Team N Final Report

MCHE 201: Intro to Engineering Design

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Abstract

Robot X is a competition where teams of engineers build autonomous robots. They are tasked with completing a variety of objectives on the competition track in order to score points. These objectives include delivering table tennis balls to the center of the track, gathering small and large beacons, and avoiding cones. Four robots run on the track simultaneously and points are totaled at the end of the run. The two robots with the most points advance in the brackets until the final round where the highest score wins. This report presents Team 3’s robot and its performance in the Final Contest. The robot was designed to deliver the three table tennis balls to the outer ring in the center of the track for five points each. It then drags two of the small beacons back to the data center before docking in the Start Zone. This was accomplished using a single drive wheel at the back of the robot, and a multi-function arm at the front to deliver the table tennis balls and retrieve the beacons. To analyze the problems presented and get a thorough understanding of them into the design, a Function Tree, House of Quality, and Specification sheet were used. For example, according to the Specification sheet the key customer requirements are the ones related to the geometry of the robot and its energy needs. In addition, multiple design concepts and ideas were considered with help from charts and table such as the Morphological Chart and Evaluation Matrix. In the final competition the robot tied for thirteenth place along with three other robots out of the twenty-three that competed. The first round resulted in a disqualification due to a coding error, with the second and third rounds yielding successful runs. The judges at the final competition were not impressed with the humble look of the robot, giving it a total score of 6.95.

Good

Introduction

The Robot X competition presents teams of engineers with the task of building a robot that can autonomously navigate and complete a variety of tasks. These tasks include finding and retrieving beacons, detecting the center of the track and delivering table tennis balls, avoiding buoys, and returning to the start zone. Each task in the competition is assigned a certain point value and presents a unique challenge. The table tennis balls can be delivered into either the inner or outer ring. The large outer ring is near the ground and completely encompasses the inner ring, which is raised with a rotating top. The top has a hole cut in it that the balls are to be dropped into. Four small beacons are aligned along the curved edge of the inner ring, as well as two large beacons on the left and right edge of the track respectively. The two buoys are located in the center of the track. Hitting a buoy results in a ten point deduction while capsizing the buoy or removing it from the team's zone results in a twenty point deduction. The total number of points scored by the robot in one run determines its standing in the contest. Before designing the robot, it had to be decided which tasks the robot would complete. This was done using a risk-reward style analysis of the available points, as well as with the help of organizational tools such as the prioritization matrix and the function tree. In addition to the challenges presented by the track, the available resources are restricted. Each team was given a limit of one large motor and two small motors, and a $100 price limit on the remaining parts. The track is divided into four equal sections allowing four robots to run simultaneously. From the time the track is powered, the robots have thirty seconds to complete as many tasks and score as many points as possible. The two robots with the most points at the end of the run advance in the competition until the final round where the winner takes all. The next section of the report discusses the final robot design, and is followed by an in depth exploration of the problem understanding in the third section. The fourth section covers the design concept evaluation. Then comes an analysis of the robot's performance in the fifth section, and finally, the conclusions are presented.

a little too team-centric

Good

Final design

The final design, shown in Figure 1, chosen to compete attempts to earn points by delivering the table tennis balls to the outer ring, retrieving as many small beacons as possible, and returning to the docking position. In the center of the robot sits an Arduino circuit board topped by a motor shield which will carry out the autonomous functions of the project. The power supply plugin is faced toward the back side of the machine to help keep entanglement of the wires from occurring. The Arduino board is mounted on a frame that is 15 inches long and 9.5 inches wide. On the left and right of the Arduino board directly underneath each of the outer frame members lies an in-line caster wheel which helps for stability of the device for forward movement. Behind the crossmembers upon which the Arduino board sits is a 4-inch gap where the driving motor rests on one side

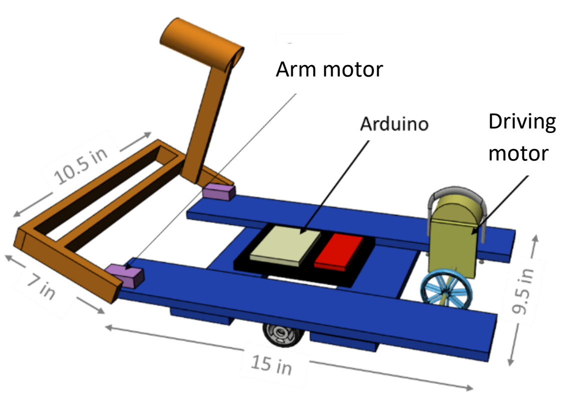

Figure 1: Final Design

of the outer frame. The motor, shown in Figure 2, is secured to the frame by a U-clamp to prohibit any uncontrollable movement. The wires from the motor are run along the outer frame to the M1 slot on the motor shield board. Threaded directly into the shaft of the driving motor is a 5/8 inch die threaded metal rod that turns as the motor turns. A 3-inch diameter drive wheel is fitted to the shaft where it is secured between two lock nuts and sealed in with epoxy to avoid free spinning of the shaft from the wheel, while still allowing motion forwards and backwards. A servo motor is fastened to the front-most position of either side of the outer frame. These two motors provide the movement action of the arm. The arm is 7-inches long by 10.5 inches wide and includes a cross-member that forms a rectangular box intended to encompass the small beacons to then drag them back to the data center. On the right side of the arm, just below the cross-member, is a right angle joint connecting a second extension of the arm with a cylinder attached to the end. This functions to deliver the table tennis balls to the outer ring once the servo action begins. In the robot’s starting position, the forearm with the cylinder attached rests perpendicular to the robot with the second arm parallel to the device. The robot is coded to run only on timing; there are no sensors used. When the robot is powered, it moves forward between the two buoys and stops near the outer ring. It is ~~then~~ programmed to stop just before the outer ring. At this point the arm rotates 110 degrees to drop off the table tennis balls and secure the small beacons. It then backs up, keeping the arm on the ground, which drags the small beacons to the data center. Finally it stops, raises the arm back to the starting position, and backs up into the start zone.

Some more-detailed figures of these sub-systems might help your reader.

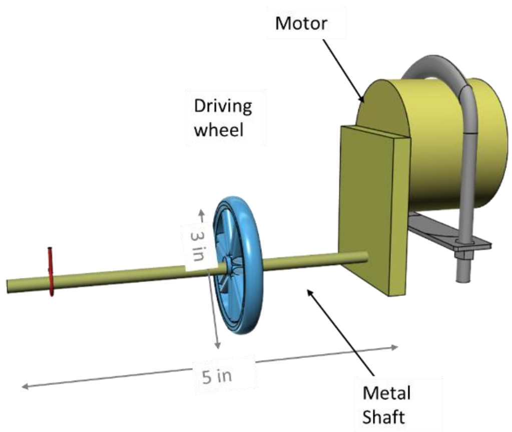

Figure2: Movement

Move figures/tables to top or bottom of column

Problem Understanding

As previously stated, the objective of the Robot X competition is to score as many points as possible given the several tasks that can be completed within a limited time frame. One of the tasks is to retrieve small beacons which are represented by four mini Tabasco bottles. The bottles are worth 10 points apiece and can net 40 total points if all are returned completely to the data center. There are also two large beacons which are represented by plastic bowling pins with modified bases to keep from being capsized. There is one beacon at the edge of each side boundary on the competition board. These pins are worth 25 points apiece if they are brought to the data center. They are given a higher point value since retrieving them is a more complex objective to complete. The third task involves delivering table tennis balls to the inner or outer ring of the competition board. Delivering a ball to the outer ring gives 5 points for a total of 15 for all 3 balls. To deliver to the inner ring however, the balls must be dropped into a rotating orifice elevated by 1 foot. As this task is significantly harder, each ball will net 20 points for a grand total of 60 points. The final objective is to avoid the two buoys which are represented as orange cones. Moving these cones will amount in a loss of 10 points per cone moved and a loss of 20 points for each cone toppled or removed from the team zone on the track.

shown in

Design tools such as the house of quality, specification sheet, and function tree help to organize ideas and simplify the design process. The house of quality, Table 1, relates the customer requirements and engineering characteristics of the project against one another for an examination of the importance of each aspect. The customer requirements were assigned a rating scale to identify a relative order of priority amongst one another. The most important requirements receive a "4" whereas the least important score a "1". Upon examination, the customer requirements determined to be most important pertain to the specific rules of the competition. These include the amount of time for setup and cleanup, the maximum dimensions in which the device is allowed to fit, autonomous operation, 30 second time limit, and the 100-dollar spending limit placed on the project. The engineering characteristics are given one of three directions of improvement. This means for each characteristic it must be decided to maximize, minimize or hit a specific target value. These directions of improvement can have positive or negative correlations when compared to the other engineering characteristics which can be found by examining the correlation pyramid. The specification sheet, Table 2, is an organization tool used to relate demanded goals for the project and goals the team has set for themselves. It is organized with separate categories for task relevancies, as well as dates of change, responsibilities of each goal, and the origin of the goal. The geometry category has the most demands out of them all which makes sense considering the strict geometric constraints in the competition. The majority of the customer requirements however are considered wants, not demands. This is in part because of the huge variety of options the robots in the competition have when it comes to which tasks to complete in which order. Also, the teams had a lot of creative freedom, leading to different wants for materials and operations. The function tree, Table 3, starts with the overall goal of the competition and is broken into multiple sub-functions until the tasks are simple enough to complete individually. In the left most branch of the tree, the scoring system is broken down for examination showing the three different path objectives for the large and small beacons, as well as the table tennis balls. In the functional coding branch, sensor operation and robot movement are broken down respectively into the simplest tasks. For motion this entails simple directional movements. For sensor operation, simple detection and multiple sensor decision making are the fundamental tasks.

what's important to your design?

what are key specs for your design?

Concept evaluation

There were two alternative concepts considered for the project that were not used. The only consistency between the two concepts and final design is the attempt to score the points for returning to the start zone to dock.

Alternate concept 1, shown in Figure 3, consists of a stationary base with an extending arm that would aim for delivering the table tennis balls to the inner ring. This concept can score a large point sum that can be from successfully completing this task alone. The arm extension would work by using the large motor to push the arm out and bring it back in. The balls would be released by an actuating servo that is activated by a sensor reading when it detects the rotating hole at the top of the ring. Alternate 2 does not run the risk of tangling any of the wires, nor does it risk making contact with the buoys because of its stationary base. Both alternate concept 2 and the design chosen would benefit from a quick running timing cycle as well as simplicity in coding. 1?

Shown in

Alternate concept 2, Figure 4, was designed to retrieve the large beacons on the outer edge of the operating zones. This design would work mainly off of sensor reading to locate the beacon and avoid the buoys and would have a fitted arm controlled by servos that would drop over the pin to drag it back to the data center. This concept would have the benefit of retrieving the large beacon(s) and netting a large point sum. However, compared to the chosen design, the coding would have been more complex as it would rely on reading sensors to determine its course of action. The design would have a tougher time avoiding the buoys since its line of movement isn't straight forward like the chosen design. Alternate 1 would struggle to finish its command set in the given time parameter of 30 seconds, and even if it managed to return both large buoys to the data center, the maximum possible point sum would be 50 points. This is rather low compared to some of the other possible point combinations.

Save for eval section

??

The final design, Figure 5, was chosen for several reasons; The simplicity of coding required to score a fair amount of points, the medium to small size and weight of the robot for practicality and maneuverability, the diversity of objectives from which points are scored, and finally the cost to build was significantly lower than the cost of the two alternative designs.

Support this with an evaluation matrix!

Label parts according to their function.

Dimension to give scale

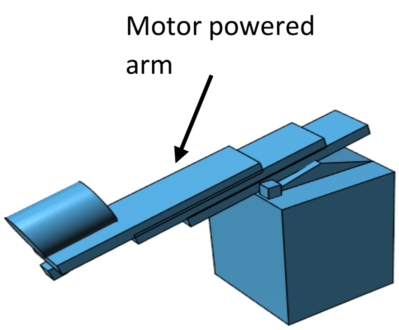

Figure 3: Stationary Design

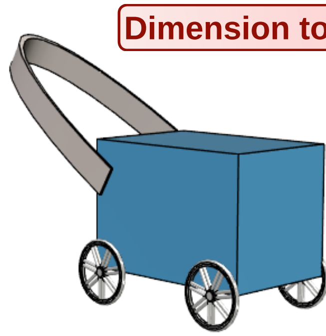

Figure 4: Beacon Design

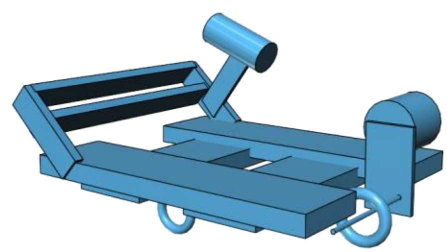

Figure 5: Final Design

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Design Performance Evaluation

In Match 1 of the final contest the robot did not perform as expected. While taking the track the robot's program started running too early and stayed on a loop. It was disqualified from the first round due to it not being boxed and ready to start at the end of the setup time. This sent the robot to the Loser's Bracket 3. In this round, the setup and boxing was successful and the robot went on to deliver two of the three table tennis balls to the outer ring. After the arm dropped, it was able to drag two small beacons back with it. Upon reaching the data center, the robot's arm lifted up to the starting position, leaving one beacon completely in the data center and one resting on the edge. It then backed up into the start zone and stopped. This resulted in a score of 55 points. Ten points were scored for delivering two of the three table tennis balls, ten more for having one of the small beacons completely in the data center, twenty points for completely leaving the team's zone, and fifteen points for docking completely in the start zone. This score ranked the robot second out of the four in Loser's Bracket 3, advancing it to Loser's Bracket 6. In this round, the robot successfully delivered all three table tennis balls to the outer

Stay formal

ring to gain fifteen points. It did not get any of the small beacons into the data center, and backed up a hair too far to earn the fifteen points for being contained in the start zone. The total 35 points earned were not enough to advance to the next round. In the end, the robot placed thirteenth, tying with three other robots. As for the judging, the robot received a total score of 6.95. This average came from a combination of the robot's design ingenuity, aesthetics and presentation with scores of 6.65, 6.70, and 7.50 respectively.

Among other things regarding the design, assumptions were made about the power available of servo motor arms. The arm used in the competition was pushing the boundaries of work that the two servos responsible for moving the arm had to do. The would stutter in place at any time could not hold the arm at 90 degrees perpendicular to the device or 110 degrees against the operating surface. Because of the false assumptions about the servo motor's strength a small arm had to be used. Because of that, the most the robot could achieve was the outer ring, small beacon, and docking points. Construction attempts were made to produce a product that could reach the inner ring with no success. Two servos were burnt out in the process, thus the final design was settled upon. The other assumption made was regarded the spacing of the small beacons around the outer ring. With the random positioning, the beacons were sometimes outside of the range of the arm, since it still had to fit between the two buoys. The final design was not made to compensate for changing small beacon placement causing a drop in the efficiency of returning the beacons to the data center. Had these assumptions been accounted for, the design would have seen a much better operating performance and higher standing in the competition.

Was this captured in the design tools?

Reference design tools or support

Conclusions

The Robot X competition brought together 23 different teams to design and build robots to compete for the highest score and the judges' interest. The competition track presented a wide variety of challenges in terms of scoring points. Points could be scored by delivering ping pong balls to either of two rings in the center of the track, retrieving both small and large beacons to the data center, and by returning completely to the starting zone. In addition, points could be lost by disturbing buoys on the track. After consideration of a couple of alternative designs, a final design was chosen. The final robot design tackled the tasks of delivering the three table tennis balls to the outer ring, returning two of the small beacons to the data center, and docking in the start zone. This was accomplished with a three wheeled design driven by the motor connected directly to the lone rear wheel. When the robot reaches the outer ring, it drops its arm delivering the balls and trapping some of the small beacons, and backs up. The arm lifts to deposit the beacons before the robot docks. In the final competition, the robot ranked thirteenth in a tie with four other robots and the judges awarded it a score of 6.95.

ok

Table 1 : House of Quality

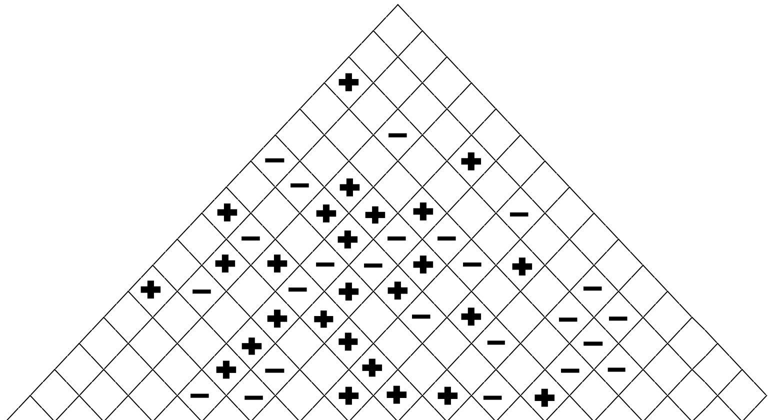
QFD: House of Quality

Project: RobotX Competition Water
Team: 3
Date: 10/25/16

Correlations	
Positive	✚
Negative	━
No correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



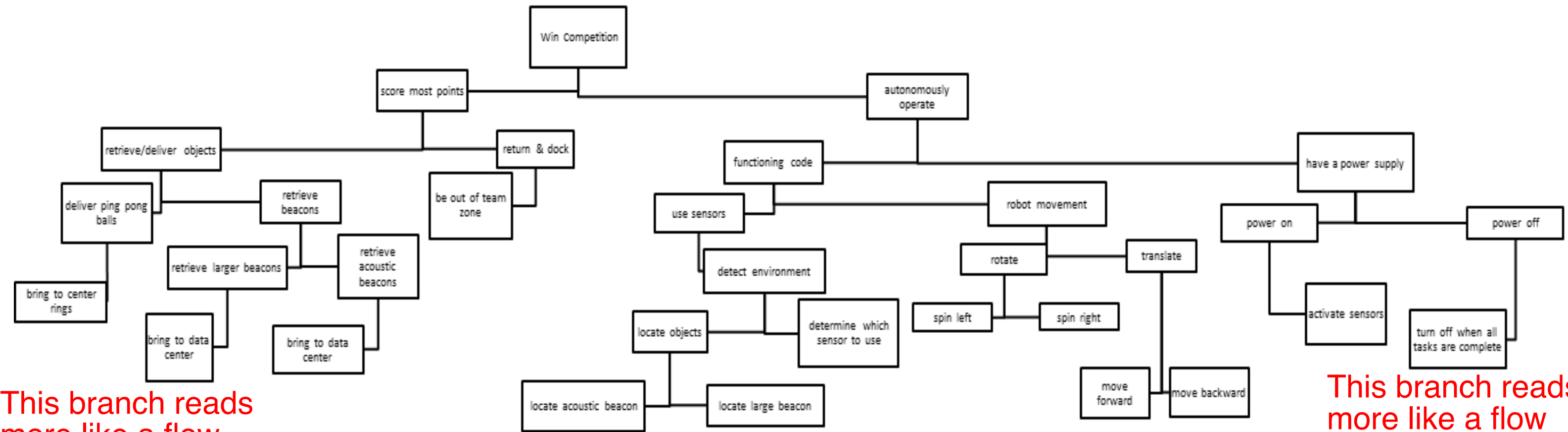
Of what?

Row #	Maximum Relationship	Customer Importance	Relative Weight	Customer Requirements / Functional Requirements	length	width	height	amount of code used	simplicity of code	number of sensors	number of motors	motor operations	operating efficiency	setup time	amount of moving parts	number of tasks	building cost	chord length	total weight
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement	◇	▼	◇	▼	▲	▼	◇	▲	▲	▼	▼	▲	▼	▲	◇
1	9	3	5%	Move small beacons to drop zone	○	○		●	▽	●	▽	▽	○			●	▽	○	
2	9	3	5%	Move large beacons to drop zone	○	○	▽	○	▽	▽		▽	○			●	○	○	●
3	9	3	5%	drop table tennis balls in required zone	●		○			●	○		○		●		○		▽
4	9	4	6%	avoid the two buoys		●	○		●	●				○	▽	●		●	
5	9	4	6%	retrieve any lost parts				●		○			●	●	○	○		○	
6	9	2	3%	return to starting position	○	○			○		●	●	○	▽	▽	●		●	▽
7	9	4	6%	Activate by start switch				○	●	▽			●	○		▽		▽	
8	9	3	5%	complete tasks in 30 seconds				○	○			○	●				○		
9	9	4	6%	shut off after 30 seconds				●		▽			○						
10	9	4	6%	set up within 3.75 minutes	▽	▽	▽		○					●				○	○
11	9	4	6%	clean up within 2.5 minutes									●		○			○	○
12	9	4	6%	fit in a 1 ft. by 2 ft. area	●	●	●							○	○				○
13	9	4	6%	max height of 1.5 feet			●					○				●			▽
14	9	4	6%	operates autonomously				●	○	▽	▽		○		●				
15	9	3	5%	operates multiple times					●		○	○	●	●			●		▽
16	9	4	6%	does not deface competition field	▽	▽				▽			○		○	▽			▽
17	9	3	5%	score most possible points				●	▽	○					▽	●	●	●	
18	9	1	2%	prevent other teams from scoring points	○		○					▽	○			●		●	
19	9	1	2%	aesthetically pleasing									▽				●		
20	9	4	6%	$100 spending limit	▽	▽	▽			○	○				●		●	▽	
				Target															
				Max Relationship	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
				Importance Rating	155.91	165	162.12	295	223.18	219.24	83.788	83.788	357.42	207.58	236.36	307.12	195.91	231.67	119.7
				Relative Weight	5%	5%	5%	10%	7%	7%	3%	3%	12%	7%	8%	10%	6%	8%	4%
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Table 2: Specification Sheet

		Final Project Specification Sheet		
Changes	D/W	Requirements	Responsibility	Source
		Geometry		
10/16/2016	D	fits within 12x24x18 inches	desgin team	contest rules
10/16/2016	W	fits within 11x23x17 inches	desgin team	design team
10/16/2016	D	must start in 2'x2' zone	desgin team	contest rules
10/16/2016	D	must drop beacons in 2'x6" data center	desgin team	contest rules
10/16/2016	D	drop table tennis balls in 6" outer ring	desgin team	contest rules
10/16/2016	D	drop table tennis balls in 12" inner ring	desgin team	contest rules
10/16/2016	W	return to stating 2'x2' zone	desgin team	design team
		Kinematics		
10/16/2016	D	Maximum component rotation < 175 degrees	design team	design limitations
10/16/2016	W	Average straight line velocity = .3 m/s	design team	design team
10/16/2016	W	Average straight line veloctiy = .5 m/s	design team	design team
		Operations		
10/16/2016	D	operates < 30 seconds	design team	contest rules
10/16/2016	W	Operates < 25 seconds	design team	design team
10/16/2016	W	motors don't run for > 7 seconds at one time	design team	design team
10/16/2016	W	code contains less than 100 lines	design team	design team
10/16/2016	W	collect all small beacons	design team	contest rules
10/16/2016	W	collect all large beacons	design team	contest rules
10/16/2016	W	deliver table tennis balls to rings	design team	contest rules
10/16/2016	W	deliver table tennis balls to inner ring	design team	contest rules
		Materials		
10/16/2016	W	wood not thicker that 1"	design team	design team
10/16/2016	W	crews no longer than 1"	design team	design team
10/16/2016	W	no etra motors used	design team	design team
10/16/2016	W	no extra sensors used	design team	design team
		Energy		
10/16/2016	D	only one arduino board	design team	contest rules
10/16/2016	D	no stored energy pre-activation	design team	contest rules
10/16/2016	D	maximum 5 volt power supply	design team	contest rules
		Dynamics		
10/16/2016	W	able to move 3 ft	design team	design team
10/16/2016	D	weigh less than 20 lb	design team	design team
10/16/2016	W	weigh less than 12 lb	design team	design team
		Costs		
10/16/2016	D	cost less than 100$	design team	contest rules
10/16/2016	W	cost less than 60$	design team	design team
		Quality control		
10/16/2016	W	Minimum of 15 device tests	design team	design team
10/16/2016	D	minimum of 10 device tests	design team	design team

Table 3: Function Tree usually a figure



This branch reads more like a flow chart than a function tree.

This branch reads more like a flow chart than a function tree.

Figure #: Caption