Wire technology. Pilots using control devices demand only parameters of the flight. They are sent to the main on-board computer, which prepares control signals for actuators. In the practice the system SPS-1 consists of following autonomous devices: main on-board computers, autonomous measurement devices, autonomous actuators, control, visualization and interface devices used for communication between the pilot and the control system (Figure 5).

SPS-1 uses CAN-2B digital data-bus [3] modules of the system can communicate each to other.

Its open structure enables adding new modules to it in the simple way. The VRM is planed to be connected with the digital data-bus (Figure 5). All data produced by all elements of system will be available in this way. The VRM will use the data-bus to transfer generated commands to main computer also. Because all flight parameters can be available to VRM it will be able to perform all calculations transforming linguistic values to proper numeric values.

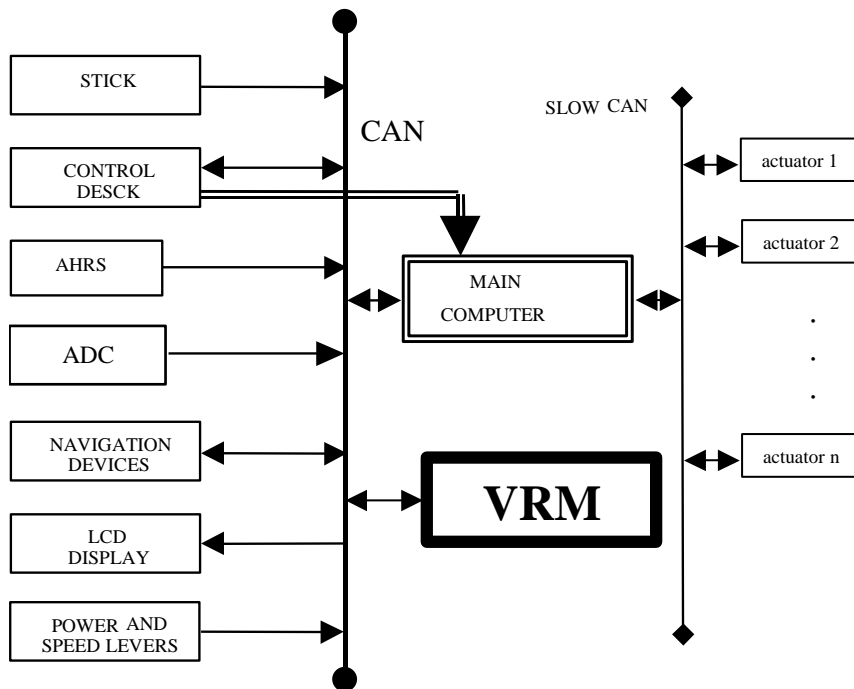


Figure 5: The general structure of control system SPS-1 for light transportation planes.

Presented modifications of hardware structure of SPS-1 will force several modifications of main computer's software of course. But they are restricted only to a few functions related to communication between computer and VRM. Any modifications of control functions of computer will not be necessary. Moreover, the approach presented in figure 5, where VRM comes into the system parallel to native control devices, makes possible to take an effort to prepare algorithms allowing cooperating the VRM and classical control devices in harmony.

7 Conclusion

Avionic systems supporting pilot on different fields are more and more popular. So, systems offering pilots possibility of voice control of any airplane's devices and flight parameters will be used by a wide group of pilots certainly.

Technically it starts to be possible to create the avionic system controlled by voice commands. The first prototype solutions have appeared already. The first VCA will be the level I probably. In not very long future the small general aviation aircraft with systems of level II and level III will appear probably. Currently it seems, systems of level I, offering only supplementary functions will not require any special algorithms to cooperate with the rest of the avionics. But algorithms, systems offering functions directly influencing to the plane's flight work according to, should be developed and tested.

The paper discusses the main problems concerning avionic systems using voice commands. It shows possible ways such systems can be developed in. It also tries to define generic rules, which should be kept.

In author's opinion one fact can not be discussed near in the future we will used much voice controlled machines including small general aviation planes. So, maybe it is the right time to start to thing about it.

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