Using Predicate Fields in a Highly Flexible Industrial Control System

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* Work done while at Rafael, Ltd.

Evaluating Predicate Fields

- Predicate oriented programming is a promising research idea that has never been evaluated in practice
  - Dynamic classification of an object into subclasses:
    - Predicate classes [Chambers et al. 93]
    - Kea language classifiers [Mugridge et al. 91, Hamer et al. 92]
    - Modes [Taivalsaari 93]
  - Predicate Dispatch [Ernst el at. 98, Millstein 04]
- We successfully deployed them in an industrial application
- Conclusion:
  - Increase software flexibility to handle changing and unknown requirements
  - Simplify certain development task

Predicate Fields Example

- A predicate field is present or not, depending on the values of other fields

First name: Shay
Last name: Artzi
…
Parking required : Yes No
License Plate :……
Dates :……….
Dates :………..

obj:Reservation
-firstName -- “Shay”
-lastName -- “Artzi”
-parkingRequired -- true
-licensePlate
-dates

Implementation with Predicate Fields

// Definition

```
pred arriveWithCar (needsParking==true);
class Reservation {
    ...
    bool needsParking;
    String licensePlateNum when@arriveWithCar;
}
```

// Use

```
Reservation r = new Reservation();
r.licensePlateNum = "44GT23"; //RUN-TIME ERROR
r.needsParking = true;
r.licensePlateNum = "44GT23"; //OK
```

Advantages of Predicate Fields

- Allow an object to change its structure during its life cycle
  - Recover from user errors in user interface
  - Emulate dynamic classification of an object into subclasses
- Expedite user interface development
- Fine-grained customization of objects

Outline

- Introduction
- Case Study: Experiment control system
- Predicate Fields Motivation
- Developer Experience
- Summary

Case Study: Experimental Control System

- System goal: define, control, execute, and examine results of experiments
- Experiment:
  - Ordered instructions on a set of devices
  - Control complex events and vast number of devices

Requirements and Design

- Non functional requirement: adaptability to physical hardware changes (new devices, device locations)
- MML language to create experiments
- Two-level system architecture
  - Knowledge level: legal configuration of operational objects.
  - Operational level: concrete model of the system.

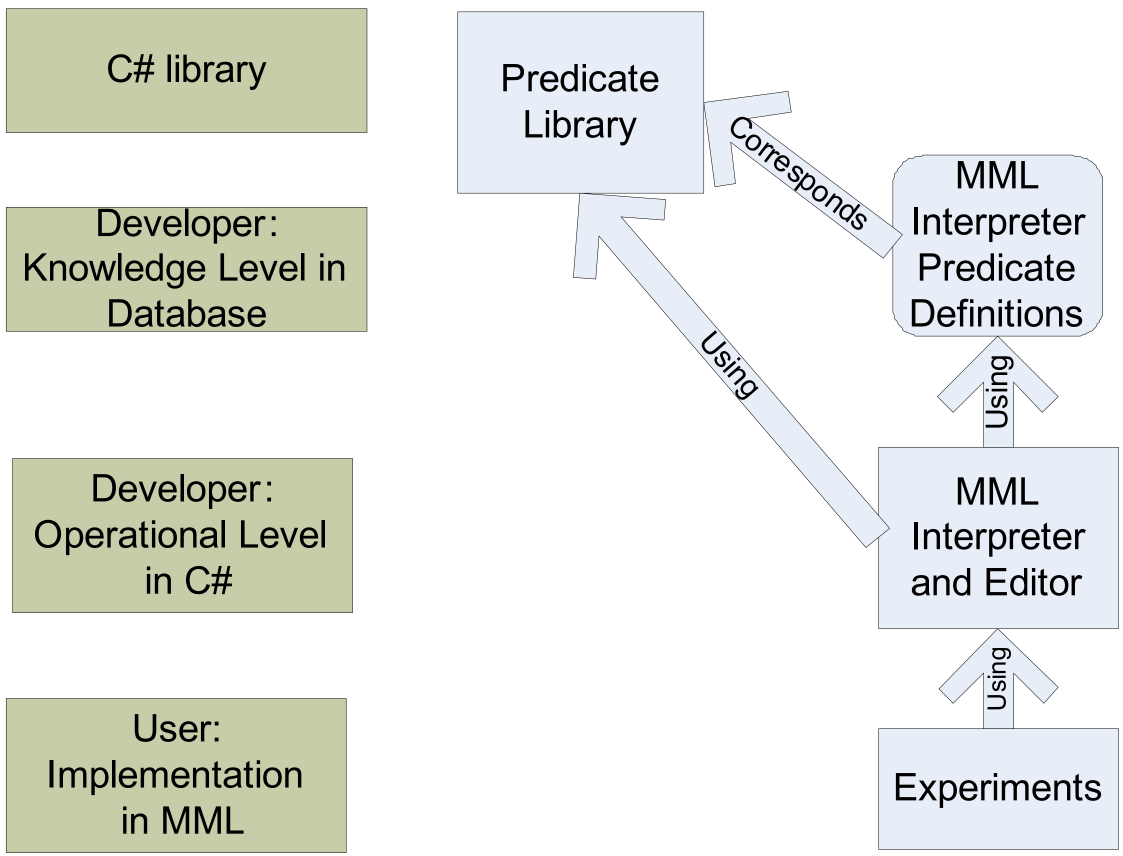
Implementation 1

- Development:
  - Fifteen man years
  - Written in Delphi IDE and the Object Pascal language
  - Component based (COM/DCOM)
  - ~100,000 lines of code
- In daily use
- Won several internal prizes
- Its deficiencies inspired the use of predicates in Implementation 2

Implementation 2

- In development since 2002 in Visual Studio . NET and C#
- Currently in integration phase (adding controlled hardware)
- Five developers
- Implementation 1 functionality was subsumed in less than two years
- Controls more complicated hardware
- Uses predicate fields.

Implementation 2 tiers



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Predicate Fields Motivation in Implementation 2

- Implementation 1 deficiencies were resolved using predicates:
  - Tight coupling of persistent objects with their user interface
  - Many custom made user interface forms
  - Can’t change object types
  - Inflexibility to some hardware changes

Motivation 1
Tight coupling

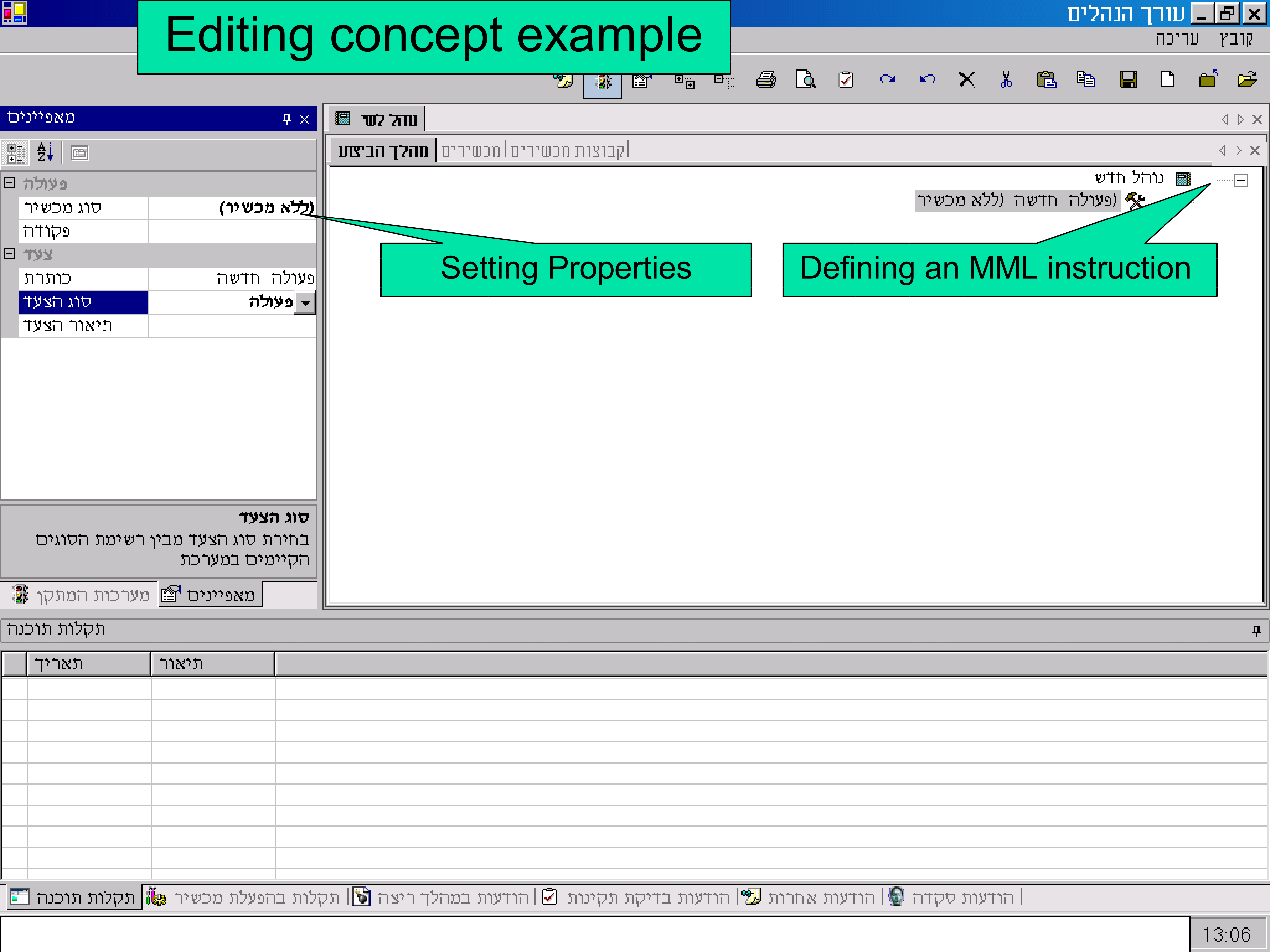
- Cause: MML statements which are persistent objects with UI representation had tight coupling with other components
- Problem: Changes to the structure of the MML statement required cross cutting modifications

- Example: adding a max_repeat field
- Solution: Dynamic objects. Structure and connections defined using predicates. Predicate fields carry the rest of the information
- Outcome: Changes to the MML statement data type can be easily done in one place (database)

Motivation 2
Many Custom Made UI Forms

- Cause: One UI form per MML statement type, and device type
- Problem: UI development and changes were costly
- Example: Adding a new measurement device type with a different number of channels
- Solution: Adopting .NET editing concept
  - One adjustable properties form
  - Object exposing properties to be edited
  - PropertyGrid uses reflection to query a selected object structure
  - Dynamic objects can be easily wrapped to expose properties
- Outcome: Homogeneous look and feel and reduced user interface development effort.

Editing concept example



Motivation 3
Can’t Change Object Types

- Cause: The user is unable to change an object type in the MML UI
- Problem: losing mutual information of the new and the old object type
- Example: Changing an automatic statement to a manual one
- Solution: Using predicate fields to dynamically classify into subclasses.
- Outcome: Allowing objects to “switch type” while maintaining mutual information

Motivation 4
Inflexibility to Hardware Changes

- Cause: New device types with components that exists in the set of known devices required cloning information
- Problem: Introducing clones into the system. Maintenance complexity increase
- Solution: Using predicate fields to support fine grained combination of existing fields
- Outcome: More flexibility to new device types

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Definitions Modifications

- Developers making modification to the MML interpreter definitions:
  - Modify the dynamic types (rarely)
  - Modify predicates, fields and fields’ types (usually).
- Initially found to be difficult due to the library use and integral limitations

Limitations

- Declarative approach
  - Far-reaching, system behavior depends on the metadata
  - Developers need to master the knowledge level
  - Type safety cannot be guaranteed
- Implemented as a library
  - Incur performance overhead
  - Software is harder to understand, less readable
  - Poor UI (MML interpreter definitions were saved in database)

Developer Experience (after further use)

- Familiarity and ease
- Easily perform seemingly complex task
- Surprising uses (E.g. wizards for the knowledge level editor)
- Change in perspective toward designing the UI
- Dynamic type errors cause distrust
- Active interest from other development teams

Summary

- Used predicate fields in a large industrial application
- Developers find predicate fields useful
- Software flexibility is increased
- UI development costs were greatly decreased
- Lack of static type checking is a problem