Collaborative Building of a Shared Library of Performance Indicators

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Introduction

Scenario
Performance measurement in collaborative environments
e.g., Virtual Enterprises (VE)

Challenges
- Performance Indicators (PI): complex data with an aggregate/compound nature
- Business view vs. technical view of PIs
- Lack of shared understanding of PI meaning
- Distribution and autonomy: heterogeneity at structure level
Motivation

Example: compare performances of two enterprises of a VE

- how to explicit the compositional semantics for PIs?
- how to keep the collaboratively built repository consistent?
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Approach

- **Ontological representation of PIs**
  - descriptive and compositional semantics for PIs
  - goal: annotation of local data with global definitions

- **Reasoning and manipulation services for PIs**
  - facts to represent PIs
  - predicates to formalize mathematical axioms for formula manipulation and check of consistency

- **Ontology editor**
  - flexible management of the ontology
Inspiring principles: VRM, SCOR, Six-Sigma, multidimensional models

Indicator \equiv \forall \text{hasDimension.Dimension} \sqcap \\
\quad \forall \text{hasFormula.Formula} \sqcap (=1 \text{hasFormula}) \sqcap \\
\quad \forall \text{hasUnitOfMeasure.UoM} \sqcap (=1 \text{hasUnitOfMeasure}) \sqcap \\
\quad \forall \text{hasBusObj.BusinessObjective} \sqcap (=1 \text{hasBusObj}) \sqcap \\
\quad \forall \text{hasAggrFunction.AggrFun} \sqcap (=1 \text{hasAggrFunction})
KPIOnto ontology

**Dimension**: coordinate along which an indicator can be computed (e.g., time, place and product for *Total Costs*)

Dimensions are organized in levels, e.g.:
- **Time**: Day $\preceq$ Week $\preceq$ Month $\preceq$ Year
- **Place**: City $\preceq$ Region $\preceq$ Country
**KPIOneto ontology**

**Formula:** mathematical expression stating how an indicator is computed  
(e.g., PersonnelTrainingCost=HourlyCost*PersonnelTrainingTime)

**Definition (Well-formed formula)**
Given a set \{f_1, ... , f_n\} of symbol of indicators and a set \{op_1, ... , op_m\} of algebraic operators,

- \( f_i \) is a well-formed formula;
- \( op_j(f_1, ... , f_k) \) is a well-formed formula.

Reference to OpenMath for semantics of operators
KPIOnto ontology

Indicator
- ProductInd
- OperationInd
- CorporateInd
- CustomerInd
  - Financial
  - HumanRes
  - Customer
  - Assets

PersonnelTrainingCosts
- hasFormula: HourlyCost*PersonnelTrainingTime
- hasUnitOfMeasure: €
- hasBusObj: Cost_Orientation
- hasDimension
- hasAggrFunction: Sum

Dimension
- OrganizationDimension
- ProcessDimension
- ProductDimension
- TimeDimension
  - Month
  - Quarter
  - 2013-01
  - 2013-02
  - 2013-03
  - 2013-04
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Reasoning functionalities

Logic programming as unifying logic layer:

- representation of formulas as Prolog facts, e.g.:
  \[ A = B + C \rightarrow \text{formula}(A,B+C,’branch\_node’) \]

- Prolog predicates for basic reasoning tasks:
  - mathematical theory for formula manipulation (PRESS: PRolgo\_Equation\_Solving\_System)
    - basic math operation
    - equation solving and formula rewriting
  - definition of specific predicates for PI management

- XSB as Prolog reasoner
Reasoning functionalities

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Reasoning: consistency check

Let $\mathcal{KB}$ be a repository of PIs, a new indicator with formula $f_{new}$ is consistent with $\mathcal{KB}$ iif:

- $\not\exists f_i \in \mathcal{KB} / f_i = f_{new}$ (no formula is identical to $f_{new}$) $\rightarrow$ identical

- $\mathcal{KB} \not\models f_{new}$ (no formula is mathematically equivalent to $f_{new}$) $\rightarrow$ equivalence

- $\mathcal{KB} \cup \{f_{new}\} \not\models \bot$ (the formula is coherent with the others in the $\mathcal{KB}$) $\rightarrow$ incoherence
Reasoning: consistency check

Evaluation of equivalent formulas:

dequivalence(F): given a formula G of the ontology, a formula F is equivalent to G if can be rewritten as G (by rewriting functionalities)

Policies:

- remove the duplicate
- keep duplicates and declare that the corresponding PIs are the same indicator
Reasoning: consistency check

Scenario: insertion of a new indicator

\[
\text{TotCostEmpTrain} = \text{TeachCosts} + \text{PersonnelTrainingTime} \times \text{HourlyCost}
\]

Result: equivalent to \text{InvestmentInEmployeeDevelopment}
Reasoning: consistency check

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Result: equivalent to \( \text{InvestmentInEmployeeDevelopment} \)
Reasoning: consistency check

Predicate to maintain a consistent ontology:

\textbf{incoherence}(F): given a new formula \( F = \textit{expression} \)

- for each formula \( G \) in \( \mathcal{KB} \) containing a reference to \( F \)
  - solve \( G \) for \( F \), obtaining \( F = \textit{expression_2} \)
  - if \( \{ \text{indicators in } \textit{expression} \} \subseteq \{ \text{indicators in } \textit{expression_2} \} \) then \( F \) is inconsistent
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Ontology editor

Creation of a new indicator

[Image of the ontology editor interface showing the creation of a new indicator named 'TotCostEmpTrain']

- Name: TotCostEmpTrain
- Acronym: TCET
- has Bus Obj: Cost_Orientation
- KPI Description: Total costs for training of employees
- Unit of Measure: €
- has Dimensions: ProductDimension, OrganizationDimension, TimeDimension

Aggregation Function: Sum

Formula: Offset

Indicators:

<table>
<thead>
<tr>
<th>Name</th>
<th>Acronym</th>
<th>Priority Dimension</th>
<th>Unit of Measure</th>
<th>Creator</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>PersonnelTrainingCosts</td>
<td>PTC</td>
<td>Cost_Orientation</td>
<td>€</td>
<td>D. potena</td>
<td></td>
</tr>
<tr>
<td>PersonnelTrainingTime</td>
<td>PTT</td>
<td>Cost_Orientation</td>
<td>Hours</td>
<td>D. potena</td>
<td></td>
</tr>
</tbody>
</table>

Showing 1 to 2 of 2 entries (filtered from 335 total entries)
### Ontology editor

#### Search/Browse indicators

<table>
<thead>
<tr>
<th>Name</th>
<th>PersonnelTrainingCosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acronym</td>
<td>PTC</td>
</tr>
<tr>
<td>KPI Description</td>
<td>Expenses to train personnel to fulfill tasks related to the project</td>
</tr>
<tr>
<td>Formula Name</td>
<td>F_PTC (is Additive: no)</td>
</tr>
</tbody>
</table>

**Formula:**

\[
F_{\text{PTC}} = (F_{\text{NTC}} \times F_{\text{PTT}})
\]

<table>
<thead>
<tr>
<th>Unit of Measure</th>
<th>€</th>
</tr>
</thead>
<tbody>
<tr>
<td>has Aggregation Function</td>
<td>Sum</td>
</tr>
<tr>
<td>Dimensions</td>
<td>OrganizationDimension, ProductDimension</td>
</tr>
<tr>
<td>has Bus Obj</td>
<td>Cost_Orientation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Creator</th>
<th>D.potena</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creation Date</td>
<td>2013/9/2T14:14:55</td>
</tr>
<tr>
<td>Last Modified by</td>
<td>D.potena</td>
</tr>
<tr>
<td>Modification Date</td>
<td>2013-09-02T12:14:55</td>
</tr>
</tbody>
</table>
Ontology editor

Creation of a new member
Experimentation

Experiments with a set of synthetic ontologies with increasing size\(^1\)
- # operands: 2..4, # nested formulas: 2..5
- 73980 unique tests

\(^1\)Intel Xeon CPU 3.60GHz, 3.50 GB RAM, Windows Server 2003 SP2
Collaborative development of a shared library of PIs:
- logical model for indicators (KPIOnto)
- reasoning services (mathematical model + set of predicates)

Current status of the work
- KPIOnto specification: w3id.org/kpionto
- KPIEditor: boole.dii.univpm.it/kpieditor
- KPIOnto adopted for a variety of applications
**Conclusion**

- **KPIExplorer**: ontology-based access and exploration of a database of PI values (in Innovation Radar 2015, European Commission)
- Exploratory OLAP: customised analytics on Linked Open Data
- Multidimensional query rewriting for Federated DWHs, using aggregation and measure decomposition

![KPI Explorer Interface](image_url)
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Future work

- purely ontological model for formulas
- recognition of similarity among formulas
- application in various domains as a support for:
  - monitoring in Public Transport Systems
  - development of Ambient Assisted Living environments
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