The three things to talk about

Motivation

Modelling

Control

Modelling: The Euler LaGrange energy-based method. Modelled as a 2D system due to constraints. Assumptions

Control: Type of control and obtaining measurements via computer vision.

Good morning/afternoon everyone. My project is the control of a rolling-balancing mechanical system, in particular the disk-on-disk system. ||

I’m going to go through the motivation for this project and why we are researching this area. Then I will speak about the modelling and simulation process. Finally, I will go through the current control method, which will involve the computer vision process being used. ||

The disk on disk system is an example of an under-actuated system. The technical definition of an under-actuated system is one which cannot be commanded to follow an arbitrary trajectory in a configuration space. What this really means is one of two things: that the system has less actuators than degrees of freedom, or there is not an actuator associated with every degree of freedom. An inverted pendulum robot or Segway is a great example of an underactuated system. It can translate along the ground and rotate about the wheel axis, giving two degrees of freedom, but there is only an actuator for the translational degree of freedom.

Under actuation makes it difficult to control a system. Normally on a Segway, we want the person to be standing upright with the wheels underneath them while they move around. Moving the Segway backwards and forwards is simple as the actuator, the motor, acts in this degree of freedom. Keeping the person upright is not simple, but highly desirable. The motor turning the wheels does not allow direct control over the angle the Segway makes with the ground.

The Segway is not the only underactuated system, though if you are studying mechatronics in Newcastle you could be excused for thinking so. Most systems are underactuated. Cars, boats, aeroplanes and even animals are all underactuated systems. Studying these systems and developing a generalised understanding of them allows the potential of robotic systems to be realised. Constraining robots to tasks for which they are fully actuated severely limits their ability to achieve the performance they are capable of. Exploiting the system dynamics when controlling underactuated systems allows this performance to be realised.

The way humans naturally interact with a system has influenced the preferred method of robotic manipulation. If we need to move an object, we pick it up and place it down in the new position using our hands. Normally we grasp objects using our thumbs, fingers and palm to enclose it. This allows us to very accurately control the position and orientation of the object. We also know exactly where the object is for the entire operation. This is called a prehensile manipulation or grasping manipulation. Prehensile manipulation is the most straightforward way we have to interact with our environment, which has led to the design of robotic systems that exclusively using grasping techniques.

Non-prehensile manipulation is any type of interaction that doesn’t involve grasping. A large portion of the things we do in a day are non-prehensile manipulation. Stirring food in a pan, pushing open a door, carrying a tray of wine glasses, even walking are all non-prehensile interactions. Using robotic manipulators to perform these actions is far more difficult than prehensile actions. The manipulation is not a closed kinematic chain and the changes of state are generally non-smooth. Additionally, as the object is free to move relative to the manipulator, the majority of these systems become underactuated.

To extend the capabilities of robotic systems beyond direct manipulation using grasping actions we need to better understand these non-prehensile manipulations.

A robotic manipulator capable of non-prehensile manipulation is useful in a wide range of applications. Surgical robots could mimic the ability to gently push away an artery, much like a human would. Industrial applications where small and fragile parts are used becomes possible. A humanoid type robot with non-prehensile movements can freely interact with world without modifications. Most importantly, robotic walking is a non-prehensile manipulation subject to a large amount of research at this time.

Understanding the interaction between the dynamics of the manipulator and object during a non-prehensile manipulation is critical to determine the appropriate control to be applied. As these interactions are usually complex for even a seemingly simple task, we tend to break the motion down into sub-tasks called primitives. Rolling, sliding, pushing and throwing are examples of primitives. Generally, each type of primitive has a defined control strategy. A complex task involving multiple primitive actions can be controlled using a combination of primitive control strategies. Control of non-prehensile primitives extends the kinematic workspace of a robotic manipulator beyond its physical region of influence and allows a far greater set of actions to be completed.

The disk on disk system isolates the rolling type primitive. In particular, the balancing action using only rolling primitives. By developing a model, simulation and experiment apparatus to test control methods we can gain further insight into the general method for controlling rolling primitive movements.

Interaction with underactuated systems is normally a non-prehensile manipulation.

System dynamics come in two flavours: the type you explain to your girlfriend when she asks what you’re doing, and the type where say “don’t worry about it”. Pushing and pulling a gripped object are examples of the first kind. The interaction between the actuator input and the result is pretty straightforward and by extension, it is much easier to control. These are prehensile manipulations and are the preferred method when using robotic manipulators. Robots like to grip things as it allows direct control over an objects position. Non-prehensile manipulations are much less straightforward as the object can move relative to the manipulator during a control action. To control the disk on disk system, we use the rolling type of non-prehensile manipulation.

Understanding how to control the disk on disk system using rolling can aid in the understanding of the general non-prehensile manipulation problem. Actions like rolling and throwing can extend the range of influence of a robotic manipulator beyond the kinematic workspace.

Simulation and control of a mechanical system requires a mathematical model. There are several different approaches for developing these models, each with their own benefits and drawbacks. Newton’s equations of motion can be used to develop a first principles approach, which is usually more suitable for non-complex two-dimensional systems. Bond graphs allow a more visual approach to modelling, with the flow of power throughout the system modelled using junctions and signal interconnections. This approach is usually more systematic than the first principles approach but requires solid knowledge of the foundational components.

Energy based approaches, such as the Euler-Lagrange method, are highly suitable for the disk on disk system. The Euler-Lagrange method focuses on energy storying elements, such as inertias and capacitors, which describe the

This approach is intuitive and elegantly captures the dynamics of the rotational