



Life-cycle management of configurable products – the Variantum way

Juha Tiihonen
Configuration Workshop
Graz 28. 9. 2018

© 2018 Variantum Oy

variantum

Outline

Personal

Variantum

Cornerstones for life-cycle management

Flexible and efficient object-oriented data model

PDM/PLM with special support for configurable offerings

Support for two-phase configuration (sales, production)

Installed base management

Research challenges

Background

- **D.Sc. (Tech), Aalto University, Lic.Sc (HUT), M.Sc (HUT)**
- **Suomen Mikrogurut 1989-1992 (SW dev, training, ...)**
- **Researcher & project manager at universities (HUT, Aalto)**
 - Conceptualizing, modeling, software development, ...
 - Design Science, cases
- **PhD work (Aalto)**
- **Senior researcher / postdoc**
 - University of Helsinki 2015 –
 - SW variability, OpenReq
- **Variantum 8/2016 – (VariConf engine)**

3

© 2018 Variantum Oy

variantum



Department of Computer Science and Engineering

Support for configuration of physical products and services

Juha Tiihonen

KNOWLEDGE-BASED CONFIGURATION
FROM RESEARCH TO BUSINESS CASES

EDITED BY
ALEXANDER FELBERING, UTHAR HOTZ,
CLAIRE BAGLEY AND JUHA TIIHONEN

State-of-the-practice in product configuration – a survey of 10 cases in the Finnish industry

Artificial Intelligence for Engineering Design, Analysis and Manufacturing (1998), 12, 357–372. Printed in the USA.
Copyright © 1998 Cambridge University Press 0890-0604/98 \$12.50

Towards a general ontology of configuration

TIMO SOININEN, JUHA TIIHONEN, TOMI MÄNNISTÖ AND REIJO SULONEN
Helsinki From: AAAI Technical Report SS-01-01. Compilation copyright © 2001, AAAI (www.aaai.org). All rights reserved.

Representing Configuration Knowledge With Weight Constraint Rules*

Timo Soininen TAI Research Centre Helsinki Univ. of Technology P.O.B. 9600, 02015 HUT Finland Timo.Soininen@hut.fi	Ilkka Niemelä Lab. for Theoretical Computer Science Helsinki Univ. of Technology P.O.B. 5400, 02015 HUT Finland, Ilkka.Niemela@hut.fi	Juha Tiihonen TAI Research Centre Helsinki Univ. of Technology P.O.B. 9600, 02015 HUT Finland Juha.Tiihonen@hut.fi	Reijo Sulonen TAI Research Centre Helsinki Univ. of Technology P.O.B. 9600, 02015 HUT Finland Reijo.Sulonen@hut.fi
--	---	--	--

AI Communications 26 (2013) 99–131
DOI 10.3233/AIC-2012-4547
IOS Press

WeCoTin – A practical logic-based sales configurator

Juha Tiihonen^{a,*}, Mikko Heiskala^a, Andreas Anderson^b and Timo Soininen^a
^a School of Science, Department of Computer Science and Engineering, Aalto University, Aalto, Finland
E-mails: {juha.tiihonen, mikko.heiskala, timo.soininen}@aalto.fi
^b Variantum Oy, Espoo, Finland
E-mail: Andreas.Anderson@variantum.com

5

variantum

Outline

Personal

Variantum

Cornerstones for life-cycle management

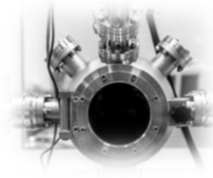
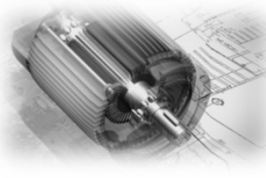
Flexible and efficient object-oriented data model

PDM/PLM with special support for configurable offerings

Support for two-phase configuration (sales, production)

Installed base management

Research challenges



**Variantum is
specialized in
managing configurable
products through their
life-cycle**



Who we are

- Finnish software company based in Espoo
- Focused on managing configurable products through their life-cycle
- Roots in academic research of product configuration technologies
 - Prof. Reijo Sulonen / Product Data Management Group
 - E.g. PhDs of Timo Soininen, Tomi Männistö, Hannu Peltonen, Tommi Syrjänen, Juha Tiihonen
 - Asko Martio



		Annual sales growth
		20%
		Countries of users
		80
Number of users	30 000	
Years of PLM experience	200	
Number of people	20	
Started in	2005	

variantum

10

© 2017 Variantum Oy

Challenges



Time to market
Variant product structures
Product evolution
Sales configuration
Engineering configuration
Installed base management
...

Variantum can help

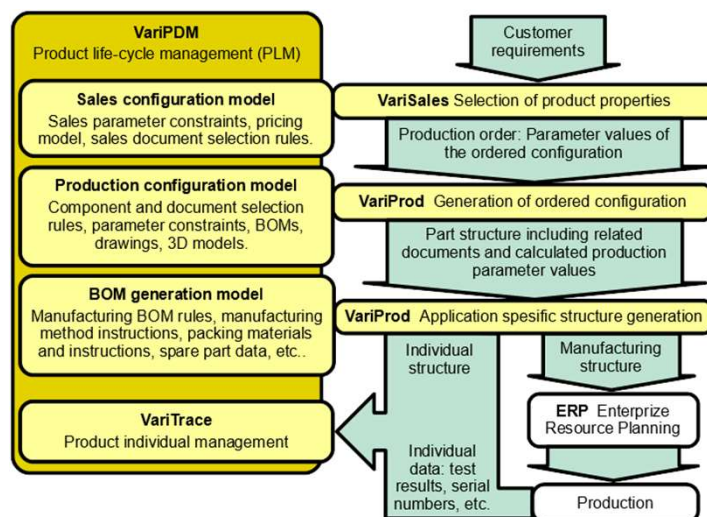


12

© 2018 Variantum Oy

variantum

Variantum Configuration System Suite



14

© 2018 Variantum Oy

variantum



KONE accelerates with Variantum technology

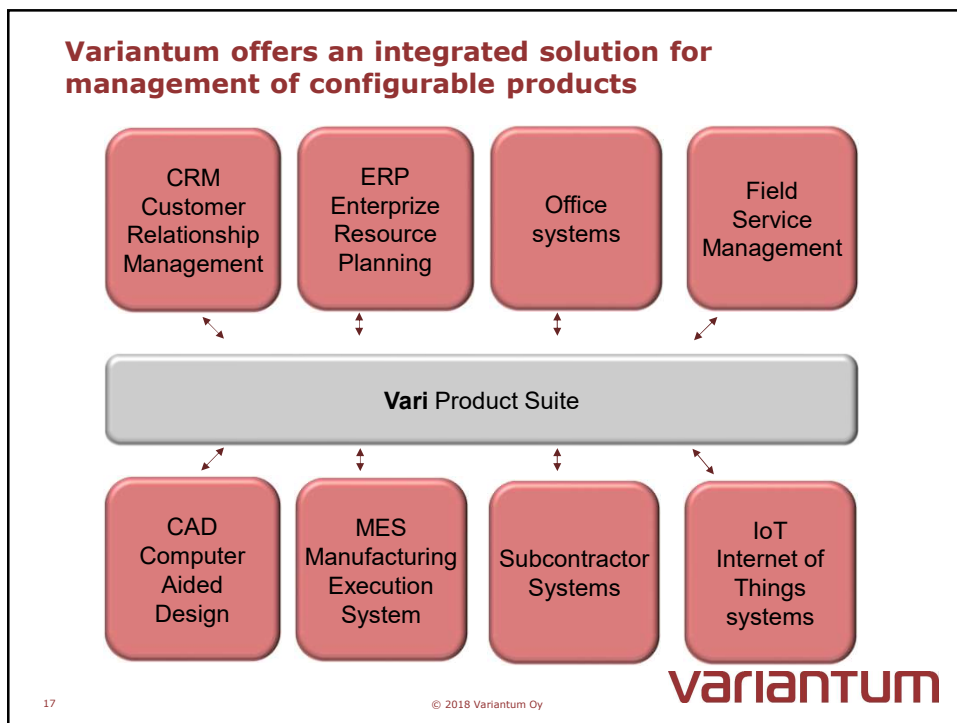
“Variantum’s technology has been instrumental in KONE product life-cycle management. KONE has achieved significant improvement in the time-to-market and order-to-delivery processes of complex configurable products.

Variantum technology has proven high performance and we are extremely satisfied with Variantum’s level of expertise and loyalty as a trusted partner.”

Antti Koskelin, Head of IT, CIO, KONE



15
© 2017 Variantum Oy

Outline

Personal

Variantum

Cornerstones for life-cycle management

Flexible and efficient object-oriented data model

PDM/PLM with special support for configurable offerings

Support for two-phase configuration (sales, production)

Installed base management

Research challenges

VariPDM

generic object-oriented environment for industrial grade modeling of configurable products

company data model

(e.g., additional item types and attributes; completely new object kinds)

base data model

(e.g., object kind 'item' with basic attributes)

core data model

(e.g., the concept of an object kind)

} standard VariPDM installation

variantum

Core data model

- **On the top-level you can define the schema of a data model by**
 - defining object types,
 - attributes to the types and
 - relationships how different objects can be linked to each other to form object structures
- **Schema definition**
 - with a graphical user interface
 - without programming
 - on the fly while the system is up and running
 - “native”, efficient schemas in the database
- **In other words, data model is not coded into the core software**
 - software updates are not affected by customized applications

variantum

22

© 2018 Variantum Oy

Some advanced OO properties

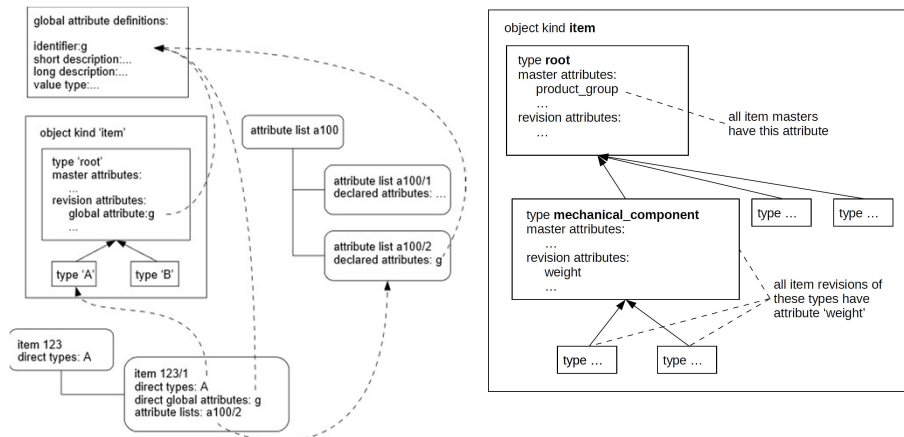
- **Multiple classification**
 - An object can be a direct instance of multiple object types
 - An object can be classified according to multiple criteria
 - Multiple classification (unlike multiple inheritance) is very useful
- **Abstract, concrete, and supplementary types**
- **Global attribute directory**
- **Objects defined like this can be instantiated (e.g. configured), i.e. objects are like types!**

variantum

23

© 2018 Variantum Oy

Different ways an object can have an attribute



24 VariPDM data model

© 2017 Variantum Oy

variantum

Revision management

- **Item 1234 is an item master**
- **Item 1234/A is an item revision**
 - Flexible revision code system (1-level, 2-level, numbers/letters)
 - Revisions of an object form a sequence (no revision branching)
- **Item 1234 and its revisions 1234/A, 1234/B, ... are separate objects**
 - Master object attributes and revision attributes are separate

25 VariPDM data model

© 2018 Variantum Oy

variantum

Item: VM00000095 (tractor): some revision attributes come from 'Item'

VM00000095/1 - Browser 1 for Variantum - demo1 (d:\variantum.com\80110)

Session Object Create Bookmarks Tools Special Help

Types Direct Attributes Parameters Assignments Script Refinements Constraints Tables Analyse Configure

State: Draft Lock Description: enFarming Tractor X2500 (VM00000095) Latest: Yes Current: No

Attribute Values Structure

Item

- Object ID (obj_id): VM00000095/1
- Created by (created_by): jaanderso
- Creation time (create_time): 2017-12-19 09:30:53
- Direct types (direct_types): Configurable Material, Item, Sales item
- Base object (base_obj_id): LIARD, REAR_CONTROL, FLASHING_ROOF_LIGHT, FLASHING_ROOF_LIGHT_COLOR, EXTINCTION_WATER_CONTAINER, REAR_SPEED_PEDAL
- Attribute lists (attribute_lists):
- State graph (state_graph): Revision states
- Current state (current_state): Draft
- Lock user (lock_user):
- Lock time (lock_time):
- Latest (is_latest_rev): true Yes
- Latest in its state (is_latest_rev_in_state): true Yes
- Current (is_current_rev): false No
- Old (is_old_rev): false No
- Description (description): enFarming Tractor X2500 (VM00000095)
- Picture (image):
- Unit of measure (unit_of_measure): PC Piece
- Mass (kg) (mass):

26

© 2018 Variantum Oy

variantum

... and Configurable Material, Sales Item, and Direct global attributes

Configurable Material

- Calculation script (nit_script):
- Sales Order (order_id):
- Sales Order Line (order_position):
- Equipment number (individual_id):

Sales item

- Attribute properties (attr_props): 18 rows
- Child properties (child_props): 2 rows
- Element groups (elem_groups): 20 rows
- Messages (msgp_obj): msgp_conf_VM00000095
- Configuration bundle id (bundle_id): X2500
- Visualization tables (visualization_tables): 1 row

Direct global attributes

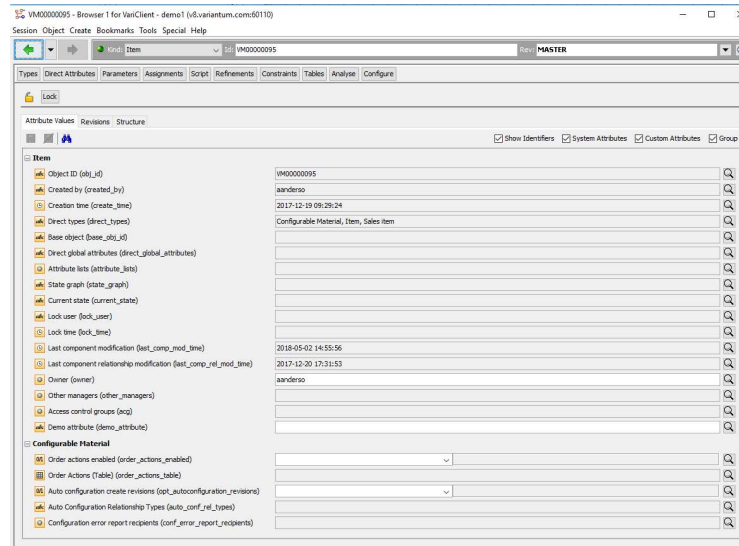
- Delivery country (DELIVERY_COUNTRY): Finland Finland
- Color (TRACTOR_COLOR): Red Red
- Speed Class (SPEED_CLASS): 40 40
- Power Take-Off (POWER_TAKE_OFF): 1000 Extra Heavy Duty 1000 Extra Heavy Duty
- Wheel Size (WHEEL_SIZE): 20.8R38 + 16.9R28 20.8R38 + 16.9R28
- DUAL WHEELS (DUAL_WHEELS): false No
- Front Fenders 4WD (FRONT_FENDERS_4WD):
- Front Weights (FRONT_WEIGHTS):
- Additional Front Weights 550 kg (ADDITIONAL_FRONT_WEIGHTS):

27

© 2018 Variantum Oy

variantum

... and Master object has different attributes



28

© 2018 Variantum Oy

variantum

(Parameter) attribute life-cycle management

- **Attributes can be defined as objects with their own life-cycle**
 - E.g. draft, active, retired, terminated
- **The life-cycle phases and their semantics can be defined**
 - Typically *active* parameters can be used in released products
 - *Retired* can added to objects, but a warning must be accepted
 - *Terminated* cannot be added to objects
- **Same attribute is always used for the same thing**

29

© 2018 Variantum Oy

variantum

Parameters

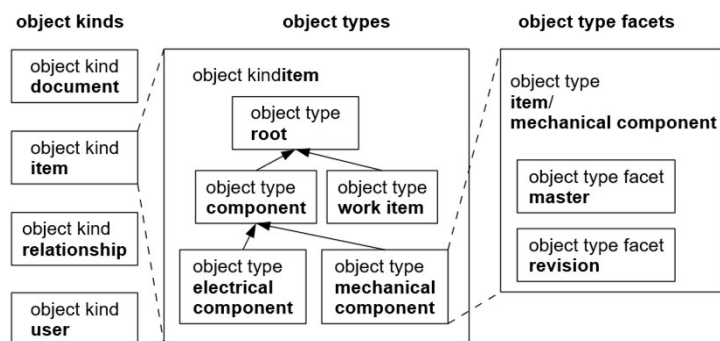
- **A parameter includes (among others)**
 - a unique identifier,
 - a multilingual description
 - a value type
- **The value type**
 - different base types (integer, string, scaled float, Boolean)
 - list items, where allowed values come from a separately defined list of possible values
 - different cardinalities (scalar, set, sequence)
 - table parameter (a scalar value type for each column)

30

© 2018 Variantum Oy

variantum

Object kinds, types and facets



31 VariPDM data model

© 2017 Variantum Oy

variantum

Outline

Personal

Variantum

Cornerstones for life-cycle management

Flexible and efficient object-oriented data model

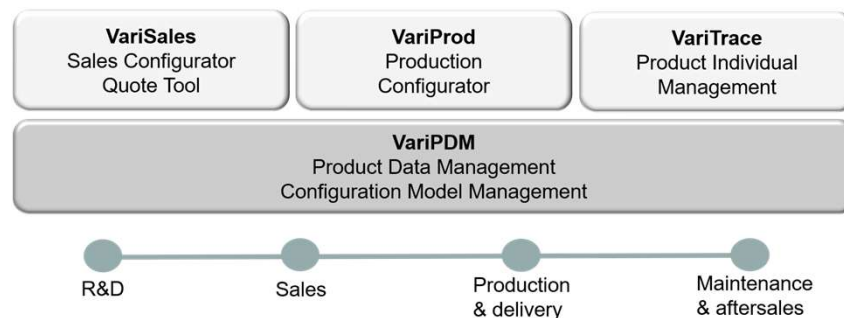
PDM/PLM with special support for configurable offerings

Support for two-phase configuration (sales, production)

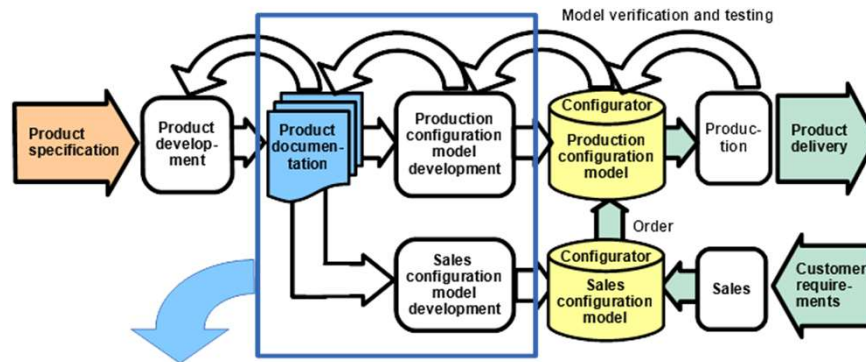
Installed base management

Research challenges

VariPDM: PDM/PLM with special support for configurable offerings



Traditional, document based modeling



- Slow time-to-market
- Error-prone
- Requires lots of work-force
- Costly
- Does not reap real benefits of digitalization

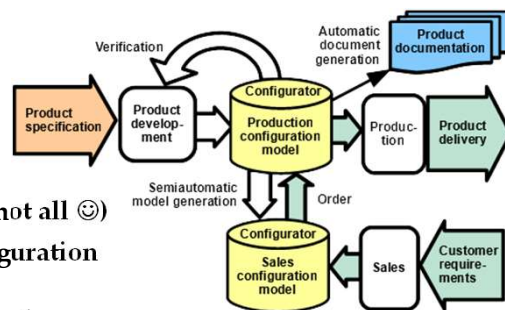
34

© 2018 Variantum Oy

variantum

Direct modeling during product development

- Designers are able to model the products
- Product model can be tested with efficient tools already during the development process
- Product documentation can be generated automatically (not all 😊)
- Basic sales/production configuration model is born automatically
 - Sales configuration model needs further elaboration, e.g. layout
- Saves **significantly** costs and time



35

© 2018 Variantum Oy

variantum

Special PLM support for configurable products

- **Product models and structures for configurable products**
 - parameter definition
 - constraints
 - product family structures
- **Objects with parameter attributes can be readily used as configuration models**
- **Variability under revision control**

36

© 2018 Variantum Oy

variantum

Configuration parameters

- **Configuration task: answer a number of questions**
- **Questions and answers: *parameters* and *parameter values***
- **A set of parameters; each with a set of allowed values**
- **Parameters are fundamentally attributes flagged as parameters**
- **Parameter value is usually one of the allowed values (*scalar*)**
- **The parameters for all configurable products in particular VariPDM installation are selected from a system-wide collection of available parameters**

37

© 2018 Variantum Oy

variantum

Refinement

- A parameter can be *refined* to allow a narrower set of values in this product
 - E.g., many products have a parameter for a colour, and this parameter is defined to take its value from a list of available colour codes.
 - A product can add a refinement that restricts the available colours in this particular product

38

© 2018 Variantum Oy

variantum

Product family structures capture variability

VM00000100/1 - Browser 1 for VariClient - demo1 (v8.variantum.com:60110)

Session Object Create Bookmarks Tools Special Help

Kind: Item Id: VM00000100 Rev: 1

Types Direct Attributes Parameters Assignments Script Refinements Constraints Tables Analyse Configure

State: Draft Lock Description: en:Activity Tower V100 Latest: Yes Current: No

Attribute Values Structure

Effective: show all View: PartsJT

	relationship	relationship	revision	relationship	revision	relationship	revision	Revision date	Current state
	Position	Subposition	Description	Quantity	Unit of me...	Condition	Picture		
VM00000100/1			en:Activity Tower V...		pc			2018-01-23	draft
has part →									
VM00000101/1	p arb 1	0	en:Basic frame	1.0	pc			2018-01-23	draft
VM00000106/1	2	0	en:Small slide	1.0	pc	SLIDE = "Small"		2018-01-23	draft
VM00000107/1	2	1	en:Big slide	1.0	pc	SLIDE = "Large"		2018-01-23	draft
(NONE)	2	2		1.0		otherwise			
VM00000108/1	p arb 3	0	en:Roof module	1.0	pc	ROOF		2018-01-23	draft
has part →									
VM00000109/1	1	0	en:Brown roof pole	4.0	pc	POLE_COLOR = ...		2018-01-23	draft
VM00000110/1	1	1	en:Yellow roof pole	4.0	pc	POLE_COLOR = ...			draft
VM00000111/1	2	0	en:Blue roof	1.0	pc	ROOF_COLOR = ...		2018-01-23	draft
VM00000112/1	2	1	en:Blue roof	1.0	pc	ROOF_COLOR = ...			draft

39

© 2018 Variantum Oy

variantum

Main mechanisms for configuring with product family structures

- **Selection conditions**
- **Assignments**
 - Parameter value calculation from attributes/parameters of parent items and siblings
 - Calculation of relationship attribute values (e.g. quantity)
- **Constraints**
 - Hard, soft, multilingual description
- **LUA scripts for special calculations, e.g. iterations**
- **Arbitrary combinations of arithmetic and logical operations**
 - can also utilize powerful Selection Table mechanism

40

© 2018 Variantum Oy

variantum

Assignments

Attribute Assignments

Relationship:
has part: Item 'VM00000100/1' → Item VM00000108/1 ('rel_8351')

Attribute assignments for relationship:

Relationship Attribute	Value (in terms of source object)
------------------------	-----------------------------------

Find:

Attribute assignments for target object:

Target Parameter	Value (in terms of source object)
ROOF_COLOR Roof color	← f() ROOF_COLOR
POLE_COLOR Pole color	← f() POLE_COLOR

Find:

Ok Apply Close

41

© 2018 Variantum Oy

variantum

Constraints

- **Constraints restrict**
 - the allowed parameter attribute value combinations
 - the allowed compositional sales structure
- **Condition expression**
- **Strictness: hard, soft**
- **Description**

Condition	Description	Strictness	Effectivity	Expiration Date
REAR_CONTROL implies REAR_SPEED_Pedal	rear floor control requires the rear speed pedal	hard	[open] ... [open]	
not (WHEEL_SIZE = "20.80x28" and REAR_FENDERS = "Narrow Rear Fender")	no narrow rear fenders not allowed with 20.80x28 + 24.90x28 wheels	hard	[open] ... [open]	
not (WHEEL_SIZE = "20.80x28" and REAR_FENDERS = "Narrow Rear Fender")	no narrow rear fenders not allowed with 20.80x28 + 24.90x28 wheels	hard	[open] ... [open]	
REAR_CLASS = 50 implies (COUNTRY in ("Australia", "Finland", "Germany", "Netherlands", "Norway", "United Kingdom"))	no 50 inch speed class tractors only allowed in Finland, Germany, Netherlands, Norway and United Kingdom	hard	[open] ... [open]	

42

© 2018 Variantum Oy

variantum

Special PLM support for configurable products

- **Multiple model verification and testing tools**
- **Document management for configurable documents**
 - configurable connections between items and documents
- **Advanced search and reporting capabilities**
 - e.g. relationship conditions, full text search to metadata and document contents, where used, ...
- **Schema Editor for object manipulation:**
 - Object kinds, types, relationships and attributes can be defined and changed by users
- **Parameter life-cycle management**

43

© 2018 Variantum Oy

variantum

'Basic' PDM/PLM? For sure ... ☺

- Item management
- Product structures
- Product change management
- Workflows managed with object revisions and object states
- Document management
- Classification of items and other product data
- Easy customization
 - flexible data modelling
 - custom program layer for special operations
- Federated database support
- Cloud storage available
- Orchestration
- Easy to configure VariClient and Web user interfaces
- Integration with various design and ERP systems
- Mailer
- Multilingual texts and Unicode

variantum

Outline

Personal

Variantum

Cornerstones for life-cycle management

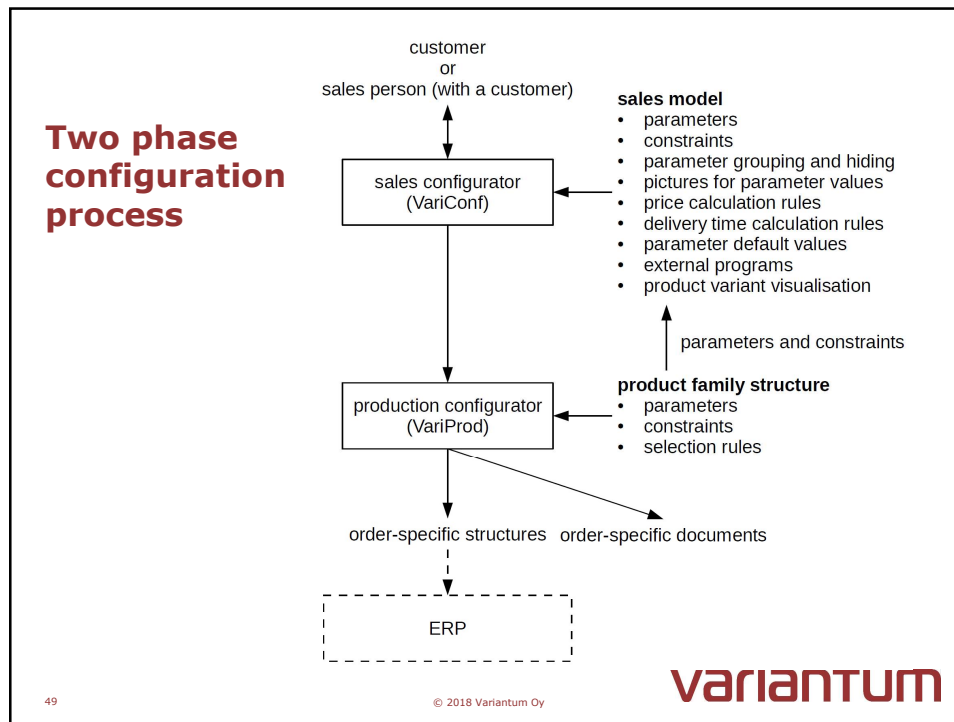
Flexible and efficient object-oriented data model

PDM/PLM with special support for configurable offerings

Support for two-phase configuration (sales, production)

Installed base management

Research challenges



Two-phase configuration process

▪ Sales configuration

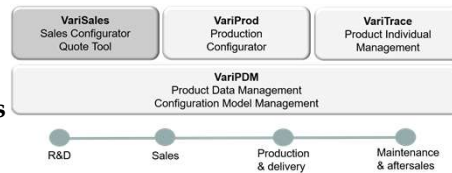
- the parameters of the configurable product are given proper values
- sales structure is created as individuals of child items (objects)
- parameters values of child individuals are determined

▪ Production configuration

- the parameter values and sales structure are used to generate an order-specific product structure (and if necessary, order-specific documents).

VariSales = VariConf + VariQuote

- **Configure, price, quote**
- **Guides the sales person or customer through the sales process**
- **Ensures a consistent and complete configuration with the right price**
- **Generates quotes and sends them to the customer**
- **Typically a custom action stores the sales configuration in VariPDM as a sales-configuration object**
 - What happens next depends on context and selected (custom) action
 - include in a quote, automatically start production configuration, etc.
 - orchestration
 - All parameters and sales structure are available as a database objects



51

© 2018 Variantum Oy

variantum

VariConf uses VariPDM models

- **VariConf configuration model is a VariPDM / VariProd model**
 - Configuration model can be changed without touching user interface code
 - Product logic not in user interface code and not replicated by coders
 - Modelling doesn't need coding experience
 - Major benefit: the same parameters and constraints can be used both in sales and production modelling
- **Any VariProd model with parameters can be configured with VariConf without additional definitions**
 - Easy to test the sales view and constraints of product models throughout the whole development process
 - saves money and shortens time-to-market
 - (production quality configurator needs a bit more)

52

© 2018 Variantum Oy

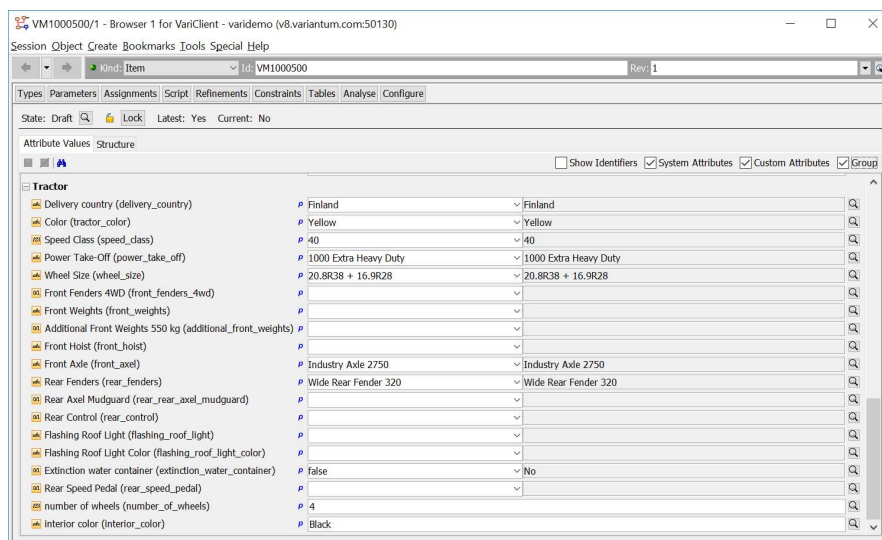
variantum

Modelling: Parameter attributes

- = Attributes of the PDM object that have been marked as parameters
- = Attribute value type
- = Refinement restrictions
- + Optionality: optional, required, fixed
- + Visibility rule
- + Default value (static and/or dynamic)

53

© 2018 Variantum Oy

variantum


54

© 2018 Variantum Oy

variantum

Modelling: children

- An item can contain a number of child items which are configured as parts of the containing item
- PDM objects attached to an object with *has_child* relationships
- The child objects with same *main position* code represent the *possible items* of a *child definition*
- **Cardinality:** min and max count
- **Similarity:** any, same item, identical
- **Note:** separate relationships for sales and production configuration, but can be mixed!
 - has_child relationship
 - has_part relationship (flag for configuring in VariConf)

55

© 2018 Variantum Oy

variantum

The screenshot displays the VariClient software interface. The main window shows the 'Attribute Values' tab with a table of child items. The 'Attribute Value Editor' dialog is open, showing the 'child_props' identifier and the 'Current value' table.

Child	Min count	Max count	Similarity	Relationship type
CABIN	1	1	identical	
DRAWER	1	1	identical	

The 'Attribute Value Editor' dialog also shows the following information:

- Identifier: child_props
- Short description: Child properties
- Long description: Child properties
- Image: -
- Value type: table
- Defined in: global attribute list

56

© 2018 Variantum Oy

variantum

Scope of VariConf inference support

- **VariConf supports all value types (cardinality, base type) of VariPDM**
 - Constraints can be evaluated, consistency and completeness of configuration can be evaluated
- **VariConf inference engine that provides graying, automatic selection of the only consistent value, detection of dead-end, etc. supports**
 - Scalar and set integers (both list and range)
 - Scalar and set strings (list only)
 - Scalar Boolean
 - Scalar float (both list and range)
- **Selection tables, LUA (SVAR, IVAR, FVAR), prices and other calculations are evaluated by the VariPDM server**

57

© 2018 Variantum Oy



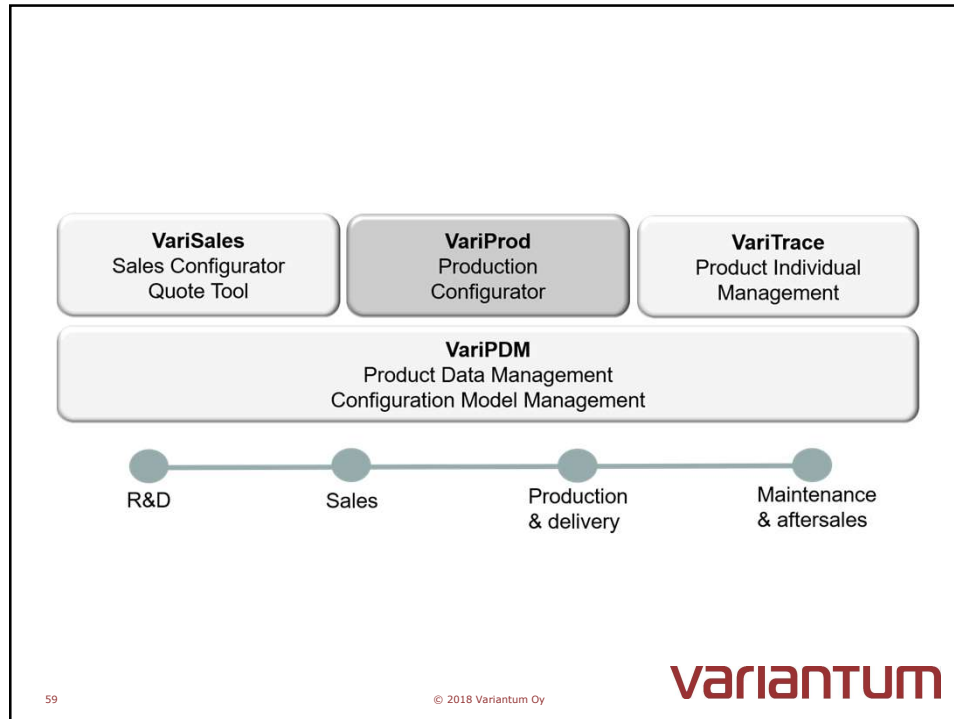
VariConf user interface

- **Guides the user during the configuration task by**
 - Indicating incompatible options with previous selections (“graying”)
 - Automatically making selections that are implied by previous selections
 - Dead-end check
 - Identifying inconsistencies (constraints violated)
 - Identifying completeness
- **Both: free order of selections and wizard-style**
- **Generated automatically based on the configuration model**
 - Additional information refines (e.g. order, defaults, grouping, optionality)
- **Multi-lingual, based on multi-lingual object descriptions**
- **Visual product information: support for texts, static and dynamic pictures and live 3D models**

58

© 2018 Variantum Oy





Production configurator VariProd

- **Non-interactive**
- **Inputs**
 - product family structure
 - order product definition (parameters, sales structure)
 - e.g., transferred from VariSales as a Configuration object
- **Output**
 - Product individual structure (engineering configuration)
 - can include parametrized at any depth
 - configurable documents, contents depends on product definition
 - activities etc.
 - Usually transferred to ERP for production
 - + sometimes component orders to subcontractors
- *Generated configurations are VariPDM objects*

variantum

Many other VariProd functionalities exist

- Configurable CAD models
- Configuration of sets of configurable products with partially the same parameters
- Support for multiple configuration processes
 - final configuration is dependent on earlier configuration's result
 - configuration rounds (e.g. first product, then documents)
- Support for tailored document configuration process (DITA)
- Management of standard configurations
- Support for order-specific design where most of the product is configured

61

© 2018 Variantum Oy



Standard variants

- The variants of a configurable product must be made to order because of combinatorial explosion on the number of variants.
- However, a company can still have a set of *standard variants*, which are product variants that the company believes to be suitable for many customers.
 - can manufacture them to stock,
 - guide customers to choose standard variants,
 - E.g. lower prices and shorter delivery times.
- VariProd supports standard variants of products and subassemblies by means of *predefined configurations*

65

© 2018 Variantum Oy



Order-specific design

- A company may sell products that are actually designed for a particular order.
- This design is often based on a product variant that has been generated from the configurable product and that is similar enough to the desired product so that it can be modified according to customer needs.
- The order-specific structure that has been generated by the production configurator is usually transferred as such to manufacturing, but if necessary, the structure can be modified manually like any product structure.

66

© 2018 Variantum Oy

variantum

Outline

Personal**Variantum****Cornerstones for life-cycle management**

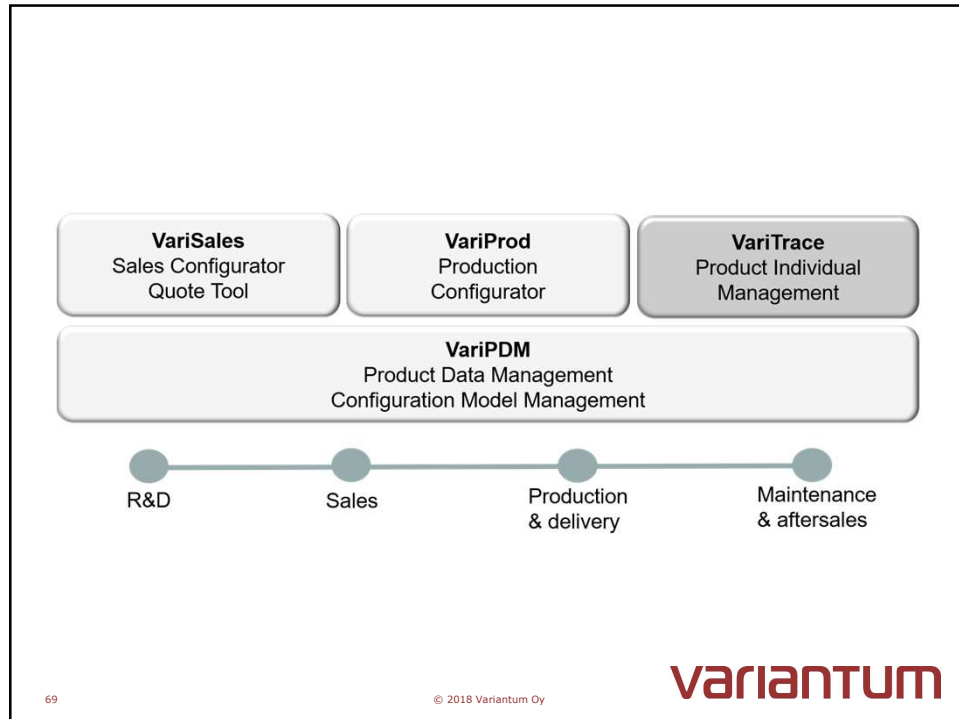
Flexible and efficient object-oriented data model

PDM/PLM with special support for configurable offerings

Support for two-phase configuration (sales, production)

Installed base management

Research challenges



Installed base management: VariTrace

- **Follow product individuals and their components by serial identification**
- **Collect outputs of Vari tools**
 - Database objects of individuals (e.g., sales & production configurations)
 - Documents
- **Collect information from ERP, MES, service operations, warranty, IoT sources, etc. (configurable, integrations)**
- **Product individual structures**
 - As designed/as configured (engineering structure)
 - Service BOM (can be generated / transformed from engineering BOM)
 - As maintained

variantum

VariTrace

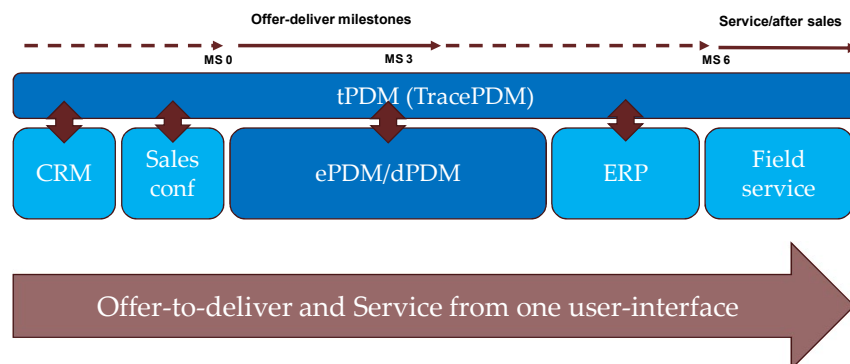
- **Full VariPDM support + relational database for information not directly 'understood' by VARI tools**
- **Automated analytics routines**
 - e.g. report / multidimension graph generation (via scripts stored in VariPDM)
- **Powerful search tools, saved queries**
 - provide information for external analytics tools
- **Management of recalls**
- **Support field letters & retrofitted change notes**
 - Based on 'where-used' etc.

variantum

71

© 2018 Variantum Oy

Installed base information collection at KONE



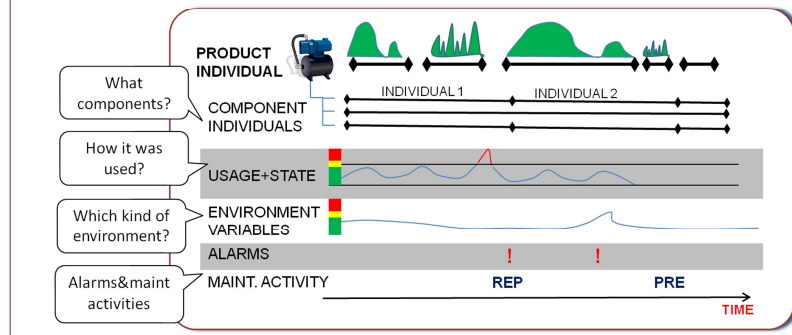
variantum

73

© 2018 Variantum Oy

A 'slightly' ambitious slide from 2014 ...

Product individual level technical view: Even this is missing!



77

© 2018 Variantum Oy

variantum

Another 2014 slide ...

Vision: Service Business Management Environment (SBME) for suppliers of equipment



- Facilitate fact-based decision making
 - more efficient and effective services by optimizing the costs and value
 - based on an integrated, global view of information about the service base
- Aim to recognise
 - decision making situations ("use cases"),
 - decision support functionality, and
 - required information contents
 - for a system that supports decision making in service business such as
 - "full service",
 - facilitator contracts (e.g. lease of maintained equipment),
 - extended warranties,
 - and operations and maintenance.

→ Eat the elephant one piece at a time

78

© 2018 Variantum Oy

variantum

Thank you for your attention!

79

© 2018 Variantum Oy

variantum