Weeks 1 - 5 Flight Simulator Design

Purpose

This is intended to demonstrate some of the benefits of object-oriented development by taking a larger project and designing and developing a system in groups.

For this terms work groups of two or three are required. Please let me know when you have formed groups and give me a list of names and student numbers. This should be done by the beginning of second semester teaching - 26th Jan 2009.

Organisation

This terms work is split into two parts, each taking five weeks. In the first part you are required to develop a UML design for the flight simulator. A model answer will be provided immediately after submission date and you will be allowed to carry out the second part of the coursework by implementing either the provided specimen design or a revised version of your own.

The same group will be involved in both design and implementation.

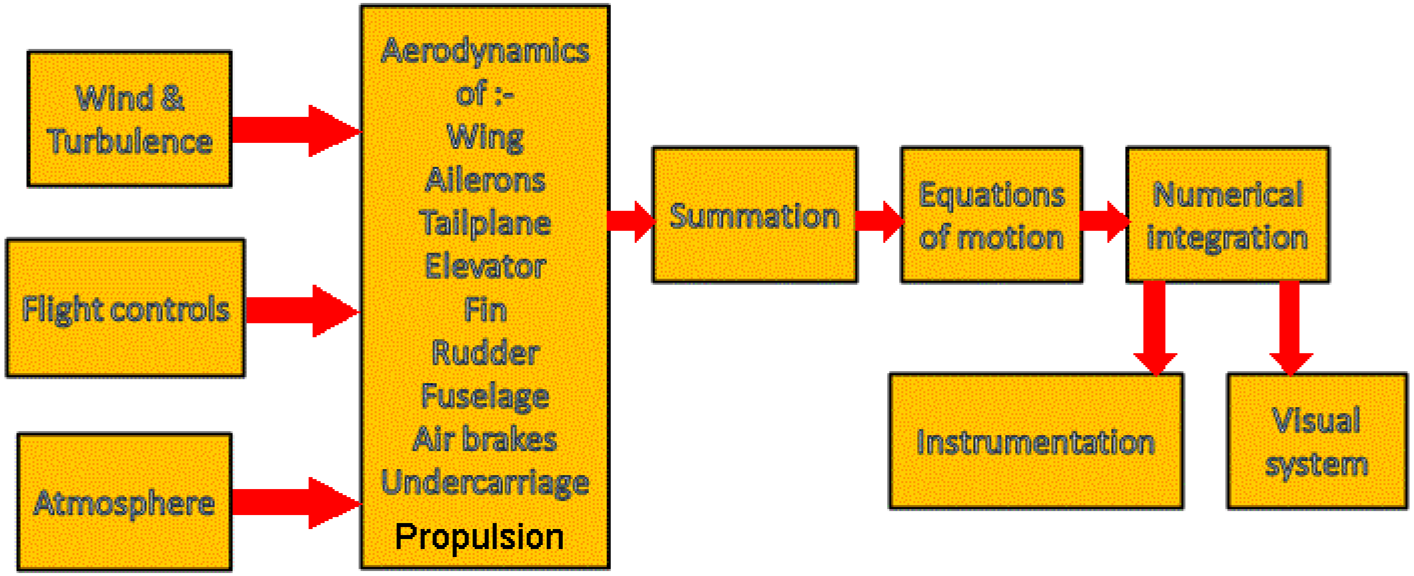
Outline

The flight simulator is a real-time fully functional simulator based on the Merlin Flight Simulator used for developmental experiments based in the engineering department. This is a generic simulator capable of simulating the behaviour of any type of aircraft.

We will be using it to simulate a variety of aircraft ranging from single propeller engine trainers to fighter jet aircraft.

The visual system will be developed in Ogre (open graphics rendering environment) and C++ and will be provided as a component for you to use. In addition, it is hoped to provide joystick control as well as on-screen GUI controls.

The system involves the evaluation of flight equations at a series of finite time steps, thus representing the behaviour of first-order differential equations. The computations are broken down into components representing the different parts of the aircraft as the following block diagram illustrates :-



A more detailed breakdown will be provided shortly.

Details of simulator

1. **Aircraft model**

   The simulator we are creating is a generic one capable of simulating a wide variety of aircraft from single propeller, trainers to fighter jets or multi-engine passenger planes.

   The data which provides the aircraft specification and characteristics is held in a parameter data file and is read into the program to initialise the plane object.

2. **Initialisation**

   Once a model of the Plane has been constructed, the aircraft is initialised by specifying the initial position and velocity.

   In addition, the wind speed and direction and the turbulence parameters are selected.

3. **Simulation**

   The simulation can then be executed and essentially consists of a loop :-

```
loop until simulation terminates

      update atmospheric conditions

      update plane status
           obtain control settings
           compute moments and forces on wings, fuselage etc
           compute power output
           compute aircraft mass and inertia
           evaluate equations of motion

end loop
```

Different components need updating at different rates - some every time through the loop, others less frequently depending on how fast they change.

4. Provided components

To assist in the development the following three components will be provided :-

- Visual system

  This will provide a 3D representation of the view from the cockpit and is updated by providing the aircraft location and attitude.

- Control inputs

  This will provide, on demand, data on the joystick position, throttle setting, rudder deflections, airbrake application and viewing direction (or look around)

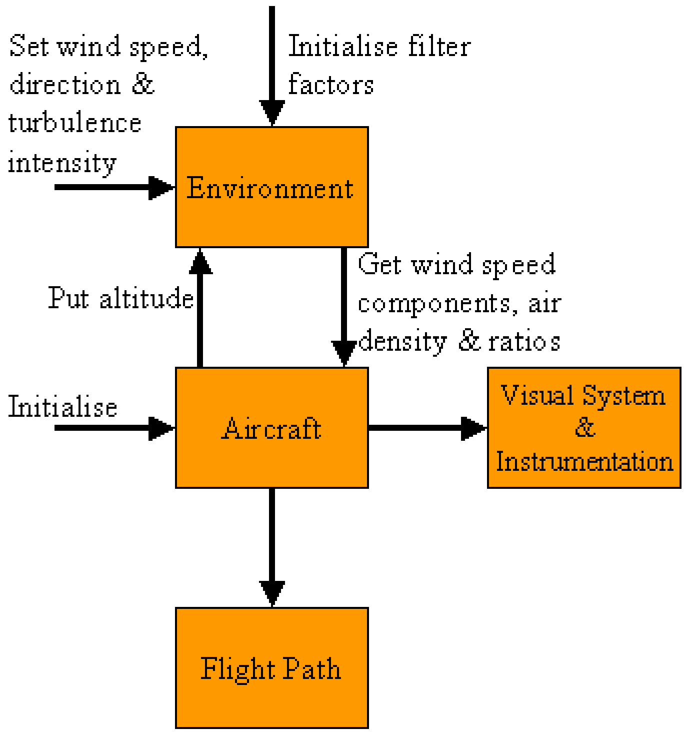
- Instrumentation

  A module which can be updated with flight data and which will display this on the screen.

5. Overall data-flows

The following diagram illustrates the overall data flows in the system.

Flight Simulation – Data Flows



- Environment

  This models the atmosphere and the change of air pressure, temperature and density with altitude. It also determines the effect of wind speed and turbulence to calculate wind speed components acting on the aircraft.

  At the start of the simulation, chosen wind speed and direction and turbulence intensity are input.

  During the simulation, the aircraft altitude is input and the air density and wind speed components output.

- Aircraft

  This models all aspects of the aircraft - control inputs, flight surfaces, propulsion and fuel system and computes the dynamic behaviour of the aircraft.

  The detailed specification of the aircraft is input from a data file during instantiation and the current position and speed of the aircraft is set during initialisation.

  During the simulation, position and attitude data is output to drive the visual system and instrumentation as well as being used to record the flight path history for later review.

- Visual System & Instrumentation

  This displays the pilots eye view of the scene through the cockpit window.

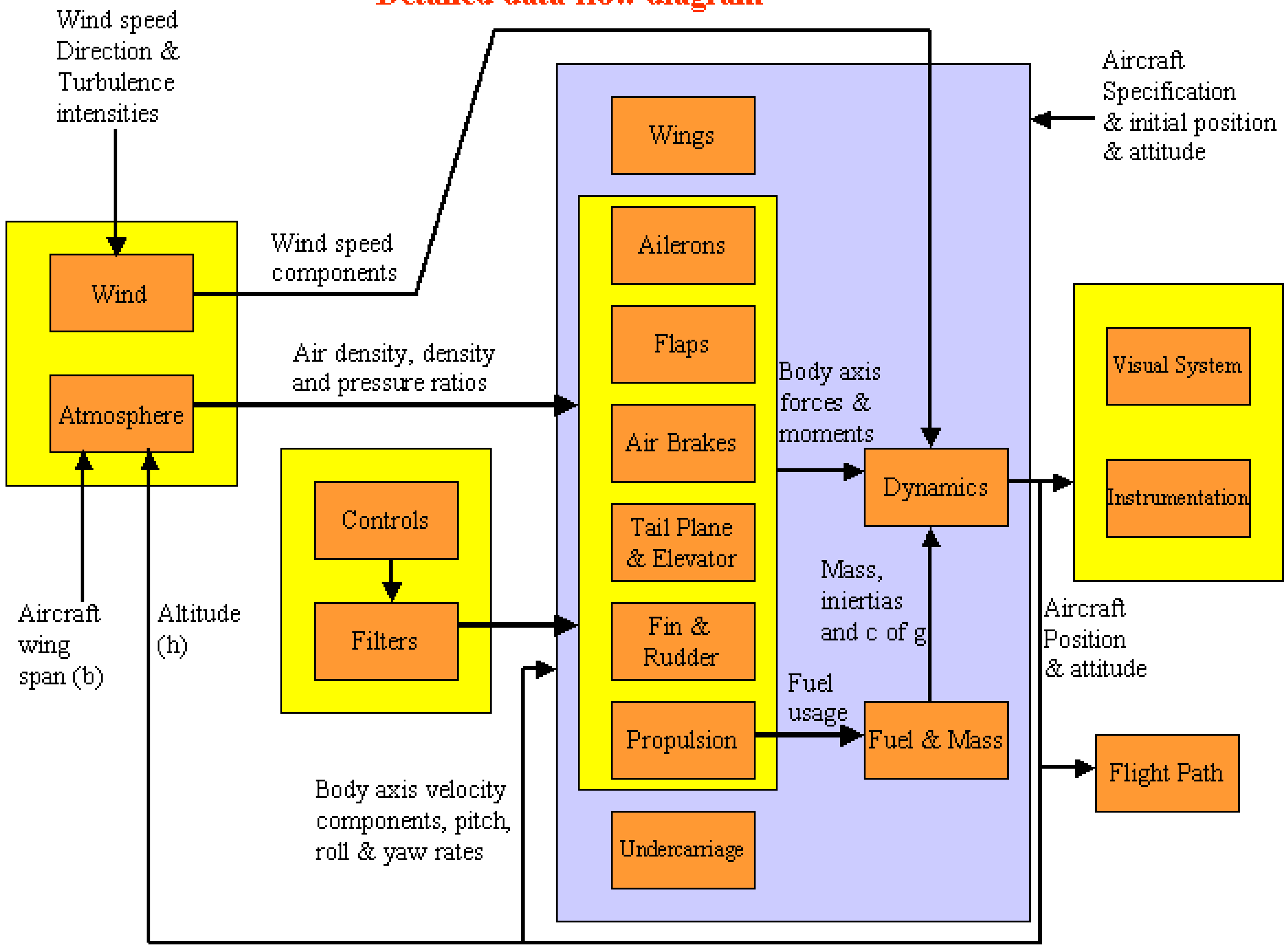
- Flight Path Info

  This records the flight path to enable post-mortem review of the pilots performance.

6. Detailed data flows

A more detailed representation of the data flows in the simulation model is shown below :-

Detailed data-flow diagram



Submission

The uml design should consist of the following documents :-

- Use case diagram
- Initial class diagram
- Sequence diagrams for use cases
- Final class diagram
- State charts as appropriate

The diagrams should be supplied as either images, powerpoint slides or word documents.

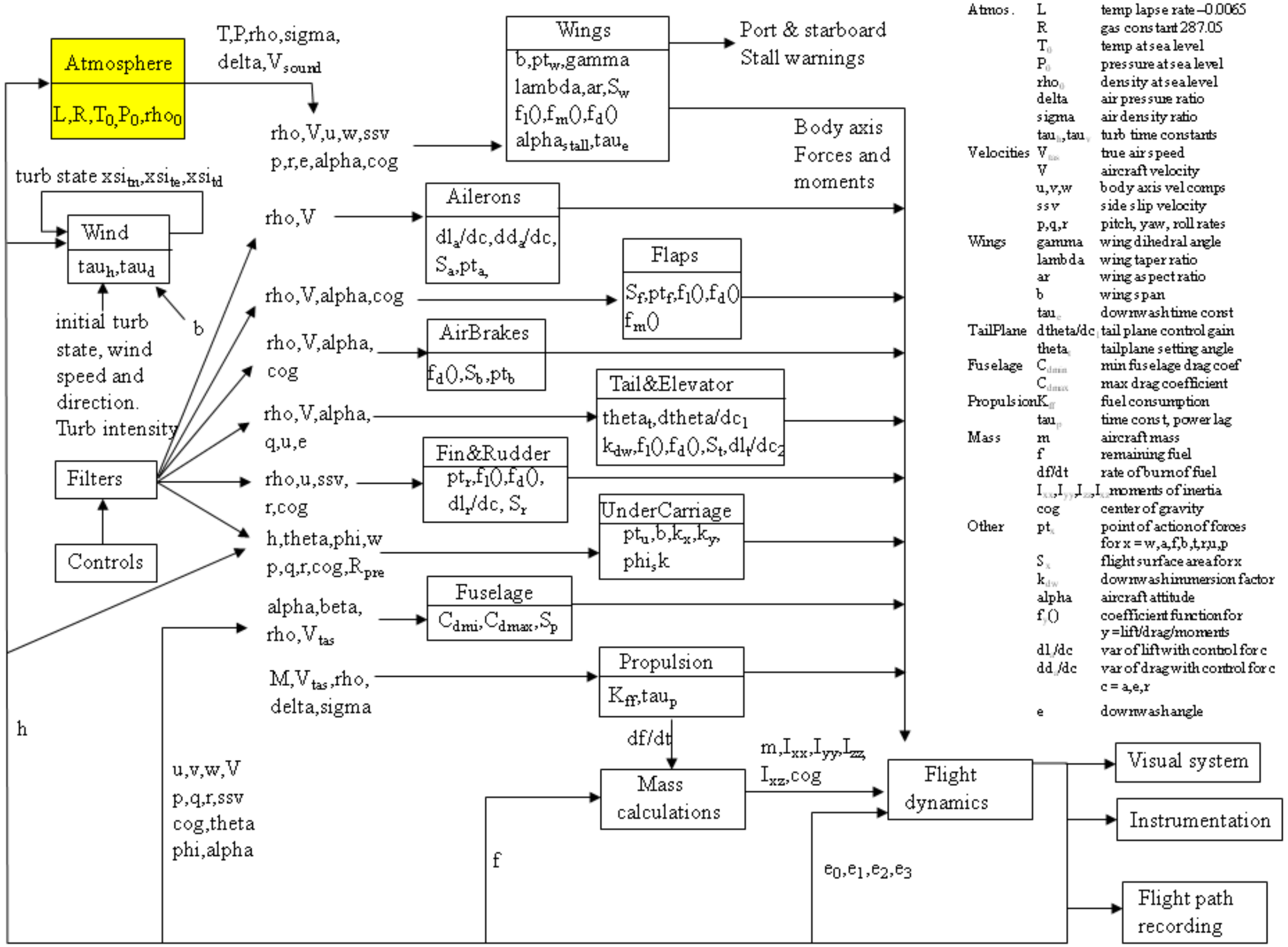
Weeks 6 - 10 Flight Simulator Implementation

Purpose

This part provides practice in implementing a UML design and developing sets of equations in C++.

Outline

A UML design for the flight simulator problem is provided and you are required as a group to implement this in C++. A more detailed description of the data flows between the components of the simulator is given in the following diagram (note that clicking on coloured sections will bring up a window giving further details of the calculations involved):-



Atmos.	L	temp lapse rate –0.0065
	R	gas constant 287.05
	T_0	temp at sea level
	P_0	pressure at sea level
	rho_0	density at sea level
	delta	air pressure ratio
	sigma	air density ratio
	tau_h,tau_v	turb time constants
Velocities	V_{tas}	true air speed
	V	aircraft velocity
	u,v,w	body axis vel comps
	ssv	side slip velocity
	p,q,r	pitch, yaw, roll rates
Wings	gamma	wing dihedral angle
	lambda	wing taper ratio
	ar	wing aspect ratio
	b	wing span
	tau_e	downwash time const
TailPlane	dtheta/dc_1	tail plane control gain
	$theta_t$	tailplane setting angle
Fuselage	C_{dmin}	min fuselage drag coef
	C_{dmax}	max drag coefficient
Propulsion	K_{ff}	fuel consumption
	tau_p	time const, power lag
Mass	m	aircraft mass
	f	remaining fuel
	df/dt	rate of burn of fuel
	I_{xx},I_{yy},I_{zz},I_{xz}	moments of inertia
	cog	center of gravity
Other	pt_x	point of action of forces for x = w,a,f,b,t,r,u,p
	S_x	flight surface area for x
	k_{dw}	downwash immersion factor
	alpha	aircraft attitude
	f_y()	coefficient function for y = lift/drag/moments
	dl_c/dc	var of lift with control for c
	dd_c/dc	var of drag with control for c
		c = a,e,r
	e	downwash angle

Submission

A demonstration of the final submission should be given by each group during practicals on the first Friday of the Summer Term.

Deliverables

Submissions should be one per group and submitted as a zip file in an email attachment on or before the due date