Droning on about control theory...

Unmanned aerial vehicles, control engineering and managing complexity with the art of approximation

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Introduction

Drones, quad-copters, remotely piloted aircraft and unmanned aerial vehicles (UAVs) are an increasingly common and visible vehicle across a wide variety of industries and disciplines. The convenience, speed, small-size and low fuel requirements (compared to large commercial aircraft) have all helped lead to the recent explosion of autonomous, semi-autonomous or remotely controlled planes and 'copters. From hobbyists to military and scientific applications, Amazon drone deliveries to silent, distant surveillance from the upper atmosphere where sleek fixed-wing planes scour the edge of our world collecting clues to our climate and tomorrow's weather, autonomous flying vehicles are forecast to continue to become a major source of technological innovation, investment opportunities and exciting new develpments.

Control Engineering and Unmanned Aircraft

Control engineering is the science and practice of applying control theory for the automation, regulation and augmentation of automatic processes and technologies. Control engineers use mathematical models of electrical, mechanical and industrial activities to apply structured processes and mathematical techniques to correct errors, regulate devices and factories, and generally ensure the safe and efficient operation of technology across a variety of disciplines. Robotics, AI, machine learning, transportation, and drones all fall under the wide umbrella of control engineering.

In the case of UAVs, control engineers work with with other specialist aeronautical, aerospace, electrical, robotic and mechanical engineers to fulfil their professional responsibilities. An important concept in all disciplines of engineering is obviously mathematics, that formal system of logic and scientific symbols that powers almost every aspect of our daily lives. A central idea in engineering mathematics is the notion of "linearity". This is a mathematical property that ensures predictable and solvable relationships between entities. A relationship is said to be linear, if the input to a system can be predictably and repeatedly related in a strictly proportional relationship to the output. In other words, the same consequence must occur every time an action is performed. If you go eating out, with a group of friends, and say that you all keep track of the cost of each ordered meal together. Then in an hour's time when you came to pay the bill, the total should definitely be the sum of the individual meal prices, not some random or unpredictable price with no clear relationship to the circumstances, or the action of ordering a known number of meal at a known price.

The problem is that many, many processes in the world are decidedly non-linear, chaotic and highly unpredictable. The hidden or complex interaction of physical processes or complex interconnected events sometimes makes it very difficult to predict with certainty what is going to happen next in all kind of circumstances. The advent of massive computational power, and ever vaster amounts of information mean that there are lots of ways that computers can help solve problems that were very difficult to solve just a few decades ago, but the role of linear mathematics is still of central importance to the science of engineering and control theory. One of the primary techniques used by engineers is called "linearisation" the process by which a natural, or complex non-linear system is *modelled* as a linear system, within strict conditions or clear assumptions.

As long as the system (or process) being simulated stays within the boundaries of these assumptions or conditions, then we can use the powerful tools of linear algebra and control theory to solve, predict and control very complicated processes and interactions in the real world.. One such highly complicated area of non-linear complexity is the physics of flight. There are 6 degrees of freedom for a powered aircraft in the air: translational (moving in straight lines in 3-dimensional space: up/down, back/forward, side-to-side) and rotational (there are also three rotational directions, that describes curved motion around a fixed point). Working out the mathematics and relationships of moving *and* rotating simultaneously, at high speeds in the air without human intervention or direct control, under the forces imposed by the atmosphere, climate, air pressure, and the highly complicated forces of turbulence... it becomes very clear, very fast, of the need to make some initial simplifications, in order to make the whole process more comprehensible, measurable and manageable.

Instead of considering all the complex non-linear aspects of flight, we can assume that the plane is already flying, at a fixed height and a constant speed. Further, we can say that just to make the model simpler, that the earth could be considered flat, not round (at least at the scale we are interested in.) We can also assume that there is no inclement weather: it's a perfect still day at a very reasonable temperature. Once we start making these small simplifications, we can strip away the difficult-to-solve bits of the problem of modelling flight, and come up with a simplified but still robust approach that allows the use of powerful mathematical techniques to control and automate the operation of an unmanned vehicle (or to augment the abilities of a pilot, making the plane easier to fly, for example.)

Once a simple model has been developed to a working standard, it can be modified or improved, with small adjustments to make the model closer and closer to representing the full non-linear world that the invention, device, vehicle or process has to operate in, eventually. The skill at making the right amount of approximation, the correct number of assumption while still having a useful model that has some correlation with reality is a genuine skill that only comes with experience and practice, as a result of discipline, learning, careful thought, and collaboration.

Conclusion

Drones are an example of a domain that involves extremely complex engineering problems. Simplifying and approximating until a working model that can use the power of linear algebra is a crucial skill for engineers to develop. The rapid expansion of unmanned aerial vehicles and other automated aircraft means that control engineers will have many opportunities and responsibilities to exercise their skill-set to ensure the safety and stability of control processes in automated vehicle flight.