Software Design (F28SD) 2019-20
Coursework Specification

Designing an Air Traffic Control System

This is an individual project which means that your submission MUST be your own work

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1 Introduction

Aviation is a major industry, and *air traffic control* (ATC) plays a vital role in assuring safety and promoting efficiency of air travel. This coursework involves you in designing a software intensive system to support the ATC activities at an airport.

In §2 background is provided on the nature of air traffic control. Your design remit is detailed in §3, while in §4 the deliverables that are expected from you are described.

2 Background and Context

The airspace around an airport is called the *Control Zone* (CZ) – a cylinder of airspace approximately 25 miles in diameter and 10 miles high. Immediately outside the CZ is the *Terminal Manoeuvring Area* (TMA). All aircraft departing and arriving at an airport will fly through the TMA. Aircraft within a TMA are the responsibility of air traffic controllers based with an *Air Traffic Control Centre* (ATCC).

Here we focus on supporting the activities and services undertaken by the controllers based at an airport, i.e. the controllers responsible for aircraft within the CZ. There are three kinds of controllers based at an airport:

Approach Controller (APC): Responsible for aircraft as they enter the CZ, through to approximately 3 miles from the runway. In particular, they are responsible for:

- maintaining a safe separation between aircraft and guiding them onto the final approach (potentially without the aid of radar).
- keeping relevant aircraft information up to date on Flight Progress Strips (see below).

- passing weather reports to the aircraft on approach.

Air Controller (AIC): Responsible for all aircraft:

- wishing to enter the runways to take off.
- on their final approach (approximately 3 miles from the runway).

Ground Movements Controller (GMC): Responsible for all aircraft movements within airport taxi way system, and allocating aircraft to gates.

Traditionally all communications between pilots-and-controllers is via radio and all communications between controllers-and-controllers is via landlines. A key tool of an air traffic controller is the *Flight Progress Strip* (FPS), *i.e.* a paper record of an aircraft's passage through the airspace. Typically a FPS includes information such as aircraft type, call sign, altitude *etc.* Different FPS are used depending upon whether an aircraft under control is outbound, inbound or overflying the airport. Before a flight can enter controlled airspace a *Flight Plan* (FP) must be submitted. The submission process generates a FPS which is then used through the life-time of the flight. The submission of a FP takes place within the airport before the pilots join their aircraft for pre-flight checks.

3 Your Design Remit

Your task is to design a new ATC system that will support pilots and controllers based at an airport terminal, i.e. GMC, AIC, APC, as well as the activity of submitting a FP. The ATC system will involve a number of subsystems. Specifically the ATC system will replace paper based FPS with *electronic* FPS – which will be referred to as an eFPS. In addition, the primary mode of communication between pilots-and-controllers and controllers-and-controllers will become a *command messaging system* – which will be referred to as the CMS. It is intended that the CMS will enable pilots and controllers to communicate effectively using pre-defined messages. Conventional radio and landlines communications will still be available as a secondary mode of communication – but these lie out with your remit.

The ATC system will be concerned with the management of eFPSs as aircraft take-off (outbound) and land (inbound) at the airport. Both the AIC and APC will have an associated software system for managing eFPSs, as well as other electronic data described below. An eFPS will contain the following basic information:

- Aircraft type
- Call sign
- Altitude
- Gate number

In addition, an eFPS for an inbound aircraft also records the airspeed and *Expected Time of Arrival* (ETA), as well as the *Actual Time of Arrival* (ATA). For outbound aircraft, *Expected Time of Departure* (ETD) and *Actual Time of Departure* (ATD) is recorded, along with route information. The AIC and APC systems maintain eFPS. Note that the GMC also has a software system to assist with their work. However, their system only maintains a record of aircraft call signs and gate numbers, and has no access to eFPSs. The AIC and APC are presented with eFPS information via touch screen displays. A controller changes information on an eFPS via a scribe, just like with a tablet PC. The AIC and APC eFPS are managed by the AIC system and APC system respectively. In the case of the AIC system, eFPS strips are classified under three headings, *i.e. pending*, *active* and *archived*. The APC system has one additional heading, *i.e. holding*, which is used for eFPS that are associated with aircraft within the holding stack.

As mentioned above, before an aircraft can enter controlled airspace a FP must have been generated. It is a requirement therefore for the ATC system to include a *Flight Plan Logging* (FPL) system. The FPL system will allow pilots to log their FPs electronically. As well as all the details required for the eFPS, a FP also records the names and licence numbers of the pilots. These details are validated via access to an external *Pilots database* (PDB). The departure gate is also required, which is provided automatically by the GMC system. Once a FP is completed it is archived to another external database, *i.e.* the *Flight Plan database* (FPDB). In addition, an eFPS is generated automatically by the FPL system and sent to the AIC system. Note that once an eFPS has be sent from the FPL system it appears as a *pending* flight within the AIC system. When an aircraft is ready for departure, the pilots communicate their readiness to the GMC via the CMS. The GMC communicates to the AIC, again via the CMS. When the AIC is ready, they instruct the GMC to allow the aircraft to push back from their gate and taxi to a holding point. Once at the holding point, the AIC takes over direct control of the aircraft. When the aircraft departure slot arrives, the AIC instructs the pilot to taxi to the end of the runway, from where final clearance is given for take-off. Once the aircraft is airborne, the AIC records the ATD on the eFPS, and sends a message to the pilot requesting them to contact the ATCC. The AIC then sends a copy the eFPS to the ATCC. Finally, the AIC tags their copy of the eFPS as archived – this completes the outbound process.

For inbound aircraft, the handover between an ATCC controller and the APC involves both CMS and eFPS communications. Firstly, the ATCC controller sends the aircraft's eFPS to the APC system, this appears as a *pending* eFPS and alerts APC to the aircraft. Secondly, just before the aircraft leaves the ATCC airspace, the ATCC controller instructs the aircraft to make contact with the APC. Once contact has been established via CMS, the APC provides the aircraft with directional information to enable them to locate the glide path for the runway. As the aircraft enters the CZ, the APC also provides the pilots with a Weather Report (WR) for their final approach. This is communicated electronically, *i.e.* between the APC system and the aircraft's on-board computers. During this period all altitude and airspeed instructions are logged on the aircraft's eFPS by the APC. The WRs are transmitted electronically from the airports Weather Station (WS). They include wind speed and direction as well as visibility. WRs are generated automatically by the WS system and are sent every 15 minutes to the APC system. Once the aircraft reaches the final approach, the APC passes control to the AIC. This handover follows the same protocol as given for the handover between ATCC and the APC. The handover may be delayed if the CZ is busy. In such situations, aircraft are routed to a holding stack until a landing slot becomes available. Finally, at the point of handover if the weather report has significantly changed then the pilots are provided with an update.

Before touch down, the AIC requests a gate number from the GMC, which is then logged on the eFPS by the controller. When the aircraft touches down, the AIC logs the ATA, and advises the pilots of their allocated gate. Aircraft are occasionally instructed to overshoot, *e.g.* if an aircraft takes too long to clear the runway. Such decisions are taken when the aircraft is established on the glide path at approximately 600 feet above the ground. If an overshoot is undertaken then the AIC hands the aircraft back to the APC. Depending on how busy the airport is, the APC may then choose to place the aircraft in a holding stack or direct it back onto the glide path for another attempt at landing. The inbound process is completed once the eFPS is archived.

For the ATC system described above, you are required to:

R1: Develop a set of functional and non-functional requirements based upon the description above of the proposed ATC system.

R2: Based upon your functional requirements develop a Use Case diagram (or diagrams) for your ATC system.

R3: For each of your use cases provide specification(s) (textual descriptions).

R4: Develop a class-responsibility-collaborator model **only three** classes of your ATC system.

R5: Develop Class Diagrams for your ATC system.

R6: Derive Sequence Diagrams for **only three** of your use cases, i.e. consider all possible scenarios (flows) within each of your use cases.

R7: Develop Activity Diagram(s) for **at least one** aspect of your ATC system.

R8: Develop State Machine Diagram(s) for **at least one** aspect of your ATC system.

4 Deliverables - Design Portfolio Report

Your submission **should** take the form of a report (**pdf format**). The front page **should** include:

- report title (including course code)
- date of submission
- your name
- your registration number
- your degree programme
- your campus of study

Your report **should** contain page and section numbers, as well as a table contents. In addition to an introductory section outlining your submission, your report **should** be divided into 9 sections corresponding to the following 9 deliverables:

D1: A set of assumptions you have made about the proposed ATC system and how each assumption has impacted upon your design decisions. *(5 marks)*

D2: Tables containing your functional and non-functional requirements. *(15 marks)*

D3: Your **Use Cases** – both diagrammatic and textual (specifications) forms. Provide a traceability matrix that links your use cases with your functional requirements. *(25 marks)*

D4: Your **class-responsibility-collaborator** model. *(5 marks)*

D5: Your **Class Diagrams** for your ATC system. *(15 marks)*

D6: Your **Sequence Diagrams** for your ATC system. *(15 marks)*

D7: Your **Activity Diagram(s)** for your ATC system. *(5 marks)*

D8: Your **State Machine Diagram(s)** for your ATC system. *(5 marks)*

D9: Based upon this design exercise, a short statement on the strengths and limitations UML. *(5 marks)*

Note that the distribution of the 70 marks associated with D3 through to D8 is indicative, i.e. the distribution of the 70 marks may vary depending upon your use of UML diagrams. Note also that 5 marks will be associated with the overall quality of your report, e.g. organization, presentation, etc.

Note that you **should** use the specification templates (i.e. use case and extension use case templates) given on the VISION course pages (see "Assessment" section). UMLet is recommended for developing your UML Diagrams, however, you may use an alternative tool if you wish. But please note that hand-drawn UML Diagrams are **not acceptable**.

This assignment counts for 40% of the overall mark for the course. Your report should be **submitted via VISION no later than 15:30 (local time) on Monday 2 March 2020. The standard penalty for the late submission of coursework will be applied unless evidence of Mitigating Circumstances is provided (see Undergraduate Programme Handbook for details).**

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