THESIS PROJECT PORTFOLIO

Design & Control of a Rotary Inverted Pendulum

(Technical Report)

Automotive Right to Repair: Legislation as Political Artifacts

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

The goal of the technical project was to design and develop a functional rotary inverted pendulum (RIP) for use as a teaching aide by Professor Michael Momot when teaching control theory to UVA undergraduates. A rotary inverted pendulum is a classic example of control engineering often used to study and demonstrate differing control strategies. In an RIP system, typically a pendulum arm is attached to a pivot point that can rotate 360 degrees by some motor or actuator. A fully developed RIP should be able to fully control the motion of the pendulum arm by precisely driving the rotary arm which the pendulum pivots about. The goal is to swing the pendulum arm up and balance it vertically in the air using rotational motion. The dynamics of a rotary inverted pendulum include both translational and rotational motion, and as such the control system needs to consider the angular position, velocity, and acceleration of the pendulum, in addition to its linear position and velocity.

This system would carry merit as a useful demonstration tool that would serve as a real-world analog for the theory and mathematics being taught within the class. Due to the nature of control theory, it can often be difficult to visualize the nature of the work, especially when learning it for the first time as many of Professor Momot's students within the section would be. The RIP is a great tool that reacts readily and noticeably to a change in its controller specifications, and as such would be invaluable in the assistance of Professor Momot. A configuration in which it is easy to manipulate the system controller and gains would be ideal to display what exactly each parameter does within control theory.

The RIP was designed with several constraints given by Prof. Momot: The RIP needed to be lightweight, portable, and aesthetically pleasing so it could be used in classroom demonstrations by Professor Momot. Specifically, the maximum weight of the RIP was given as

16 pounds, and it should be no more than 1 foot tall. Additionally, the volume of the RIP should remain under 1 cubic foot. These constraints ensure that the RIP can be easily carried from room to room and set up quickly and with minimal space necessary. The RIP must be designed to be easily disassembled, so parts could be swapped out in the event of wear and tear. To be of use in classroom demonstrations of system variation within control systems, the weight of the pendulum arm should be easily moved across the arm. During use, the RIP should have minimal vibrations, i.e. not move along the surface it is placed upon or move a small table. It should also be able to attain an inverted state and hold it within 1 degree of equilibrium for a minimum of 10 seconds. Parameter gains K_P , K_D , and K_I should be easily changed through the microcontroller, ideally during use.

Repair is the synthetic connection between my technical report and my STS paper. Repairability was an important factor while designing the RIP, with one of the criteria being that it be easy to disassemble and repairable. Repairability is also of great importance in the Right to Repair debate which my STS paper centers around.

As automotive technology advances, car companies can improve the quality of their products, but doing so also increases their complexity. Third party services such as independent mechanics and service centers struggle to react to this increased complexity without the necessary specialized knowledge or equipment. In an industry as massive as the automotive aftermarket, problems can ruin the lives of hundreds, if not thousands of people. Right to Repair is potentially the most important regulation protecting third parties in automotive aftermarkets. Right to Repair is a blanket term for bills, proposals, memorandums, and state laws which directly address consumer's right to accessible repair and maintenance information or practices for automobiles and automobile systems. Prior to the industrial revolution, the right of a

consumer to repair their product was a matter of course. In the days when the vast majority of equipment and tools were homemade, the act of repair was limited by the owner's ability to repair; so while repair was perhaps more difficult, there was very little to restrict a consumer's right to repair. The advent of steam power brought with it mass production and factory production, the combination of these factors meant complicated production processes were not only possible, but economically feasible on large production scales. This massive increase in the complexity of products created a disparity of capability, and with it the first distinction between producer and consumer. With goods being produced via a long journey through a complicated, factory assembly line, the average consumer was now unable to make a comparable product by hand. The same disparity applied for repair parts, and so if producers didn't make or sell parts for repairs, consumers could not repair their goods, so must instead opt to replace. The consumer's right to repair was placed in the hands of the producers. Some producers decided to benefit from the reputation that repairability afforded them. Of these, automotive pioneer Henry Ford was at the forefront, priding himself on the crucial role that repairability played in his product development. The notion of automobiles as durable products began with Ford, at the beginning of the twentieth century. A car from Ford could be bought once and repaired forever, while still retaining its value. This reputation of cars grew until the 1960s, when cars found widespread popularity. In the 1970s, advancements in economics and management sciences led to several studies which uncovered a way to encourage consumers to replace instead of repair. A policy of material obsolescence sought to intentionally reduce durability in part by making repairs more difficult, or otherwise removing incentive for repair. This system remains in place to this day, you see evidence of it in trim levels, in discontinued older parts, in the incompatibility between different generations of the same vehicle. The right to repair has been increasingly ignored by

those producers who control it, and the call for federal legislation has grown in kind. Right to Repair regulation has been adopted at the state level in several forms since an initial senate proposal in 2001. Several bills enacted in Massachusetts from 2012 to 2013 became the basis for a memorandum of understanding (MOU) signed in early 2014 by several large automotive associations which would commit the signing parties to meet the requirements of the Massachusetts law nationwide. While a crucial milestone, the 2014 MOU is lacking in several key capacities. Fortunately, the automotive industry is enormous, and there are of course many different associations, conglomerates, alliances and unions which are happy to put forward their own solutions. All these organizations benefit from supporting the right to repair, but not all benefit from the right to repair. This paper investigates the political motivations on the issue of the right to repair in the auto aftermarket as understood from the Winner perspective, using the REPAIR Act and Automotive Repair Data Sharing Commitment (Pact) as artifacts designed by their associated interest groups.