Team 67
2003 Tech Notes

Tech-Notes

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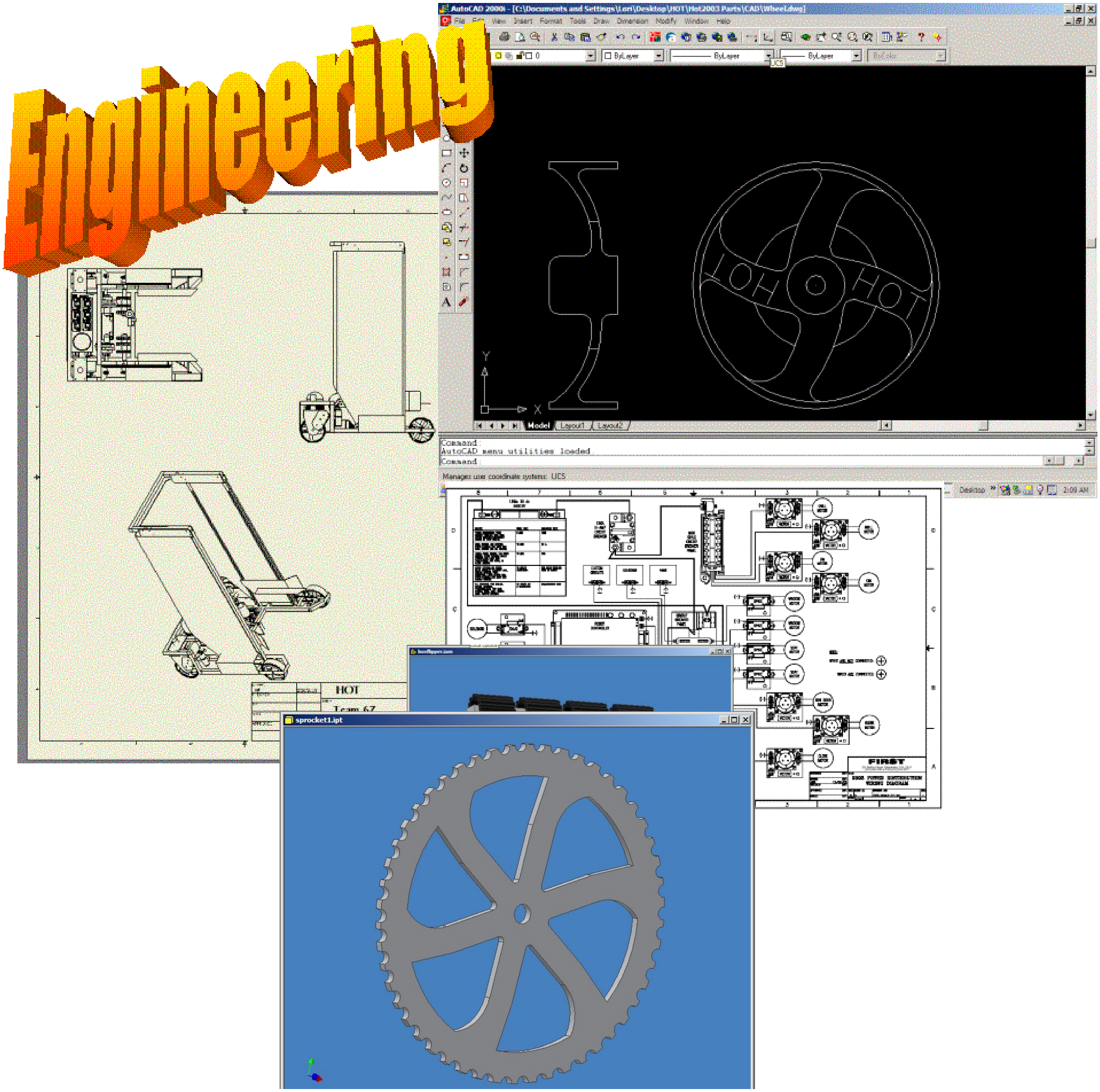

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The Stacker and Flipper

We decided the primary object of "Stack Attack" is to produce stacks of Sterilite boxes. We designed the HOT Bot with machine features that will achieve this. Thus, the main feature of our robot is a box stacker. The box stacker is designed to lift multiple boxes to form stacks as high as seven boxes. The stacker is powered by two Fisher Price motors, which gives us enough power to lift and hold the desired number of boxes. The left and right sides of the box stacker are mechanically linked to make sure the stack is not tipped as the boxes are raised or lowered.

As our stacks grew higher than four boxes we decided we needed a feature to hold the boxes steady as we moved and continued to stack. We built our stack-holder as an extendable arm that moves with the top of our stack. We also realized that most boxes will not fall oriented the way that we would need to have them so that we can pick them up. We developed a box flipper that could be used to flip boxes in any orientation on the field and could also be used to right our robot in case it gets upset. We feel these features combine to achieve the objective of "Stack Attack."

Our robot is modular. We can easily adjust, replace, or repair each major feature. We built a second identical robot from which we can exchange parts. The box flipper is removable by 4 bolts, as is the entire box stacker. We also have built a very robust robot. Our frame is built out of 1" square aluminum, welded to be strong and light. We have used this philosophy in designing our Lexan paneling. We covered everything with the polycarbonate, anticipating being jounced around quite a bit. Now, all features of the robot are protected from the jarring hits anticipated on the playing field.

Meets Criteria for the “Industrial Design” and “Quality” Awards.

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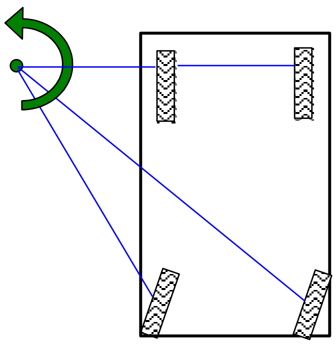
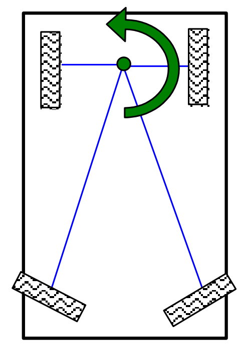
The Drive System

One of the more unique features of our robot is its drive system. In our early strategy sessions we identified three robot attributes that we felt were critical to being a good box stacker. First, the

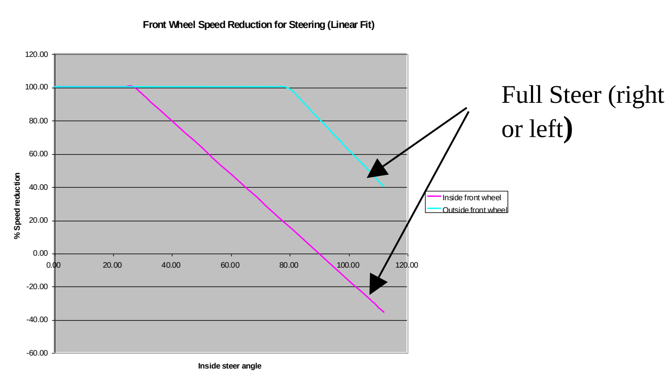


robot would have to be both fast and maneuverable in order to quickly pick up and stack bins. Second, the robot must also be very strong, to protect those boxes once they were stacked. And third, the robot must be able to get over the ramp quickly during the autonomous mode to have enough time to stack boxes and knock enough boxes off the ramp to have something to stack. The culmination of these design requirements led us to a four-wheel drive robot with two of the wheels being steerable. The four-wheel drive part gives us the strength needed, but turning by skidding wheels makes the machine turn somewhat slowly. Our steerable wheels solve that issue along with giving the machine much better directional control than a torque-steering robot. This enhanced directional control allows us to make a precise 180^{o} turn and reliably get over the ramp in spite of any boxes it might encounter in this process.



While many common vehicles have two steerable wheels, we required something that would turn much sharper than traditional vehicles; in fact, we needed something with the maneuverability of the torque-steering robots we have built in the past. To achieve this, we implemented Ackerman Steering (illustrated at right). This was executed by independently closed-loop controlling the angle of each rear wheel with a software algorithm that maintains proper alignment of the steerable wheels. Each wheel turns to a different angle based on the desired turning radius.

Furthermore, as the robot enters a turn, each wheel turns at a different speed. Using the Ackerman steering geometry, the wheel speed reduction for each wheel was calculated and approximated by linear functions. These functions are shown in the graph below for the front wheels (the change in speed for the rear wheels is not as significant and was neglected in the interest of simplicity). When the operator commands full steer (right or left), the machine pivots about a point midway along the front axle. At this steer angle, the front wheels turn at the same speed but in opposite directions. This method of independently controlling the wheel speeds affords the operator smooth control of the robot while keeping computation to a minimum.



Meets Criteria for the "Driving Tomorrow's Technology" Award

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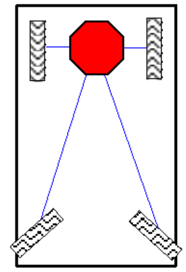
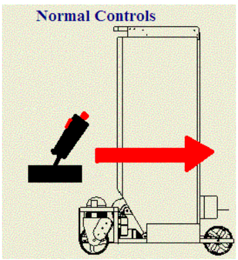
Park Brake



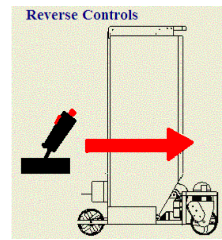
Independently steerable wheels allowed an innovative park brake feature. When the drivers hit a large stop button on the control station , the wheels turn out 45º, preventing the robot from being pushed out of position.

Reversible Controls

Another original feature incorporated into the robot is a reversible control button.

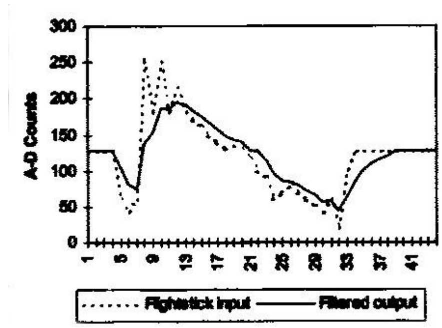


Our robot can perform many functions. Some of these are executed more efficiently when the robot is traveling in reverse. The reversible controls feature was designed to make driving in reverse more intuitive for the driver. A single button at the top of the drivers control stick toggles the reversible control feature on and off. The reversible control automatically inverts the drive direction and steering angle so that the driver is always oriented in the same direction as the robot.



Digital Filter for Motion Control

In the heat of competition, operators tend to “slam” the travel-control joystick from stop-to-stop. Such violent maneuvers tend to produce wheel slip, tipping, and inaccurate positioning. A first-order low-pass digital filter (integrator) is used to smooth the joystick signal, limiting the violent maneuvers. The digital filter provides a trapezoidal trajectory for discrete inputs and an integrated trajectory for proportional inputs such as joysticks. The algorithm allows us to use a larger filter coefficient, while retaining smooth elevator-like operation when the joystick is “slammed.”



The digital filter removes the “stair-step” edges from the pulse-width commands sent to the motor controllers. The filter coefficient is related to the mechanical time constant of the robot. It remains relatively large in order to have good response at low speeds. If the joystick should be moved suddenly and violently, the algorithm clamps the delta A-D to a small value, resulting in a trapezoidal trajectory.

The digital filter is used to control the motors driving the stacking mechanism and the stack hold-down feature as well. Accurate control of these features is essential to accurate stacking during the match and depositing at the end of the match.

Meets criteria for the Leadership in Controls Award

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Control Systems

This year controls were essential to the operation and function of this year's HOT Bot. Our autonomous programming is one of our major control features. Our other major control features

are the wearable heads-up display outputs that are a part of our driver's station and the feedback steering control on the robot. This steering control is described in more mechanical detail on its own page, but electronically below. We also spent a lot of time developing software and programming for many different inputs, including potentiometers, a yaw rate sensor and Banner optical sensors.

We have numerous autonomous dead reckoning programs (counting left and right side as separate programs). The goal of the primary autonomous mode is to make a sharp 180 degree turn and run up the ramp at full speed, knocking over boxes at the top of the ramp in the process. To accomplish this, the robot first commands a fixed steering angle toward the ramp and full throttle. As the robot begins to turn, the robot controller uses the yaw rate sensor to determine when the robot has turned 180 degrees. When the 180 degree turn has been achieved, the robot controller straightens the wheels and continues to command full throttle. By using the yaw rate feedback, the process is less prone to variation in battery voltage, obstacles, and other unknown factors, resulting in a reliable autonomous move. This program can be executed from either side of the ramp. Our second set of programs allows us to be of more assistance in knocking down the boxes on the ramp. In this program, we ride up the ramp at an angle to have contact with the most possible boxes at any given time. Again, the yaw rate sensor is used to control turn angle, but it doesn't cause the robot to turn 180°. Once again, there is a program for each side of the bridge. Our last competition autonomous program is a dead-reckoning seek-and-destroy technique.

This program makes the robot drive forward to knock down any stacks that may be in front of it before it uses the yaw rate sensor to turn and crest the ramp. We also developed algorithms for such tasks as line-tracking and box-seeking with the optical sensors which may be used in situations with less demanding time limitations. We have so many digital inputs ready to be used or in use now on the HOT Bot that there are only 3 pins on the digital DB-25 that we haven't used!

Meets Criteria for the "Leadership in Control Award"

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Robot Controller and Optical Interface Inputs and Outputs

INPUTS

Analog Inputs	Sensor	Pin
sensor1	left wheel angle pot	2
sensor2	right wheel angle pot	16
sensor3	stacker pot	5
sensor7	yaw rate sensor	11
sensor4	Auxiliary	19

Digital Inputs	Sensor	Pin
rc_sw3,4	Left line track optical sensor	15,16 (b, w)
rc_sw5,6	Right line track optical sensor	4,5 (b, w)
rc_sw7,8	Right stack seek optical	18,19 (b,w)
rc_sw9,10	Left stack seek optical	7,8 (b, w)
rc_sw1	Autonomous function 1	1
rc_sw2	Autonomous function 2	2
rc_sw11	Autonomous function 3	21
rc_sw12	Autonomous function 4	22
rc_sw13	Crate detect	10

Operator Interface Inputs

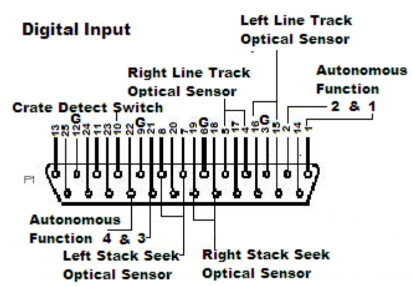
p1_y	Throttle
p2_x	Steer angle
p3_y	Box flipper
p4_x	Stacker position target
p4_y	Manual lift control
p4_sw_top	Park brake
p4_sw_trig	Manual stacker on/off
p4_sw_aux1	Stack hold down up
p4_sw_aux2	Stack hold down down
p1_sw_trig	Autonomous function 1
p1_sw_top	Autonomous function 2
p1_sw_aux1	Autonomous function 3
p1_sw_aux2	Autonomous function 4

OUTPUTS

PWM Outputs	*Location/function*	*Component*	*Variable name*
PWM1	left front motor	Drill	leftfrontmotor
PWM2	right front motor	Drill	rightfrontmotor
PWM3	left rear motor	Chiaphua	leftrearmotor
PWM4	right rear motor	Chiaphua	rightrearmotor
PWM5	left rear steer motor	Globe	left_globe
PWM6	right rear steer motor	Globe	right_globe
PWM7	stacker lift motor 1	Fisher Price	fpmotor
PWM8	stacker lift motor 2	Fisher Price	fpmotor
PWM9	Box flipper	Van door	p3_y

Relay Outputs

relay1	Spinning light on	Spinning light	relay1_fwd
relay2	Stack hold down	Window lift	relay2_fwd, relay2_rev



The Heads Up Display

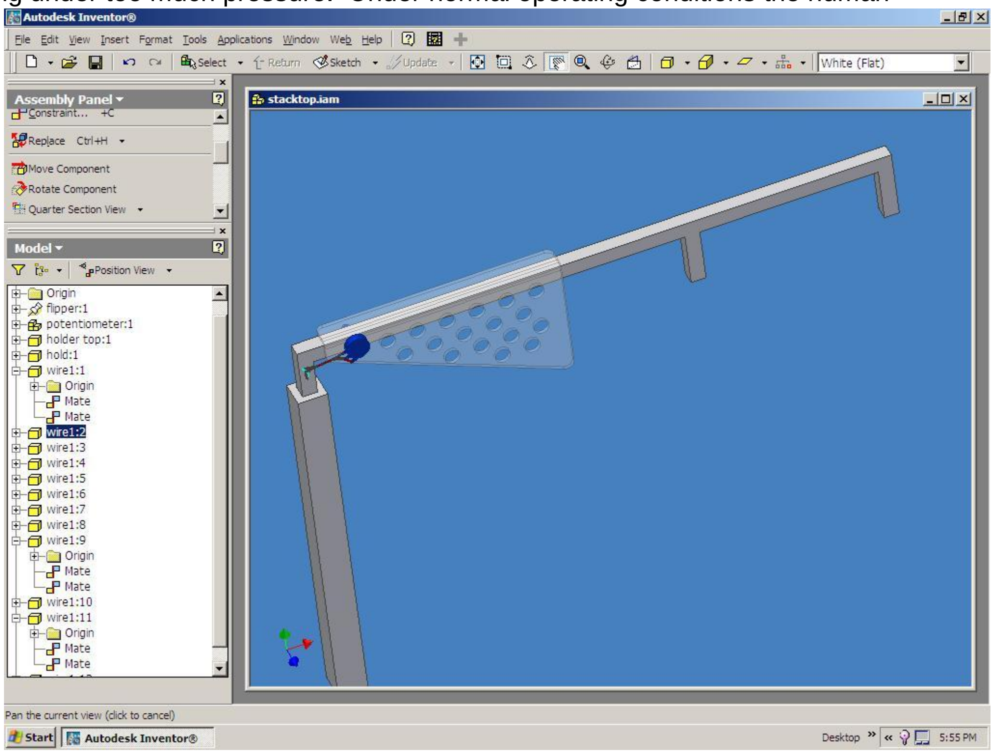
Our two human robot controllers each have a wearable heads-up display (HUD) which plugs into the control station. In order for the drivers not to take their eyes off the field, we designed hat clips with LEDs (Light Emitting Diodes). The stacker's HUD is actually a signal from the robot. When a box enters the stacking mechanism, it pushes against a limit switch when it is in far enough. The driver's HUD signals the activation of the reverse controls mode. The HUDs enable a new channel of communication between the controllers and the robot.

Potentiometer Control

Potentiometers control many things on our robot. They control our steering, our stacker height, and the hold down arm positioning. There is a potentiometer on each of our back wheels. The program tells the potentiometer to read the value of the “angle” at which it is positioned. Then it considers the desired “angle” and makes the values match. Another place that a potentiometer is used on the robot is to control the height of the stacking mechanism. A 10-turn potentiometer is used here, and it was turned one-quarter turn when it was mounted. It then completes 9-3/4 turns, stopping the chain that controls the mechanism.

Meets Criteria for the “Leadership in Control” Award

A potentiometer similarly controls the stacker height. The potentiometer allows the program to perform integral position controls. A potentiometer is also mounted at the top of the stack hold down arm. This potentiometer determines the separation between the top box and the hold down. As the top box approaches the hold down arm, the upward motion of the stacker is gradually slowed to a stop when the box and the hold down arm are in contact. This keeps the stack from buckling under too much pressure. Under normal operating conditions the human controller is relieved of coordinating the stacker with the stacker arm position. (There is a manual override, so that the human controller may control the stacker and the hold down arm separately.)



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