challenges in domain-specific modeling

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outline

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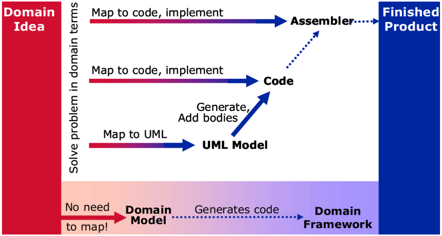
0110s to dsm

why not abstract?
generated code less efficient? general purpose languages less expressive?



why abstract?

- ▷ mapping to develop, maintain, debug... is error prone and difficult
- ▷ increased productivity compensates for loss in efficiency
- ▷ domain-specific languages should be less expressive

how is productivity increased?

- user's mental model of problem is closer to "implementation"
- more intuitive and less error-prone development
  → dsm environment constrains user to create valid domain models
- leverage expertise
  → *domain* experts play with domain models
  → *programming* experts play with APIs and frameworks
  → domain, programming and *transformation* experts play with model-to-artifact transformations

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→ increased productivity

modeling concepts

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models are cheaper, safer and quicker to build, reason about, test and modify than the systems they *represent*

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common approaches are *graph grammars* and (augmented) *uml class diagrams*

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defining model semantics

common approach is mapping down to domains with well-defined semantics (*e.g.* mathematics, *statecharts*, python)

dsm vs. code generation

traditional code generation...

not popular because generated code is often awkward, inefficient, inflexible and/or incomplete

→ source domain is too large
→ target domain is too large

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but!

dsm is different...

▷ source domain restricted from all models of all applications to models of applications from 1 domain
▷ target domain restricted from all applications to applications from 1 domain

→ enables generation of complete and optimized artifacts

dsm challenges

the "coding community" has mature tools that facilitate

- editing
- debugging
- differencing
- versioning

of text-based artifacts (*e.g.*, code, xml)

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how can the these activities and their underlying principles be generalized to dsm?

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generative programming (gp)

basic idea

bring software engineering to the same level of automation as other forms of manufacturing i.e.,

- standardized components (*e.g.*, $\frac{1}{4}$" bolts)
- standardized interfaces (*e.g.*, category B plug)
- customizable assembly lines (*e.g.*, same line for red and blue *Corolla*s)

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instead of coding a `LinkedList`, an `ArrayList` and a `SyncList`, code a `List<T>` which can be "instantiated" with arbitrary "configurations"

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gp vs. dsm

an appropriate technique for implementing domain frameworks

model-driven architecture (mda)

the *object management group*'s (omg) approach to model-driven engineering

basic idea

- software development viewed as a series of model refinements where lower and lower level models (referred to as *platform-specific models*) are (semi-)automatically generated from higher level ones (referred to as *platform-independent models*)
- modelers are expected to modify and contribute to generated intermediate models

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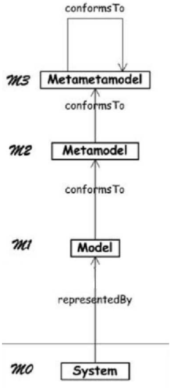
mda vs. dsm

▷ between UML modeling and dsm...
▷ interaction with intermediate models prevents true raise in abstraction

metamodeling



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- complex operations on models and metamodels should not be developed from scratch for every metamodel
- they should take metamodels as parameters
- hence, all metamodels should conform to a *metametamodel*

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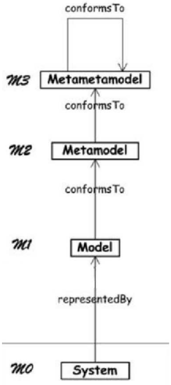

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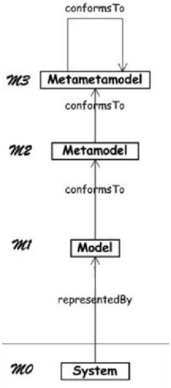

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metamodeling vs. dsm

there is a consensus that metamodeling is the key to empowering model based techniques

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simulation

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approach 1 : hard-coded simulators

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approach 2 : rule-based simulators

- rules define "simulation steps"
- simulating equals the sequential (and interactive) application of these rules
- a metamodeling tool can generate a simulation environment from these rules

debugging

premise

- error tracking and reproduction are key activities in debugging software
- modern coding tools allow setting/clearing *breakpoints*, stepping *over/into* expressions, pausing/resuming execution and reading field values
- these facilities should also be offered by model debugging tools

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current best approaches...

- deal with textual dsls only
- instrument code generation rules to store mapping of dsl statements to gpl statements
- instrument code generation rules such that generated gpl code updates dsl variable values
- reuse gpl debuggers (*e.g.*, gdb, jdb) to provide debugging operations at the dsl level (*e.g.*, a breakpoint set in the dsl code will call jdb's breaking function from the matching line in the generated java code)

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computing differences

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- means to merge, version and store sequential and parallel versions of models are needed
- means to visualize differences between models are needed

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lexical differencing approaches

- differentiate between textual documents (*e.g.*, code, xml)
- no sense of semantically meaningful and meaningless differences (*e.g.*, layout changes)
- no sense of design-level differences

$\longrightarrow$ wrong level of abstraction

computing differences...

model differencing approaches

1. create some kind of abstract syntax graph (asg) of the models
2. establish matches between both asgs using *unique identifiers* or *syntactic and structural similarities*
3. determine creations, deletions and changes from one asg to the other

metamodel-specific and -independent approaches exist

computing differences...

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metamodel-specific and -independent approaches exist

unique identifiers

- 100% reliable matching
- tool dependence/lock-in

similarity heuristics

- tool independent
- sensitive to principled versioning

representing differences

premise

given a difference Δ between two models, how can it be represented?

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edit scripts approaches

- differences are sequences of invertible operations (*e.g.* create element, modify attribute) which specify how a model can be procedurally turned into another
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coloring approaches

- overlay 2 models and color differences; more familiar to modeler but doesn't scale
- color *document object model-* (dom) like view of the model; more compact and scalable

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difference models

- differences are models
- enables the use of higher-order transformations to manipulate, apply, merge, invert and represent model differences
- tool-, metamodel- and differencing method-independent

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sources of evolution

domain-driven

- dsls are tightly coupled with their domain
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convenience-driven

- language extensions and new syntactical constructs maybe added to a language
- these typically shouldn't invalidate existing models

model and model intrepreter co-evolution

traditional approach : do it yourself

manually *co-evolve* models and model intrepreters as metamodels evolve

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current best approaches... (models)

- distinguish between "easy" and "difficult" metamodel changes
- use higher-order transformations to generate model co-evolution transformations from metamodel difference models

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only current approach... (intrepreters)

- instrument model co-evolution rules with instructions to rewrite code patterns in coded model intrepreters

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with code

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with xslt

- serialize models to xml and then transform xml using xslt
- awkward transformations due to tree-based nature of xml vs. graph based nature of models
- lacking expressiveness for complex transformations
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with pre-/post- conditions

- pre-conditions express conditions the host model must satisfy for the rule to be applicable
- post-conditions express conditions the host model must satisfy after the run has been applied
- declarative approach well suited for transformation *bi-directionality*
- power contingent on constraint solving facilities

specifying transformations...

with graph transformations rules

- rule-based approach
- left-hand side and right-hand side patterns (which use domain concepts)
- theoretically founded
- possible bi-directionality achievable via *triple graph grammars*

executing rule-based transformations...

default graph grammar semantics

- any applicable rule may run
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structured approaches

- rule-based approaches become more powerful when control flow and scheduling mechanisms are added
- some tools offer conditions, loops, transactions and hierarchy
- these may be reflection-based or graphical

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weaving features together

traditional approach

1. study the domain
2. extract domain concepts, associations and constraints
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possible future approach : feature weaving

- *motivation*: a new formalism where notions of state and transition exist may benefit from reusing parts or all of the statechart formalism
- *idea*: inspired from aspect-oriented development where modularly defined *concerns* are weaved together with core concerns to form complete systems

1. determine basic *feature* set for "all" dsls (*e.g.*, *state-based*, *continuous time*)
2. select basic features of a dsl
3. compose them somehow to yield new dsl

- very modular approach axed on reusability
- synthesized dsls should remain bound to the features composing them allowing for automatic generation of certain artifacts (*e.g.*, basic simulators)

outline

recap

- over the past decades, software development has naturally **evolved towards dsm**
- dsm **improves productivity by reducing the conceptual gap** between the requirements and the solution
- to replace traditional software development approaches, robust and scalable means to **simulate, debug, difference, version, transform and co-evolve models** are required
- dsl engineering may benefit from techniques from aspect-oriented development

questions?

thanks!