Listing of components

Areas of design which allow for flexibility

Method of fabrication

Method of fastening

Method of assembly

Accessibility

Option for redesign

Estimate of mass

Tests

Risks

**>>Main chassis**

The main characteristics we wanted in the chassis were simplicity, rigidity and modularity, as it will be the structure onto which the rest of the robot components will be mounted. The base of the chassis will consist of a flat rectangle of 3mm aluminum sheet metal, with arms extending forward leaving a gap for the brush. 3mm aluminum provides enough stiffness for our requirements, and allows us to add threaded holes to the chassis. Clearance holes and tapped holes will be cut in the base to allow for rapid mounting of components, and two large holes are located near the rear corners of the chassis for the wheels, where the drive system will be located. This part will be fabricated using the waterjet, and the majority of mounting will be done using M3 screws, either directly screwing into the chassis, or using clearance holes and nuts. Making the base out of one single flat piece means that we are able to add additional holes after the initial fabrication if we should need to modify or add component mounting.

**>>Brush Mounting Structure**

The second part of the chassis is structure for mounting the brush and wall that is used for ball collection, which is also made out of 3mm aluminum. The division of the chassis into two major parts was done to simplify fabrication (fewer sheet metal bends required) and to allow for independent development and testing. As it is, the brush and ball collection mechanism can be assembled and tested separately from the main chassis, which will have the TINAH, the sensors and motors mounted to it. This will allow us to test the robot’s movement and sensing without having mounted the collection mechanism. The brush mounting structure will be waterjet cut, and the flanges and two holding arms will be bent. While the two arms are bent to an angle just under 90o, there is sufficient flexibility in the design that the error which is likely to be present in our fabrication will not affect its effectiveness.

**>>Brush**

The brush is the critical component of the robot’s ball collection mechanism. It spins at low speed, pulling in any balls that it encounters, lifting them up a vertical wall and funnelling them towards the storage and firing mechanisms.

The brush consists of two disks of different diameters (80mm and 60mm) mounted axially on a shaft 260mm apart. The two disks have inward-facing T-slots cut at equally spaced intervals around the outer diameter, which are strung with fishing line. The fishing line passes back and forth between the slots on both disks, forming a long cylindrical surface with which to grab and pull in balls. Fishing wire was chosen as it is very lightweight, yet has a high tensile strength, which is important as each loop is tensioned between the end disks. Fishing wire is also flexible, allowing it to deform inwards when it is rolling over a ball – this allows us to leave a gap smaller than the ball diameter (approximately 20-30mm for a 40mm ball) between the ground and the outer diameter of the brush. Testing has shown that the brush will easily pull in a ball and push it up the vertical wall behind the brush, however further testing will need to be done to determine the optimal spacing between the brush and the floor/wall, as well as to verify what surface finish will provide sufficient friction on the vertical wall to allow it to pushed up. The spacing of the strung wires is such that balls should not pass through the string into the interior of the brush, however an inner tube may be added if testing showing that this intrusion is a possibility. In the prototypes fabricated so far, the brush has been strung with a single length of fishing line. This presents a risk, as if one section of the line breaks, the entire brush will be rendered useless. To overcome this, we are considering stringing the brush with multiple shorter lengths of fishing line, or else fully threading the entire brush with a few long overlapping lengths of line. Another property of fishing wire is that it is fairly slippery, so that balls will not jam against it. This brings up the reason for the unequal wheel diameters: the lower edge of the brush will be parallel to the ground, meaning that the upper edge will be at an angle to the horizontal. Extending the vertical wall (up which the ball is pushed) above the brush allows the ball to roll between the top of the brush and the wall instead of simply being pushed over, and due to the slope of the brush, it will be pushed along the top of the brush towards one end. Because the brush is constantly rolling, if multiple balls are on top of the brush at once, they will not jam together, which was our concern with using a static ramp or tube; it also means that we do not need another mechanism for funnelling the balls to one point.

The size of the brush has been determined based on various constraints; however the optimal size has yet to be finalized. The maximum brush diameter is 130mm, as if the brush is any larger than this the brush can’t pull in a ball from the rear wall. Minimum diameter is harder to calculate, however smaller is better, as it leaves more space for other components on the chassis. The difference between the two disk diameters, which creates the slope for the ball to roll down, can be fairly small; about 20cm difference in diameter. This sizing is an initial estimate, however the size will likely change as we perform tests.

The brush will be driven by a belt running around the end of its shaft, outside the vertical mounting arms. The drive motor will be mounted rear of the vertical wall. A flexible belt allows the axes of the brush shaft and motor shaft to be slightly off-parallel, as will be the case.

The brush will be mounted at the front of the robot between the two arms of the brush mounting structure. Preliminary prototypes have used disks made using laser cut wooden disks constrained with nuts on a threaded rod. We are considering using metal disks for reasons of strength; however this will increase mass and increase the chance that the fishing wire will be cut by sharp edges.

**>>Brush Holders**

There are two brush holders which act as an interface between the brush shaft and the chassis. They were designed to allow for easy removal of the brush assembly from the chassis, as we will likely have to modify it frequently in testing. These components will be 3D printed, as they contain angles which would be difficult to machine. The idea it that both holders will slide onto either end of the brush shaft, and the holder will then slide into the slot cut in the vertical sheet metal brush mounting structure. This allows for flexibility in the horizontal position of the brush shaft. Once the correct location has been determined, the screws at the top and bottom the part will be tightened, closing the upper and lower arms against the chassis structure and preventing sliding. To remove the brush, one needs only to loosen the screws and slide the entire assembly out of the slots.

**>>Ball Guard**

A ball guard will be mounted above the brush, connected at each end to the chassis using screws. Its purpose is to prevent any balls that are being conveyed along the top side of the brush from flicked back out of the robot. It will be made of hand or waterjet cut sheet metal aluminum, which will be bent at the ends. In testing we observed that it is possible (though unlikely) for a ball to get caught between this guard and the brush, and forced into the inside of the brush, so testing will be performed to ensure that the geometry of the ball guard prevents this.

**>>Omni-Bearings**

The robot will be driven by two powered wheels at the rear of the chassis, however it will also have unpowered bearing wheels near the front of the robot. These will consist of 3D printed holders for small (about 1cm) diameter ball bearings. The printed part will be screwed into the bottom of the chassis, allowing the bearing to roll freely between the printed holder and the chassis sheet metal.

**>>Internal Ball Routing**

**>>Mass Budget**

Base Chassis Structure (aluminum) – 460g

Brush Mounting Structure (aluminum) – 370g

Brush (wood, fishing line, aluminum)

2x Brush holder (ABS) – 13g

4x geared Barber Coleman motors

2x servo motors

Calculations/approximation

Brush size + justification

Brush speed and torque required