# Slide Intro (Adrian)

Hi, I’m Adrian, and with me I’ve got Xander, Sylvain, Seun, and Bethany, for Team 15. For our choice of case study, we opted to have a look into the development of a basic assembly robot.

# Slide Scenario (Adrian)

From the brief we were given, we had to design, manufacture, and control a robotic arm which could pick up a pin and insert it into the hole of a cylindrical bar (hence, assembly), all on a budget of £60 plus whatever other parts we could scrounge up. Fundamentally a straightforward task, but because of that, there’s many, many different designs of robotic arm which could achieve this.

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Slide 4 – Design Evolution

During our initial design phase, the type of robotic arm for this application was the first consideration. From the available selection, a serial robot was chosen for this application. A serial robot is a robot consisting of a number of rigid links connected with joints.

A cartesian, cylindrical and SCARA robot designs were considered, although cartesian and cylindrical designs were deemed to be functional but limited, while the SCARA robot was the next best alternative. Although this design is suited to assembly for pick and place requirements, this design was also deemed limited for a wider range of application. It was therefore decided upon that the final design would be a serial robot, which would be able to complete multiple other process from the same base design, if the end effector could be modified.

Following this logic, the first CAD model designed was a rough draft of a serial robot with 4 links, and therefore 4 servos required. At this stage of the design the servos had not yet been chosen, with a draft shape it was assumed 3 larger servos would be used for the first 3 joints, with a smaller servo required for the end effector.

End effector:

After the first design, the team was provided with 3x HS-645MG servos and 1 S3003 servo. Once these servos had been measured, the CAD model could then be built to fit the shape of the given motors. At this stage the design of the end effector was considered, where simplicity and functionality were the most important aspects. For this reason, it the end effector was chosen as 2 gears, one gear connected to a final additional servo, and one connected the cylindrical extrusion on the end effector, to allow for rotation of the gears. For the end effector, a minimal servo size was required, due to the low torque requirement coupled with the insufficient load (tiny pin). It was therefore decided that an SG90 servo would be suitable for the end effector servo gear.

Assembly/Adaptations

During the assembly of the robotic arm, there were some minor complications which led to some design adaptations to allow the final design to function as intended. After the initial finalised CAD model had been printed, assembly of the servos and links could be started. During this initial assembly, the S3-003 Servo was noticed to be damaged on one side, which affected the stability of the servo once in place. To solve this problem, a new base top was designed with a housing unit for the broken servo, which would connect the servo on one side, while the shape of the housing unit would ensure sufficient stability for the servo while in use.

Additionally, the initial end effector gears would not turn when connected to the SG-90 servo, this was due to the large number of teeth on the servo, and the method for servo-gear connection. It was therefore decided that the servo gears would be reprinted with less teeth (with a slightly different shape), as well as an interior extrusion for the servo horn to be fixed to the servo gear, to allow for easy and reduced friction motion.

Testing Grippers – different shapes and different end effector options for a wider range of applications.

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# Slide Workspace Analysis (Adrian)

To see how flexible the arm would be, we did a quick workspace analysis on it with Inventor to get this.

The workspace of the robot is a 318mm sphere with the bottom part of it rounded in. This is because the first link there in red with the angle, is limited to rotating no more than 34 degrees below the horizontal plane, because otherwise it would collide with the rotating base.

Given the near-sphere workspace of the arm, we concluded that this would be sufficient for the task.

# Slide Static Analysis (Adrian)

To see how strong our motors needed to be, we did a static analysis of the robotic arm at maximum extension holding the pin, since this would be the most difficult scenario for the motors to handle. To get the weight of each component, we designated each part to be made of PLA in Inventor, and obtained masses from there. But, these masses assumed that the parts were solid PLA, but in reality because we were going to 3D print the parts, we used a percentage infill in fabrication, so to approximate the actual masses we multiplied them by the infill percentage. Then using the moment equations below, we got the maximum moments that each motor could be expected to experience.

Should be noted that this static analysis ignores the gripper motor because due to the relatively few degrees of freedom, the gripper motor never has to fight gravity.

# Slide 3D Animation (Adrian)

Given time constraints for testing the robotic arm, we wanted to demonstrate its motion with a 3D animation built in Inventor. The animation here picks up a pin and proceeds to drop it into the pin holder.

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# Slide Fabrication (Adrian)

Deciding on how we were going to manufacture the robot really came about during the design stage since we knew that, should we go with 3D printing in the end, we would need to design the robot parts with that in mind.

In fact, we did ultimately opt for a 3D printed design over something like metal or wood, thanks to the flexibility it afforded and for it being more novel than the traditional alternatives.

Material wise, we decided to make everything out of PLA because of it being easy to work with, inexpensive, and its properties well understood.

Each part (besides the grippers) was printed using a 20% cubic infill structure. Despite each of the parts being functional, we found that the 20% infill sufficed because of the relatively low load we were working with. The choice of cubic infill we made because it brought a good balance of strength in each direction (particularly important for the final link) and printing speed/material usage.

The grippers were printed with a 50% grid infill, 50% because these were a small component tasked with actually gripping the test rod so needed to be reliably strong, and a grid infill because the stresses would be mostly within the plane of printing.

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