ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0012.4798

PYTHON PROGRAMMING LANGUAGE AS A TOOL FOR CREATING THREE-DIMENSIONAL FIGURES OF GLIDER AEROBATICS

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Abstract

The article presents the possibilities and validity of the implementation in the field of developing mathematical models for aerobatics trajectory. Proposing a catalogue of three-dimensional figures and those described mathematically will allow improving judging and scoring level, as well as the art of piloting in aerobatics. In the first chapter, article describes the processes of aerobatic flight, judge evaluation method and the current state of technology supporting the scoring process. The second chapter presents the capabilities of the Python programming language, which will be a tool for the construction of three-dimensional models. The third chapter of this article is a description of the comparative analysis of ideal trajectories and obtained in real flight. This chapter also demonstrates the validity and necessity of introducing new standards for assessing aerobatic flights. Aerobatics flights and judging, intelligent system to control aerobatic flights, three-dimensional models of aerobatic flights are presented in the article. The article concerns on use modern technologies to support the judges during the competition. The introduction of ASSD + PL system and the possibility of implementing designed models of aerobatic figures open new paths for improving the art of pilotage and arbitration.

Keywords: *aerobatics, general aviation, fly trajectory, mathematical programming*

1. Introduction

Not only in the process of flight training, but also during the air shows, it is extremely important to precisely determine the position of the aircraft in space and basic flight parameters. Early detection of even small deviations from a properly performed flight will reduce the risk occurrence of dangerous accidents [1].

Aerobatic flights as a sports discipline are one of the most difficult not only for competitors, but also for judges assessing the correctness of performing particular flight elements. Flights are made at a large distance from the judges' positions, who only evaluate three-dimensional figures based on their visual experience. Aerobatic composition is made within the specified three-dimensional space (Box) (Fig. 1), which is an additional difficulty for the judges, who, among other things, assess the behaviour of the aircraft's position in the zone [2].

The flight within competitions consists of the so-called programme of aerobatic figures. Usually 10 individual figures are combined into one flight. Judges gives their scores based on their own experience. They are assisted by a card with the order of occurrence of figures in a given flight.

Over the years, the need to introduce a system that controls flight in a real time has become more and more noticeable. Such software will allow not only to increase the safety of aerobatic flights, but also to increase the accuracy of awarding judges for individual figures. In addition, if it is possible to designate and introduce to the system designed models of "ideal" figures, all pilots will be assessed equally objectively. They will also have an excellent tool to improve their piloting skills in the training phase [1].

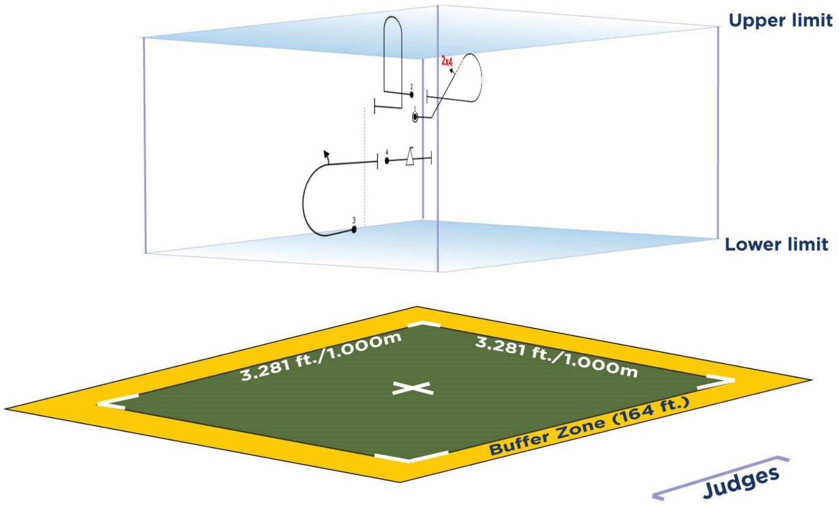

Fig. 1. Aerobatic Box and judges position [3]

2. Aerobatics flights and judging

In most sports, the order of players determines either scoring points or achieving best times. It is simple and very transparent. However, when it comes to aerobatics, the most important thing is the quality of every element of flight [4]. This can be compared to figure skating, where judges, when assessing the competition, also focus on the harmony and dynamics of the entire journey.

Aerobatics is one of the most difficult sports. Typically, training flights, as well as demonstration or competition flights take place in uncontrolled airspace, and supervision over them is conducted from the ground, among others by instructors or judges. Often, these are not sufficient methods. That allow pilots to bend the rules; and flight parameter control is performed only by the pilot on the aircraft.

The judges first of all assess the correctness and quality of performing certain aerobatic figures. As mentioned in the introduction, the judges evaluate the trajectory of the flight only based on their own judgment – without actually having any point of reference. Apart from the fact of flying at a far distance and various atmospheric conditions, (e.g. wind can significantly affect the course of the flight), the task of the judges is also hampered by the fact of various gliders, which fly the pilots-players. Different gliders have unalike parameters and aerodynamic capabilities. The figures should be the same, but you cannot (even subconsciously) eliminate the fact of the flight with a different machine. Many factors can affect the referee's final judgment. Starting from the most trivial one, it is missing one element. Unfortunately, man remains the weakest link in the aviation, not only as pilots, but also as ground observers.

International standards and regulations are established by the FAI – World Air Sport Federation and CIVA – FAI Aerobatics Commission. Many years of experience have led to the introduction of principles as the best compromise between objectivity and the quality of refereeing. The Fair Play system was also introduced, which is to convert the judges' scores and establish the order of the players in the best possible way. This system is aimed mostly for eliminating the favouritism and granting of unfair assessments [5, 6]. The authors of the rule are Steven Green, Derek Pike and Alan Cassidy. Thanks to the FPS, all anomalies are replaced by a statistical value. Based on FPS, Nick Buckenham, the current CIVA president, created software for entering, counting and printing competition results. The system, which was called ACRO, is used by referees and champions of the championships all over the world [5]. Since 2008, it has been used to evaluate over 50 international professions [7].

Each figure is rated on a scale of 1 to 10 with 0.5 interval. An example of the competition flight is shown in Fig. 2. Then the points are converted by the Fair Play system, which also takes into account the place of the judge in the general classification of the judge.

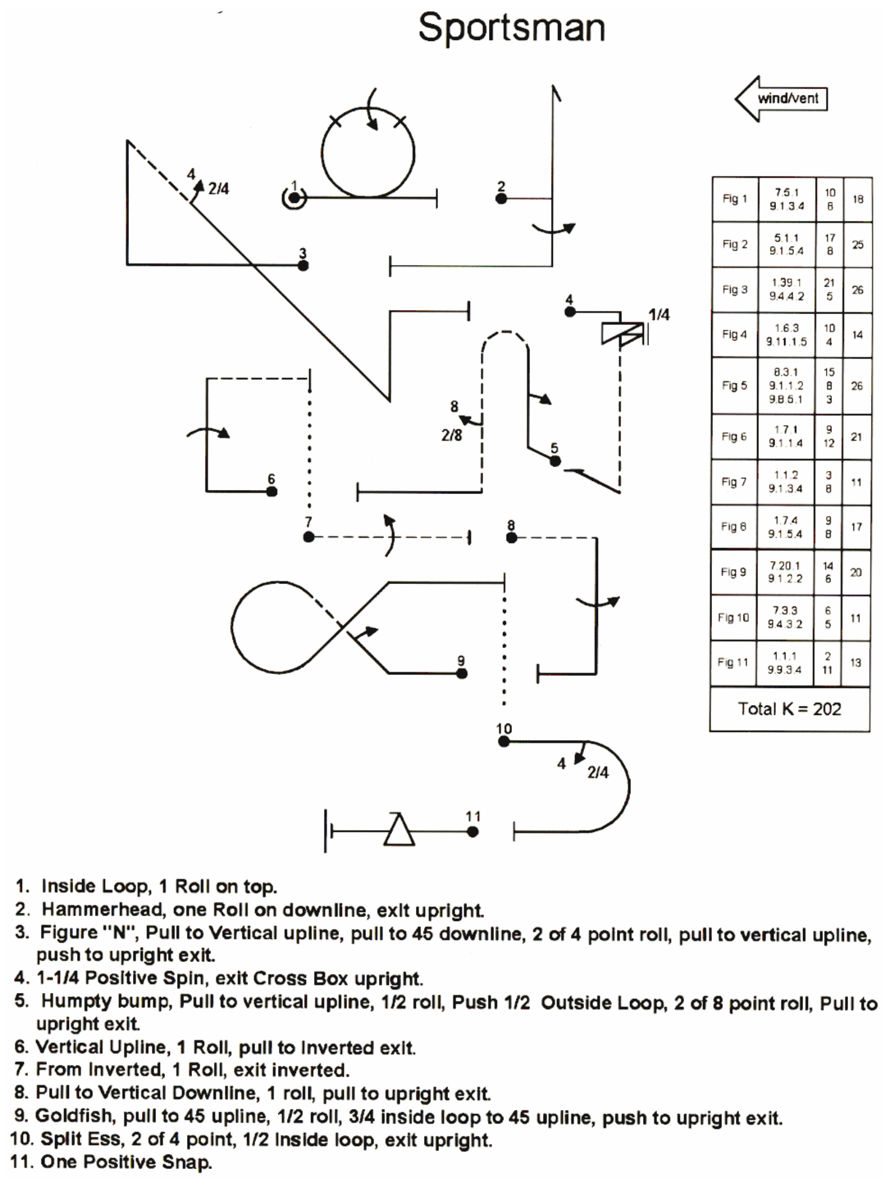

Fig. 2. Aerobatic flight programme [8]

However, despite all efforts of FAI and CIVA, there are still situations of unclear final grades and the conversion of points by ACRO system. Pilots have repeatedly complained about the lack of detailed explanations for their assessment. Apart from the fact that ACRO may have a hidden error in algorithms, the introduction of an automatic assessment and documenting flight system would be a key to eliminate all objections and complaints.

3. Intelligent system to control aerobatic flights

Ideal proposition, currently only one in the world, is a system of supervision and control flights in a real time. AeroSafetyShow Demonstrator+PL (ASSD+PL) system was invented and put into use by a research consortium composed of Żelazny 6 – Wojciech Krupa company and Poznan University of Technology. A group of pilots, scientists and constructors noticed in 2013 the need to develop a system that will allow to increase the level of safety of performing air operations in the area of General Aviation, and in particular aerobatics. As a result, a consortium was formed and in 2015, first version of system was presented at domestic and international glider aerobatic competitions. The system met with great interest and support from competitors, referees, and competition organizers. The main components of the system are transmission modules placed in aircraft and a receiving station connected to a computer with a loaded Fly Monitor visualization application. The functional scheme is shown in Fig. 3.

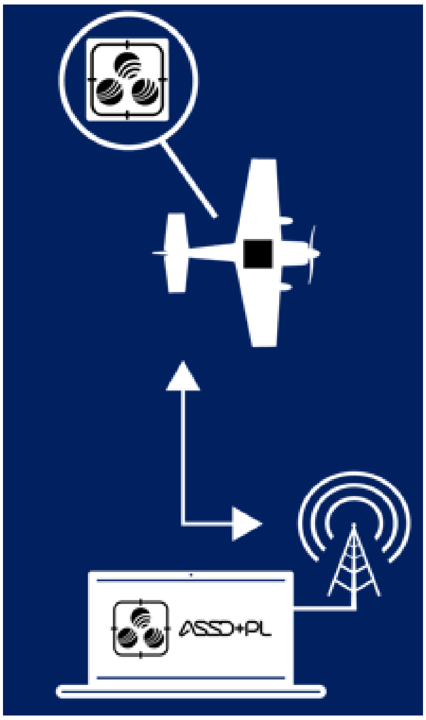

Fig. 3. Functional scheme of ASSD+PL [ASSD+PL team own materials]

The main functionalities of ASSD + PL are:

- conducting real-time observation,
- three view modes: 3D, altitude graph, plan view,
- print reports and statistics after flights (even automatically after competition flight),
- automatic data archiving on the computer hard drive, the ability to replay the entire flight,
- archiving data on the memory card in a transmitter located in the aircraft (even if the connection is lost it is still possible to reconstruct the flight),
- current preview of basic flight parameters: speed, altitude, position, direction,
- ability to designate a strict supervised flight zone, e.g. an aerobatic box,
- drawing by the aircraft of the trajectory of the performed figure as part of the application [10].

Figure 4 shows three view modes in Fly Monitor application during execution of loop figure.

As it can be seen in Fig. 4, one figure can be analysed under each account thanks to the system. What's more, after flight is completed, reports for the judges are automatically printed. Reports include the altitude graph, top view of the trajectory of the entire flight and point comparison. The last report contains the average position in the zone and all exits beyond it along with their times. This tool is perfect as well as for the judges and competitors who want to see their flights and all mistakes made.

What's more, the authors of this article claim that the application can be improved by introducing an automatic trip assessment. It is possible to design ideal figures for individual evolutions and then compare them with the actual flight trajectory obtained through the ASSD + PL system.

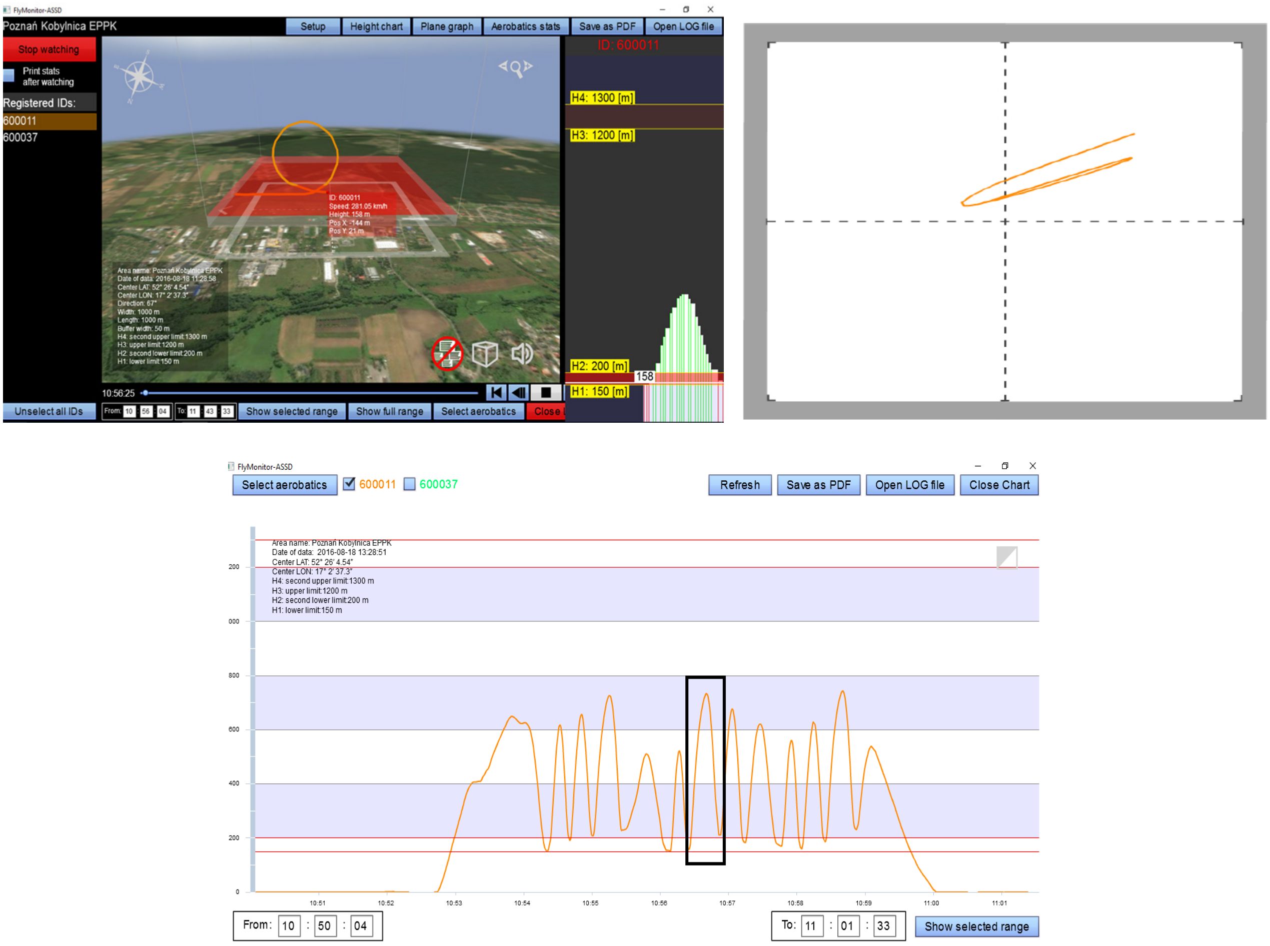

Fig. 4. Views in Fly Monitor Application [ASSD+PL team own materials]

Currently, work is underway to develop graphic and mathematical models of figures as a part of the doctoral dissertation of one of the authors. After completing this stage, it will be possible to compare real and ideal trajectory. Of course, possible deviations from the ideal path will be assumed, which will include, among others, the type of glider and weather conditions.

4. Three-dimensional models of aerobatic flights

Mathematical and graphical modelling of flights trajectory is widely present in world's literature and publications [11-19], which indicates great interest in a given scientific aspect. However, there are no studies referring strictly to the modelling of figures for the purpose of their implementation into the supervisory system. In the result, an autonomous and complete flight assessment program will be created [1].

One of the tools that can be used to design figures is the Python programming language. Python is a dynamic object-oriented programming language that can be used to create a variety of software. This system is distributed on an open license, allowing also for closed commercial projects. Python is actively developed and has a wide range of users around the world [20].

Python is widely used to create websites, applications or games. Its resources are used by such giants as Google, Yahoo, Nokia, IBM or even NASA. Besides creating a variety of applications, Python is also used in the world of science to prepare complicated algorithms for data processing, charts or PDF files. Reportlab can generate PDF files and format any reports contained therein. Matplotlib offers the generation of various types of charts. Scipy offers implementations of various algorithms for complex calculations in Python. PIL provides graphics processing (such as scaling, sharpening, rotating, etc.), and xlwt and xlrt save and read Excel sheets [20].

Python is distinguished, among other things, by its syntax, which is simple and very readable. Python is fully open, thanks to which it has a very large community that develops it. The offer of available Python libraries is huge, which definitely facilitates the work. OpenCascade is a library released and developed by the company OPEN CA-SCADE S.A.S. It is used to model, produce, perform graphical calculations and visualization of 2D and 3D objects. Thanks to numerous advantages, it is used in many CAx programs, among others FreeCAD or in the popular commercial Autodesk program [21].

Python can be used to design geometries of various types. Examples of such graphics are shown in Fig. 5.

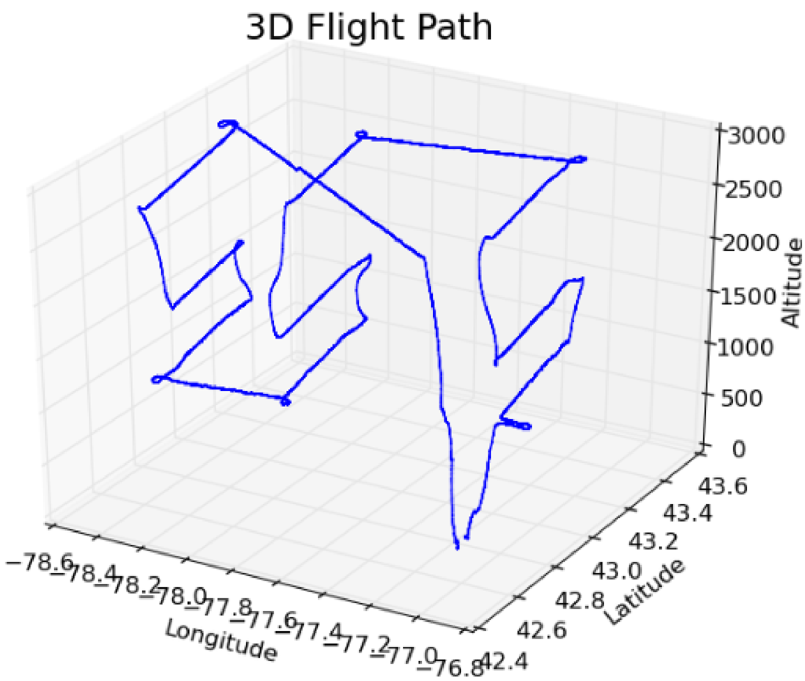

Fig. 5. Python graphics – flight path [22]

As it can be easily seen, both Fig. 5 and first view from Fig. 4 can be surely comparable. The modelled trajectory can be applied to the real trajectory, and any deviations can be quickly pointed out. Such a process must be based on a few basic steps (in a big simplification):

1. Mathematical modelling of ideal figures.
2. Graphical modelling in ideal Python environment.
3. Obtaining data from the ASSD + PL system (location data – geographic coordinates of each flight stage).
4. Applying models of figures on the current trajectories.

Such a comparison will not only allow for a correct and objective assessment of flight, but also allow judges, pilots and instructors a wider look at moving around in a specific space. It is not always possible to observe the training flight; therefore, the more important is to have possibility of its reproduction.

The creation of a catalogue of mathematical descriptions of figures and their programmatic use as part of a flight supervision application will be a significant step improving both the safety and quality of airborne evolutions, but also will enable the refinement of the refereeing in this field.

Many sports use modern technologies to support the judges during the competition, such as the latest VAR system used in football. In comparison to other sports, air acrobatics are extremely difficult to evaluate, and so far, no modern technology has been supported. The introduction of ASSD + PL system and the possibility of implementing designed models of aerobatic figures open new paths for improving the art of pilotage and arbitration.

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Manuscript received 10 July 2018; approved for printing 31 October 2018