The MULTI Warehouse Challenge

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***Abstract*—The "MULTI" workshop series has set a number of multi-level modeling challenges, each designed to allow competing multi-level modeling approaches to demonstrate their capabilities and/or to tease out their limitations. The challenges therefore have been serving a three-fold purpose: First, they have allowed technologies to demonstrate their abilities. Second, they have pointed out where technologies still fall short of providing optimal modeling support. Third, they have provided a basis for comparing competing technologies, often revealing the trade-offs implied by certain design choices. The MULTI Warehouse Challenge described in this paper is the fourth installment in this series, defining a new unique set of demanding modeling challenges.**

***Index Terms*—Multi-level modeling, challenge, MULTI workshop**

1. Introduction

Multi-level modeling addresses the modeling of subject domains that benefit from an explicit recognition of multiple levels of domain representation, i.e., domains such as software development, process modeling, organizational roles, biological taxonomies, product hierarchies, etc. Over the span of two decades many approaches for multi-level modeling have been proposed, all sharing the goal of extending traditional two-level approaches with constructs and concepts that naturally support multiple levels of domain representation, with the goal to increase the expressiveness of models while simultaneously reducing their complexity.

Numerous advances in multi-level modeling approaches and tools have, however, lead to a proliferation of available approaches with a diverse set of technological underpinnings, thus displaying a lack of consensus on what kinds of constructs and concepts provide the best support for multi-level modeling. The respective lack of a common basis for multi-level modeling principles has been making it challenging to compare and integrate models constructed using different approaches. While plurality undoubtedly has undisputed advantages, and should be welcomed in general, it can also lead to an unnecessary fragmentation of efforts, cause confusion of interested parties, and thus, ultimately, become an obstacle to the further adoption and advancement of multi-level modeling.

Despite various efforts to better understand the various trade-offs made by different multi-level modeling supporting technologies – e.g,. three multi-level modeling challenges [1]–[3], a Dagstuhl seminar [4], and an EMISAJ special issue [5] which invited solutions to the EMISAJ "Process Challenge" [6] – much remains to be achieved in terms of fully understanding the implications of design choices of the past and which design choices of the future will best support the modeling of challenging subject domains.

The modeling challenge described in this paper is intended to add to the previous canon of MULTI multi-level modeling challenges and, as such, be a basis for

- allowing technologies to demonstrate their abilities,
- stress-testing technologies in order to expose any potential weaknesses, and
- comparing competing technologies, by revealing the trade-offs implied by their respective design choices.

The "Warehouse" challenge described below references a domain featuring representations of product copies, product specifications and product specification types. A particular emphasis is on how to guarantee certain properties at the product level without fully determining them, in other words, to support flexible but constrained variability.

Challenge responses will be reviewed against the following criteria:

1) Does the response address the domain requirements as described in Section 2?
2) Does it evaluate/discuss the proposed modeling solution against the criteria presented in Section 3?
3) Does it discuss the merits and limitations of a technology in the context of the challenge?

Papers that present adequate model solutions that clearly address the review criteria listed above will be accepted for presentation at the workshop and for inclusion in the workshop proceedings, to be published by IEEE. Tool demonstrations that are suited to show the strengths of the proposed solution are appreciated as well. Authors may add further requirements that clearly demonstrate the utility of multi-level modeling, but should do so in a manner that does not compromise on the ability to compare their solution to other solutions.

2. Domain description

An international online warehouse sells products; typically copies of products to be precise. The range of products includes books, DVDs, mobile phones, etc. A product copy is an actual item to be sold to a customer. Product copies may have properties such as "open box", "accessories missing", "returned on 23 March 2023", etc. A product copy is described by a product specification such as "Moby Dick, classic book, price = 9.99". A product specification in turn conforms to a product specification type such as Book Spec.

All model elements representing product copies must have a price property which constrains values to be in a currency (e.g., "EUR"). Copies conforming to the same product specification are always sold in the same currency, and product specifications conforming to the same product specification type also always specify the same currency. However, currencies may differ between product specification types. Price assignments should be type safe in the sense that they respect currencies. For instance, it must not be possible to assign the numerical value of a USD price to a product whose price is expressed in SEK.

Some products are not available for purchase as individual copies; rather they are sold in bulk quantities, such as fuses which are sold in sets of five or battery cells which are sold in packs of ten. Unlike identifiable products, such as DVD players with serial numbers, these bulk products cannot be distinguished from another. They do not even carry a batch number and therefore individual items are not explicitly represented in the warehouse data model. Bulk products are therefore only represented by their respective product specifications which store the number of respective items available.

All product specifications must adhere to the same stipulations, regardless of whether they have copies or represent bulk products. For instance, if the warehouse decided to introduce a "minimum price", representing a lower bound for special sales offers, then this property would have to exist for products with copies and bulk products alike.

For each product specification the warehouse sets an SSP (standard sales price). Product copies furthermore may have a "reduced price" which must be lower than the SSP of their product specification. The warehouse also needs to keep track of the sum of all prices of products sold of 1) a product specification, and 2) of a product specification type.

Each product specification type has its own tax rate which is applied when selling a product copy. Copies are able to report on their "final price" which is made of their nominal price (which could be reduced) with the tax rate applied. The tax rate is 7% for books and 15% for any other products.

The warehouse dynamically adds and removes product specification types and needs to keep track of at what date a product specification type was added to its portfolio.

Some products have product recommendations associated to them. For instance, the DVD Spec "2001: A Space Odyssey" recommends the purchase of the "haChi 779" DVD player. Each product specification type, such as DVD Spec, must only recommend products of a specific kind, in this case DVD Player Spec. Mobile phones must not recommend anything else but mobile phone cases.

The warehouse needs to be able to iterate over all copies and bulk products it currently has in stock for inventory purposes. It must not matter which product specification or product specification type a copy or bulk product relates to, however, features such as SSPs should still be accessible. In other words, it is not sufficient to regard inventory items as mere "objects" which have no known properties.

The following glossary provides information on a specific scenario that the solution should capture.

1) A Product Specification Type
   a) has a tax rate
   b) specifies a currency
   c) has an introduction date
   d) describes copy specifications or bulk representations
2) Book Spec
   a) is a Product Specification Type
   b) has a tax rate of 7%
   c) specifies the currency EUR
   d) was introduced on 1 February 2003
   e) describes copy specifications
3) Moby Dick
   a) is a Book Spec
   b) has an SSP of EUR 9.95
4) MB copy 1
   a) is a copy of Moby Dick
   b) has an SSP of EUR 9.95
5) MB copy 2
   a) is a copy of Moby Dick
   b) has an SSP of EUR 9.95
   c) has been returned on 23 March 2023
   d) has a reduced price of EUR 1.95
6) DVD Spec
   a) is a Product Specification Type
   b) has a tax rate of 15%
   c) specifies the currency USD
   d) was introduced on 2 March 2004
   e) describes copy specifications
7) 2001: A Space Odyssey
   a) is a DVD Spec
   b) has an SSP of USD 19.95
   c) recommends haChi 779
8) DVD Player Spec
   a) is a Product Specification Type
   b) has a tax rate of 15%
   c) specifies the currency USD
   d) was introduced on 3 April 2005
   e) describes copy specifications
9) haChi 779
   a) is a DVD Player Spec
   b) has an SSP of USD 99.99
   c) describes copies which have serial numbers

10) Mobile Phone Spec
    a) is a Product Specification Type
    b) has a tax rate of 15%
    c) specifies the currency SEK
    d) was introduced on 4 May 2006
    e) describes copy specifications
11) Mate 0815
    a) is a Mobile Phone Spec
    b) has an SSP of SEK 599.15
    c) recommends Matey
12) MP Case Spec
    a) is a Product Specification Type
    b) has a tax rate of 15%
    c) specifies the currency SEK
    d) was introduced on 5 June 2007
    e) describes copy specifications
13) Matey
    a) is an MP Case Spec
    b) has an SSP of SEK 17.95
14) AA Battery Cell Spec
    a) is a Product Specification Type
    b) has a tax rate of 15%
    c) specifies the currency NZD
    d) was introduced on 6 July 2008
    e) describes bulk product representations
15) Energetic Plus
    a) is an AA Battery Cell Spec
    b) has an SSP of SEK 1.50
    c) represents 271820 batteries which are sold as part of 10-packs

3. Solution submission requirements

Submissions responding to the challenge should describe a multi-level model conforming to the case description, including justifications for non-trivial design decisions. In order to support comparability between solutions, respondents are asked to ensure that the domain concepts listed in the scenario description list in section 2, are explicitly represented in the solution.

The solution should be presented in a paper with the following components:

1) Technology description (a brief characterization of the technology employed).
2) Domain discussion (account of how the challenge was interpreted, stating of assumptions, mentioning added or removed requirements).
3) Model presentation (step-by-step presentation of the solution, including justifications for design decisions);
4) Discussion (reflecting on requirements that could not be addressed, analyzing the impact of any workarounds used, etc.).
5) Conclusions (summary of critical analysis of the solution, reflections, future work, etc.).

3.1. Mandatory discussion aspects

Challenge respondents should discuss their multilevel model solution with respect to the following aspects:

- **Basic modeling constructs**: Discussion of the basic modeling constructs used in the solution.
- **Levels**: Discussion of the nature of "levels" in the model and which relationships (such as "instance-of") may feature between elements at different levels; providing a rationale for assigning elements to levels. The nature of levels should ideally be captured by explicitly stating the level segregation and the level cohesion principles employed [7].
- **Integrity mechanisms**: Discussion of how the integrity of level contents is preserved when changes occur.
- **Abstraction**: Discussion of the abstraction level of the solution. Does it cover invariants of the domain with minimal redundancy? Are some of the solution blocks applicable to other domains?
- **Deep characterization**: Discussion of how the solution achieves a balance between prescriptiveness and variability, by stipulating certain expectations at the top level but not fully determining properties at the bottom level.
- **Constraints**: Discussion of constraints (e.g., OCL constraints) used, e.g., how easy they are to understand and maintain, i.e., how resilient to model changes they are and/or whether they can be reused in other domains.

Respondents are furthermore invited to position their solution with respect to related work according to the aspects listed above. Finally, responses should –

- highlight limitations of the solution, including explicitly mentioning any requirements that were not covered.
- list key advantages and drawbacks of the presented solution with regard to the challenge.
- list key advantages and drawbacks of the presented multi-level modeling approach that may not be evident in the solution to the challenge.
- document any extensions that have been made to the requirements.
- list any lessons learned and potentially suggest future work intended to improve modeling support.

Challenge responses must be submitted as challenge papers; each submission must be subtitled: "A contribution to the MULTI Warehouse challenge". Any potentially existing artifacts should be made available for review in material accompanying the paper, e.g., in a shared repository or in an archive as supplementary material.

Acknowledgments

We would like to thank Bernd Neumayr, Colin Atkinson, Gergely Mezei, João Paulo A. Almeida, and Ulrich Frank for multi-level modeling related discussions that gave rise to some of the modeling challenges established by this multi-level modeling challenge description, and Zoltán Theisz for providing feedback on the challenge description.

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