SYST 101: Intro to Systems

Lecture 27

Apr 29, 2003

C. Wells, SEOR Dept.

Announcements

- Remaining Semester Schedule
  - May 1 Review for final
  - May 2 SYST 490/495 presentations
    Theater in Johnston Center, 8:30
  - May 13 Final Exam 10:30 – 1:15

Agenda

- Semester Review
- Course-Instructor Evaluations (11:30)

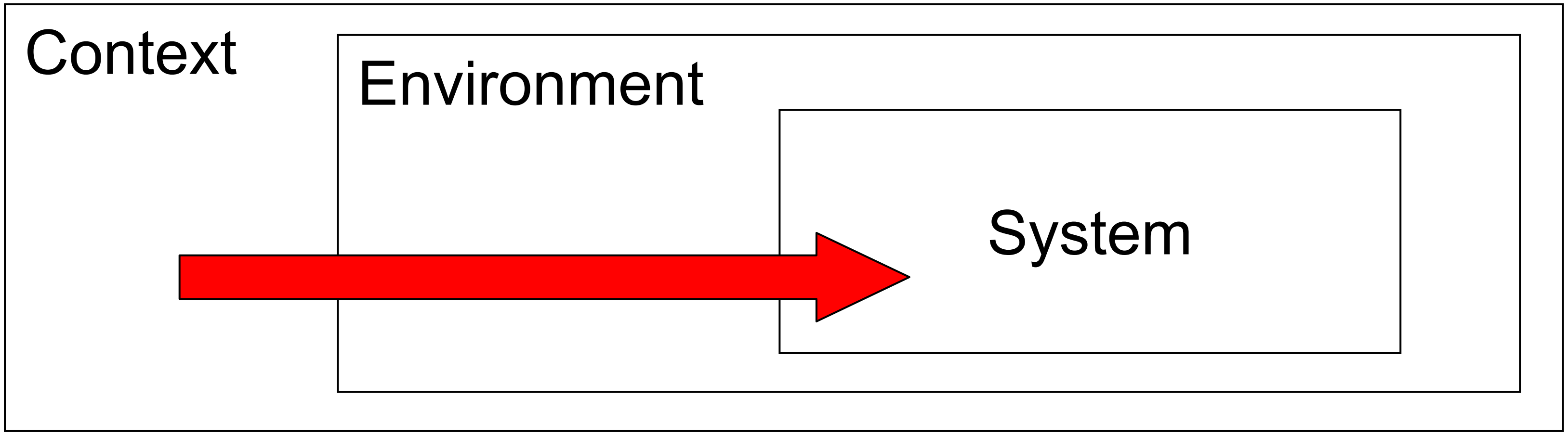
Semester Review

- What is a System? - Definition
  - System, Its Environment & Context
- Why is the System - Purpose
  - User Objectives, System Requirements
- How is the System Designed?
  - Functional Decomposition
- How is the System Built?
  - Engineering Process
  - Tradeoff Analyses

What Is A System?

- A System is:
  - A set of interacting components that together accomplish some goal or behavior; it exists within an environment, and can interact with that environment.
- Systems can be natural or man-made.
- ***Understanding of both kinds from a systems engineering viewpoint is key to changing or avoiding change to those systems.***

System, Environment, Context



- There are things outside of the system that
  - Can affect the system AND
  - Can be affected by the system.
  - This defines the *Environment* of the system.
- There are things outside the system which
  - Can affect the system BUT
  - Cannot be affected by the system.
  - This defines the *Context* of the system

Making the Distinction

- Sometimes it is difficult, and sometimes fuzzy.
- Example:
  - System: GMU
  - Environment: Fairfax County, other VA State schools
  - Context: VA State Budget, state and national economy

Why Is A System?

- All systems exist to accomplish some purpose.
  - Natural systems evolve, others are made.

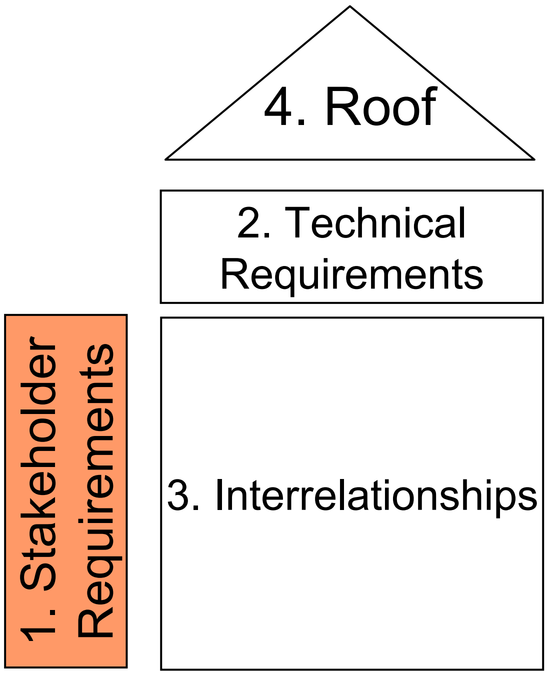
Issues Analysis

- What’s important to achieving these goals?
- How does each issue (wheelbase, wheel size...) relate to the goals and subgoals?
- The goals and subgoals are often called the Customer or Stakeholder Requirements.
- The issues that help you achieve these goals are technical requirements.
- The relations from one category to the next must be kept clear throughout the lifecycle.

Issues Analysis

- Requires logical and careful thinking about the desired end result, and how you plan to get there.
- May require re-thinking your concepts and plans as you proceed.
- May require mathematical analysis or computer simulation.
  - Calculus, Analytical geometry,

House of Quality



1. what does it need to do?

2. detailed aspects that help it do what it needs to do

3. how things on list 2 achieve things on list 1

4. how things on list 2 are inter-related

Invention Versus Need

- Invention Driven by need
- Needs not always concious and perceived
  - needs may exist that you don’t realize
  - but, revolutionary inventions create their own need
    - did we “need” the internet, webpages and browsers before they were invented?

Need is critical to success

- 1) Dont build things that aren't needed.
  - Clear recipe for going out of business.
  - You can convince some folks to buy things they don't need for a while, but not for long.

Satisfying a Need

- When a system satisfies a need, we say that it has “utility”.
- “Utility” - The system (or device) serves some purpose and does it better (in some measure) than other things. It may do it cheaper, faster, more efficiently, easier for the user, more reliably....

Utility

- "Cost-Benefit"
  - A standard term used often
  - All systems have an associated "cost"
    - Cost to buy, time to learn and use, maintenance costs
  - All (good) systems have a benefit when used.
  - Cost-Benefit is the ration of cost to benefit
    - Is what you get out of them worth what you put in?

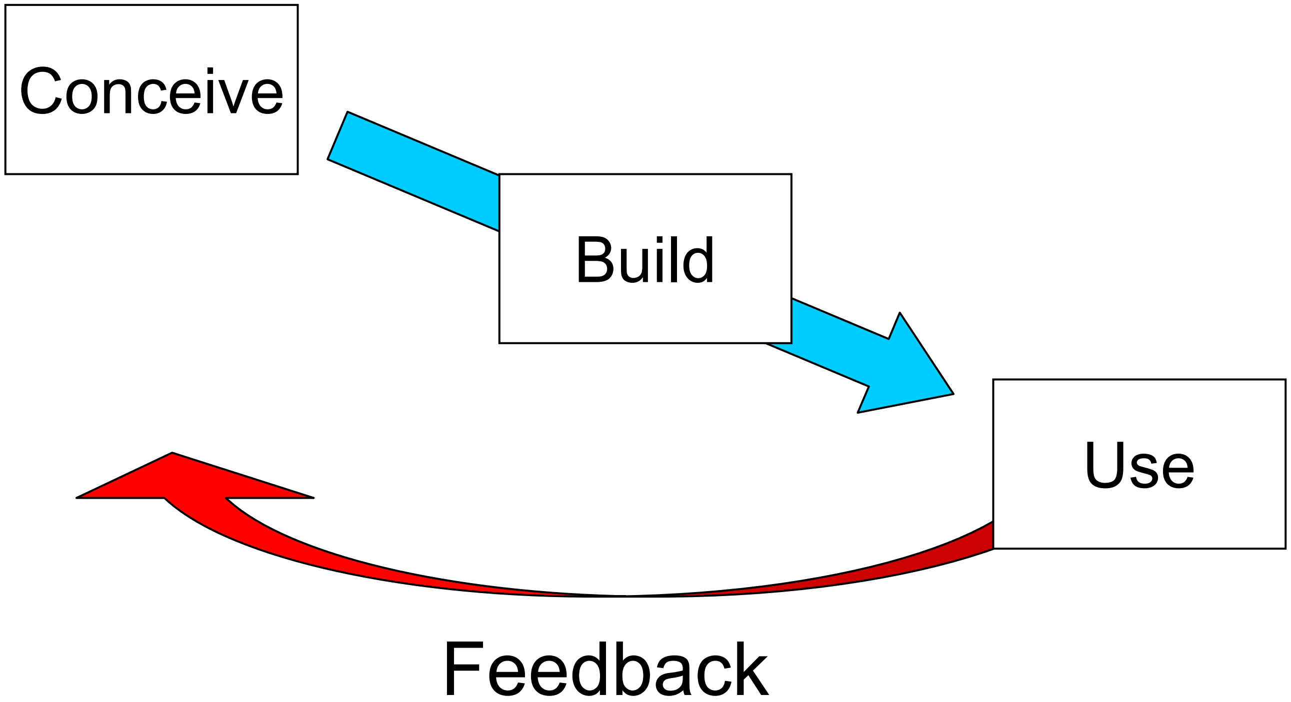
What Questions Should You Ask?

- What do you need to know to build a successful car?
- What characteristics of the track will affect how you build your car?
- What performance characteristics of your car will you measure?

Assumptions in Analysis

- Always starts with simplifying assumptions.
  - Solve the easy problem first, then add complicating factors and issues
- Always keep in mind your assumptions
  - You not really solving the real problem, you're solving something similar (you hope)

How Do Things Get Improved?



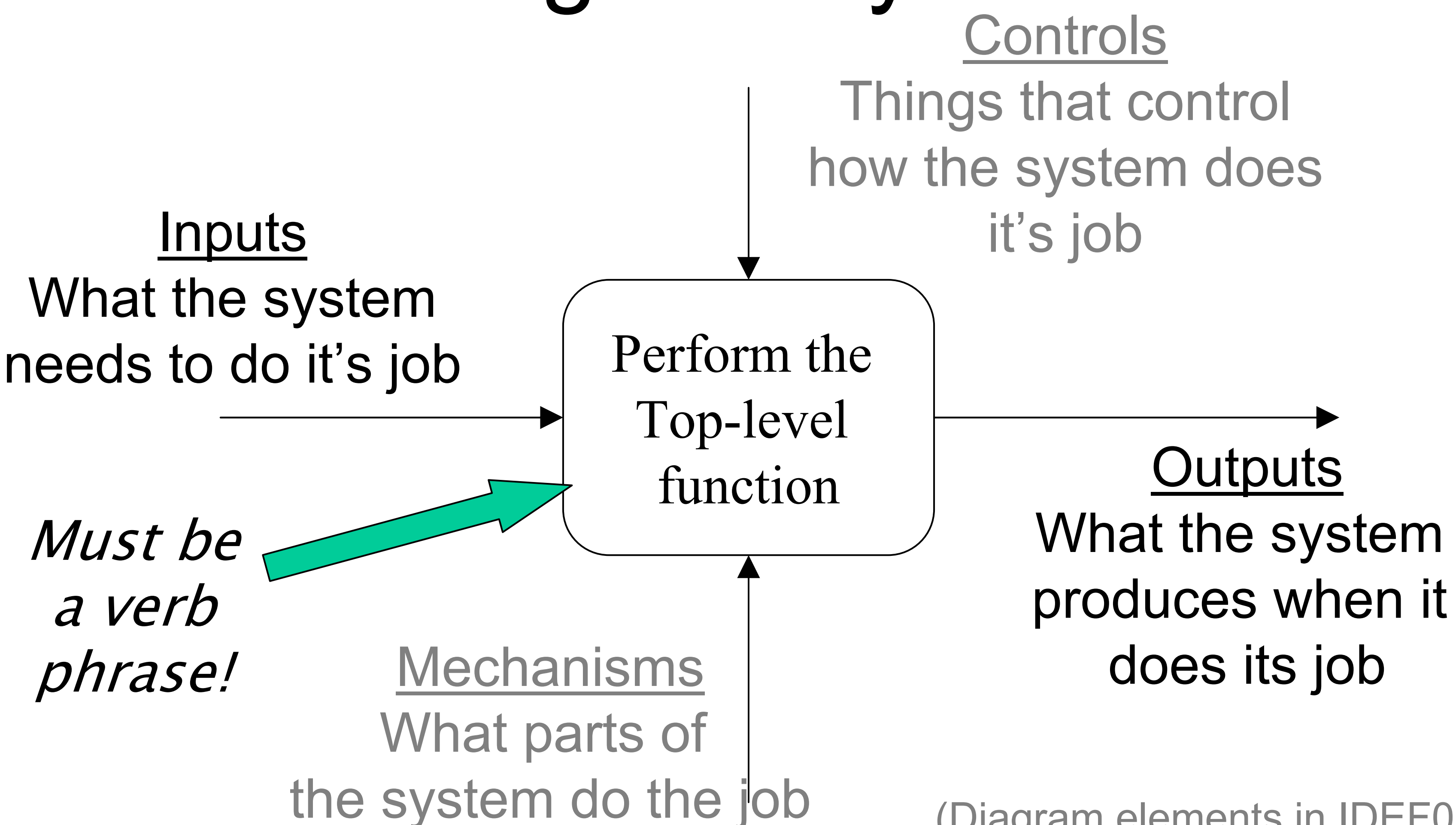
- By Feedback, where the use of the first version provides input to the second version.

Process Description

- Just knowing the functions is not sufficient
  - What's the order? What makes me decide to this OR that? When can I start doing a function?
- Dynamic descriptions are also important.

George Mason University

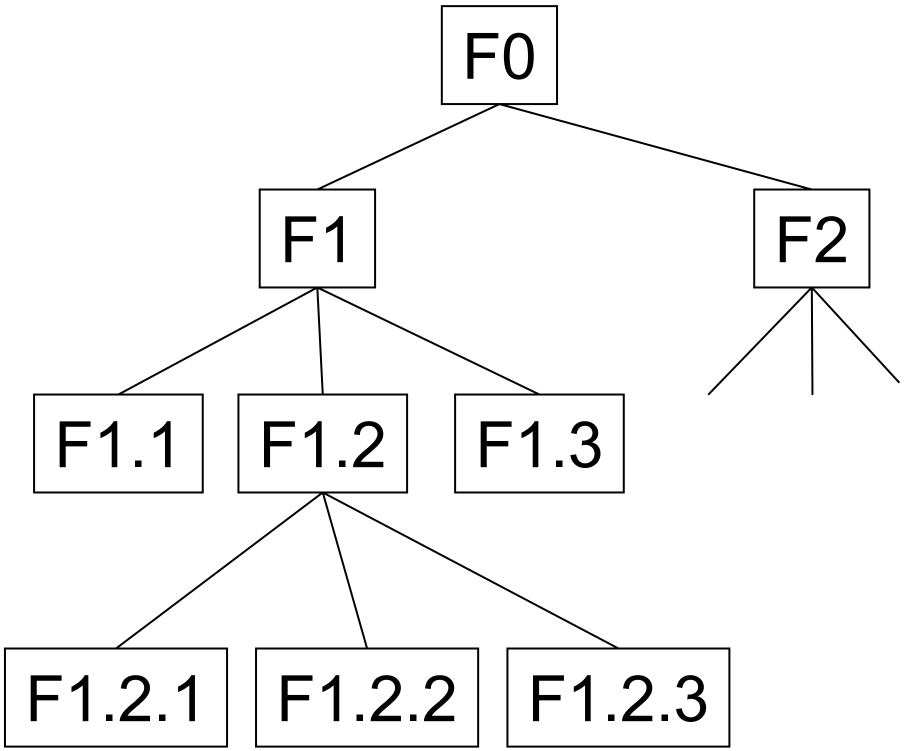
Diagram Syntax



(Diagram elements in IDEF0)

Functional Decomposition – Representation Techniques

Graphical Representation



Outline Form

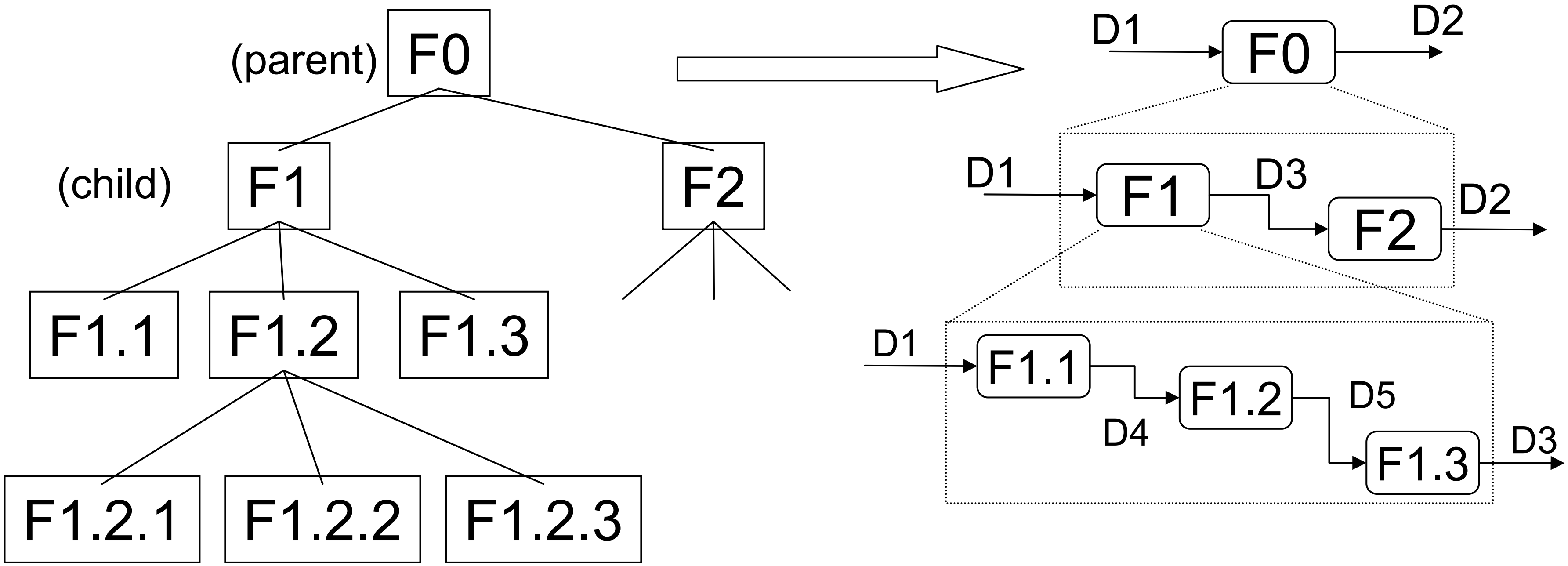
- F0
  - F1
    - F1.1
    - F1.2
      - F1.2.1
      - F1.2.2
      - F1.2.3
    - F1.3
  - F2

Functional Decompositions

- Every function that is decomposed gets it's own diagram

Hierarchical Tree

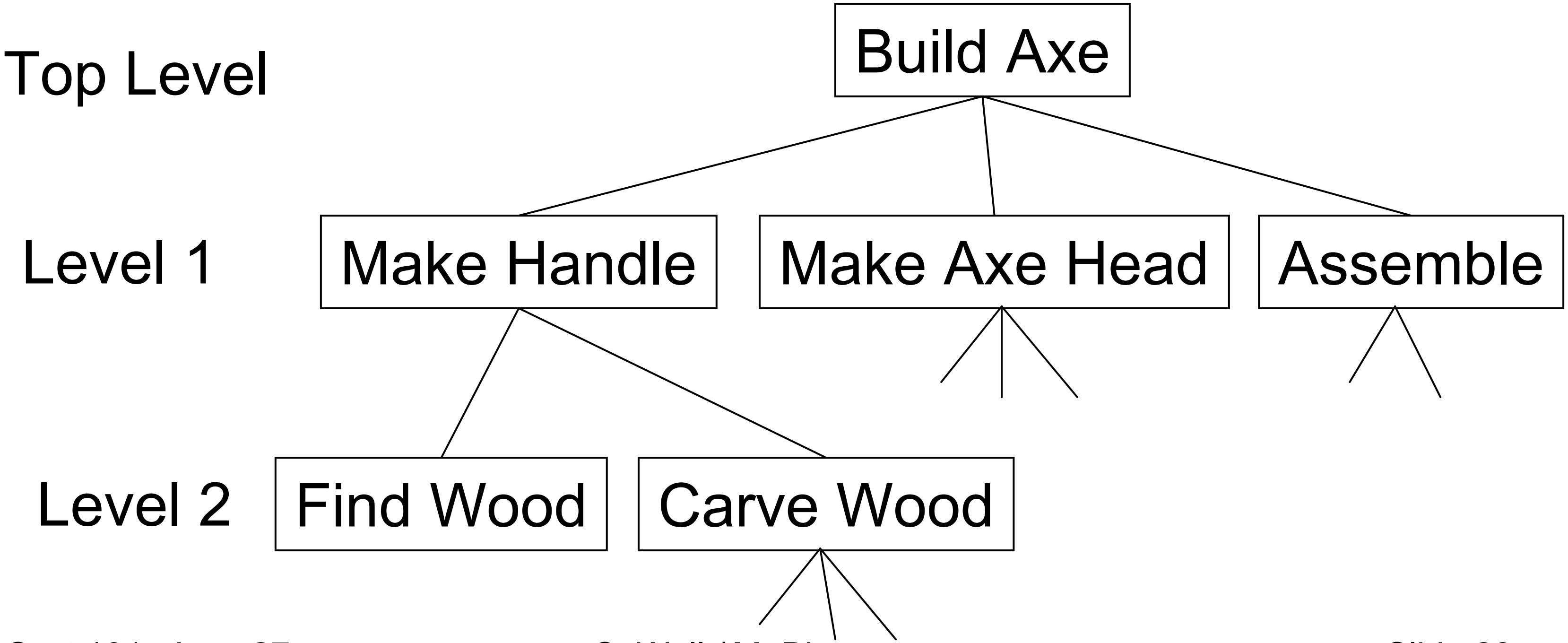
Hierarchy of diagram pages



D = "data"

Details of "Build Axe"

- The hierarchy branches out as it gets more detailed, resembling an upside-down tree.



How Is A System Built?

System Interfaces

- Systems connect to each other through interfaces
- In man-made systems, the interfaces are pretty easy to see...

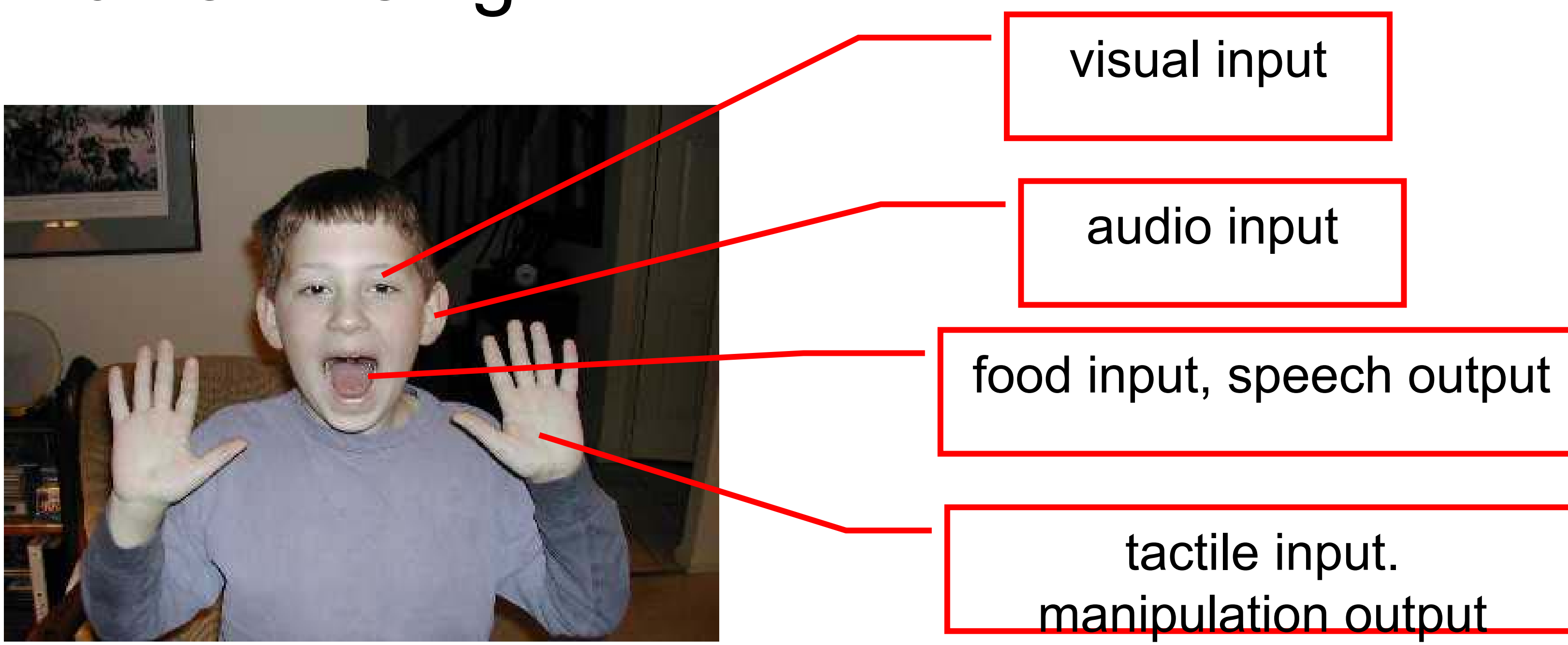
Interfaces on Common Systems

- The components of a PC have interfaces to each other

- and some of them have interfaces to you.

Interfaces to a familiar system

- Some of the interfaces to the system Human Being



Events

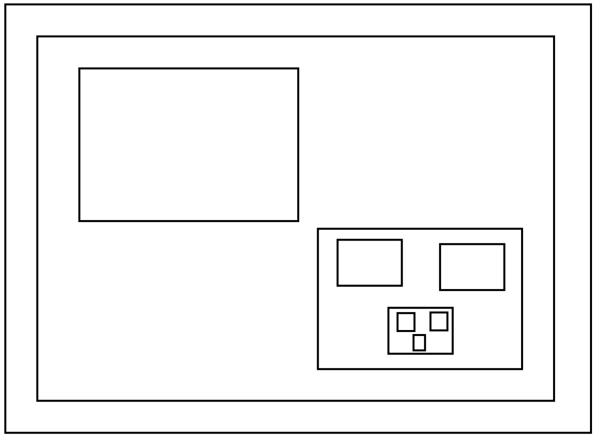
- Events are things that happen in or to your system
- Events usually have relatively short time durations.
  - Functions, on the other hand, can take a long time to perform

Example Events & Systems

- System: Road Traffic System
  - Events: Accident, Repair Activity starts
- System: PC
  - Event: Type on keyboard, move & click mouse
- System: Human Being
  - Event: Burns hand on stove, sees pretty picture, gets hungry

Internal vs External Events

- Systems are made up of sub-systems.
  - And often a system can be viewed as a sub-system to some larger system



Systems inside systems inside systems ...

Internal vs External Events

- A system can experience events that come from external systems, or can experience events that come from one of its internal systems
  - When you get hungry, your brain sub-system is responding to low-sugar signals from your endocrine system.

Events vs Functions

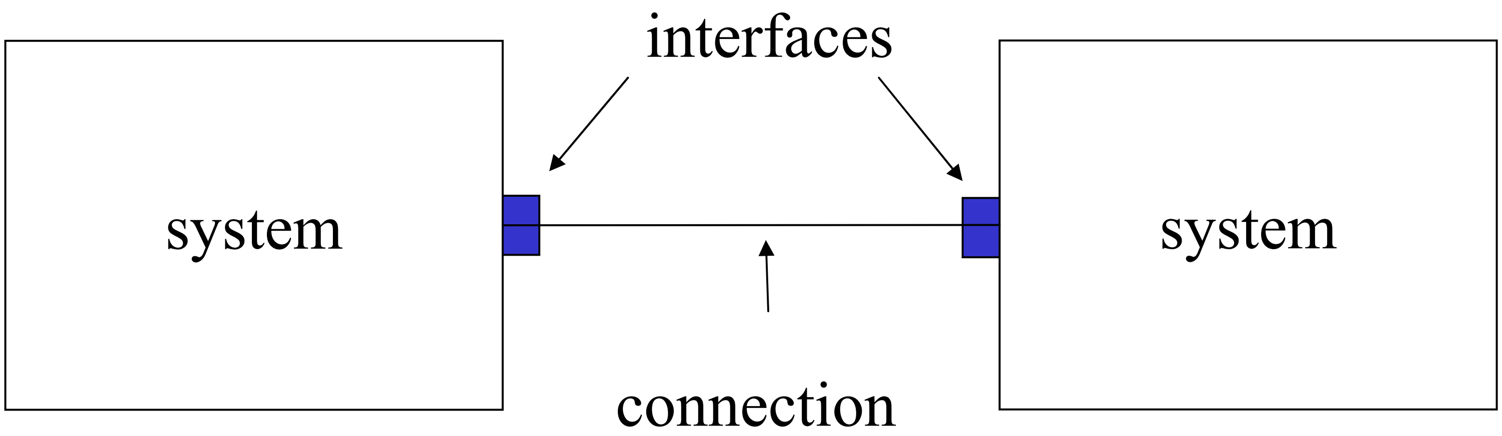
- A common modeling technique:
- Envision systems as responding to events by performing a function.
- Events “trigger” functions
- Biology: Stimulus-response

Events & Interfaces

- Systems relate to each other through their interfaces
  - Events are often “transmitted” through some sort of interface.
  - Interfaces are much easier to see in man-made systems
  - Sometimes not so easy to see in natural systems.
    - That’s what makes medicine so hard...

Events, Interfaces & Functions

- Basic modeling concept:



Stimulus-Response

- Basic general form: “When event {a} comes in over interface {i}, then do function xyz.”
  - Optional: “and send event {b} out over interface {k}.”

Failure Analysis In Lego Robots

- Like many real systems, we have a combination of hardware and software.
- When behavior is not as expected, where is the problem?
- Typically, on large project, you have your hardware team and your software team.

A Basic Problem

- Knowing you're right
- Leads to
  – Dead ends
  – Being stuck
  – Conflict with others who know they're right too.

The Pencil Point Analysis

- All the steps were right, so why isn't the answer right?
  - An assumption was invalid, but was overlooked.

Human Nature

- It's human nature, so it happens to all of us
- Not really feasible to avoid it happening
- Learn to recognize and learn how to get unstuck.

You May Be Stuck If...

- You're sure you've done everything right, and it's not working
- You know there's this hidden thing that is messing you up that you can't get to.

Model - Definition

- A model is a representation of some entity.
- A model can be an entity
- The entity does not have to actually exist.
- The model itself does not have to have physical existence.

WARNING!

- Models are not reality
  - They represent reality
  - They are simplistic
  - They are erroneous (but may be good enough)
- The problems we encounter in system engineering are really problems in the adequacy of our models

Adequacy

- The problem of adequacy is exposed when we attempt to make the “entity”
  - The realized model does not match expectations
- The problem of adequacy is exposed when we attempt to model reality
  - The model’s behavior does not match reality

Mental Models

- You have a mental model of your system in your head.
  - Especially when you designed it.
- As it operates, your mental model stays in step.
- Your assumptions about your mental model may lead you to overlook the actual behavior of your system.

Why Doesn’t It Work?

- The model is wrong
- The model is not sufficiently accurate
- The entity doesn’t match the model
- The entity is broken

- So what’s wrong, the model or the entity?
- What to you do about it?

The Secret Ingredient

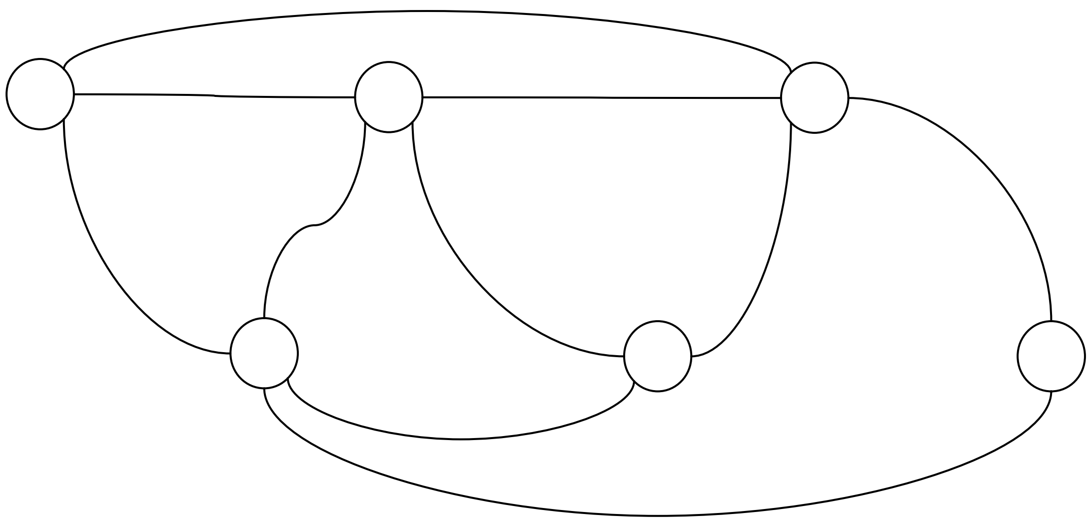
- There is a critical modification to the cycle when comparing reality and a model
  - ***OBSERVE*** the operation of the entity
    - Note the differences between reality and the model
    - Identify the (possible) cause of the differences
  - Formulate (guess) a “solution” that addresses the causes for the differences
  - Analyze the solution
  - Interpret the analysis to see if the solution is adequate

Separate Testing

- Disconnect the hardware from the software:
- Is is supposed to roll in a straight line? Does it?
  - A Test” Disconnect the motors from the wheels (remove gears) and roll it down a hill.

The Transportation Network

- When the nodes are connected together, showing various routes, one has a network



Balanced Flows

- Pick any node
- The outflows of that node must be the inflows of the other nodes.
- **Full capacity**: the flows between the nodes are so large that they cannot be increased any more without exceeding the capacity of at least one node.

Increasing the U.S. Air System Capacity

- Many advocate building more runways at select airports:
- The US network is very large (> 1000), and very interconnected.
- Increasing the capacity at one node (building runways) in a network already at full capacity has essentially no benefit
  - High cost/ low benefit.

Facsimiles & Networks, Lesson 1

- Because of the “systems-within-systems” concept, a single system cannot evolve extensively independent of the other systems in it’s enviroment.
- Linked systems must evolve together
  - Forced advancement of a single system without its associated systems will not work.

The VHS-Betamax Competition

- Early 80's, two competing video tape formats became commercially viable
  - VHS (Panasonic)
  - Betamax "Beta" (Sony)
- Pretty much universal agreement: Beta has higher picture quality.
- Example of "diffusion" into the marketplace

New Technology Diffusion

- New video technology “diffused” into the marketplace.
  - Filled a vaccuum (no real existing alternative)
  - Very useful
- Why do we only see VHS now?

Licensing = Higher Diffusion Rate

- Sony refused to license other companies to manufacture their format
  - Retain all profits for themselves
  - It's the better machine - everyone will have to come to us
- Panasonic licensed numerous other makers
  - Essentially flooded the marketplace with VHS machines
- More VHS machines, more VHS tapes made, more stocked in video rental stores....

Result

- Vast majority of consumers had VHS machines, only wanted VHS tapes.
- Movie makers stopped making Beta versions because the market was too small
- Beta essentially disappeared.
- Same phenomenon with laser videodiscs.

Lesson 2

- The best product does not guarantee success.
- VHS succeeded because *as a system*, it provided more utility to its environment:
  - Environment = the public, the collection of other manufacturers, movie makers, video makers
- Sony fatally limited the utility of Betamax to the environment by refusing to license other manufacturers to make Beta decks.

Lesson 3

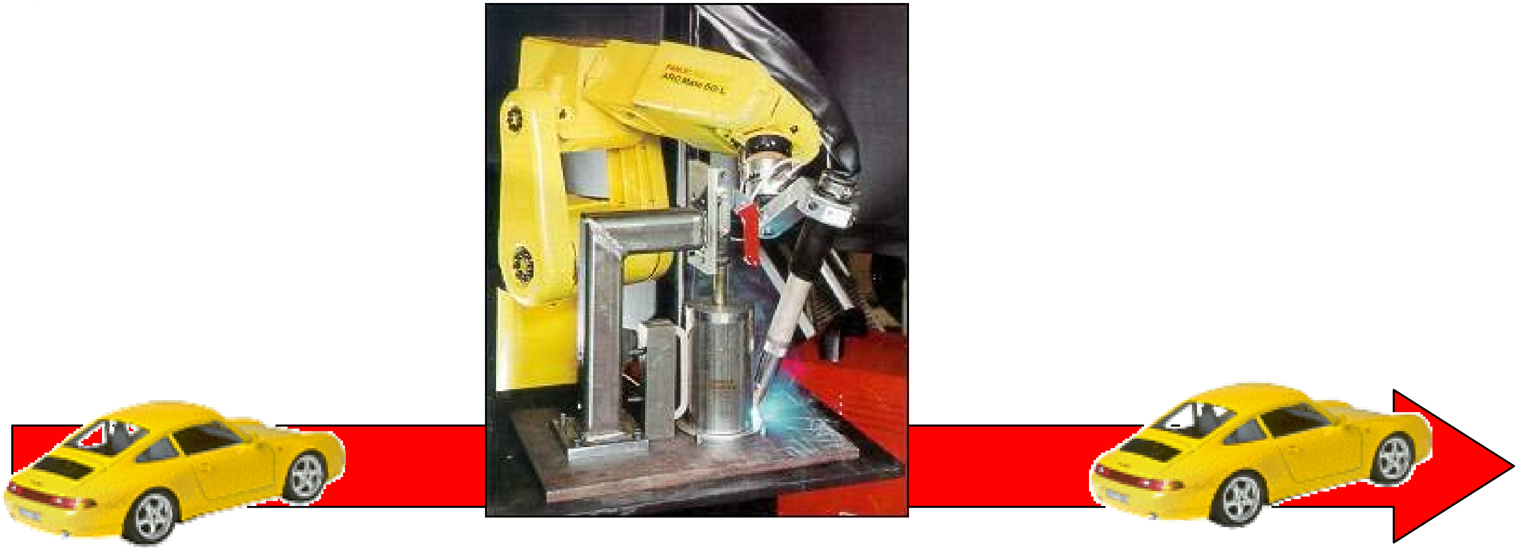
- Standardization can improve utility
  - "Item X doesn't work with anyone else's system, just their own."
- Unless you're so unique, so good (and so arrogant) that
  - your product doesn't need to work with anyone else's, or
  - there are no other products for yours to work with.

Lessons

- The tools of systems engineering are changing
- Evolution supported by computing power will continue to improve the basic engineering process

Assembly Station View

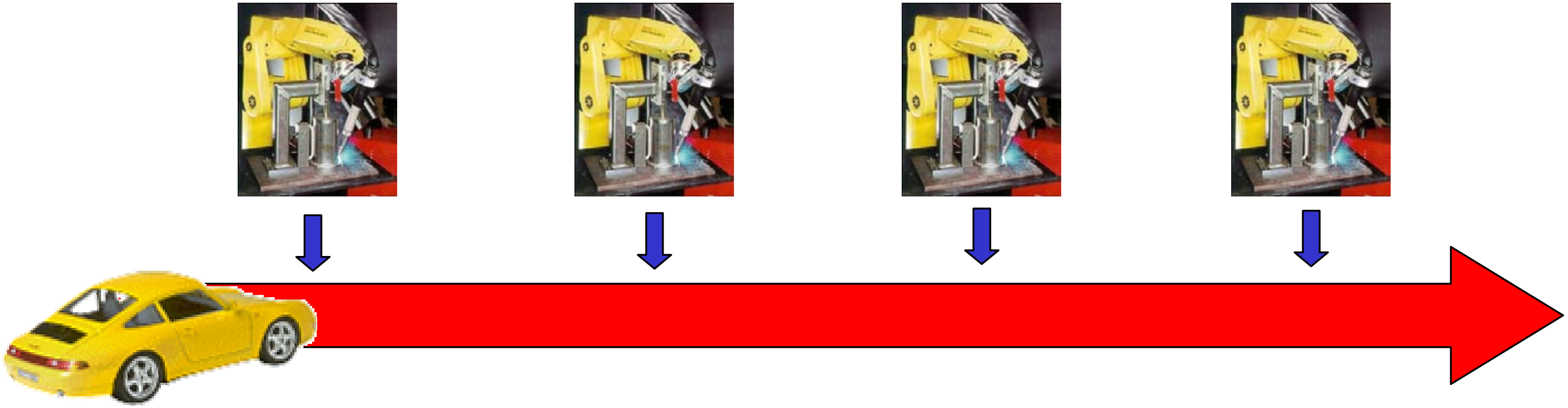
- Take the view of the assembly station
- Cars come in, you do your work, cars go out...



George Mason University

Automobile View

- (I am a car)
- I move through a series of stations, each one provides me with one of my parts.



Alternate Views

- Often taken during the system design process
- Helps assure completeness
- In software, often associated with the object-oriented paradigm.
  - "Active" versus "passive" objects

The Waterfall Process

- Hall systems engineering life cycle

Program Planning

Project Planning

System Development

Production

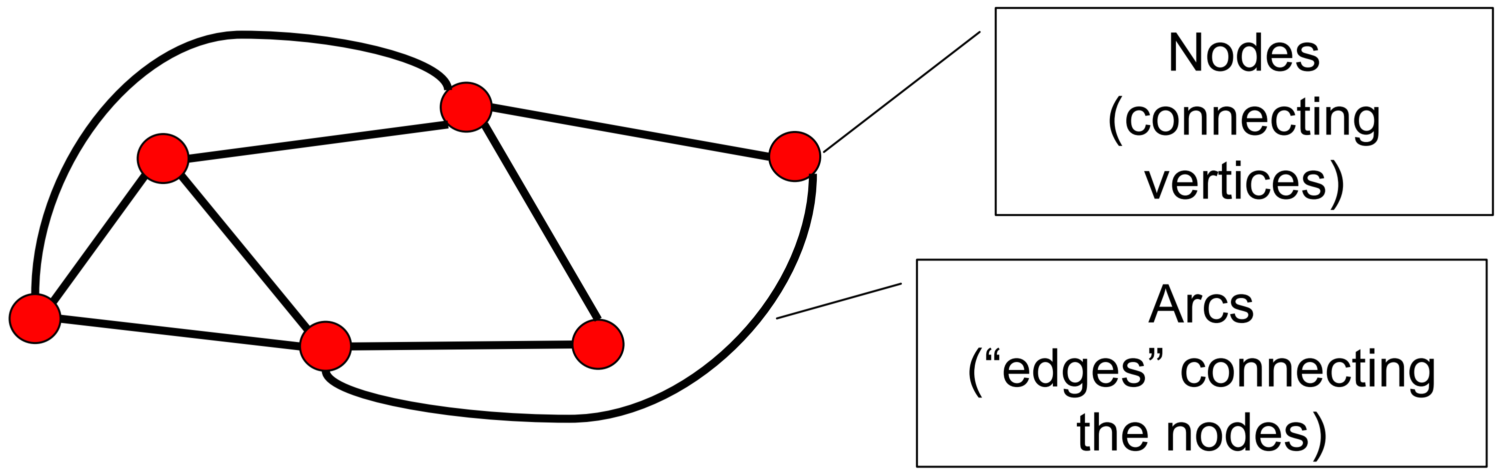
Distribution

Operation

Retirement

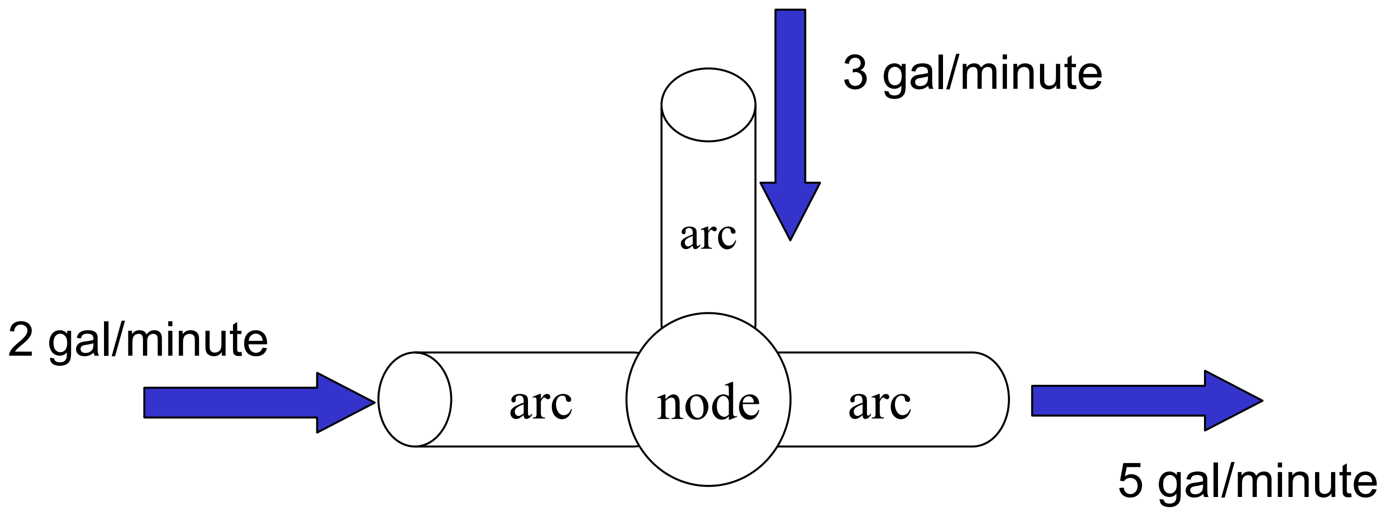
Network Calculations

- A set of water supply or sewage pipes in a city can be considered a network
- (Almost) any combination of nodes and arcs can be considered a network



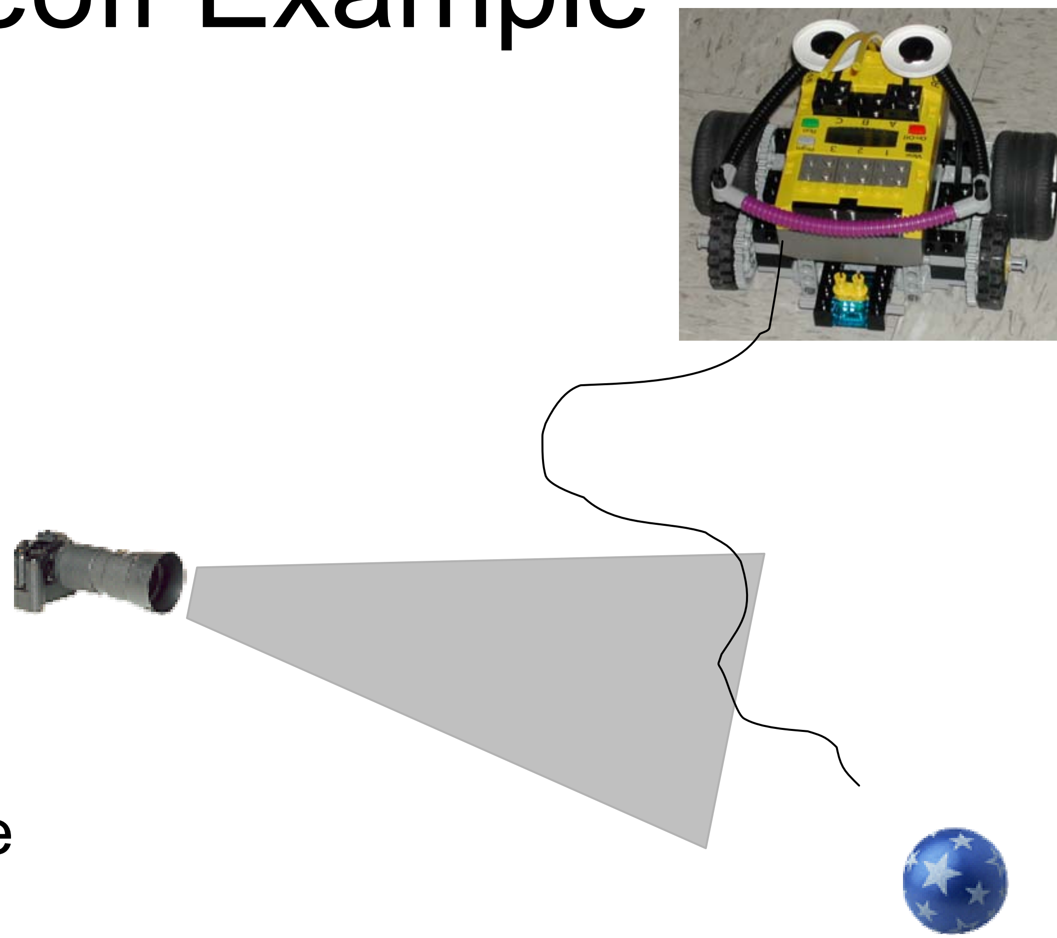
"What Goes In, Must Come Out"

- In electrical engineering, it's known as Kirchoff's Current Law:
  - The sum of the flows entering a node must be equal to the sum of the flows exiting the node.



Tradeoff Example

- Robot guided by fixed, remote sensor.
- The sensor guides the robot towards the ball; when the robot gets close enough, it uses its own sensors to detect and grab the ball.

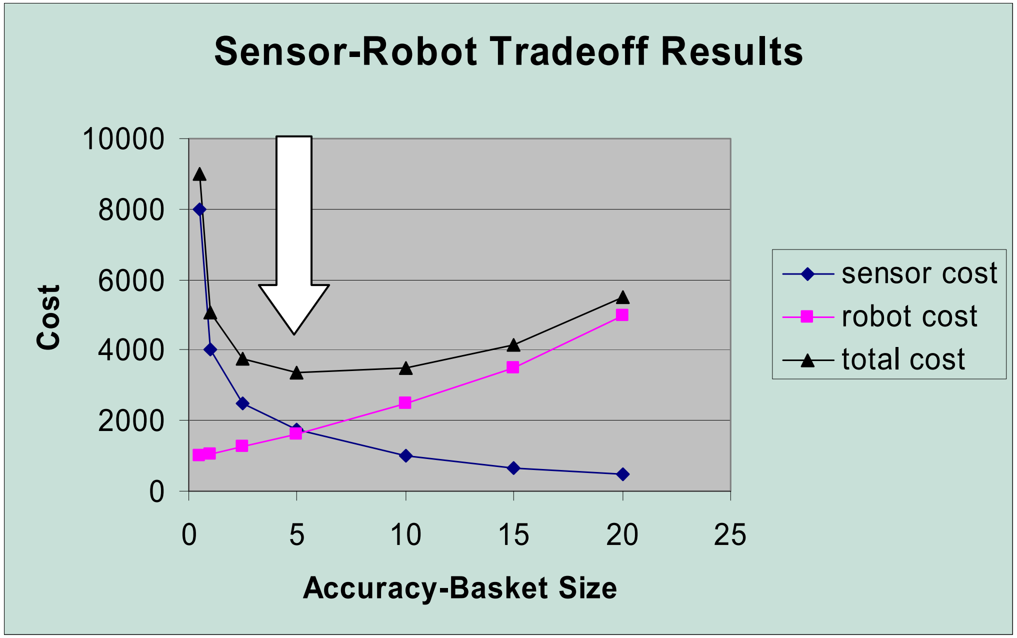


George Mason University

Total System Costs

- one independent variable - sensor accuracy
  - for each sensor accuracy value, use the cheapest robot possible

sensor acc	sensor cost	robot cost	total cost
20	500	5000	5500
15	650	3500	4150
10	1000	2500	3500
5	1750	1600	3350
2.5	2500	1250	3750
1	4000	1050	5050
0.5	8000	1000	9000



Course Evaluations

- A “volunteer” will collect and deliver completed eval sheets to:
  - Book Depository, across from the Info Desk in the Johnson Center

Assignments

- ORGANIZE NOTES
- STUDY FOR FINAL