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Edinburgh, UK
July 18 - 21, 2016

A Cognitive Journey for Requirements Engineering

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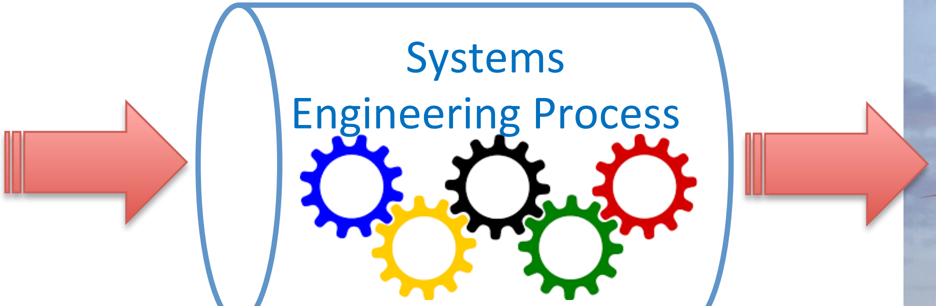
*The opinions in this presentation do not represent an official position of the IBM Corporation.

Paper to Product



Motive

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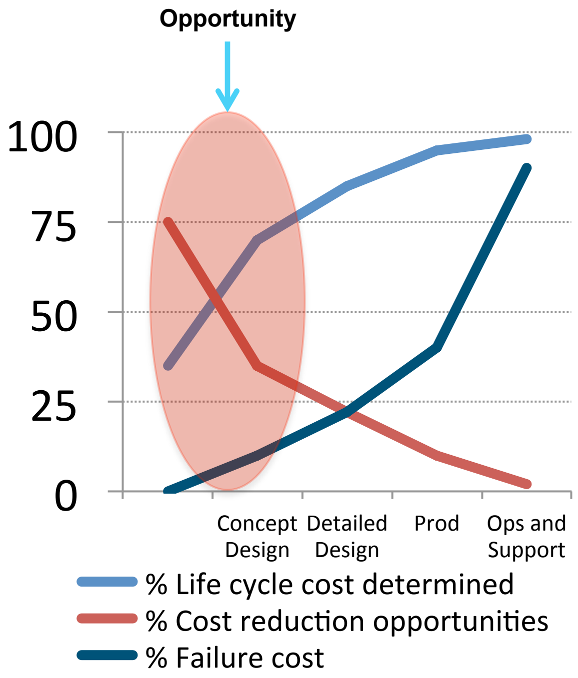
70%*

life cycle costs fixed by the time concept design is complete

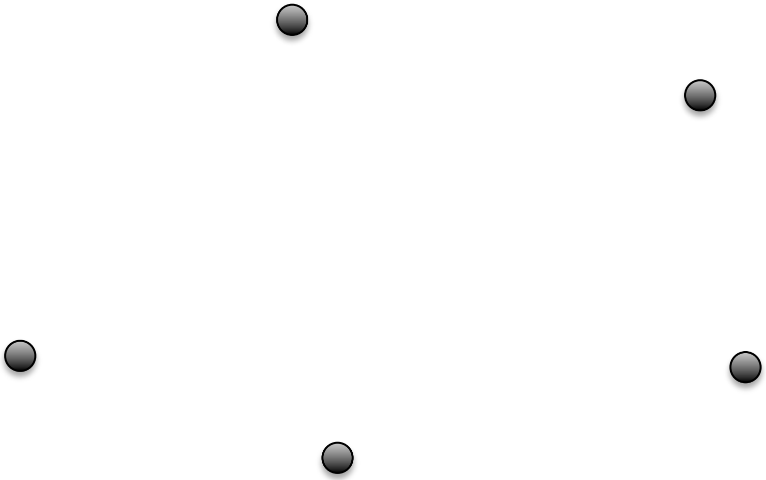


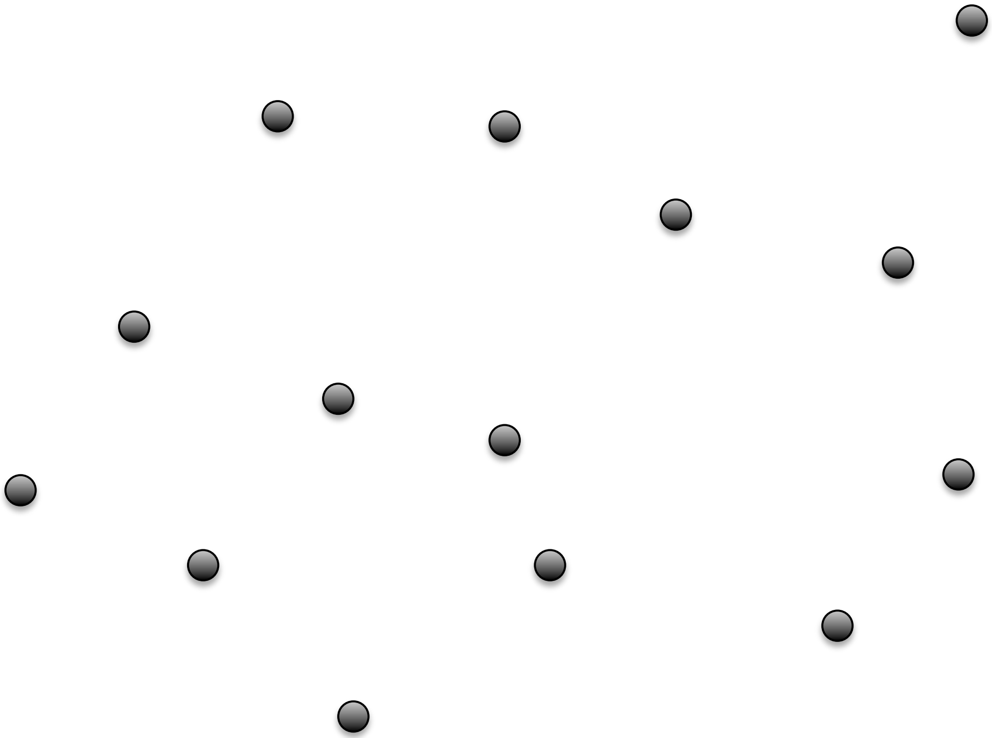
*INCOSE *Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities*, 4/e, D.D. Walden et al., ed., INCOSE-TP-2003-002-04, 2015.

Chart: DARPA Rapid Design Exploration and Optimization Project

Assumptions

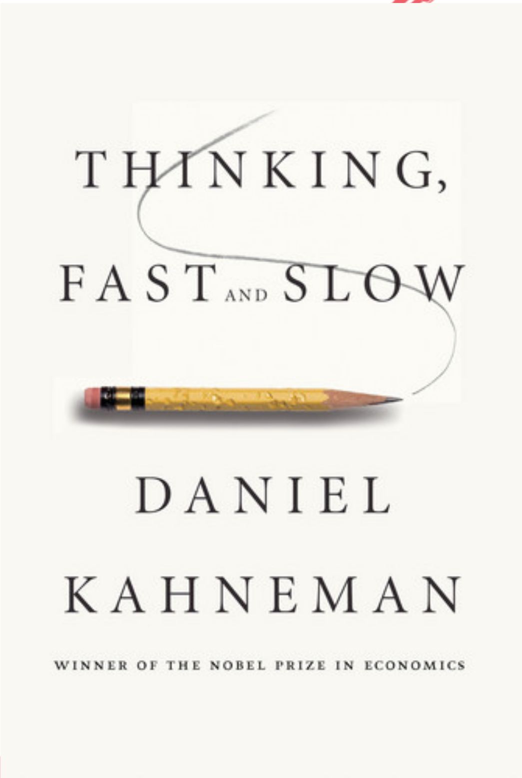
- Textual requirements will continue to be used in the foreseeable future
- Inputs include other textual sources not under control of the organization (RFPs, standards, regulations, …)
- Full formalization is not practically achievable
- Partial formalization can realize significant improvements
- Tool support for the formalization of natural-language engineering texts can provide considerable benefits





What is "Cognitive"?

- Fast thinking ("System 1")
  - automatic, instinctive, fast, parallel, and emotional
  - jumping to conclusions
  - optimized for common cases
  - has biases that result in wrong conclusions in unusual situations
- Slow thinking ("System 2")
  - deliberative, conscious, slow, and logical
  - more accurate
  - more difficult
- Engineering requires both types of thinking
  - Fast thinking to zero in on a small number of candidate solutions
  - Slow thinking to evaluate these solutions carefully
  - Slow thinking to consciously overcome biases of fast thinking
  - Slow thinking to direct new burst of fast thinking
- The challenge
  - Combine statistical and logical methods to support systems engineers



Objection!

WITHDRAWN

The Case for Dumb Requirements Engineering Tools

Daniel Berry[1], Ricardo Gacitua[2], Pete Sawyer[2,4], and Sri Fatimah Tjong[3]

. Regnell and D. Damian (Eds.): REFSQ 2012, LNCS 7195, pp. 211–217, 2012.

- "In some scenarios, for some tasks, any tool with less than 100% recall is not helpful and the user may be better off doing the task entirely manually."
- True, heuristic tools cannot replace human oversight
- But they can reduce cost by finding problems early
- Dan Berry agrees!

Opportunity

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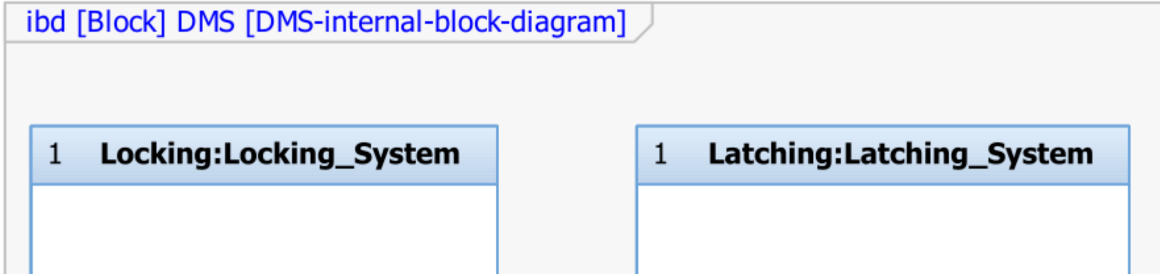
- A formal representation of requirements, regulations, and similar documents would enable:
- Discovery of deep logical inconsistencies
- Creation of downstream artifacts
  - (partial) models
  - simulations
  - execution monitors
  - code
  - …

Modi Operandi

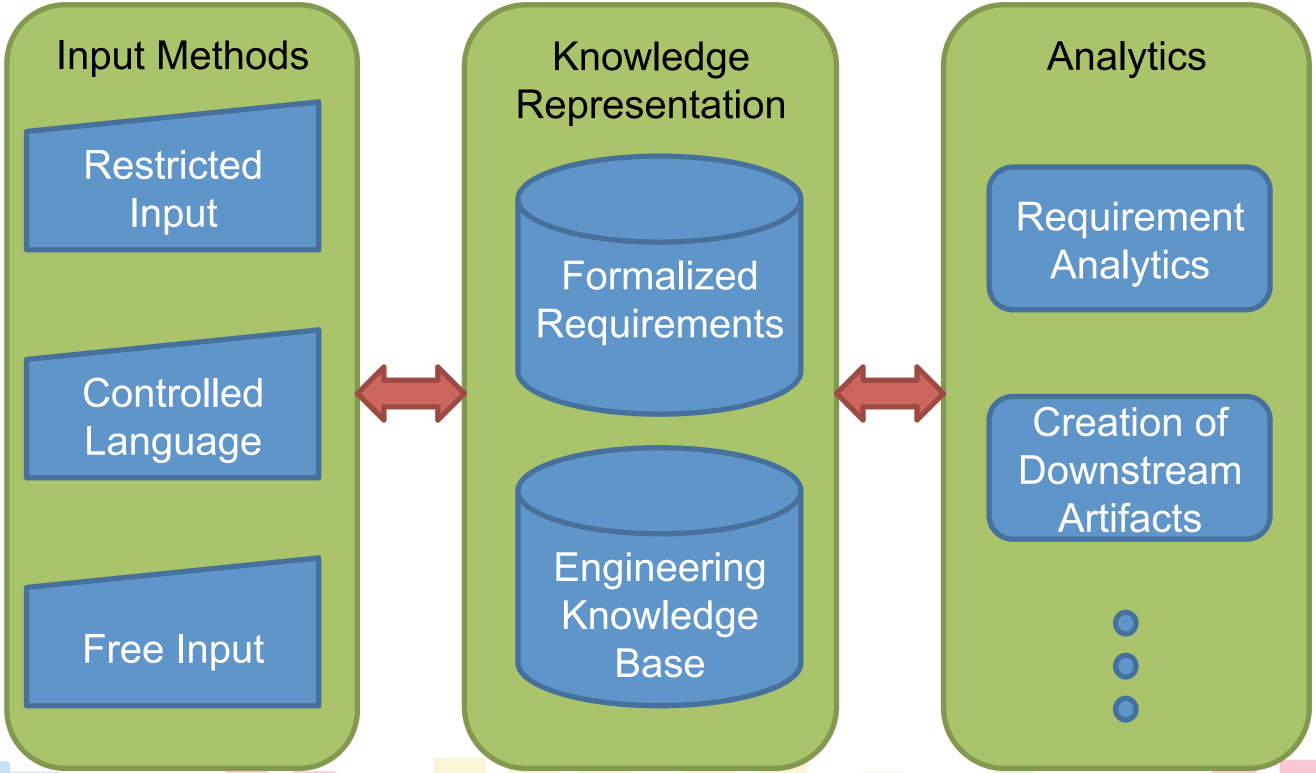
- Compose new requirements
  - can use authoring tools to enforce use of templates
- Reuse existing requirements
  - might use authoring tools to rewrite requirements
- Analyze regulations
  - no control over language
- Respond to RFP
  - no control over language

The Case

- DMS-039:
  The target mass of the locking system shall not exceed 260 kg.
- DMS-040:
  The target mass of the latching system shall not exceed 250 kg.
- DMS-019:
  The weight of the Doors Management System shall not exceed 500 kg.



Experiments



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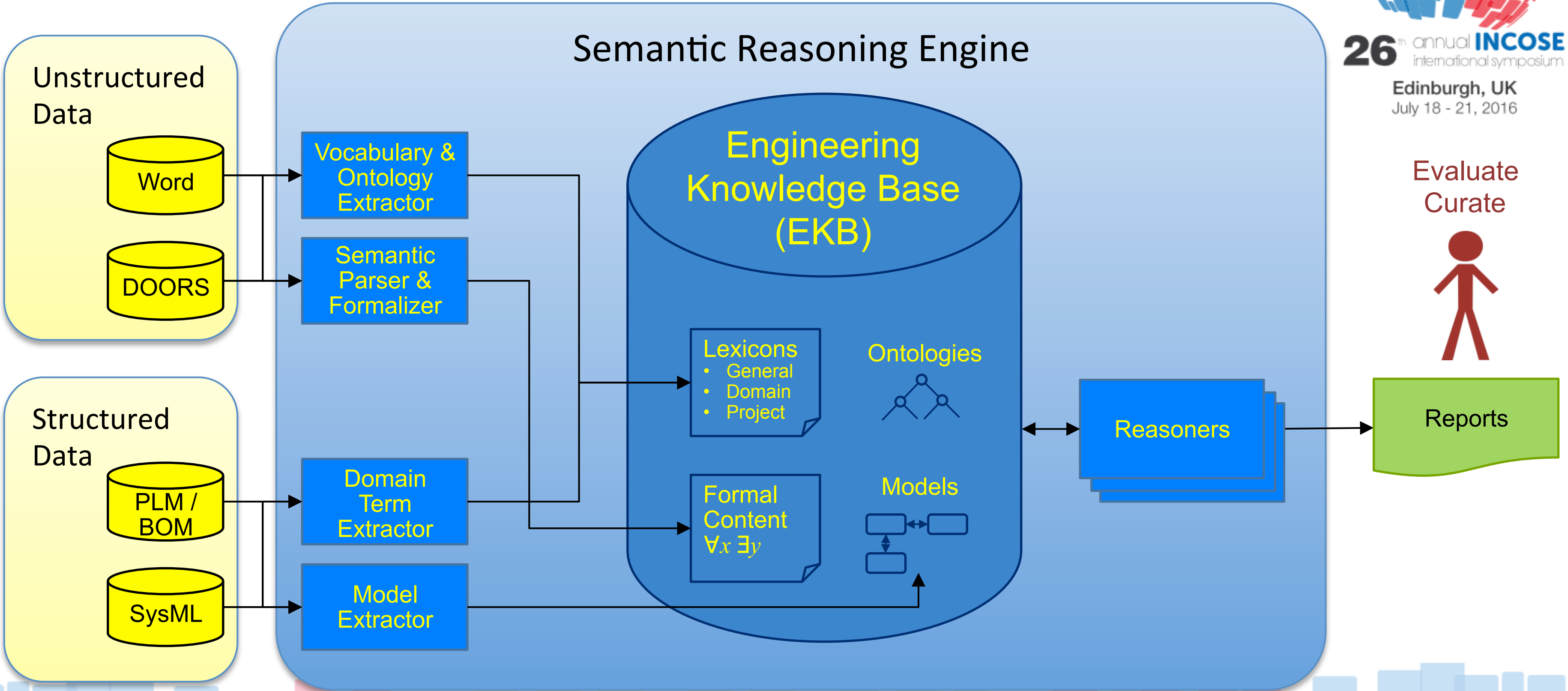
Architecture



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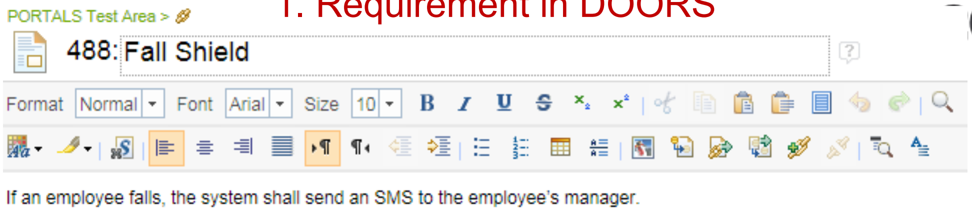
Scenario 1: WorkRight

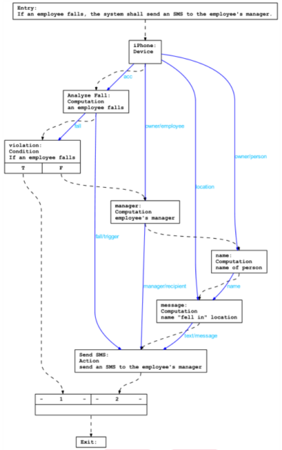
1. Requirement in DOORS



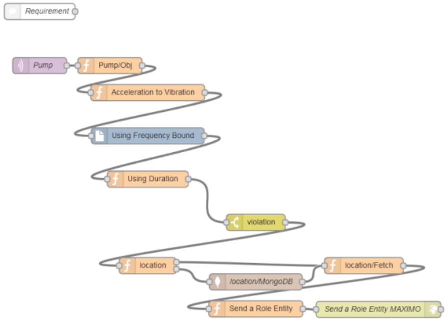
2. Paraphrase

if "an employee" falls then "the system" shall send [an abstract entity] "an SMS" (direction) "manager" of "the employee's"

3. Process Model



4. Implementation in Node-RED



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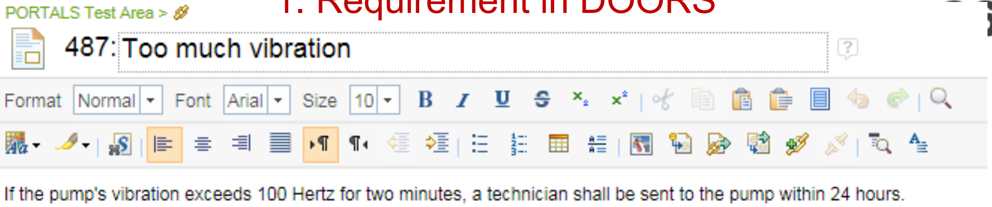
Scenario 2: IoT Pump

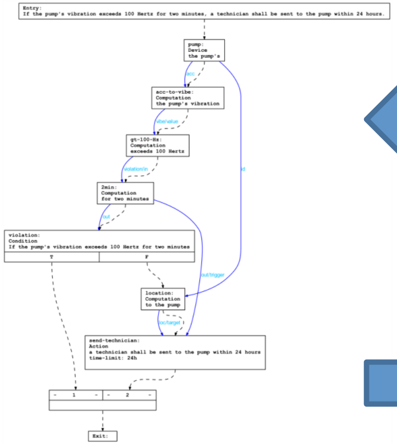
1. Requirement in DOORS



2. Paraphrase

if "vibration" of "the pump's" is greater than 100 Hz (duration) 2 min then "?" shall send [a role entity] "a technician" (duration) 24 hr; (direction) "the pump"

3. Process Model



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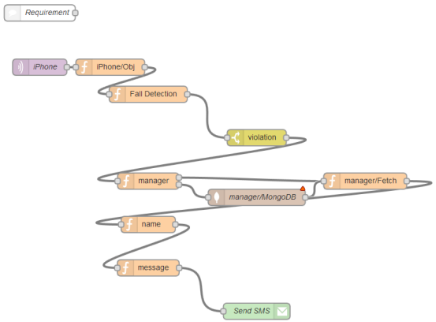

Semantic Reasoning Engine (SERENE)
IBM Research - Haifa

Yishai Feldman
Vladimir Lipets
Aviad Sela
Evgeny Shindin

Budgeting Demo

SERENE | Vocabulary | Requirement | Analyze

System | DMS Budgets

Describe the system and sub-system structure and corresponding alias:

System	Alias	Parent Systems	Actions
Doors Management System	DMS		edit del
Latching System		Doors Management System	edit del
Locking System		DMS	edit del

Add System

SERENE | Vocabulary | Requirement | Analyze

System | DMS Budgets

Add system requirements:

ID	Requirement Description	Actions
1	The weight of the Doors Management System shall not exceed 500 kg.	edit del
2	The target mass of the locking system shall not exceed 260 kg.	edit del
3	The target mass of the latching system shall not exceed 250 kg.	edit del
4	The volume of the Doors Management System shall not exceed 1000 cubic feet.	edit del
5	The volume of the latching system shall not exceed 30 cubic meter.	edit del
6	The volume of the latching system shall not exceed 35 m3.	edit del

SERENE | Vocabulary | Requirement | Analyze

System | DMS Budgets

SERENE System Analysis

Find Conflicts

Analysis Results

Expand all | Collapse all

- Inconsistent volume requirements for Latching System; values are 30 m^3, 35 m^3
- A volume budget requirement for subsystem Locking System was not found; budget for containing system (Doors Management System) is 1000 ft^3
- The volume budget for system Doors Management System, 1000 ft^3, is exceeded by budgets for subsystems (Latching System = 30 m^3)
- The weight budget for system Doors Management System, 500 kg, is exceeded by budgets for subsystems (Locking System = 260 kg; Latching System = 250 kg)

SERENE | Vocabulary | Requirement | Analyze

System | DMS Budgets

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- Inconsistent volume requirements for Latching System; values are 30 m^3, 35 m^3
  - The volume of the latching system shall not exceed 30 cubic meter
    The "volume" of the "latching system" shall be less than or equal to 30 m^3
  - The volume of the latching system shall not exceed 35 m3
    The "volume" of the "latching system" shall be less than or equal to 35 m^3

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SERENE Budgeting Demo
IBM Research - Haifa

Yishai Feldman
Aviad Sela
Boris Daich

Means

- The Engineering Knowledge Base
- Natural-Language Processing (NLP)
- Computational Semantics
- Analysis of structured sources

The Engineering Knowledge Base

- Understanding the text isn't enough
  - Need domain- and project-specific knowledge
  - The EKB is the central repository for this knowledge
- General and domain-specific knowledge
  - "Obvious" requirements (e.g., "Pilots are situated in the cockpit")
  - Vocabulary (e.g., "Master Minimum Equipment List")
  - Ontologies (is-a, part-of, …)
  - Reasoning algorithms
- Project-specific knowledge
  - Models (e.g., system structure)
  - Catalogues
  - Devices and computational units

What Linguists Worry About

- Quantification
  - A diplomat visited every country.
- VP anaphora
  - John loves his mother and so does Mary.
  - John loves her and so does Fred.
- References
  - Faulkner is hard to understand.
    [his pronunciation, his actions, or his literary work?]
- Figures of speech: metaphors, parables, puns, irony, hyperbole, colloquialisms, …
- Discourse structure
  - Who is the prime minister of the UK?
  - David Cameron.
  - Since when?
  - 2010.

What Engineers Deal With

- Regulatory documents, including system requirements and test plans
- Complex and convoluted natural language
  - nested quantifiers, complex relationships, physical units, …
- Domain-specific vocabulary
- Written purposefully to be clear and unambiguous
- **No** discourse elements, metaphors, parables, irony, hyperbole, colloquialisms, etc.
- Only complete sentences, no fragments
  - not always completely correct syntactically, written by non-native speakers
- Deontic irrealis mood
- English primary but not exclusive language
- Need full precise semantic understanding with high accuracy

Natural-Language Processing

- Shallow parsing
  - POS tagging, chunking, …
  - Can handle slightly ungrammatical text
  - Can handle large amounts of text
  - Useful for search and clustering
- Deep parsing
  - Produces full parse trees
  - Less reliable than shallow methods
  - Computationally expensive
  - Required for semantic understanding*
- Both require training on manually-annotated texts

Computational Semantics

- Several competing formalisms
- Mostly variants of first-order logic
- Much discussion of how to represent all possible meanings of all possible utterances
- Rather preliminary work on automatic generation of semantic representations from text*
  - Each effort focuses on a small set of issues
  - No attempt to combine and generalize
  - Doesn't seem to be scalable

Summary

- Requirement formalization can be valuable
  - Done incrementally
- Needs to be combined with project- and domain-specific information
- Requires focus shift in NLP/semantics research
- Less precise techniques can be useful now
  - See paper for more details

I rest my case

Cross-examine?

Backup

EKB: WorkRight Catalog

Events

Overexertion
- Heart Rate
- Body Temperature
- Sweat & Tears

Fall Detection
- Accelerometer
- Radar

Devices / Systems

iPhone
- Accelerometer
- Orientation
- Vibration
- Send SMS
- Device ID
- Owner ID

Fever Smart
- Temperature
- Device ID

TI SensorTag
- Accelerometer
- Temperature
- Device ID

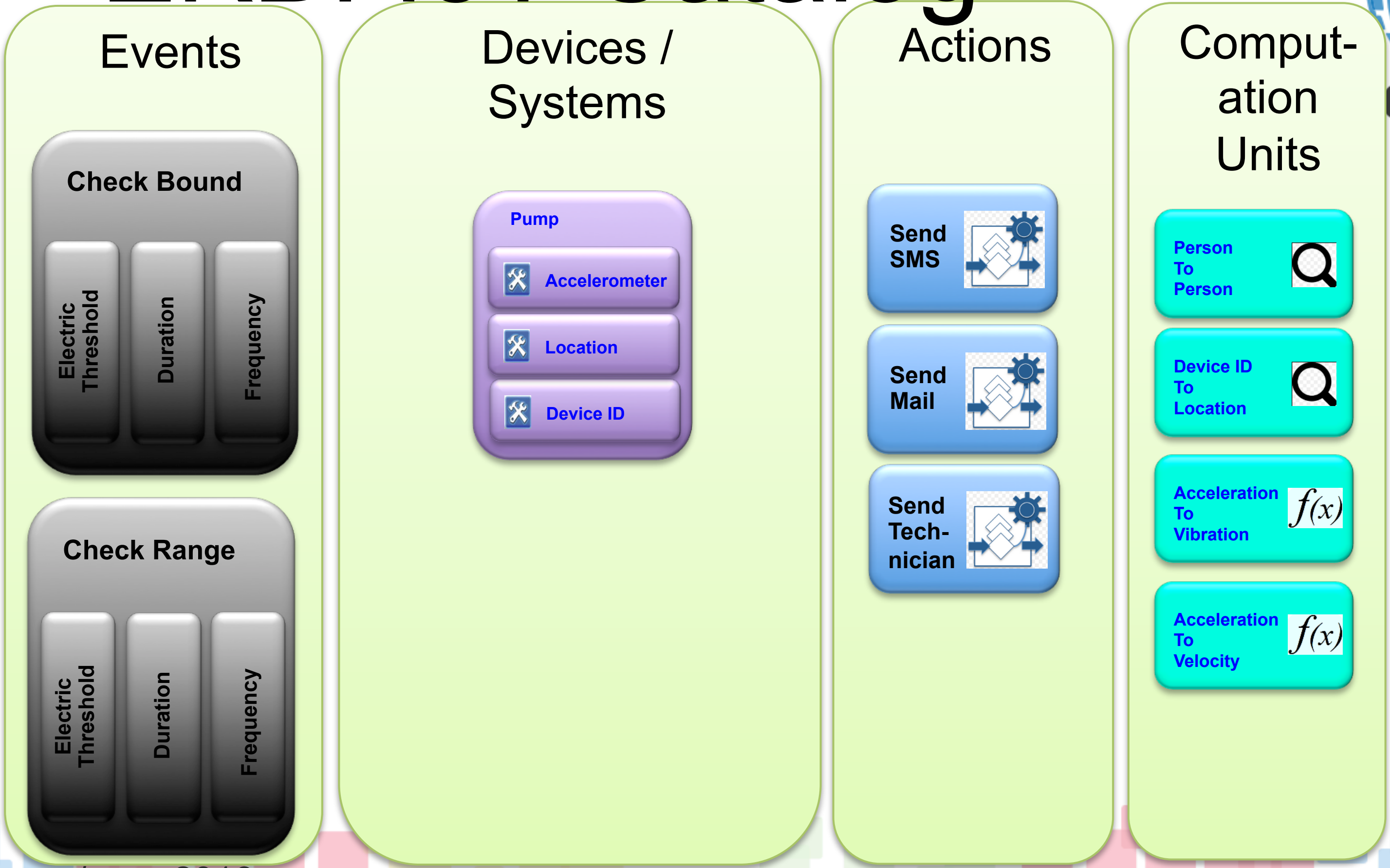
Actions

- Send SMS
- Send Mail
- Vibrate

Computation Units

- Person To Person
- Device ID To Person

EKB: IoT Catalog



WorkRight: Reasoning

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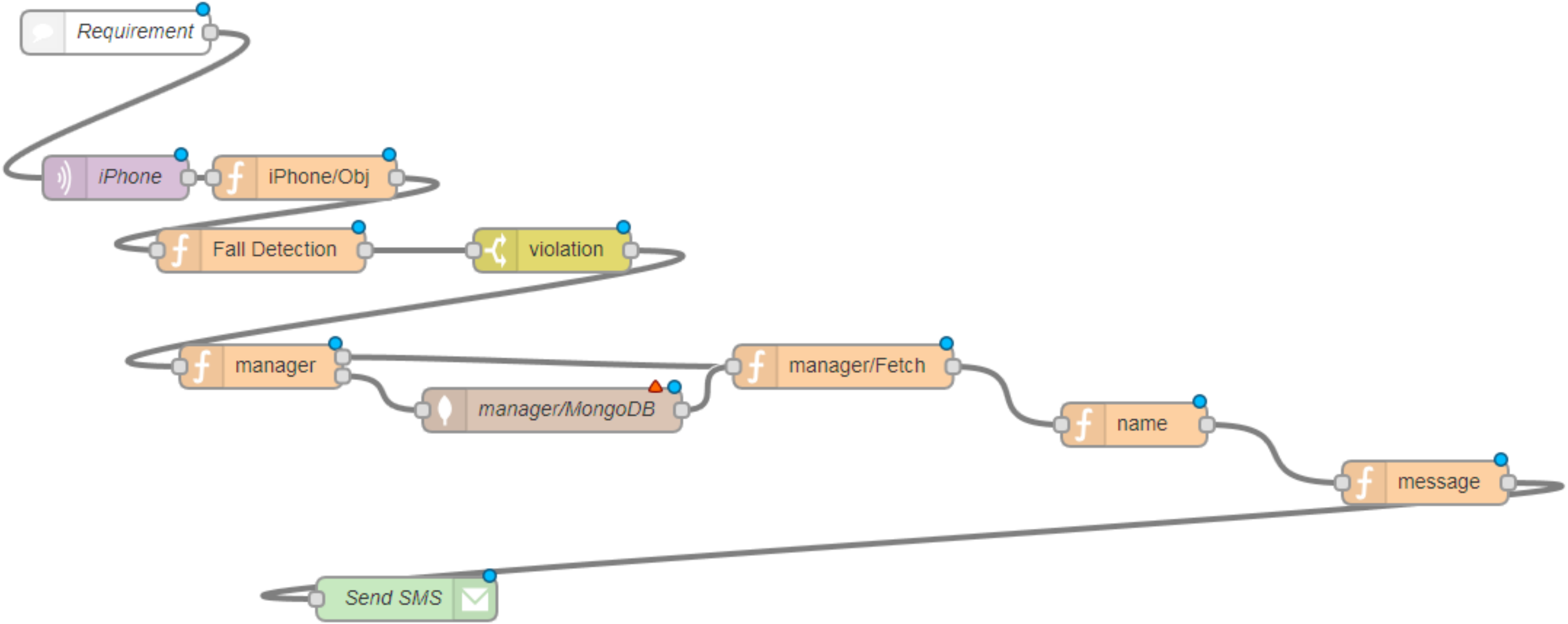
```
Event is "Fall Detection"."Fall Detection" event has 2 methods:
    "Using Acceleration"
    "Using Radar"

Method "Using Acceleration" requires device input "acceleration".
Method "Using Acceleration" has 2 devices, adding them to
selection.

Method "Using Radar" requires device input "radar".
No Device provides output "radar".
Method "Using Radar" is unavailable.

Please select a device to supply input "acceleration": iPhone
User selected Device "iPhone" to provide input "acceleration" for
calculating Event "Fall Detection".
Action to take "send".
Choosing action "Send SMS"
Plan is ready.
```

IoT Pump: Reasoning

```
Selecting bound method "Using Frequency Bound".
Connecting "Using Duration" to bound method "Using Frequency
Bound".
Event checks bound on the "vibration" of device "pump".
Device "pump" does not have output "vibration".
Searching for computation units to connect device "pump" to bound
input "vibration".
Connecting output "acceleration" from service "Accelerometer" of
device "Pump" to input "acceleration" of computation unit
"Acceleration to Vibration".
Connecting output "vibration" of computation unit "Acceleration to
Vibration" to input "quantity" of bound event "Using Frequency
Bound".
Action to take "send".
Choosing action "Send a Role Entity".
Plan is ready.
```

WorkRight Implementation



IoT Pump Implementation

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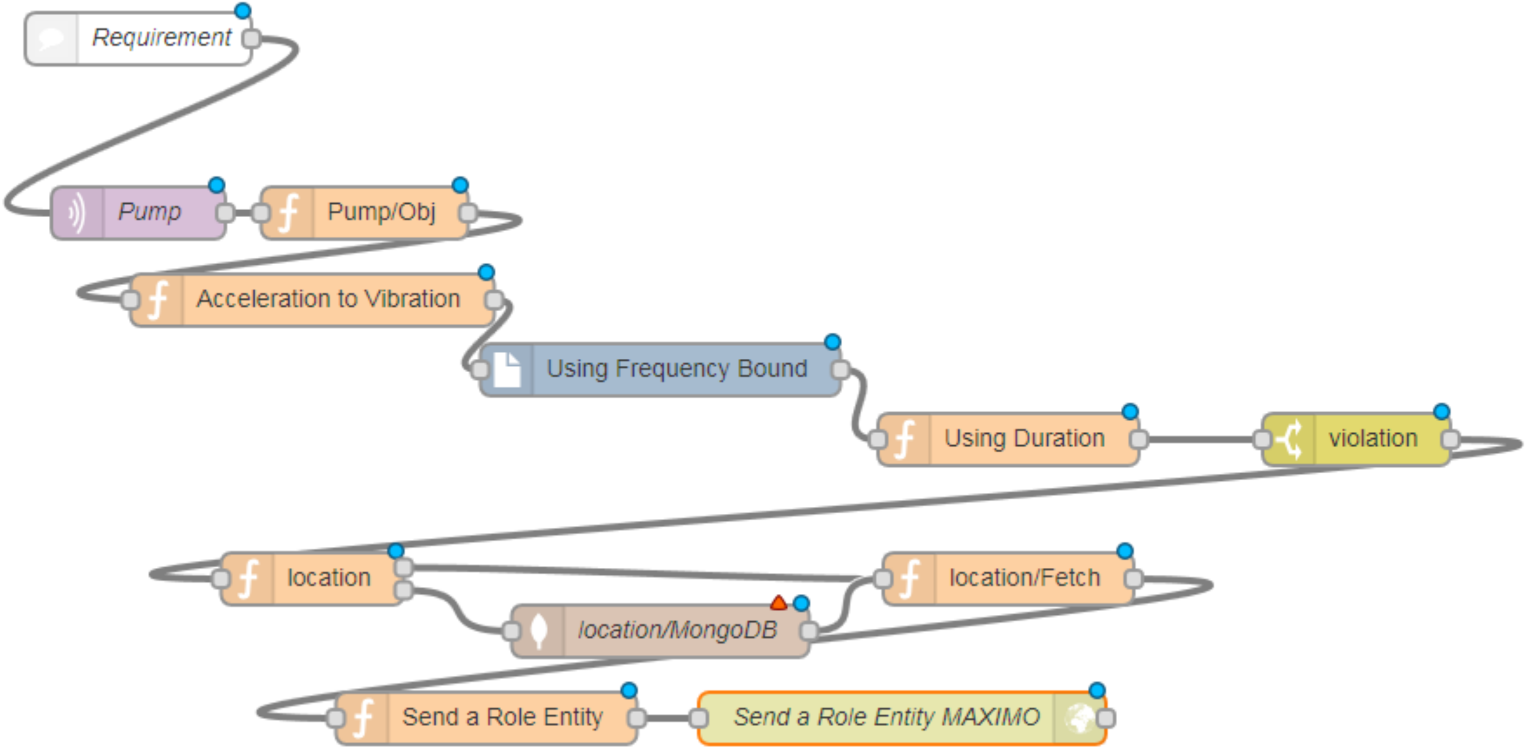

If the pump's vibration exceeds 100 Hertz for two minutes, a technician shall be sent to the pump within 24 hours.

Name	Using Frequency Bound
msg.payload.	vibration
msg.payload.	event
Lower bound	Lower_bound
Upper bound	100

Name: Using Duration

Function

```
//Available Inputs: event(trigger)
//Required Outputs: event(trigger)

context.type = "duration";
context.unit = "Minute";
context.time_threshold = 2; //2 min

//ADD YOUR CODE FOR: for two minutes

//CUSTOM CODE

```

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