Making Data Meaningful: The Business Intelligence Model and its Formal Semantics in Description Logics

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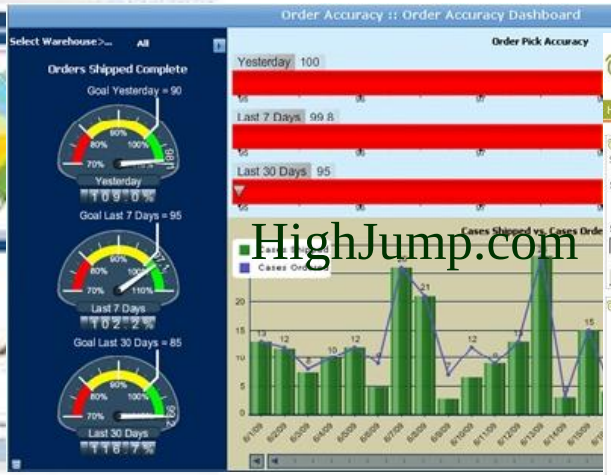
Business Intelligence

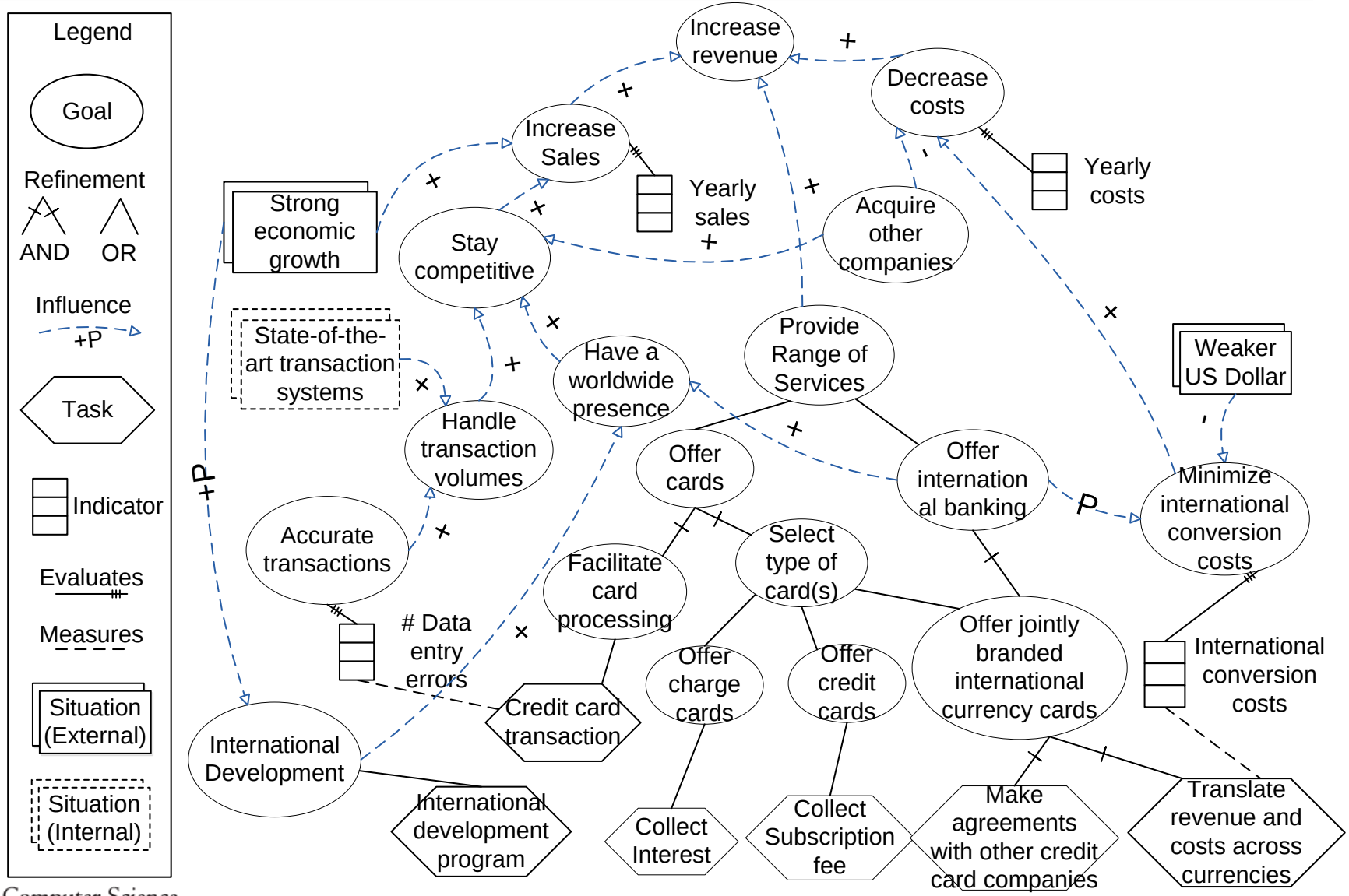
- Organizations produce data on processes, sales, personnel, etc.
- Business Intelligence analyzes and displays business data
- Analysis allows businesses to bettor monitor their business, develop strategies, gain a competitive edge



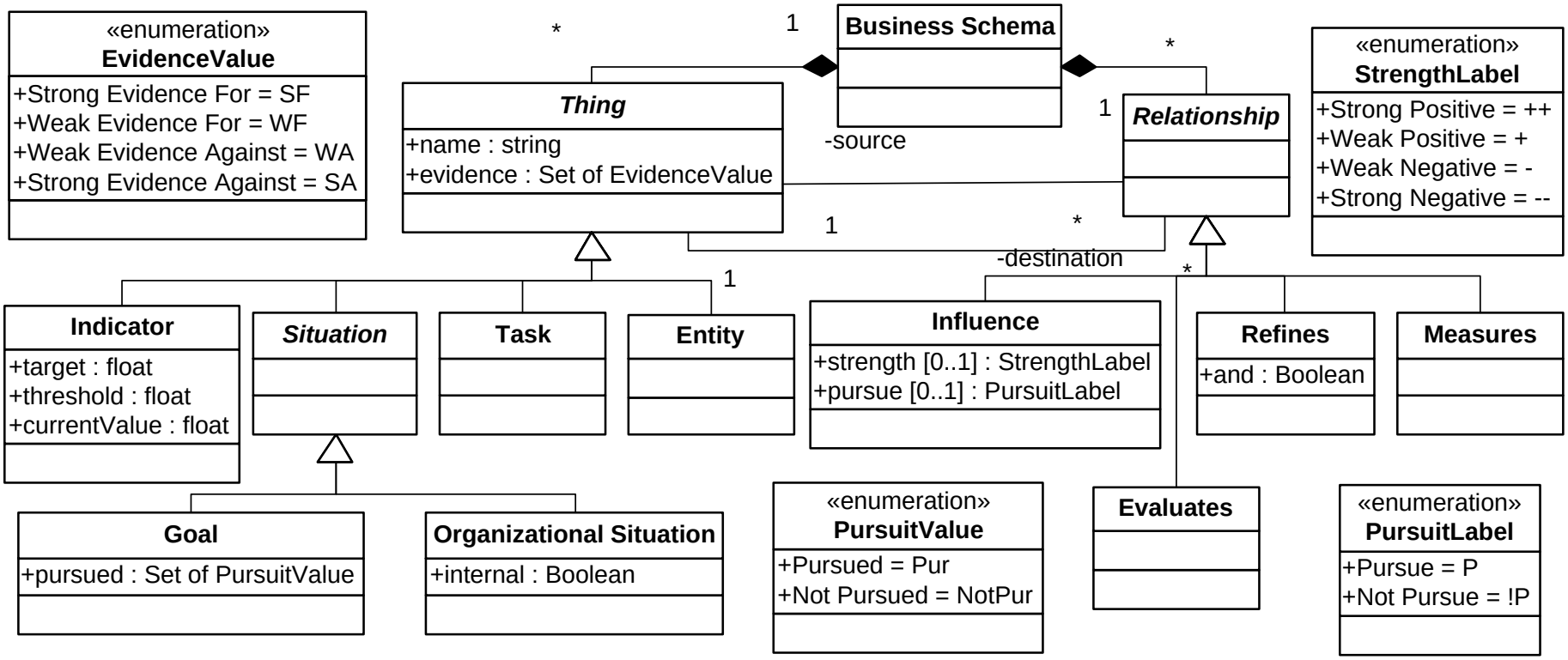
Business Intelligence Model (BIM) Aims

- BI is widely used, but is **technical and data-oriented**
  - Gap between business and IT-supplied data
- Business people would rather reason using familiar terms:
  - Objectives, strategies, processes, markets, trends, risks, etc.
- **Raise the level of abstraction** of BI systems via a modeling language using familiar business concepts
- Existing techniques for modeling business strategy:
  - Strategy Maps and Balanced Scorecards, Business Motivation Model, Dynamic SWOT Analysis, Goal Models
- Offer many useful but often not clearly defined concepts
  - E.g., visions, objectives, goals, means, strategies, plans, etc.
- BIM offers a **consolidated set of clearly defined core concepts**
  - Definition via OWL2 Description Logic

BIM Example: Credit Card Industry



BIM Concepts and Relationships



BIM Things

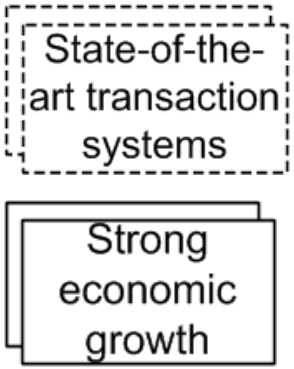
- All things are BIM *Things*, e.g.,
  Class: Situation **SubClassOf:** Thing
- BIM considers multiple sources and degrees of *Evidence*, either for or against each thing
- "Evidence for…?" is answered depending on the specific type of thing:
  - *satisfaction* of goals, *occurrence* of situations, …
- Use a qualitative evidence scale similar to the satisfaction/denial scale used in goal models
  - **S**trong/**W**eak evidence **F**or/**A**gainst a thing, **SF**, **WF**, **WA**, and **SA**

Property: evidence **Domain**: Thing **Range**: {SF,WF,WA,SA}

Class: SFThing **EquivalentTo:** Thing **and** (evidence **value** SF)

Situation and Goal

- Must take into account *Situations* which may effect business objectives, from SWOT analysis
  - BIM schemas are from the point of view of a particular organization, situations are *internal* or *external*
  - Situations *occur*



Property: occurence **Domain**: Situation **SubpropertyOf:** evidence

- *Goals* are intentional situations that are desired by the (viewpoint) organization
  - Goals are *satisfied*

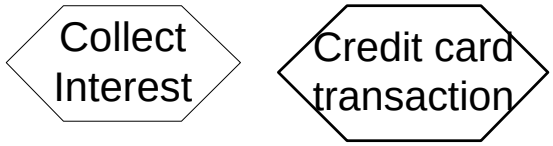
Property: satisfied **Domain**: Goal **SubpropertyOf:** evidence

  - Goals have a *Pursuit* attribute, indicating whether they are actively being pursued

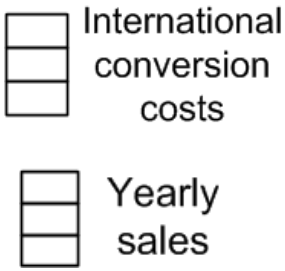
Property: pursuit **Domain**: Goal **Range**: {Pur, NotPur}

Task, Indicator, and Entity

- *Tasks* are processes or sets of actions
  - We collect *evidence* for/against *the execution* of tasks



- *Indicators* link schema elements to data sources
  - We collect strong/weak evidence for or against the *performance* of indicators



- *Entities* relevant to the schema can be modeled
  - BIM can represent evidence for/against the *existence* of individual entities
- The ontology and modeling of entities and processes/events has been well-studied (UEMO, etc.)

Refines Relationship

- *Refinement* provides direct *evidence* for/against a thing

  Property: refines **Inverse**: refinedBy

- Concepts can be refined into other concepts of the same type

  Class: Situation **SubClassOf:** (refines **only** Situation)

  Class: (refines **some** Situation) **SubClassOf:** Situation

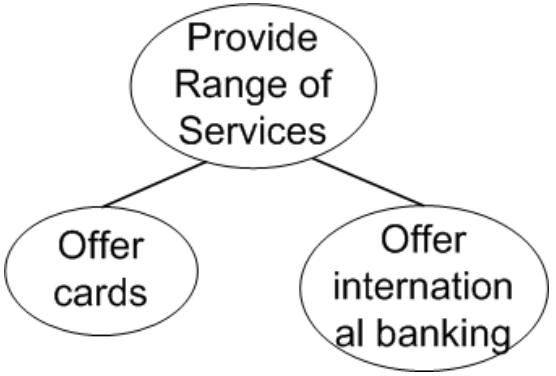
  (similar axioms for all Thing sub-classes)

- Refinements are by default disjunctive (ORed), but can be indicated as explicitly conjoined (ANDed)

  Class: AND_Thing **SubClassOf**: Thing

  Class: OR_Thing

  EquivalentTo: Thing **and not** AND_Thing



Reasoning with Refines

- We use the rules for combining evidence on AND and OR refinements from Goal Modeling (Giorgini et al., 2004)
- E.g., for positive evidence:
  - AND Refinements: all refiners must have value to propagate value to source
  - OR Refinements: enough to have one refiner with a value to propagate value to source

SF	Strong For
WF	Weak For
WA	Weak Against
SA	Strong Against

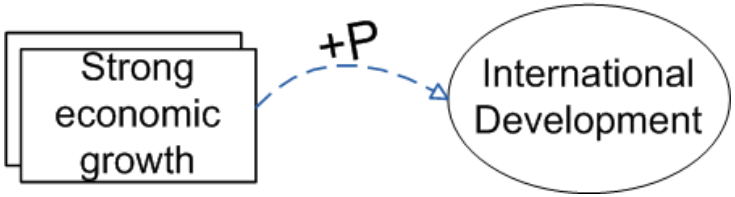
- Refines, sample axioms for WF evidence (2 of 8 total):

  OR_Thing **and** (refinedBy **some** WFThing) **SubClassOf**: WFThing

  AND_Thing **and** (refinedBy **only** WFThing) **SubClassOf**: WFThing

Influence Relationship

- The *influences* relationship is used to represent the transmission of (un)favorable effects on situations



Property: influences **Domain**: Situation **Range**: Situation **InverseOf**: infBy

- From goal modeling, there are four kinds of *influences* links:
  - ++/+ (make/help) link represents strong/partial positive effect
  - --/- (break/hurt) link represents strong/partial negative effect

- Influence can also affect pursuit, using labels: P and !P
  - Influence axioms are organized into a hierarchy, examples (3 of 8):

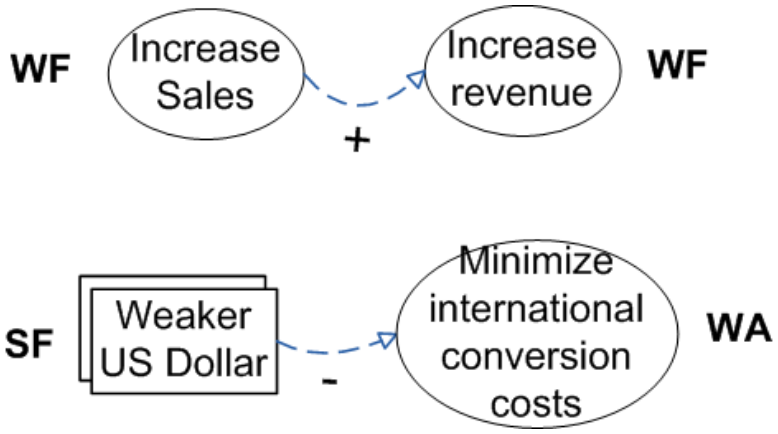
+ **Property**: infBy+ **InverseOf**: influences+ **SubpropertyOf:** infByPositively

P **Property**: infByP **InverseOf**: influencesP **SubpropertyOf**: infBy

+P **Property**: +P_infBy **InverseOf**: +P_influences **SubpropertyOf**: infByP, infBy+

Reasoning with Evidence and Influence

- We use rules for propagating evidence on influence links adapted from Goal Modeling (e.g., Giorgini et al., 2004)



	Link Label Contains			
Source Evidence Set Contains	++	+	-	--
SF	SF	WF	WA	SA
WF	WF	WF	WA	WA
WA	WA	WA	WF	WF
SA	SA	WA	WF	SF

Evidence propagation depending on influence label (destination Evidence value in grey)

- Sample axioms (2 of 16):

  (infBy+ **some** WFThing) **SubClassOf** WFThing

  (infBy- **some** SFThing) **SubClassOf** WAThing

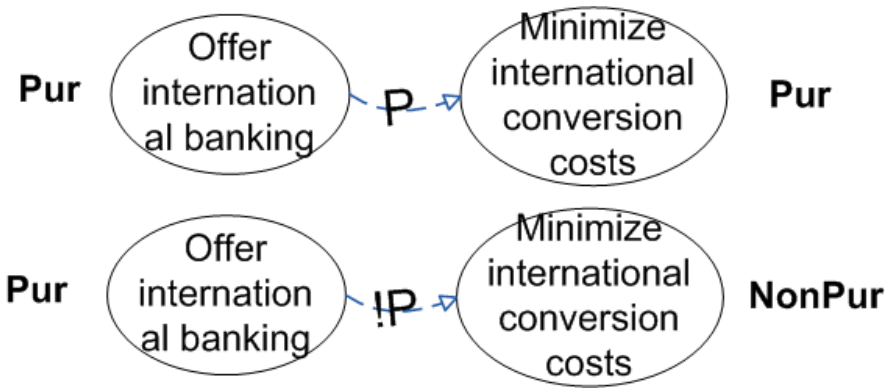
SF	Strong For
WF	Weak For
WA	Weak Against
SA	Strong Against

Reasoning with Pursuit and Influence

- Useful defined classes:

  Class: PurGoal **EquivalentTo:** Goal **and** (pursuit **value** Pur)

  Class: NotPurGoal **EquivalentTo:** Goal **and** (pursuit **value** NonPur)



	Link Label Contains	
Source Pursuit Set Contains	**P**	**!P**
Pur	Pur	NonPur
NonPur	NonPur	Pur

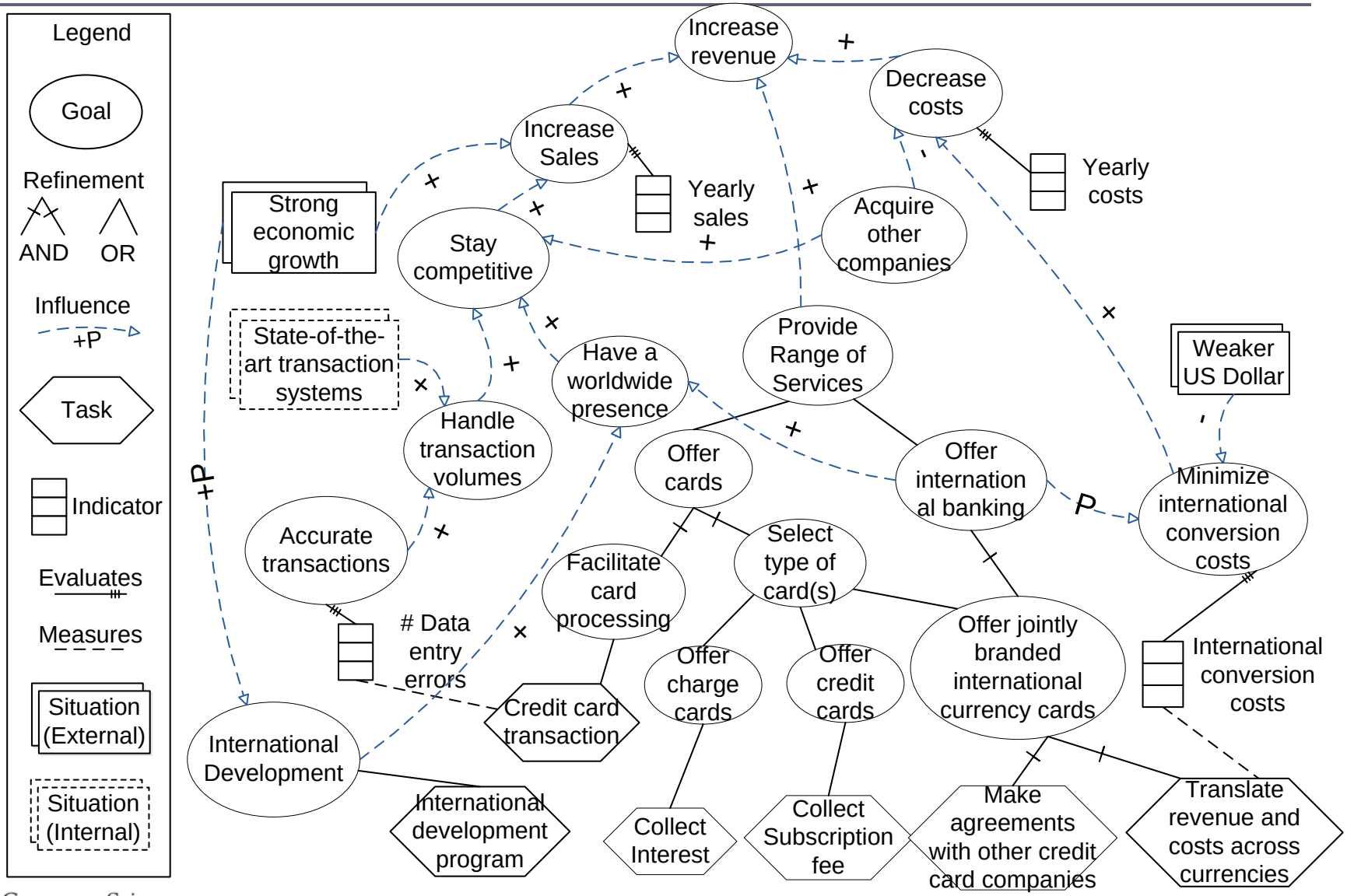
Pursuit value propagation depending on influence label (destination Pursuit value in grey)

- Influence with pursuit (goal to goal), sample axioms (2 of 4):

  (infByP **some** PurGoal) **SubClassOf** PurGoal

  (infBy!P **some** PurGoal) **SubClassOf** NotPurGoal

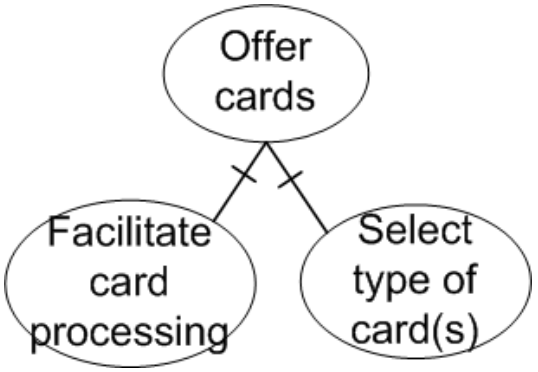
Representing Specific BIMs in DL



Representing Specific BIMs in DL

1. Create a concept with proper subclass for every node

   Class: OfferCards **SubClassOf:** Goal **and** AND_Thing



2. Add disjointness axioms between all the concepts

   DisjointClasses: HaveAWorldwidePresence, MakeAgreementswithOtherCreditCardCompanies, …

3. Represent all the edges/relationships and their inverses

   Class: OfferCards **SubClassOf**: (refinedBy some SelectTypeOfCards)

   Class: OfferCards **SubClassOf**: (refinedBy some FacilitateCardProcessing)

   Class: SelectTypeOfCards **SubClassOf:** (refines exactly 1 OfferCards)

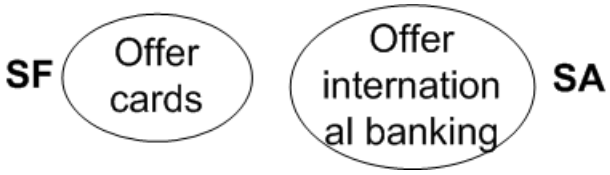
   Class: FacilitateCardProcessing **SubClassOf:** (refines exactly 1 OfferCards)

4. Add cardinality constraints for every edge type

   Class: OfferCards **SubClassOf:** (refinedBy **exactly** 2 Thing) **and** (refines **exactly** 1 ProvideRangeofServices)

Reasoning with BIM Models

- "What if?" scenarios,
  - In our example, what if we Offer Cards but don't Offer International Banking?



Class: OfferCards **SubClassOf:** SF_Thing

Class: OfferInternationalBanking **SubClassOf:** SA_Thing

  - Then check which elements are subclasses of SF_Thing, WF_Thing, Pur, etc.
- Consistency testing
  - Find classes which may always be empty/inconsistent
  - Find errors in using the language constructs
- Automatic classification of defined concepts, e.g.:

Class: AmbivalentThing **EquivalentTo:** (influencesPositively **some** Goal) **and** (influencesNegatively **some** Goal)

BIM Meta-properties

- Allow users to introduce more specialized concepts from other languages (e.g., Vision, Mission, Strategy (BMM), Softgoal, Hardgoal (GM), Initiative (BSC))
- Use six meta-properties over elements
  - *duration* (long-term/short-term), *likelihood of fulfillment* (high/low), *nature of definition* (formal/informal), *scope* (broad/narrow), *number of instances* (many/few), *perspective* from BSC (financial/ customer/ internal/ learning and growth)
  - E.g., **Vision** is a "goal with a long duration, broad scope, low chance of fulfillment, informal definition, and few instances"

Have a worldwide presence

Property: duration **Domain**: Thing **Range**: {long_term, short_term}

Class: Vision **EquivalentTo:** Goal **and** (duration **value** long-term) **and … and** (nature_of_definition **value** informal).

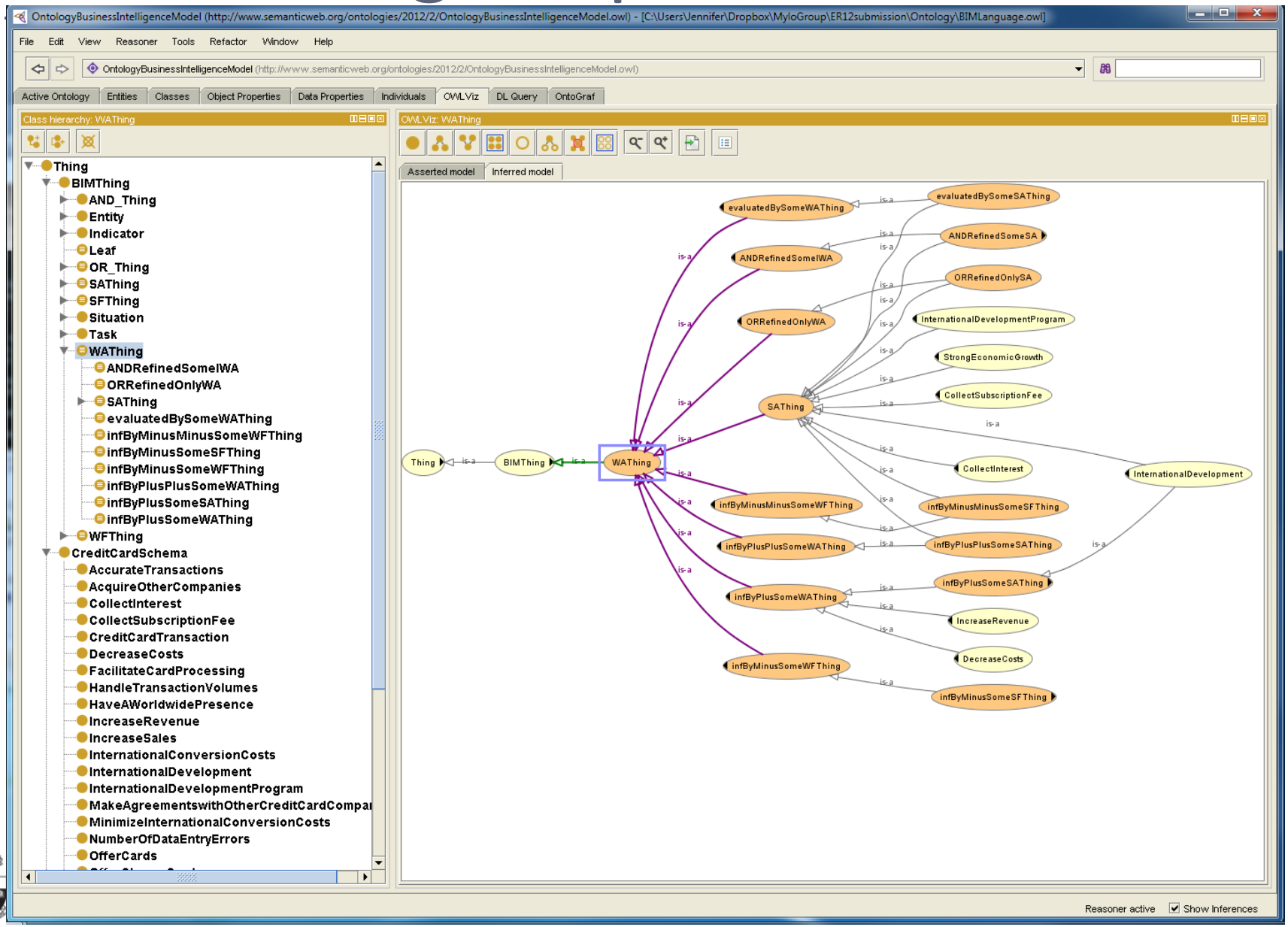
Evaluation

- Consider coverage of concepts in existing languages

BIM Concept/ Relationship	Covers Concept (Language), possibly using metaproperties
Goal	End, Vision, Objective, Goal (BMM); Soft/Hardgoal (GM), Objective (SWOT); Mission, Vision, Goal/Objective (BSC/SM);
Task	Means, Course of action, Mission, Strategy, Tactic, Business process (BMM); Task (GM); Strategy, Initiative (BSC/SM);
Situation	Internal/External Influencer (BMM), Issue (SWOT)
Situation + influence	Strength, Weakness, Opportunity, Threat (SWOT)
Indicator	Metric (BMM), Measure (BSC/SM)
Indicator target	Target (SWOT), Target (BSC/SM)
AND/OR Refinement	AND/OR Decomposition (GM); aggregation (UML)
Influence	Contribution (GM)

- Earlier version of BIM has been applied in a health care setting (Barone et al., 2012)
- Implemented BIM language and Credit Card example in OWL Protégé

OWL Protégé Implementation



Advancements over Previous Work

- BIM has been proposed (mainly informally) in previous work (PoEM'10, ER'11, ER'11, PoEM'11, SoSym'12)
  - Mapped BIM models to existing models to facilitate reasoning
- In this work we consolidate, formalize, and expand BIM
  - Formal semantics via translation to OWL2 Description Logic (DL)
  - Syntax uniformity via *evidence* attribute for *all* things
  - Introduce the novel concept of goal *pursuit*, used in BIM analysis
  - Specific BIM models can be translated and published as OWL ontologies on the Semantic Web
  - Utilize the reasoning capabilities inherent in DL: inconsistency detection, "what if" scenario evaluation, defining and classifying new model concepts
  - Introduction of more specialized concepts via meta-properties

Limitations, Future Work

- Limitations
  - Quantitative analysis with indicators
- Future work
  - User interfaces
  - Concrete syntax
  - Further validation

Thank you!

- Questions?

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