DESIGN OF A WRIST AND OPERATOR INTERFACE FOR AN AGRICULTURAL MANIPULATOR

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"I invented the cordless extension cord"

Steven Wright

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SUMMARY

This project is involved with the development of a wrist and control system for an agricultural manipulator called the Hydra Trim. The Hydra Trim is intended for use with regional Councils and private contractors for roadside mowing and hedge trimming.

Background research was conducted. This research established that the hedge trimmers on the market are large, bulky and intended for a single purpose. The intention of the Hydra Trim is a lightweight machine that may take longer to perform a specific task, but it is capable of many tasks.

The development of the wrist was based on the human forearm and wrist, with "bend" and "twist" action. To achieve this action the wrist was split into two rotator units that when combined create the wrist. The rotator units are powered by hydraulic pressure. Hydraulics was chosen because it is the main power source of the Hydra Trim. Thus no other type of control servo would be required.

The Hydra Trim has a total of eight functions, five main working functions, two telescopic and one hydraulic motor function. Only one hand is available to operate the Hydra Trim as the other is required to operate the vehicle, therefore a single joystick was required that could control all eight functions. Standard joysticks were investigated, but at best could only control three proportional axes at once. A stackable modular design was developed. Each module controlled one axis. The modules were assembled to replicate the geometry of the Hydra Trim. Moving the end of the modular joystick causes the Hydra Trim to follow in the same direction at a velocity proportional to the displacement of the joystick.

To control the hydraulic flow a system was required that is capable of operating at least eight functions. A stackable valve system was the best option. Three valve types were considered. The valve types were solenoid proportional, servo and pulsar operated. The pulsar system was chosen as it gave good control at a lower cost than the others did.

An interface between the joystick and the hydraulic valves was required. Using the standard controller that comes with the valves was considered, but each unit can only control three actions. Two options were considered for a controller, these were individual analogue controllers or a digital micro-controller. The analogue controller is much simpler than the micro-controller but is unable to perform intelligent operations. The analogue controller was chosen because it was simple and would speed up the development process.

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1 INTRODUCTION

Roadside mowing and tree pruning has always been a job that most people would consider as unpleasant. This project is concerned with the development of a system to make these tasks simpler, safer and more pleasant for the operator.

1.1 Software

This project is involved with the design of a complex mechanical system, which could be done using a modern CAD package. To achieve this, research into what modelling package was best was necessary. Several contenders were considered. These include SolidWorks [1], Mechanical Desktop [2] and CADKEY [3]. CADKEY was disregarded early as it is not as expandable as the other two. Both SolidWorks and Mechanical Desktop have additional software packages that allow for motion, force and stress analysis. The major difference between SolidWorks and Mechanical Desktop, is that SolidWorks is a true three dimensional modelling package, whereas Mechanical Desktop is based on the two dimensional AutoCAD system with a three dimensional toolbox. The choice was finalised to SolidWorks as it handles three dimensional modelling more efficiently. Massey University also uses SolidWorks. This allowed the project to continue while studying at the Turitea campus.

1.2 Overview

This project is involved with the development of a wrist mechanism and hydraulic control system for an agricultural manipulator. The manipulator is called the Hydra Trim and was developed by Pivot Engineering Ltd, Napier [4]. The wrist mechanism is an integral part of making the Hydra Trim a success. The hydraulic control requires not only the valves but also an interface between the operator and the valves.

2 BACKGROUND

2.1 Market Niche

The concept behind the Hydra Trim is to fill a market niche. The Hydra Trim is primarily aimed at regional Councils and private contractors. Most systems available to contractors for roadside mowing, hedge trimming/pruning require separate large bulky single purpose machines. The Hydra Trim is different in that it is smaller, lighter and is able to perform a multitude of tasks by changing the blade mechanism on the end of the wrist. It may take longer to perform a task with the Hydra Trim as it is smaller, but within a matter of minutes it can be performing a completely different task whereas other systems would require a separate machine.

2.2 Other Systems

Of the mowing systems found, most are mounted on the rear of a tractor. They are large and bulky with substantial counter balance weights and require tractors that exceed a minimum weight. As the mowers are mounted at the rear of the tractor the operator has to continually look forward and backward to maintain their correct direction and monitor the mower. As the booms extend vertically from the tractor, when the mower is close to the tractor overhead clearances need to be monitored. Most tractors with these mowers attached have cabs and/or safety cages so that the top of the boom becomes invisible from the normal seated position. This means that the operator must lean back out of the seat to look up for overhead obstacles.

2.2.1 Bomford Turner Ltd.

Bomford Turner Ltd [5] is based in England and produces "Arm Type Flail Mowers". The smallest machine has a reach of 4.25m with a minimum tractor weight of 2000 kg (Figure 2-1) and the largest has a reach of 8.30m, with a minimum tractor weight of 4600kg (Figure 2-2).

Figure 2-1. Bomford Turner B407

Their entire range is rear mounted with the exception of one model that is front mounted, but a special tractor is required that has the engine to the rear and the cab to the front.

Figure 2-2. Bomford Turner B83-83

2.2.2 McConnel Ltd

McConnel Ltd [6] is based in England and produces "Power Arm Hedge Trimmers". The smallest machine has a reach of 3.10m with a minimum tractor weight of 1500 kg (Figure 2-3) and the largest has a reach of 7.70m, with a minimum tractor weight of 4500kg (Figure 2-4).

Figure 2-3. McConnel PA90

All of the McConnel "Power Arm Hedge Trimmers" are mounted to the rear of the tractor by either the standard three-point linkage or permanently fixed to the rear axle. These arms feature a parallel arm system (Figure 2-5) that allows adjustment of reach using a single lever without constant adjustment of height.

Figure 2-4. McConnel PA7000T

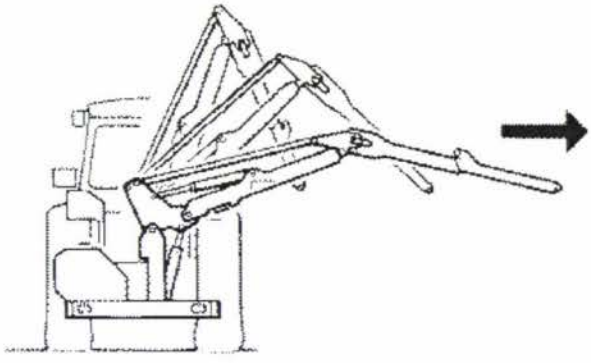

Figure 2-5. McConnel "Parallel Arm"

2.2.3 Alamo Industrial Ltd

Alamo Industrial Ltd [7] has seven manufacturing plants in U.S.A. and four in Europe. They produce tractor-mounted mower and cutters. The smallest machine has a reach of 3.80m and the largest has a reach of 10.25m (Figure 2-6). The minimum vehicle weights were not disclosed.

Figure 2-6. Alamo Industries Slopemower

The 10.25m boom requires the tractor to have an additional 640kg weight put on the opposite rear wheel to the boom. Their range includes rear mount, mid mount and front mount mowers. The front mount mower has the same criteria for the Bomford Turner front mount mower in that a specialised tractor must be used (Figure 2-7).

Figure 2-7. Alamo Industries Front Mount Boom Mower

2.3 The Hydra Trim

The first prototype (Figure 2-8) Hydra Trim that was built consisted of a central vertical mast mounted onto a Land Rover stub axle allowing it to rotate about a vertical axis. Connected at the top of the mast was the main boom that extended horizontally and was controlled by a hydraulic ram. The dipper extended vertically downwards from the end of the boom in a similar fashion. The wrist consisted of a single axis joint controlled by a hydraulic ram. A hydraulic motor at the top of the dipper drove the main drive for the cutter on the end of the wrist. The power was transferred to the cutter via a long flexible shaft similar to that found in shearing sheds, used to drive the shearer's hand piece. The concept of the boom and dipper arrangement worked very well but the drive mechanism for the cutter would continually break where the wrist pivoted.

When the second prototype (Figure 2-9) was built the geometry of the boom and dipper remained the same with the exception of the actuation of the dipper. Instead of the hydraulic ram being mounted to the boom it was mounted to the mast. The desired effect was to achieve a parallel geometry similar to the McConnel system (section 2.2.2). But as the hydraulic ram was used as one of the parallel arms difficulties were encountered. When the ram was altered the geometry would change causing the positioning of the cutter to become unnatural to the operator and occasionally jamming the linkages. The cutter motor was moved from the top of the dipper to the wrist, thus overcoming the drive mechanism problems. The wrist had another axis added allowing it to be moved in two directions. To activate the wrist, two hydraulic rams were used to move the upper and lower wrists respectively in the appropriate direction. The

problem was the two motions were not mutually exclusive. Before the second movement could be activated the first had to be returned to the centre position; otherwise the wrist would bind and damage could be inflicted on the wrist. The rams were connected via a bell crank arrangement to the wrist mechanism. This restricted the wrist to less than 180° of motion due to the ram and wrist approaching an infinite gain situation at the end of travel. Thus the wrist suffered from a lack of range of motion.

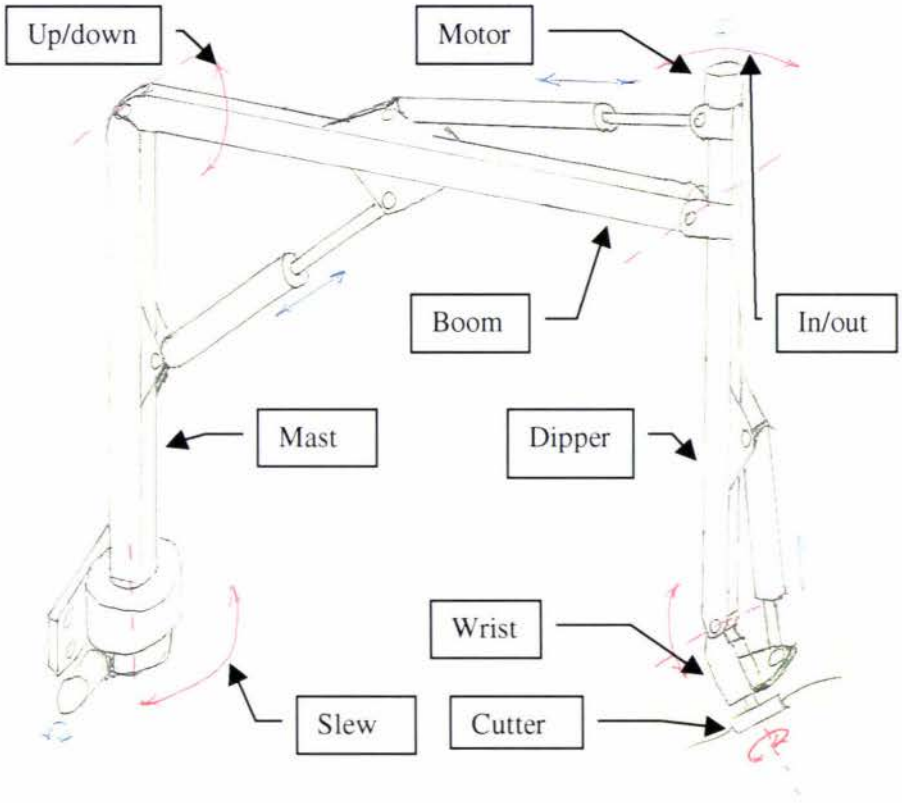

Figure 2-8. First Prototype

The control consoles for both of these prototypes were bulky and contained several levers and switches. This was difficult to use as the operator could only use one hand, as the other is required on the steering wheel of the tractor.

From the testing of the first two prototypes the main slew mechanism, boom and dipper geometry was finalised to a system similar to the first prototype, without the parallel arm arrangement on the second prototype. The slew action of the mast, the up/down action of the boom and the in/out action of the dipper constitute the three main operations of the Hydra Trim. By adding the bend and twist motion of the wrist, brings the count to five.

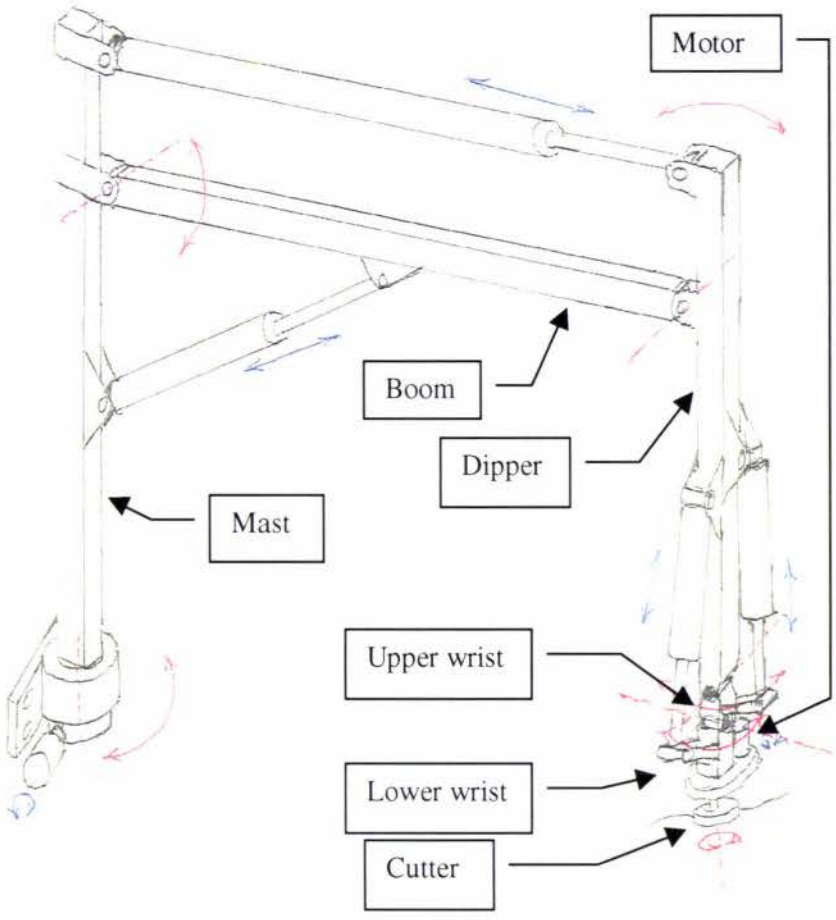

Figure 2-9. Second Prototype