Requirements Based Robot Design

Indiana FIRST Forums

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Hello, I am Rufus Cochran

- 447 student from 2001 to 2006
  - From Co-Operation FIRST to Aim High
- FIRST mentor for a decade+
  - 447, 5010, and 6721
- Rose-Hulman Alumni
  - Computer Engineering
  - Mechatronics
- Controls Engineer at Roche Diabetes Care
  - High Speed Vision Systems
- Started a BattleBots team
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The Problem

- How does a team decide how to play the game?

QUESTION

- How does your team decide how to play the game?
  - Gut feeling?
  - Team politics?
  - Lord of the flies?

The Problem

- How does a team decide what to build?

QUESTION

- How does your team decide what to build?
  - King of the Hill?
  - Team Vote?
  - Free for All?

The Problem

- Once decided, how does a team follow through on that design?

QUESTION

- How does your team follow through on a design?
  - Does one mentor/teacher/student tells everyone what to do?
  - Does everyone do their own thing and hope for the best?
  - Does the team run in circles for 5 weeks then build whatever they can in the last few days?

The Risks

- What happens when you are halfway through build season and:
  - You find out the robot violates a rule?
  - You realize there is a better strategy?
  - Part of the team wants to build something else?
  - Part of the team is building something else?
  - Your out of time and can’t build everything you wanted?
  - Your out of weight and can’t build everything you wanted?

QUESTION

- How does your team choose a path forward when things go awry?
  - Dictatorship?
  - Democracy?
  - Anarchy?

One Solution

- The following process is one possible way to guide your team during the build season, but remember:
  - Every team is as unique as the people that make it up
  - One size rarely fits all
  - A process is as good as the leaders carrying it out
  - If you put junk into a process, you get junk out

The Process

- Robot Mission Statement
- Game Theory
- Strategy and Research
- Robot Requirements and Constraints
- Design Elements

The Process

- Establish a **Robot Mission Statement**, then use the tool of **Game Theory** to determine a **Strategy** which will allow for the definition of **Robot Requirements** and **Design Elements**

Robot Mission Statement

- Before we dive into the game, we have to decide what we want to accomplish as a team with our robot

- Do we want to build a robot that might perform average in the qualifying matches, but will position us to be **picked onto a strong Alliance** for the Finals?
- Do we want to build a robot that will best position us to **win all of our matches** and be a top Alliance Captain?
- Do we have limited resources and want to **build the simplest robot that can give us the highest impact** in any given match?
- Do we want to build a technically advanced robot and compete for technical awards?
- Do we want to build a robot that is fun to drive and really good for demonstrations at evens?

Robot Mission Statement

- Compete for a State Championship.

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FIRST STEAMworks

Part One: Game Theory

Game Theory

- Game Theory is a tool used in several fields of Science including Political Science and Economics.
- A very simplified version is used where the model consists of a rational agent competing in a mathematically defined competition.
  - Rational Agent: Always chooses to perform the action with the optimal expected outcome for itself from among all feasible actions
- To put it more plainly, we are going to try and find the theoretical scoring maximums for each part of the game.

Game Theory

- Using a game theory based evaluation of the scoring system accomplishes three things:

1. Makes sure the students understand the scoring rules
2. Positions optimized scoring strategies at the front of the discussion leading into system strategy brainstorming
3. Provides the team with an objective reference that can be used as an unbiased evaluation of strategies in later phases of design

Strategery (Steamworks)

- The “OPTIMAL” scoring is determined by assuming a robot that can do everything.

- “OPTIMAL” Autonomous Mode: 75 pts
- “OPTIMAL” Teleoperation Mode: 120 pts + 1 RP
- “OPTIMAL” End Game: 50 pts

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Part Two: Strategy/Research

Strategery

- Now you have a tool to evaluate the optimal scoring of an FRC game
- Add constraints to the rational agent (for example, the robot is only allowed to score in a certain goal)
- Approximate the scoring potential of strategies and confirm/deny your initial assumptions
- By walking through the optimal match flow for each maximized scoring objective, new strategies and design considerations can be found.

Strategery

- These exercises also build buy-in with the students and mentors on a strategy, reducing confusion and conflict later in the season, and provide a focus moving forward for defining Robot Requirements.

Game Theory (Steamworks)

- The "MAX" scoring is determined by assuming a robot that can do one thing maximally.

- MAX BOILER Autonomous Mode: 15 pts
- MAX GEARS Autonomous Mode: 65 pts

- MAX BOILER Teleoperation Mode: 66 pts + 1 RP
- MAX GEARS Teleoperation Mode: 80 pts

- MAX End: 50 pts

Game Theory (Steamworks)

- The "MID" scoring values are determined by assuming a robot that can do a mix of things. For example, only shooting in the high boiler with no hanging.

- "MID" Autonomous Mode: 15 pts
- "MID" Teleoperation Mode:83 pts + 1 RP
- "MID" End Game: 0 pts

Game Theory (Steamworks)

- The "MIN" scoring value is determined by asking: What is the bare minimum a robot able to navigate the easiest objectives of the game could score?

- "MIN" Autonomous Mode: 8 pts (3 + 1/3 kPa)
- "MIN" Teleoperation Mode: 38 pts (38 + 7/9 kPa)
- "MIN" End Game: 0 pts

Research

- Gather perspective on your assumptions and aspirations
- Research existing technologies
- See what other teams were able to accomplish in previous games with similar scoring objects and objectives
- Stand on the shoulders of giants

Research

- Students can put into perspective what is possible and begin to formulate better and more efficient ways of accomplishing the game objectives by building on the work of their forerunners

- By researching previous games with similar scoring objectives, strategies can be put in perspective and novel approaches can be uncovered.

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Part Three: Robot Requirements

Robot Requirements

- In engineering/business, requirements are the building blocks of a new product.
- A requirement is a clearly defined and measurable function of the product.
- When running development teams with several people in multiple locations, requirements allow everyone to have an understood path forward.

Robot Requirements

- Requirements (**REQ**) are derived from your robot **Strategy**, guided by your Robot Mission Statement (**RMS**), and bound by your CONstraints (**CON**).

Robot Constraints

- **<u>CON</u>**straints are the rules in the game manual!
  - Each one of those clearly defined and observable rules serve as anti-functions for our robot, by explicitly explaining the things our robot can not do.

Robot Constraints

- **[CON.G16]** ROBOTS may not intentionally detach or leave parts on the FIELD.
- **[CON.G27]** ROBOTS may not control more than one GEAR at a time.
- **[CON.R03]** Maximum ROBOT size, including BUMPERS and all extensions, must be constrained to one of two volumes:
  - A) 36 in. by 40 in. by 24 in. tall
  - B) 30 in. by 32 in. by 36 in. tall
- **[CON.R04]** The ROBOT weight must not exceed 120 lbs.

Stakeholder Requirements

Stakeholders

- Customers (Sponsors, Parents, Mentors)
- Business (FIRST)
- User (Students)

- Stakeholder Requirements (STR)
  - **[STR.01]** Sponsor logos visible
  - **[STR.02]** Aesthetically pleasing design
  - **[STR.03]** Competitive robot

Robot Requirments

- Given our **RMS** we are going to choose the strategy that allows us to have the largest individual impact on a qualifying match.
- We know which strategy will allow us to do this because we did a thorough Game Theory analysis.

Robot Requirments

- Using 2017's game STEAMWORKS as an example, our Game Theory analysis showed that a team could have the single largest impact on a match by building a robot that would most efficiently retrieve and deposit GEARS.

Robot Requirments

- **[REQ.01]** The Robot shall be capable of traversing the playing field quickly.
- **[REQ.02]** The Robot shall be capable of collecting a GEAR.
- **[REQ.03]** The Robot shall be capable of securely transporting a GEAR.
- **[REQ.04]** The Robot shall be capable of correctly orienting a GEAR for deposit.
- **[REQ.05]** The Robot shall be capable of depositing GEARS at the AIRSHIP.

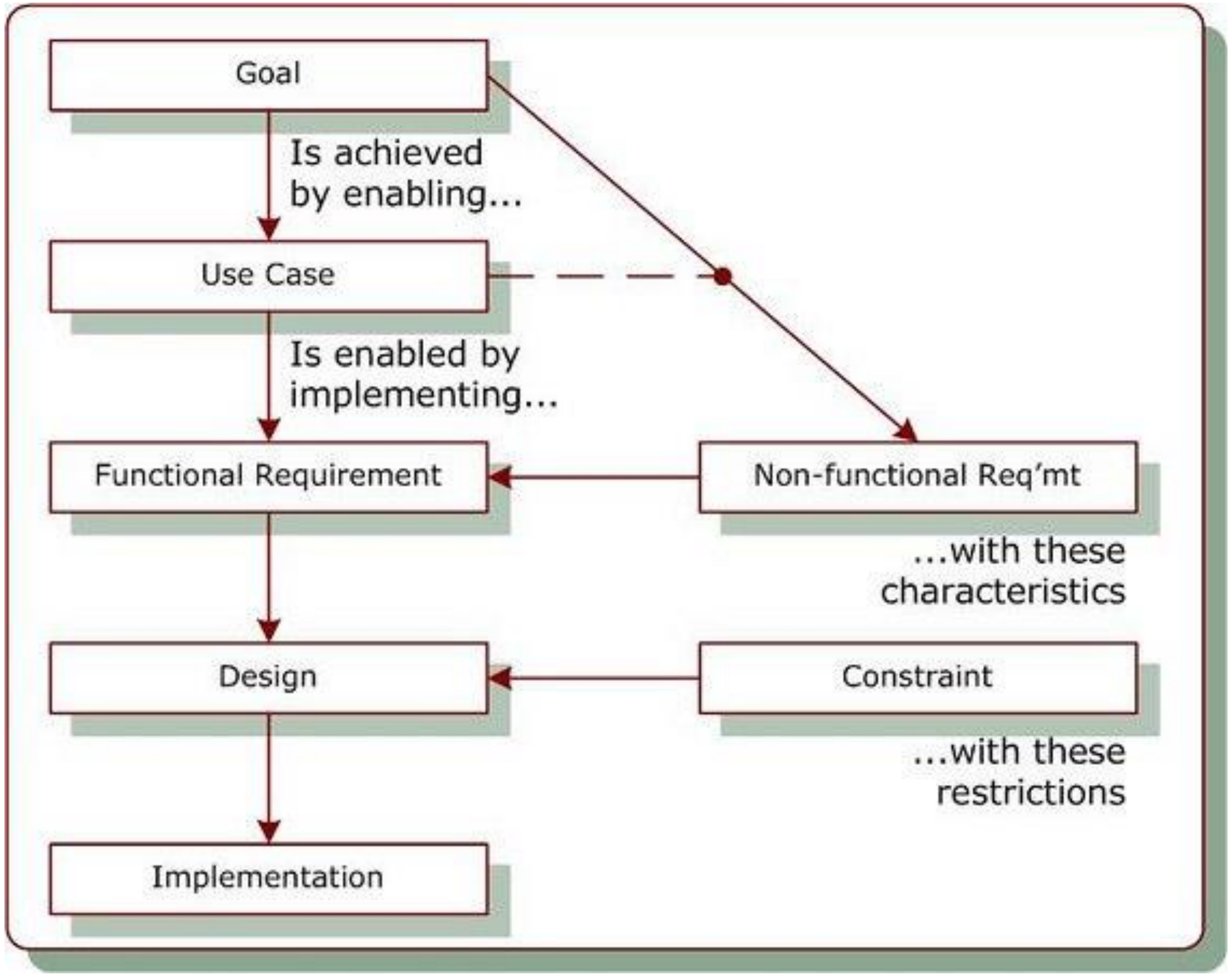
Robot Requirments

- Notice that we do not say how we are going to score a GEAR, pickup/transport GEAR, or anything specific.
- We are just defining the high level system functionality at this point.
- By codifying these initial strategy decisions in **REQ**s, we ensure that all following design decisions are made only to achieve these system functions.

Design Elements

- Next, we take the research we did in and the requirements we set, and define Design Elements (**DE**).
- **DE**s answer the question “how will we accomplish this requirement?”
- At this stage of the design phase, we begin prototyping.

What this looks like in business



Prototypes

- Build prototypes quickly, but deliberately; make sure prototypes are fair representations of the final product.
- Be cautious of "under-building" the prototype of a design you are not fond of and using that as justification for a different design.
- Use clear and objective rubrics to judge prototypes.

Summary

- By using an inclusive and objective process that brings in all team members to define a clear path forward, a team is much **less likely to waste time arguing** about the overall design of the robot or lose time due to confusion about the robot's objective.

Summary

- By clearly codifying the robot objectives in well defined and measurable Robot Requirements, **mentors and students are much less likely to get distracted or lose focus** when designing/building subsystems to help the robot achieve those requirements.

Summary

- By researching existing technologies, building prototypes, and fairly testing those prototypes; the team can be confident in its decision and path forward which **increases morale, expedites fabrication, and allows for creativity and inspiration** to drive the creation of the team’s mechanisms and subsystems, not stress and pressure.

Advice

- Where possible, try to accomplish the most **REQ**s with the fewest mechanisms possible.
- Choose the most repeatable, durable, robust solution whenever possible.
- Pick the best solution, not your solution

Live long and prosper…

- Hopefully this process can help you and your team start a new season off right.
- Feel free to adapt these exercises and methods to fit your team's style.
- Most importantly, remember why you do this:
  - "The direction in which education starts a man will determine his future in life." Plato
  - "Education is an ornament in prosperity and a refuge in adversity." Aristotle
  - "Education is the most powerful weapon which you can use to change the world." Nelson Mandela

Questions?

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Presentation

at denkbots.com