Enabling OODA Loop with Information Technology

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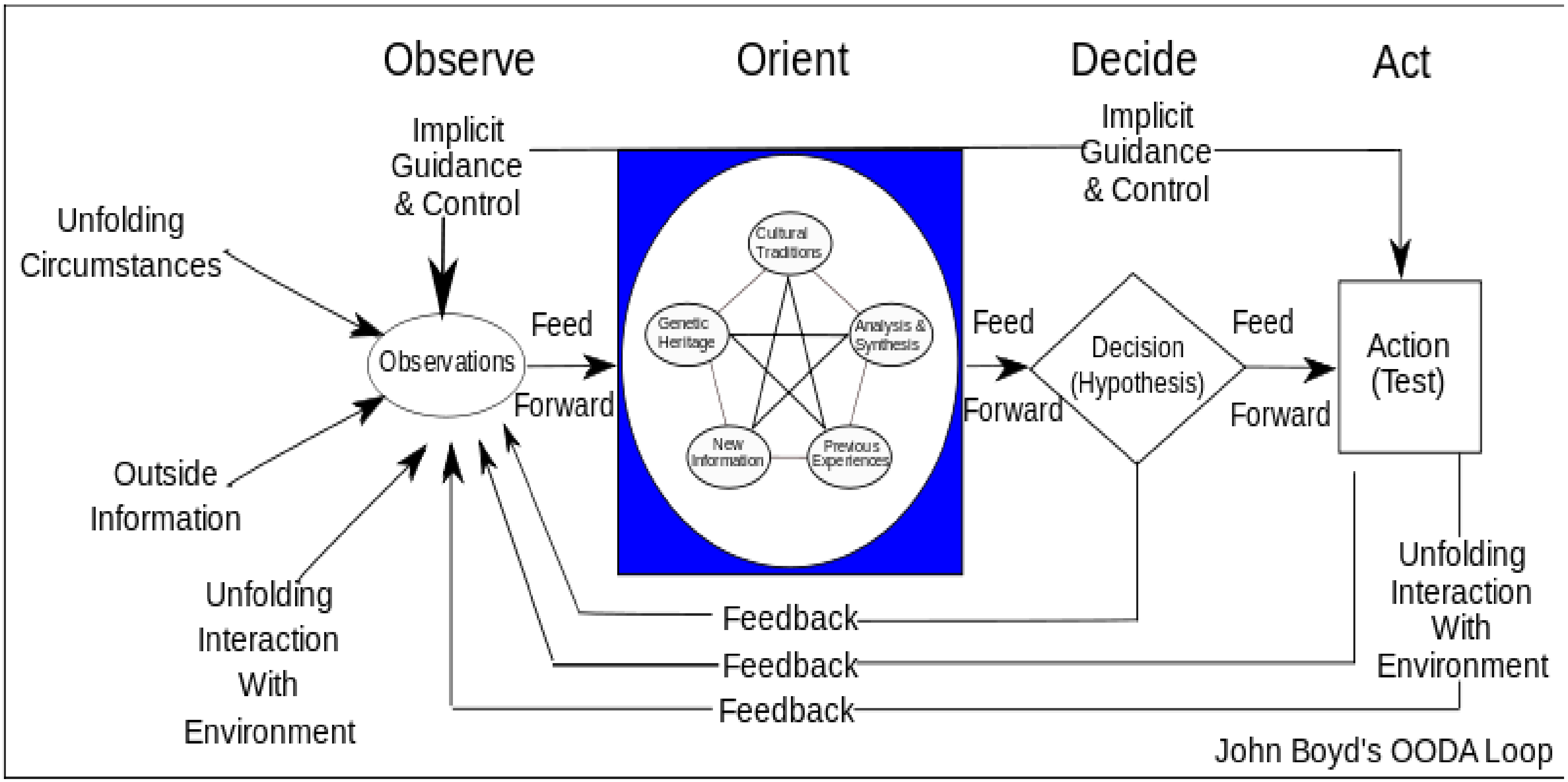
Pre Information Technology Process: OODA Loop

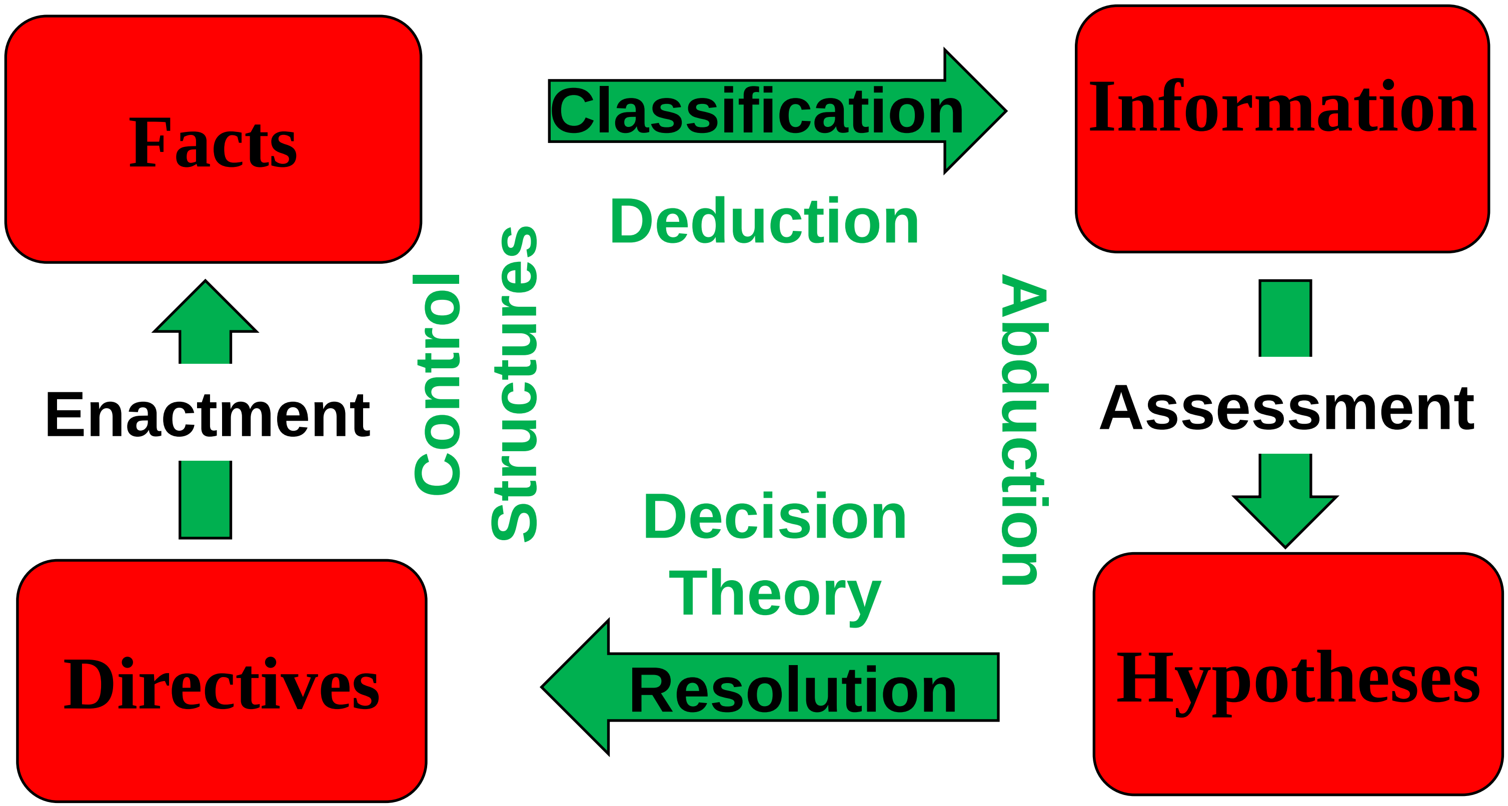


From http://en.wikipedia.org/wiki/File:OODA.Boyd.svg

OODA Loop

- Observe, Orient, Decide, and Act (OODA) Loop
  - Observe the entities and environment,
  - Orient the participant to the observations, by cultural tradition, generic heritage, previous experience, analysis and synthesis, new information
  - Decide on the directives based on the hypotheses that best explains the observations, and
  - Act on the directives to interact with the entities and environment, to test the hypothesis
- The importance of the Loop and Provenance is substantiated by fighter pilots
  - (loop) rapid iteration of the loop to get inside the adversary’s OODA loop
  - (provenance) regular debriefing of the pilots after the missions to propagate the effective technique

FIHD, CARE Loop (IT version of OODA Loop)



Data FIHD = Facts, Information, Hypotheses, and Directives

Knowledge CARE = Classification, Assessment, Resolution, and Enactment

Knowledge Intensive Database System 1

- Normalizes the data and knowledge
  - four categories of data (fact, information, hypothesis, directive)
  - four categories of knowledge (classification, assessment, resolution, enactment) that transforms the data
    - classification knowledge transforms fact to information
    - assessment knowledge transforms information to hypothesis
    - resolution knowledge transforms hypothesis to directive
    - enactment knowledge transforms directive to fact

- Normalizes the application structure into OODA, CARE, FIHD loops
  - classify the quantitative facts to derive the qualitative information,
  - assess the information to infer the hypotheses,
  - resolve the hypotheses to formulate the directives,
  - enact the directives to collect new facts, and
  - repeat the loop

Knowledge Intensive Database System 2

- Represents the entity model of the world
  - manage entity model in a multi-temporal database
  - concepts hierarchy and concepts lattice
  - OLAP operations in multidimensional data cubes

- Propels a faster iteration of the OODA loops in real-time
  - process management engine
    - continuously interacts with the environment to assess and adapt to the changes
  - manual or semi-automatic human interaction, tacit knowledge profiling
    - interaction is more powerful than algorithms
  - automatic agents, knowledge representation, machine learning

Knowledge Intensive Database System 3

- Materializes the OODA, CARE, FIHD loops in the data for provenance of the data and knowledge evolution
  - involves multiple iterations of the CARE loop
    - substantiated by bug database and customer service request lifecycles
  - annotates the CARE and FIHD loops in data
    - what are the fact, information, hypothesis, and directive in the problem report?
  - provenance of data and knowledge evolution

- Enables the development of evolutionary applications
  - knowledge is application
    - capture knowledge as much as possible declaratively and not in procedural code
  - data and knowledge are intertwined
    - desired application behavior evolves from the convergence of data and knowledge
      - when knowledge changes, data is re-analyzed
      - when data changes, knowledge is re-characterized
  - application development framework
    - graphical programming
    - meta-programming

KIDS Ontology

KIDS = (*Actor*, *Entity*, *CARE*, *Metadata*, *Reification, Profile*)

CARE = (*Data*, *Knowledge*)

Data = (*Fact*, *Information*, *Hypothesis*, *Directive*)
Knowledge = (*Classification*, *Assessment*, *Resolution*, *Enactment*)

KIDS Data Categories

$Fact = (Entity \times FSD^n) \cup (Entity \times Feature^n)$

$Information = Entity \times Feature^n \times ValidTime \times FigureOfMerit$

$Hypothesis = Entity \times Feature^n \times ValidTime \times FigureOfMerit$

$Directive = Entity \times Feature^n \times ValidTime \times FigureOfMerit$

$FSD = Value^n \times ValidTime \times FSDType$

$Feature = Value \times ValidTime \times FeatureType$

$ValidTime = [DateTime, DateTime \cup \{\infty. \mathrm{NA}\})$

KIDS Knowledge Categories

$$Classification = \{ f \mid f : Fact \rightarrow Information \}$$

$$Assessment = \{ f \mid f : Information \rightarrow Hypothesis \}$$

$$Resolution = \{ f \mid f : Hypothesis \rightarrow Directive \}$$

$$Enactment = \{ f \mid f : Directive \rightarrow Fact \}$$

$$SymptomResolution = \{ f \mid f : Information \rightarrow Directive \}$$

$$Kfun = Classification \cup Assessment \cup Resolution \cup Enactment \cup SymptomResolution$$

KIDS Tacit Knowledge Profile

$Profile = (ActorProfile, KnowledgeProfile, Personalization)$

$ActorProfile : Actor \to Entity \times Feature^n \times ValidTime \times FoM$

$KnowledgeProfile : Kfun \to Entity \times Feature^n \times ValidTime \times FoM$

$Personalization : Kfun \times Actor \to Kfun$

$Personalization(Kfun, Actor) \equiv curry(Kfun)(ActorProfile(Actor))$

KIDS Meta-Program

$MetaData = (FSDType, FeatureType, Influence)$

$FSDType = Name \times Encoding \times Language$

$FeatureType = Name \times Type$

$Influence = (Input, Output)$

$Input = DType \times Kfun$

$Output = Kfun \times DType$

$DType = FSDType \cup FeatureType$

KIDS Reification Provenance

Reification = (*CARE-Loop*, *Classified*, *Assessed*, *Resolved*, *Enacted*)

CARE-Loop = (*Classified* × *Assessed* × *Resolved* × *Enacted*)^{n}

Classified = *Fact* × *Classification* × *Information* × *Actor* × *TxnTime*

Assessed = *Information* × *Assessment* × *Hypothesis* × *Actor* × *TxnTime*

Resolved = *Hypothesis* × *Resolution* × *Directive* × *Actor* × *TxnTime*

Enacted = *Directive* × *Enactment* × *Fact* × *Actor* × *TxnTime*

TxnTime = [*DateTime*, *DateTime* ∪ {∞. NA})

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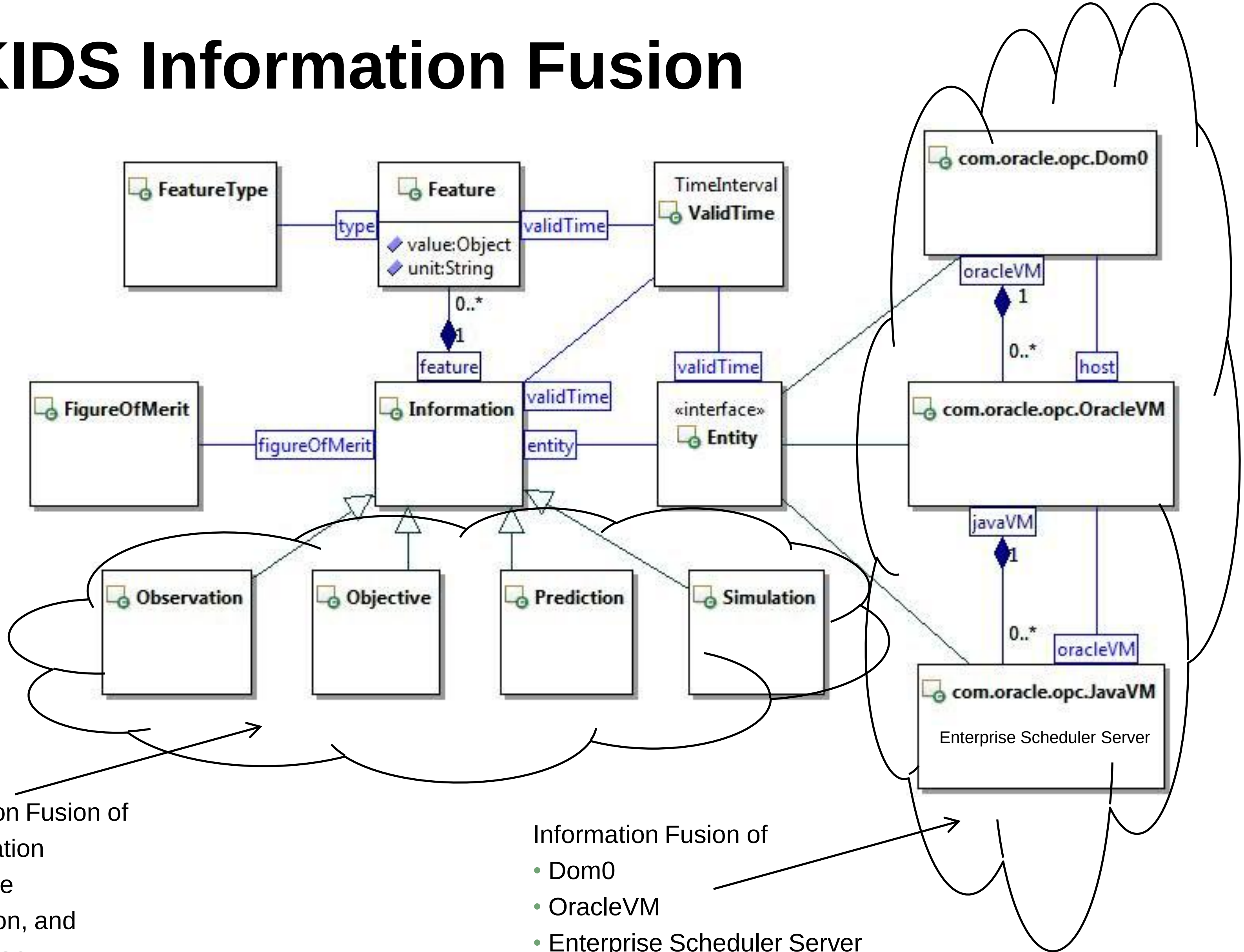
KIDS Normalizes the Knowledge Representations 1

- Classification knowledge - deductive reasoning
  - Support Vector Machines
  - Naïve Bayesian Network
  - Neural Network
  - Clustering, Association Rules, Decision Trees
  - Multivariate State Estimation Technique (MSET)
- Assessment knowledge - abductive reasoning
  - Bayesian Belief Network
  - Least-Squares Optimization or Regression of solutions for inverse problems
- Resolution knowledge – decision theory
  - Influence Diagrams (Bayesian Belief Network with decision nodes)
  - Dempster-Shafer theory
  - Decision Trees
  - Prognosis of Remaining Useful Life (RUL)
- Enactment knowledge - control structures
  - scripts, plans, schedules, GOLOG, BPEL, BPMN

KIDS Normalizes the Knowledge Representations 2

- Situation Knowledge - situation theory
  - Entity Model
    - data cubes
    - dimensions
    - concepts hierarchy and concepts lattice
  - Situation Theory Ontology
    - situation calculus
  - Provenance
    - reifications
    - bi-temporal database
- Tacit Knowledge
  - Knowledge profiles
  - Preferences
  - Personalization

KIDS Information Fusion



Information Fusion of
- Observation
- Objective
- Prediction, and
- Simulation

Information Fusion of
- Dom0
- OracleVM
- Enterprise Scheduler Server

KIDS Propels the Process Interactions

Influence table enables dynamic scheduling of processes

Input	Knowledge
OS boot log (FSD Fact)	OVM Crash Watcher (Classification)
OS Watcher Log (FSD Fact)	OVM Memory Watcher (Classification)
Enterprise Scheduler Service Log (FSD Fact)	ESS Process Watcher (Classification)
OVM Memory Spike (Information)	OVM Memory Diagnosis (Assessment)
ESS Process Spike (Information)	OVM Memory Diagnosis (Assessment)
OVM OutOfMemory Prediction (Information)	OVM Memory Diagnosis (Assessment)
OVM Crash (Information)	OVM Crash Diagnosis (Assessment)
Dom0 has Elastic Memory (Information)	Elastic Memory Advisor (Resolution)
Needs Elastic Memory (Hypothesis)	Elastic Memory Advisor (Resolution)
Unlock Memory in Dom0 to DomU (Directive)	Dom0 Memory Manager (Enactment)

Knowledge	Output
OVM Crash Watcher (Classification)	OVM Crash (Information)
OVM Memory Watcher (Classification)	OVM OutOfMemory Prediction (Information)
OVM Memory Watcher (Classification)	OVM Memory Spike (Information)
ESS Process Watcher (Classification)	ESS Process Spike (Information)
OVM Memory Diagnosis (Assessment)	Needs Elastic Memory (Hypothesis)
OVM Crash Diagnosis (Assessment)	OVM OutOfMemory Crash (Hypothesis)
Elastic Memory Advisor (Resolution)	Unlock Memory in Dom0 to DomU (Directive)
Dom0 Memory Manager (Enactment)	Dom0 and DomU Memory (Feature Fact)

KIDS Entity Model in a Temporal Database

- Situation Calculus is dynamic First Order Logic
  - can leverage temporal database
- Entity model of software and hardware components in Oracle Cloud is dynamic
  - new software releases
  - patches for bug fixes
  - hardware upgrades
  - capacity scale out
  - dynamic resource management
- Monitoring anomaly to avert SLA violation
  - time-series model of loads, system changes, and system responses
    - load distribution – e.g. Poisson arrival process
    - seasonal trends – daily, weekly, monthly cycles
    - configuration changes
    - software patches
    - hardware upgrades

Entity Model Enables BIG Data Analytics

- Entity Extraction from BIG Log Data

- Concepts hierarchy and lattice of Fusion Application
  - pillar dimension
  - pod dimension
  - resource dimensions

- OLAP operations in multidimensional data cubes
  - Roll-up
  - Drill-down
  - Slice and Dice
  - Pivot
  - Drill-across, Drill-through

Entity Extraction from BIG Log Data

Example: Entity Identification in WebLogic server.log

Log file metadata includes Pod, Domain, Server information.

####<Feb 3, 2014 2:18:02 AM UTC> <Error> <HTTP> <a12345.oraclecloud.com> <TalentManagementServer_1> <[ACTIVE] ExecuteThread: '24' for queue: 'weblogic.kernel.Default (self-tuning)'> <<WLS Kernel>> <> <112wNGH4Klp96313VJjOB8911126u001a11> <1391393882108> <BEA-101017> <[ServletContext@664091965[app:HcmTalentApp module:hcmTalent path:/hcmTalent spec-version:2.5 version:V2.0]] Root cause of ServletException.

java.io.IOException: javax.el.ELException: oracle.jbo.ReadOnlyAttrException: JBO-27008: Attribute PersonId in view object WorkerList1 cannot be set

a12345.oraclecloud.com identifies the OVM

TalentManagementServer_1 identifies the JVM

HcmTalentApp identifies the application

hcmTalent identifies the web module

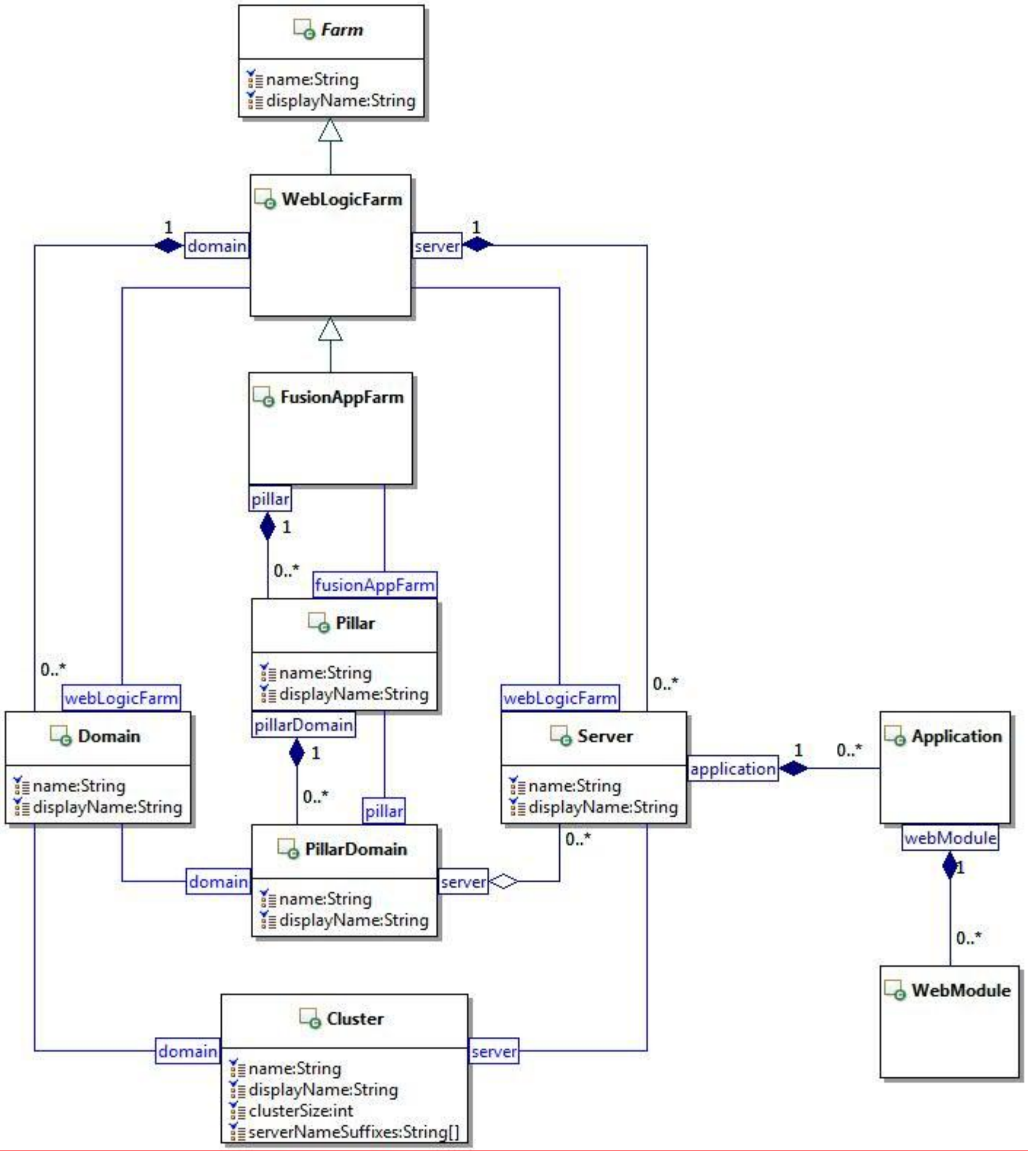
/hcmTalent identifies the url

112wNGH4Klp96313VJjOB8911126u001a11 identifies the Execution Context ID

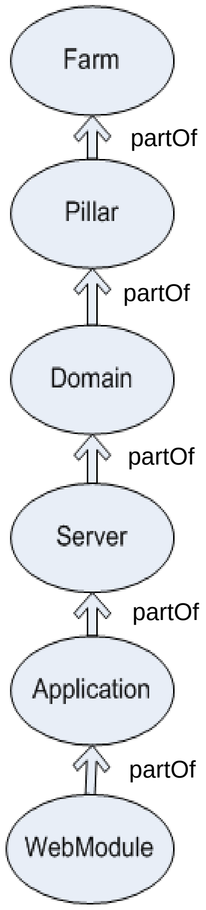
BEA-101017 identifies the source of the exception

JBO-27008 identifies the cause of the exception

Entity Model of Fusion Application Pillar



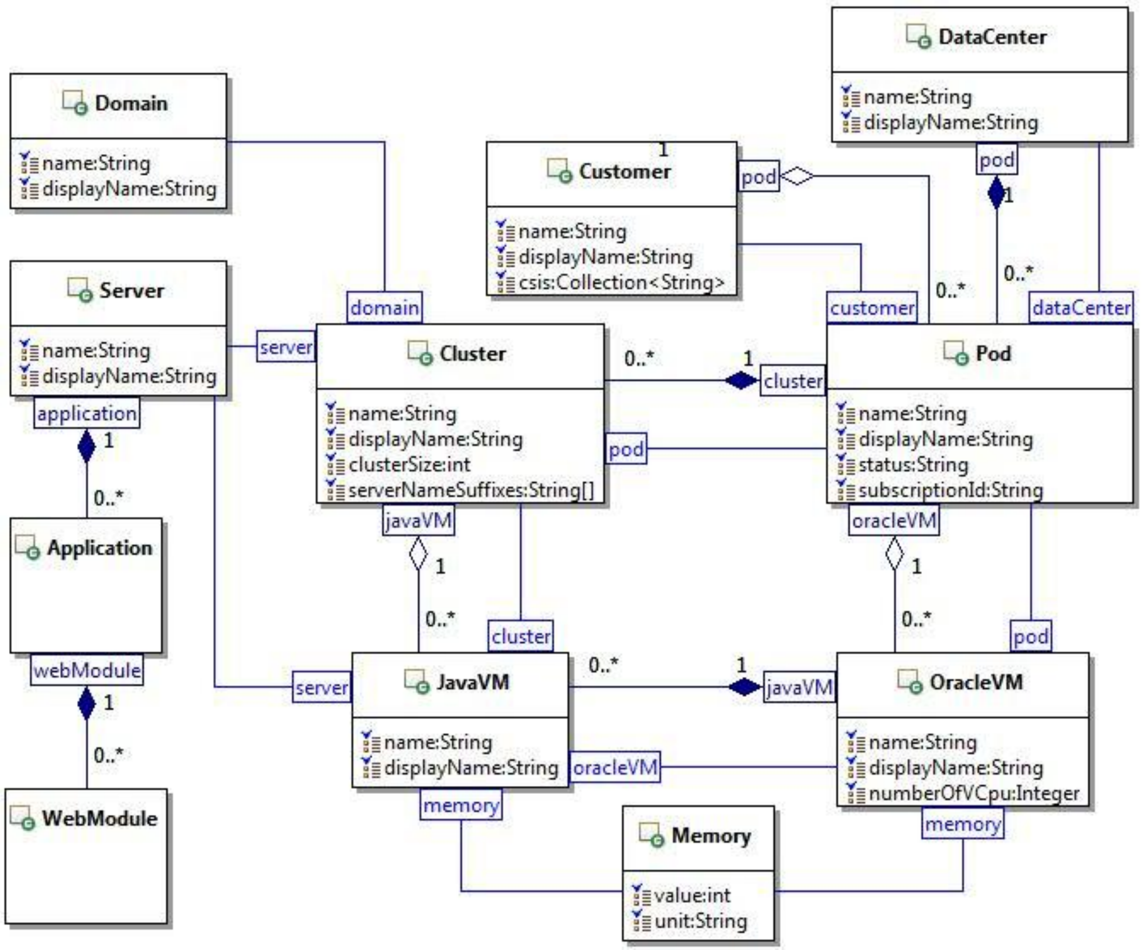
Concepts Hierarchy



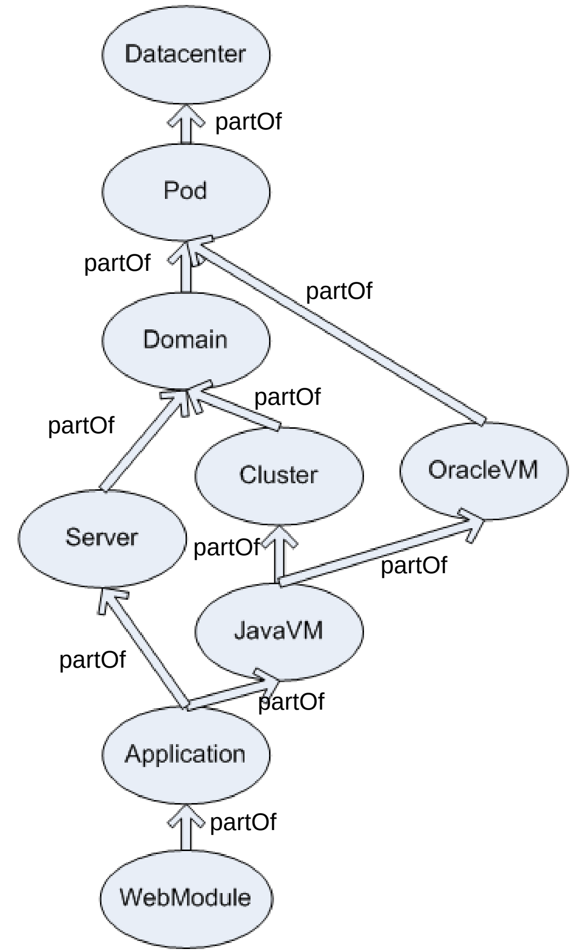
Concepts Hierarchy in the Pillar Dimension

```
CREATE DIMENSION pillar_dim
   LEVEL webModule        IS (pillar.webModule_name)
   LEVEL application      IS (pillar.application_name)
   LEVEL server           IS (pillar.server_name)
   LEVEL domain           IS (pillar.domain_name)
   LEVEL pillar           IS (pillar.pillar_name)
   LEVEL farm             IS (pillar.farm_name)
   HIERARCHY pillar_rollup (
       webModule          CHILD OF
       application        CHILD OF
       server             CHILD OF
       domain             CHILD OF
       pillar             CHILD OF
       farm);
```

Entity Model of Fusion Application Pods



Concepts Lattice



Concepts Lattice in the Pod Dimension

```
CREATE DIMENSION pod_dim
    LEVEL webModule       IS (pillar.webModule_name)
    LEVEL application     IS (pillar.application_name)
    LEVEL server          IS (pillar.server_name)
    LEVEL domain          IS (pillar.domain_name)
    LEVEL javaVM          IS (pod.javaVM_name)
    LEVEL oracleVM        IS (pod.oracleVM_name)
    LEVEL cluster         IS (pod.cluster_name)
    LEVEL pod             IS (pod.pod_name)
    LEVEL dataCenter      IS (resource.dataCenter_name)
```

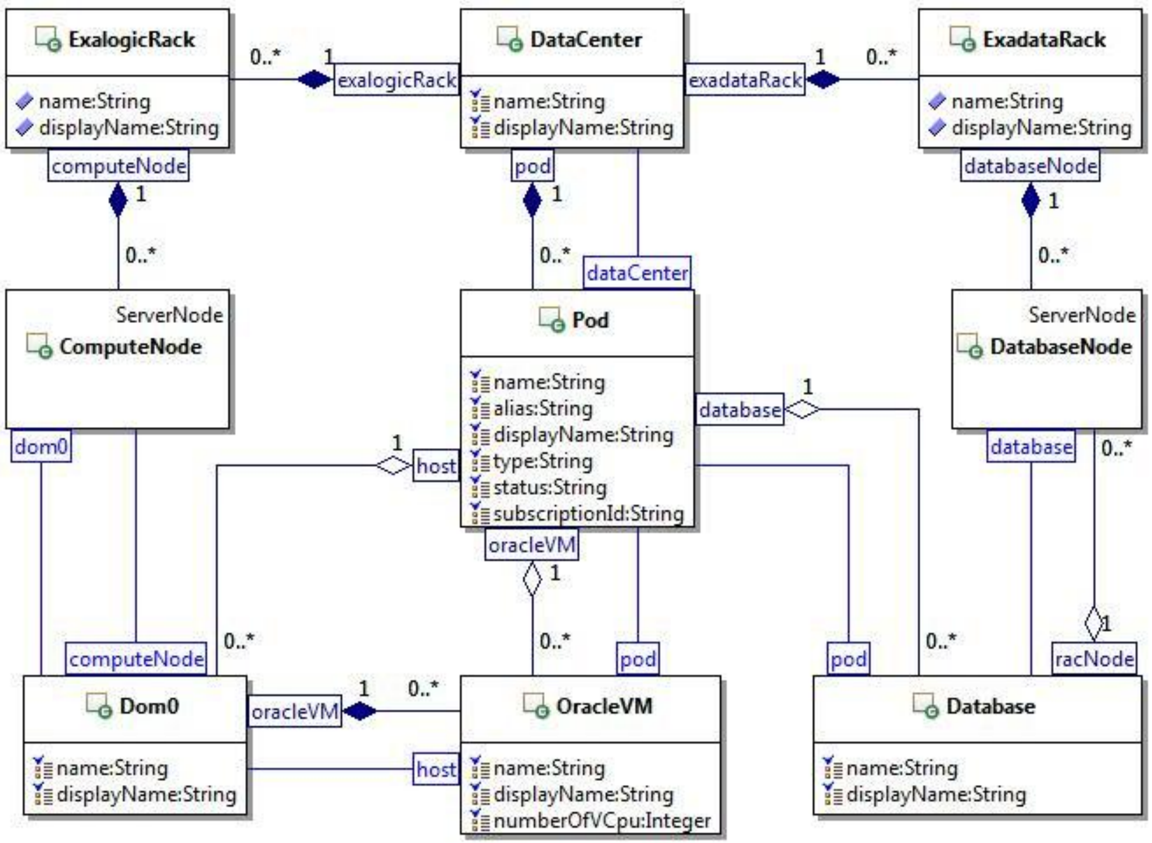
```
HIERARCHY pod_rollup (
        webModule         CHILD OF
        application       CHILD OF
        server            CHILD OF
        domain            CHILD OF
        pod               CHILD OF
        dataCenter)
```

```
HIERARCHY cluster_rollup (
        webModule         CHILD OF
        application       CHILD OF
        javaVM            CHILD OF
        cluster           CHILD OF
        domain            CHILD OF
        pod               CHILD OF
        dataCenter)
```

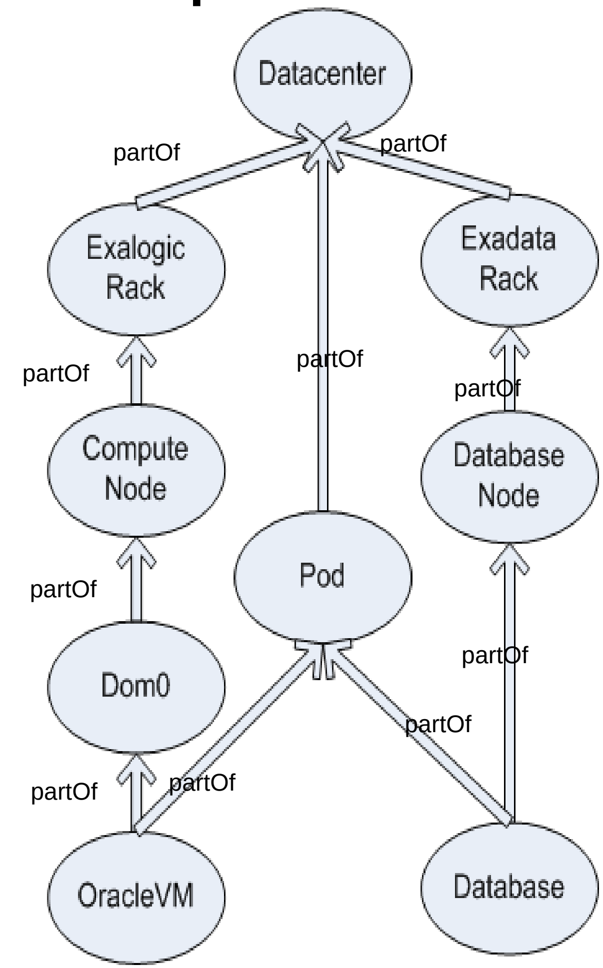
```
HIERARCHY vm_rollup (
        webModule         CHILD OF
        application       CHILD OF
        javaVM            CHILD OF
        oracleVM          CHILD OF
        pod               CHILD OF
        dataCenter)
```

```
JOIN KEY (pod.domain_name) REFERENCES domain
JOIN KEY (pod.dataCenter_name) REFERENCES dataCenter;
```

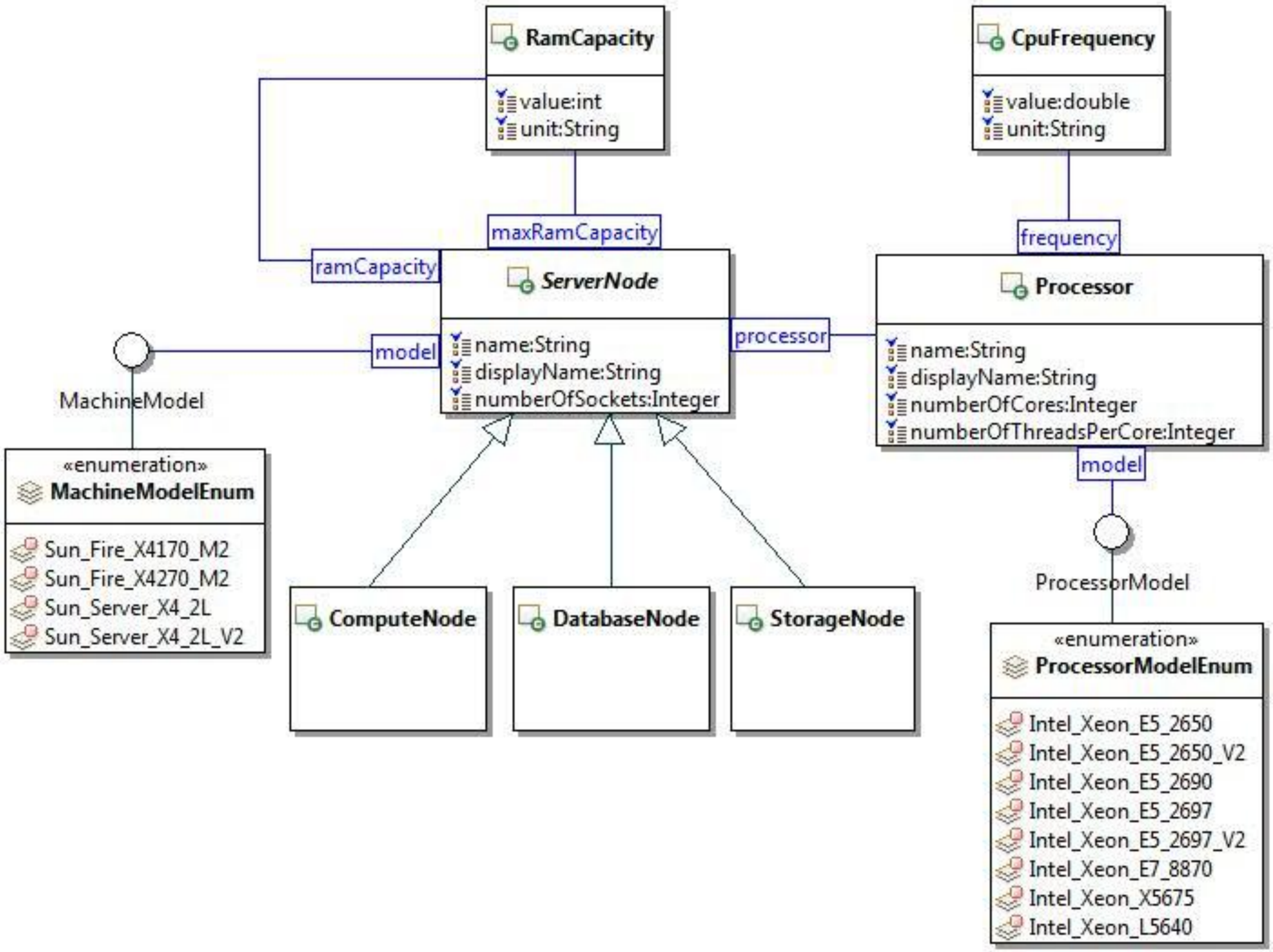
Entity Model of Virtual and Physical Resources



Concepts Lattice



Entity Model of Physical Machines



Concepts Lattice in the Middleware Resource Dimension

```
CREATE DIMENSION compute_resource_dim
   LEVEL javaVM          IS (pod.javaVM_name)
   LEVEL oracleVM        IS (pod.oracleVM_name)
   LEVEL dom0            IS (compute_resource.dom0_name)
   LEVEL computeNode     IS (compute_resource.computeNode_name)
   LEVEL exalogicRack    IS (compute_resource.exalogicRack_name)
   LEVEL processor       IS (processor.processor_name)
LEVEL dataCenter         IS (resource.dataCenter_name)
HIERARCHY compute_resource_rollup (
       javaVM            CHILD OF
       oracleVM          CHILD OF
       dom0              CHILD OF
       computeNode       CHILD OF
       exalogicRack      CHILD OF
       dataCenter)
ATTRIBUTE computeNode DETERMINES
       (computeNode_name, serverModel, ramCapacity, ramCapacityUnit,
        numberOfSockets)
ATTRIBUTE processor DETERMINES
       (processor_name, processorModel, cpuFrequency, cpuFrequencyUnit,
        numberOfCores, numberOfThreads)
JOIN KEY (compute_resource.oracleVM_name) REFERENCES oracleVM
JOIN KEY (compute_resource.processor_name) REFERENCES processor
JOIN KEY (compute_resource.dataCenter_name) REFERENCES dataCenter
```

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Concepts Lattice in the Database Resource Dimension

```
CREATE DIMENSION database_resource_dim
   LEVEL database          IS (database_resource.database_name)
   LEVEL databaseNode      IS (database_resource.databaseNode_name)
   LEVEL exadataRack       IS (database_resource.exadataRack_name)
   LEVEL processor         IS (processor.processor_name)
   LEVEL dataCenter        IS (resource.dataCenter_name)
HIERARCHY compute_resource_rollup (
       database            CHILD OF
       databaseNode        CHILD OF
       exadataRack         CHILD OF
       dataCenter)
ATTRIBUTE databaseNode DETERMINES
       (databaseNode_name, serverModel, ramCapacity, ramCapacityUnit,
        numberOfSockets)
ATTRIBUTE processor DETERMINES
       (processor_name, processorModel, cpuFrequency, cpuFrequencyUnit,
        numberOfCores, numberOfThreads)
JOIN KEY (database_resource.processor_name) REFERENCES processor
JOIN KEY (database_resource.dataCenter_name) REFERENCES dataCenter
```

KIDS Materializes OODA Loops in Data

- Intelligent Behavior = Data + Knowledge + Process
- Captured by an invariant structure of data, knowledge, and process
  - Data: fact, information, hypothesis, directive
  - Knowledge: classification, assessment, resolution, enactment
  - Process: observe, orient, decide, act
- Annotate Log Data with CARE Data
- Materialize the OODA loops in Data for provenance
- Enable a faster OODA loop in real-time

Annotate the FIHD and CARE Data

Fact: server.log and node_manger.log
Information: OOM Exception
Directive: restart by node manager

Fact: node_manager.log
Information: High level drift
Directive: restart by operator

Fact: Heap Dump JVM23456.hprof
Information: Leak site HashMap XYZ.cache
Hypothesis: Memory Leak (Bug 11111)
Directive: Implement soft reference
Enactment: Apply Patch-12345

Fact: GC data
Information: High memory variance
Hypothesis: Need LRU in Cache (Bug 22222)
Directive: Soft ref on hash value, not HashMap
Enactment: Apply Patch-45678

Conclusion

- KIDS Ontology
  - leverages existing database, knowledge, and social interaction systems
  - tackles variety problem of BIG data
    - significant amount of data
    - significant amount of rapidly evolving knowledge
    - large scale state tracking for provenance
    - rich social interaction and collaboration