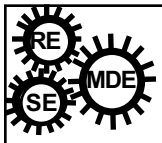
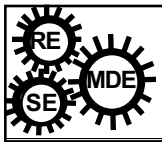


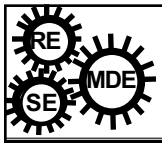
Introduction to KAOS Goal Modeling

Acknowledgements: Erik Fredericks



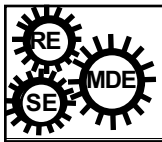
Agenda

- What is goal modeling?
- Goal modeling with KAOS
- Models at run time



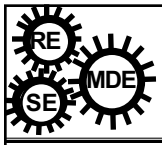
What is goal modeling?

- What is a goal?
  - Representation of stakeholder objectives
- Who are the stakeholders?
  - Anybody interested in system
    - Developers, customers, maintainers, etc.
- What is a goal model?
  - Hierarchical arrangement of goals
  - Demonstrates relationships between goals



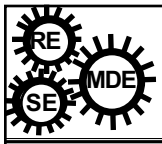
What are goals?

- Examples of goals:
  - Camera sensor must have 180 degree field of view
  - Radar sensor is always on
  - All sensors must provide reliable data
- Examples of non-goals:
  - Camera software implemented in C
  - Radar housing painted red

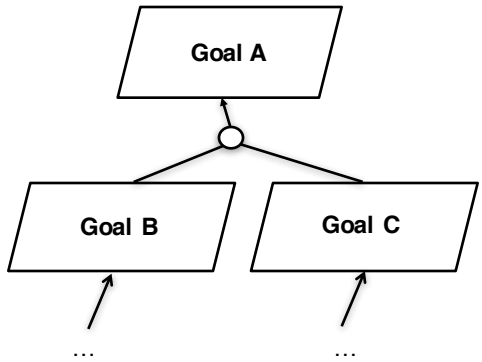


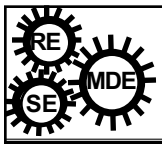
Goal hierarchy

- Goals can be decomposed from high-level objectives to low-level requirements
- Each goal refined with sub-goals that define how it can be satisfied
- Leaf-level goals are considered to be **requirements**



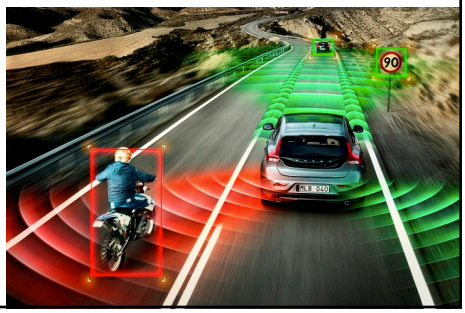
Goal hierarchy

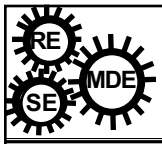




Running Example

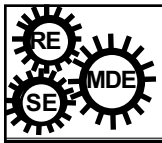
- Autonomous vehicle
  - Different types of sensors
    - E.g., camera and radar
  - Main objective: keep vehicle within lane





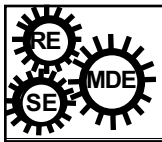
High-level vs. low-level goals

- Order these goals from high level to low level
  - Camera sensor provides data to processing unit
  - Vehicle must always stay within lane markings
  - Camera sensor must always be ON
  - Camera sensor detects objects within 10 meters



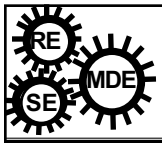
High-level vs. low-level goals

- Order these goals from high level to low level
  - Camera sensor provides data to processing unit
  - (1) Vehicle must always stay within lane markings
  - Camera sensor must always be ON
  - Camera sensor detects objects within 10 meters



High-level vs. low-level goals

- Order these goals from high level to low level
  - (2) Camera sensor provides data to processing unit
  - (1) Vehicle must always stay within lane markings
  - Camera sensor must always be ON
  - Camera sensor detects objects within 10 meters



High-level vs. low-level goals

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  - (2) Camera sensor provides data to processing unit
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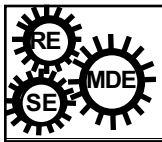
  - (3) Camera sensor detects objects within 10 meters



High-level vs. low-level goals

- Order these goals from high level to low level
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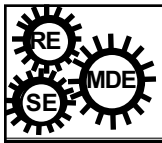

High-level vs. low-level goals

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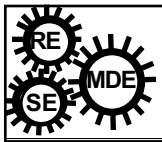
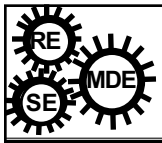


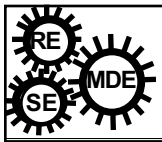
Types of goals

- Functional goals
  - "Hard" goals
  - Functions that system will perform
  - Well-defined criteria for satisfaction
  - E.g., vehicle always stays within lane markings
- Non-functional goals
  - "Soft" goals
  - Desired system qualities
  - Hard to define and quantify
  - Reliability
  - Quality
  - E.g., automatic stop is not jarring to passenger



Types of goals

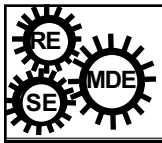
- Safety goals
  - Ensure system consistently runs safely
  - Does not endanger people or system itself
  - E.g., sensor automatically shuts off if voltage exceeds maximum
- Failsafe goals
  - Provide safe fallback state in case of error
  - E.g., system shuts off if camera sensor is damaged



Goal exercise

- Identify the **goals** in the following paragraph:

Company X is designing a new autonomous vehicle. Their autonomous vehicle system comprises at least two sensors: a camera and a radar. Both the camera and radar are responsible for sensing objects at a minimum distance of 10 meters. These sensors can communicate to a CPU via a secure CAN bus, at which point the CPU parses the incoming data. For safety purposes, at least one sensor must be active at all times.



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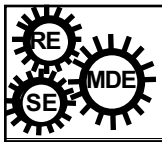
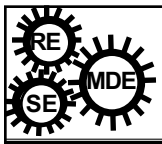


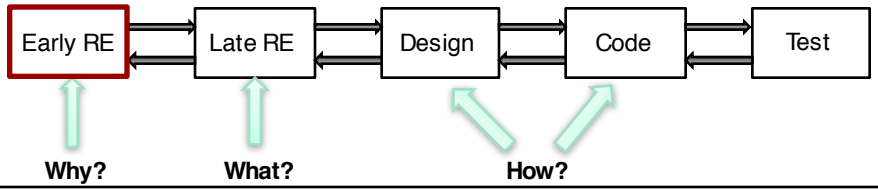
Why do we use goal models?

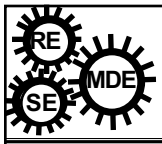
- Provide rationale for requirements
- Identify stable information in system objectives
- Guide requirements elaboration / elicitation
- Provide visual depiction of relationships and dependencies between objectives



When to use goal models

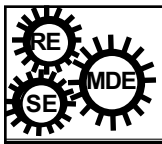
- Early in requirements engineering process
  - Identify problems
  - Explore solutions and alternatives
  - Performed prior to UML modeling
  - Continually refine goal model as new requirements or obstacles surface





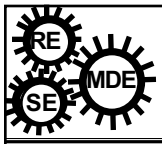
Goal modeling with KAOS

- Different approaches exist for creating goal models
  - KAOS, i*, UML (use cases)
- We will be using KAOS in this class for goal modeling

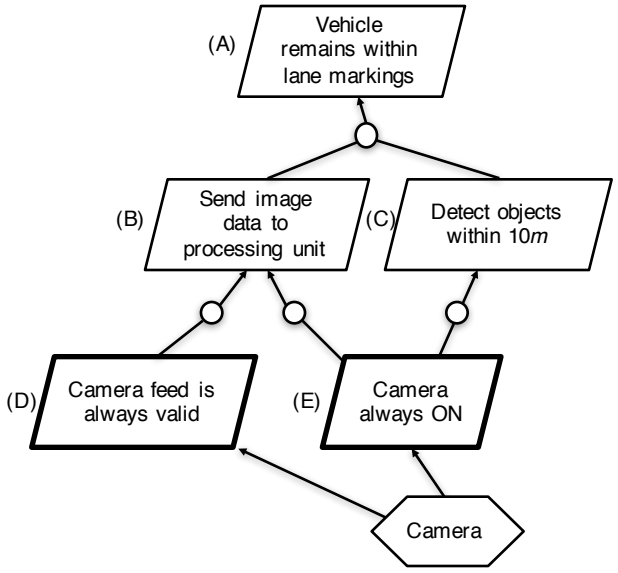


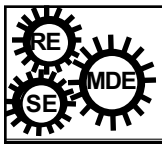
KAOS notation

- Refine goals into requirements
- Objects in KAOS goal model
  - Goal
  - Agent
  - Requirement / Expectation
  - Refinements



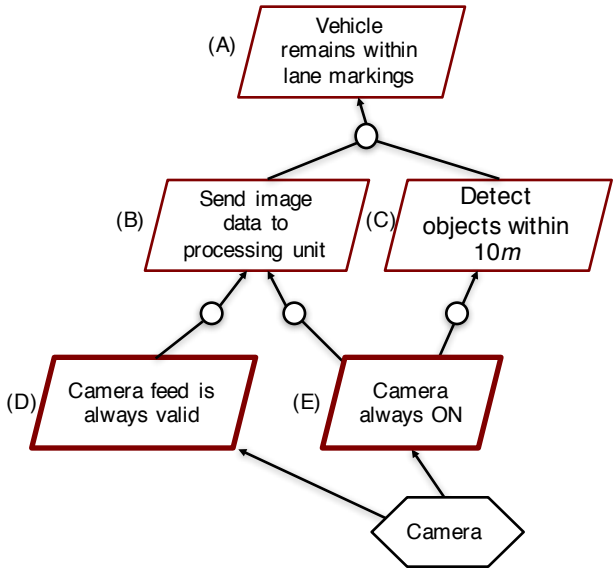
KAOS notation

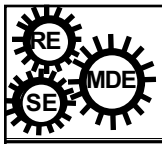




KAOS notation

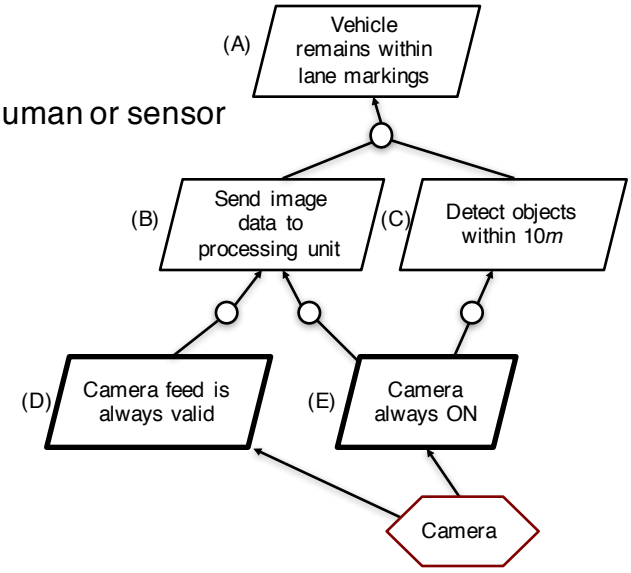
- Goals





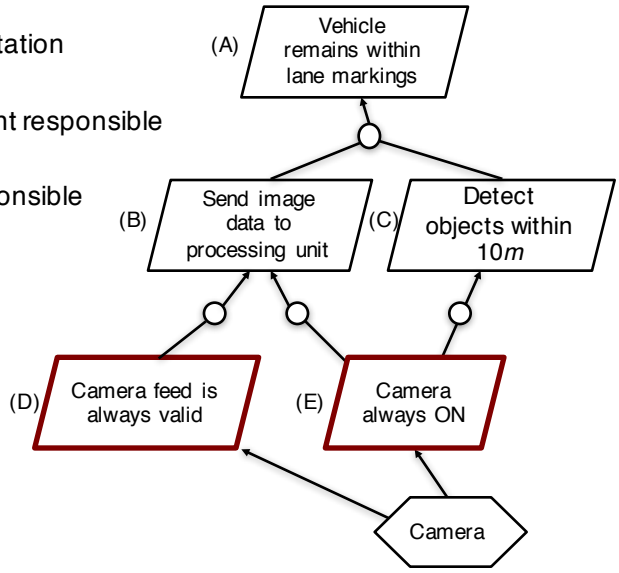
KAOS notation

- Agent
  - Agent can be human or sensor

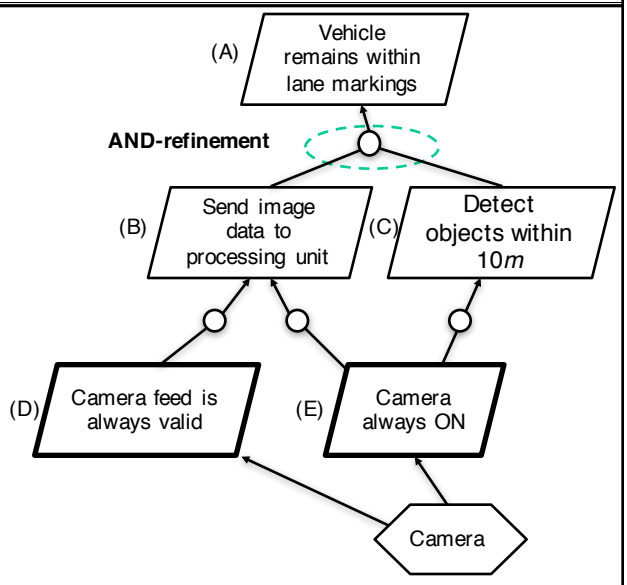


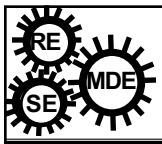
KAOS notation

- Requirement / Expectation
- Requirement:
  - System component responsible
- Expectation:
  - Environment responsible



KAOS notation





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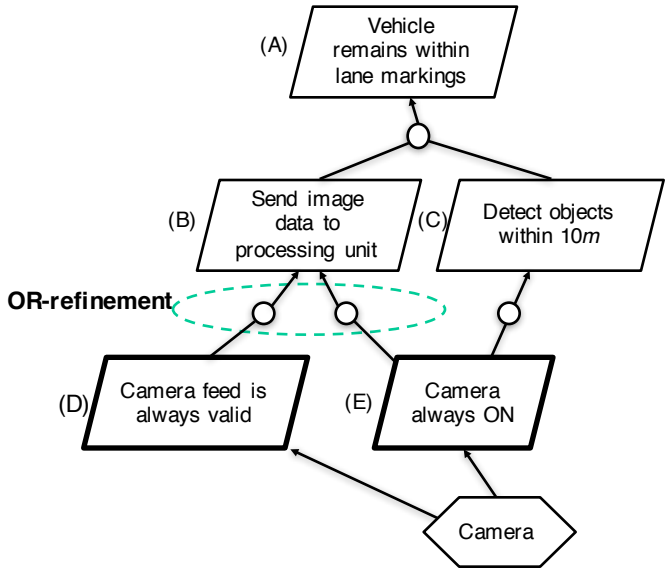
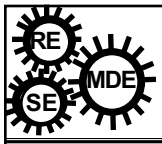
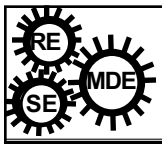


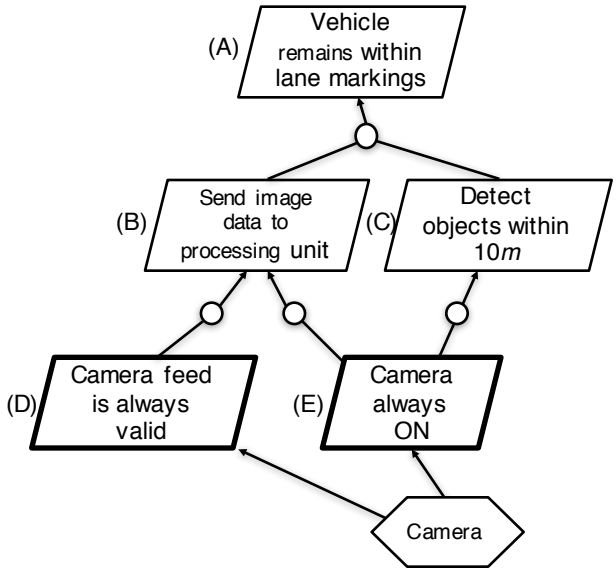


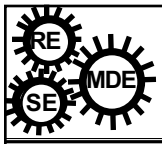
Goal categories

- Invariant
  - Must **ALWAYS** be satisfied
  - Safety, failsafe, or system invariants
  - E.g., vehicle can never collide with an obstacle
- Non-invariant
  - Temporarily **tolerate** unsatisfied goal
  - Transient conditions
  - E.g., sensor temporarily occluded

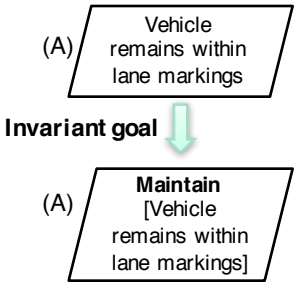


Goal examples

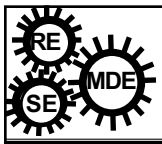




Goal examples



(**Avoid** also considered invariant)
E.g., **Avoid** [Collision]



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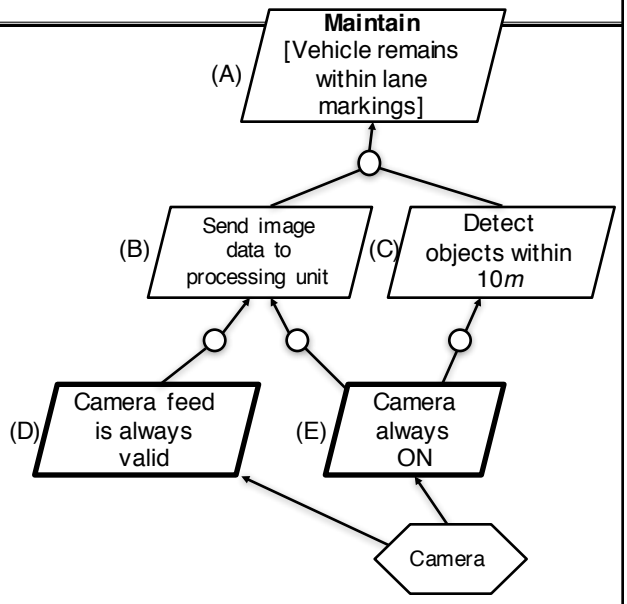
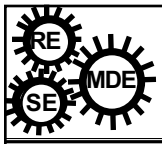
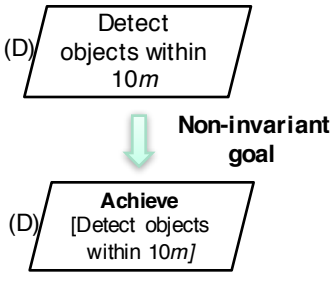
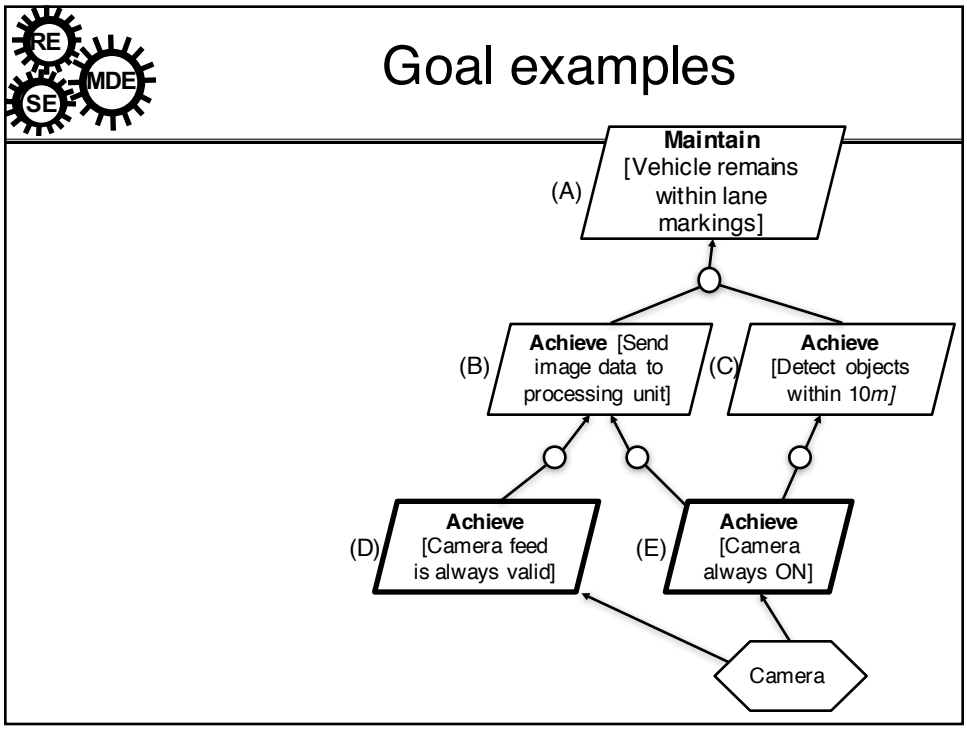
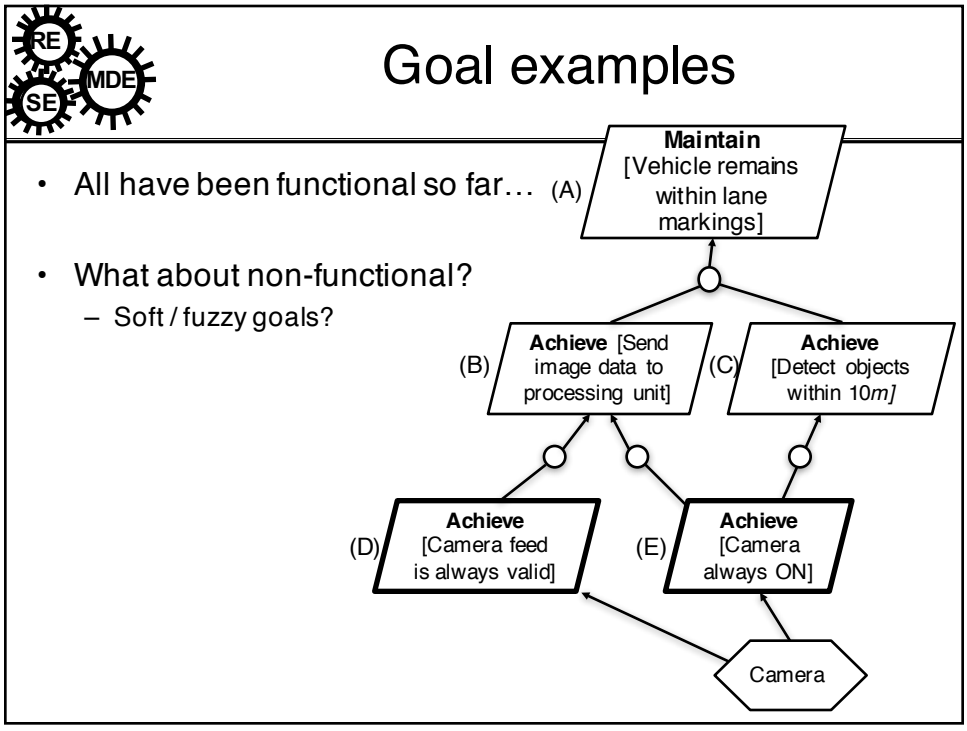




Goal examples




RE
MDE
SE
Goal examples
(A)
Maintain
[Vehicle remains within lane markings]
(B)
Achieve [Send image data to processing unit]
(C)
Achieve
[Detect objects within 10m]
(D)
Achieve
[Camera feed is always valid]
(E)
Achieve
[Camera always ON]
Camera


RE
MDE
SE
Goal examples
• All have been functional so far…
• What about non-functional?
– Soft / fuzzy goals?
(A)
Maintain
[Vehicle remains within lane markings]
(B)
Achieve [Send image data to processing unit]
(C)
Achieve
[Detect objects within 10m]
(D)
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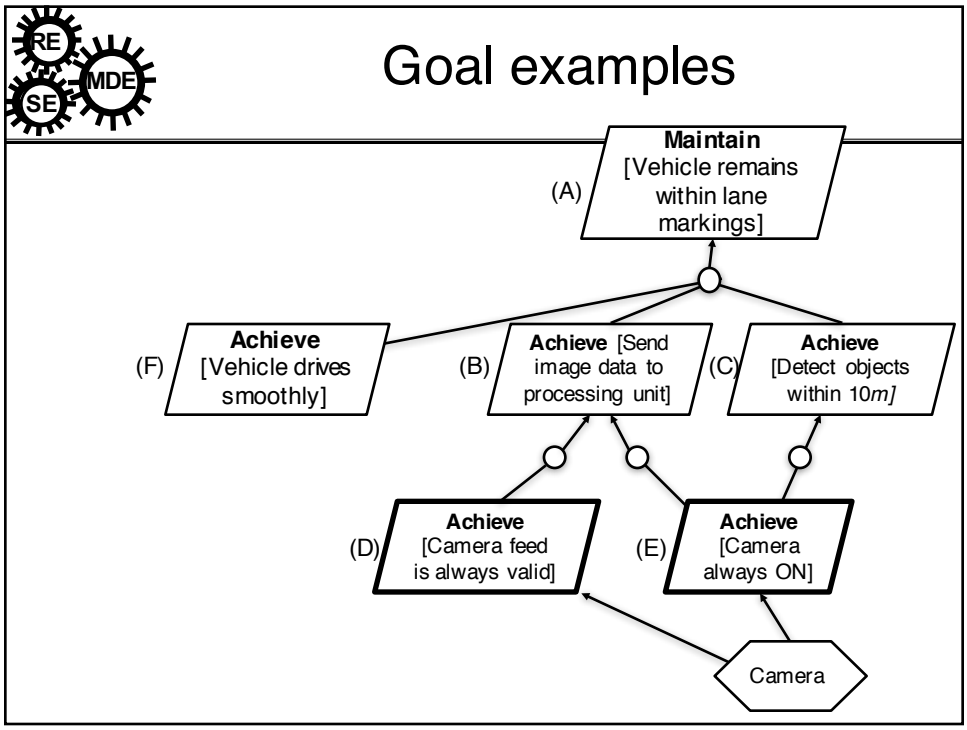
RE
MDE
SE
Goal examples
(A)
Maintain
[Vehicle remains within lane markings]
(F)
Achieve
[Vehicle drives smoothly]
(B)
Achieve [Send image data to processing unit]
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Achieve
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(D)
Achieve
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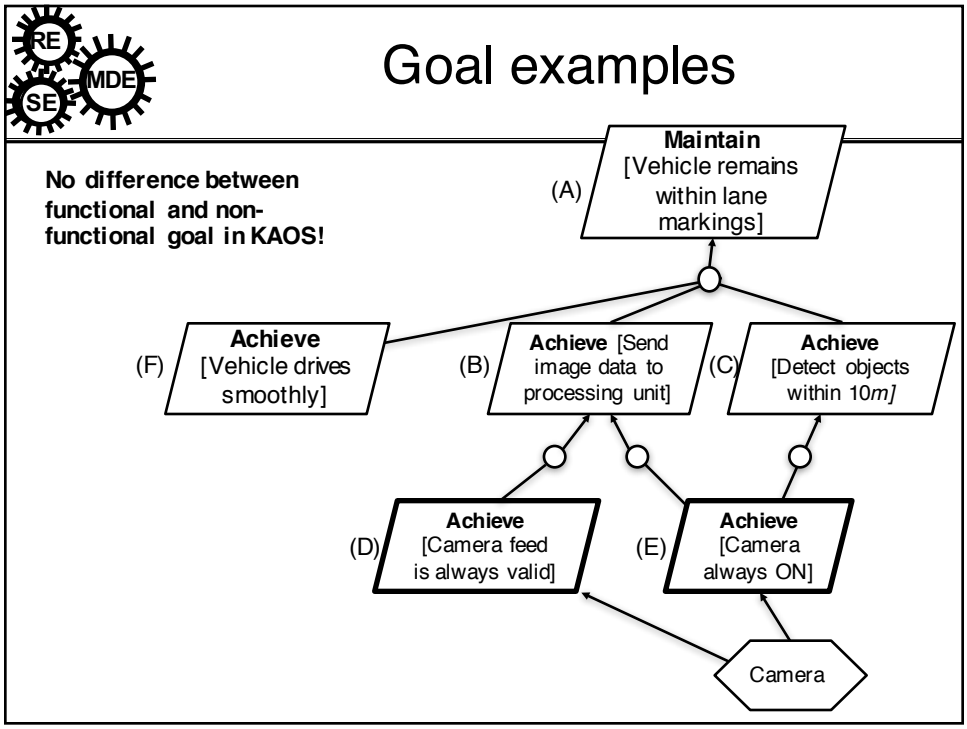
RE
MDE
SE
Goal examples
No difference between functional and non-functional goal in KAOS!
(A)
Maintain
[Vehicle remains within lane markings]
(F)
Achieve
[Vehicle drives smoothly]
(B)
Achieve [Send image data to processing unit]
(C)
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[Detect objects within 10m]
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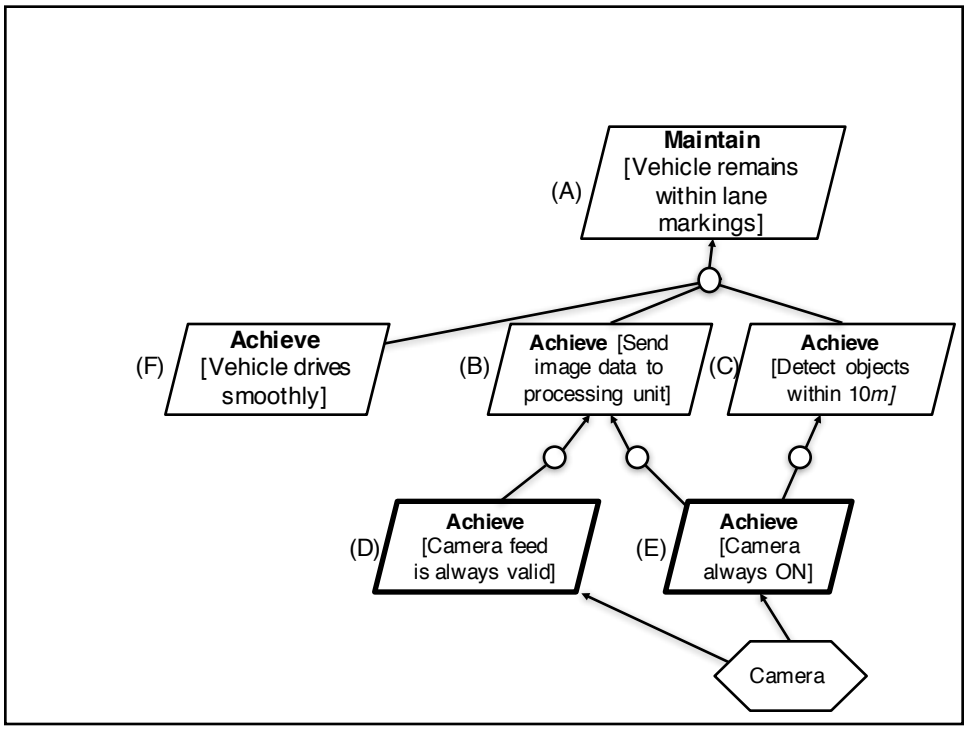
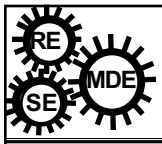
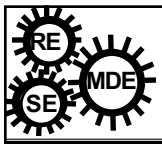
[Camera always ON]
Camera





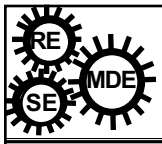
Using models at run time

- Goal models can provide measure of system performance
- Is system satisfying its invariants
- How well is system satisfying its non-invariants?

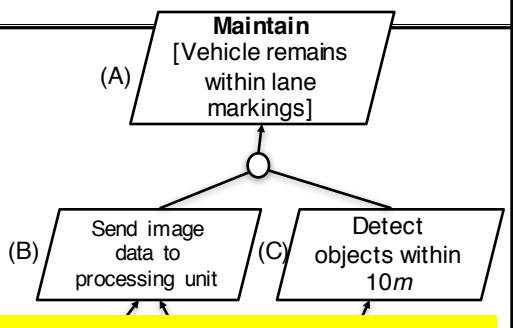


Utility functions

- Derived mathematical function for each goal
- Provides **degree of satisfaction** for each goal
- Normalized on [0.0, 1.0]
  - 0.0 ➔ goal is **violated**
  - 1.0 ➔ goal is **satisfied**
  - [0.0,1.0] ➔ goal is **satisfied to some degree (i.e., "satisficed")**

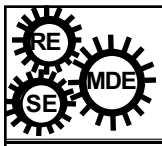


Goal examples

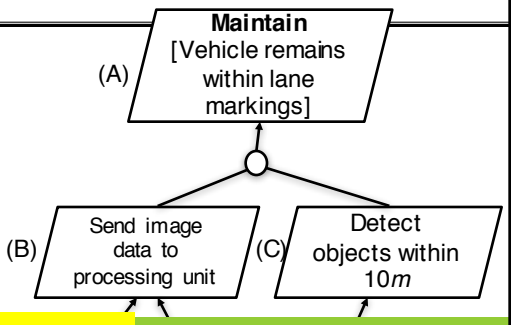


Invariants are typically Boolean functions

Goal (A) = 1.0 if vehicle has never crossed lane boundary
Goal (A) = 0.0 otherwise
Also, Goal (A) = 0.0 if (Goal (B) = 0.0) OR (Goal (C) = 0.0)



Goal examples



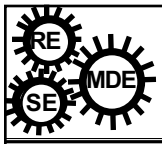
Non-invariants are typically real functions

$$\text{Goal (C)} = 1.0 - \frac{|\,\text{distance}_{\text{detected}} - \text{distance}_{\text{max}}\,|}{\text{distance}_{\text{max}}}$$

Detected at 8m instead of 10m

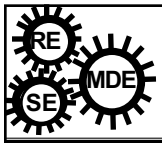
$$\text{Goal (C)} = \frac{1.0 - |8.0-10.0|}{10.0}$$

$$\text{Goal (C)} = 0.8$$



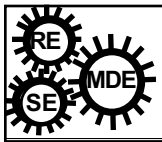
What can we do with a utility value?

- Determine if an objective has been violated
  - Or, determine if an objective is not being satisfied *enough*
- Refactor goal model
- Introduce a bugfix or patch
- Reconfigure system



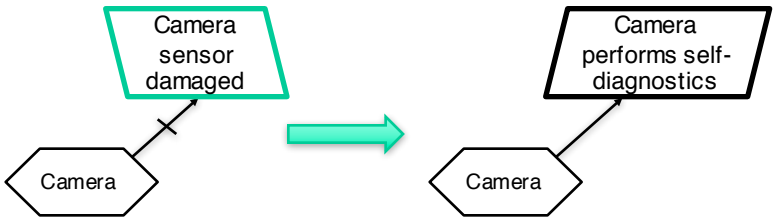
Other types of KAOS models

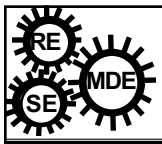
- Responsibility models
- Operation models
- Object models
- Obstacle models



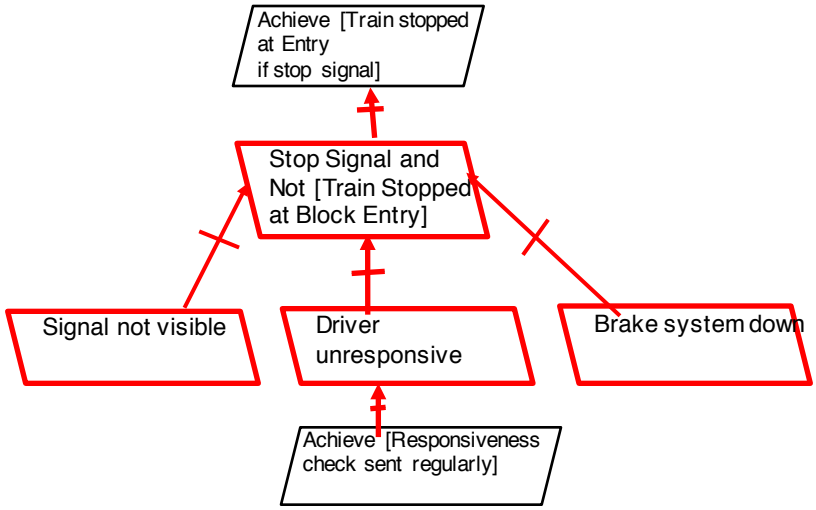
Obstacle models

- Defines an obstacle to goal satisfaction
- Attempt to identify resolve obstacles in advance by refining goal model





Obstacles



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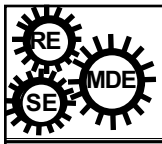

Assignment Part 2

- For your original goal model:
  - Define at least 2 utility functions to assess the satisfaction and/or satisficement of a goal
  - Identify sources of uncertainty and how to account for them in your goal model?
- Define an obstacle model to complement your homework assignment
  - Define **(2) obstacles** to the success of your goal model
  - Provide a strategy for resolving each