Chief Chefs of Z to Alloy: Using A Kitchen Example to Teach Alloy with Z

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Outline

Introduction

Z to Alloy Tutorial

Case Studies with Novice Students

Discussion

Conclusion

Related Work

The Problem

- Z is a well-defined and well-known specification language.
- Model checkers enable automatic checking of specifications.
- The lack of student interest in Formal Methods causes educators to focus only on one aspect.
- Educators need a technique to master tool usage besides Z without burdening the students to learn a new language.

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Contribution

- Alloy is a model checking tool that provides a language substantially similar to Z.
- There is a lack of examples and educational material for the transition from Z to Alloy.
- To populate the materials, we suggest the use of an easy and yet comprehensive and self-explanatory example.
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Birthday Book

- It records people's birthdays and places a reminder when that day comes.
- It can be populated and depopulated, and there is a search option.
- Its Z specification reviews concepts from set theory and teaches the notation.
- An Alloy model is used to automatically check some assertions.

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Kitchen Environment

- It simulates the actions of a kitchen chef to direct other cook(s) in the preparation of a dish.
- The primitive object types and built-in functions are given.
- We define a list of assertions that are crucial for our system.
- An event-driven programming approach is suggested.
- We develop an approximate Z specification to later convert it into a full Alloy model.

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Kitchen Schema and Signature

Kitchen

$cooks : \mathbb{P}\, COOK$
$items : \mathbb{P}\, KITCHEN\_ITEM$
$ingredients : \mathbb{P}\, INGREDIENT$
$AvailCook : COOK \leftrightarrow \mathbb{N}$
$AvailItem : KITCHEN\_ITEM \leftrightarrow \mathbb{N}$
$DirtyItem : KITCHEN\_ITEM \leftrightarrow \mathbb{N}$
$HeatedItem : KITCHEN\_ITEM \leftrightarrow \mathbb{N}$
$AvailIngr : INGREDIENT \leftrightarrow \mathbb{N}$
$UsedIngr : INGREDIENT \leftrightarrow \mathbb{N}$

$\mathrm{dom}\ AvailCook \subseteq cooks$
$\mathrm{dom}\ AvailItem \subseteq items$
$\mathrm{dom}\ DirtyItem \subseteq items$
$\mathrm{dom}\ HeatedItem \subseteq items$
$\mathrm{dom}\ AvailIngr \subseteq ingredients$
$\mathrm{dom}\ UsedIngr \subseteq ingredients$
$\forall t : \mathbb{N} \bullet \mathrm{dom}\,(AvailIngr \rhd \{t\}) \cap \mathrm{dom}\,(UsedIngr \rhd \{t\}) = \emptyset$
$\forall t : \mathbb{N} \bullet \mathrm{dom}\,(AvailItem \rhd \{t\}) \cap \mathrm{dom}\,(DirtyItem \rhd \{t\}) = \emptyset$

```
one sig Kitchen {
    cooks : set Cook,
    items : set KitchenItem,
    ingredients : set Ingredient,
    AvailCook : cooks → Time,
    AvailItem : items → Time,
    DirtyItem : items → Time,
    HeatedItem : items → Time,
    AvailIngr : ingredients → Time,
    UsedIngr : ingredients → Time
} {
    all t : Time | no AvailIngr.t & UsedIngr.t
    all t : Time | no AvailItem.t & DirtyItem.t
}
```

Kitchen Environment

- At each step, we point out the differences and similarities between the two versions.
- We explain what the limitations of model checking are.
- We formalize a guarded event implementation.
- Our final Alloy model is long but once a rough Z specification is at hand, Alloy development is not cumbersome.

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Design

- With Kolb's theory [4], we decided to have multiple-choice questions within the tutorial.
- The questions ask the student to think beyond what is given rather than passively reading the text.
- The students reveal the correct answer once they are satisfied with their answer.

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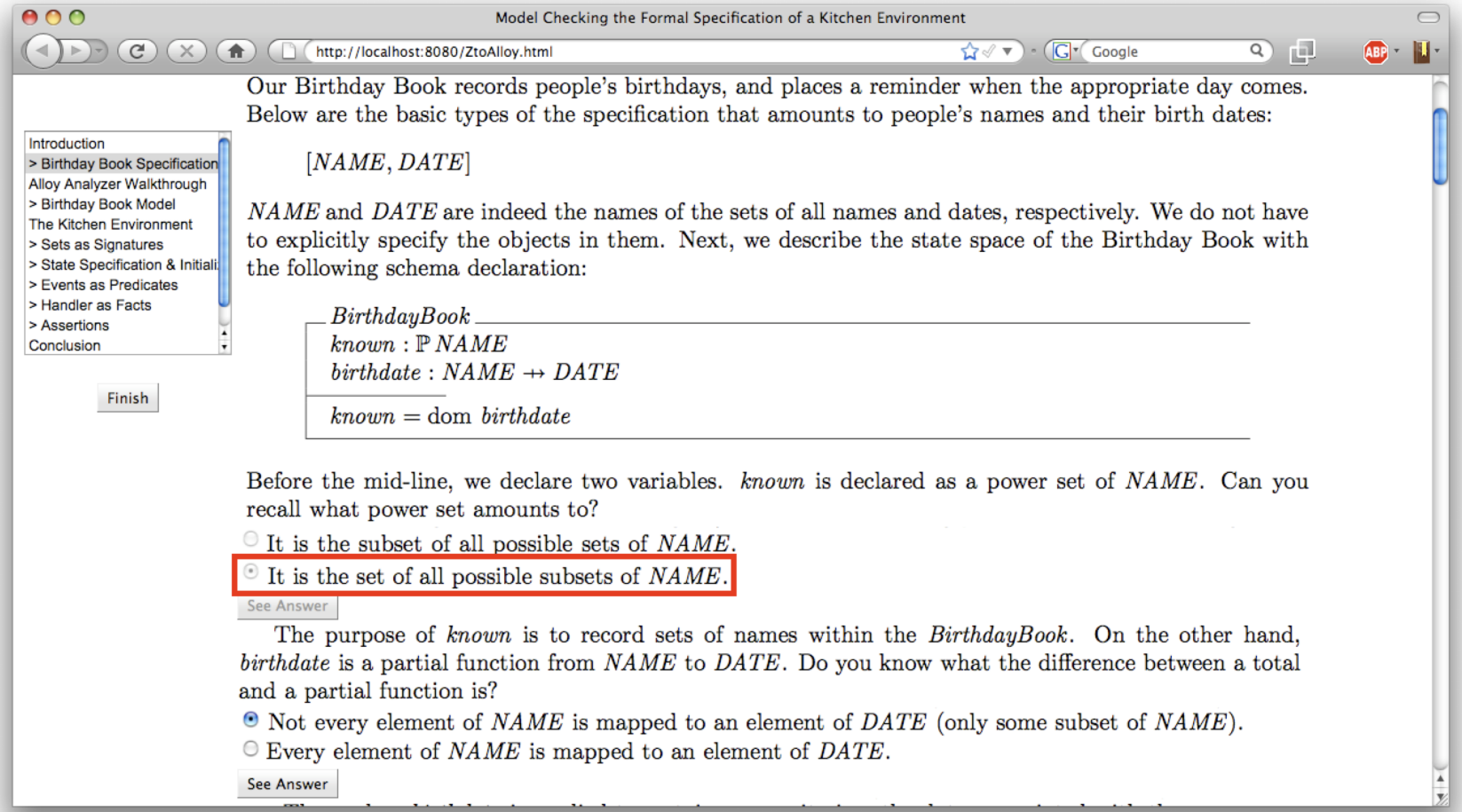
The Online Interactive Tutorial



Basics

- *Task & Procedure*
  - The students were asked to answer all the questions in the tutorial and fill out the surveys.
  - Each student spent 1-3 hours working on the tutorial.
- *Student Background*
  - 8 students took our tutorial.
  - Students strongly agreed that they have experience with small- and medium-sized software projects.
  - Students strongly agreed that they have not had much experience with formal methods.

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Tutorial Questions

- Initial questions reviewed the math background but later, more questions became related to the specifics of the examples.
- Both the Birthday Book specification and model were well-received.
- Excluding 2 students who dropped out of the Kitchen Environment, there were 45/58 correct answers on average.

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Assessment

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- The questions were evaluated based on legitimate rationale rather than exact syntax.
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- Students' appreciation of formal methods, formal specification, and model checking were moderate.
- Students strongly agreed with our statements on the ease of transitioning from Z to Alloy with the tutorial.
- Students agreed that the teaching material and the examples were good and that they were satisfied.
- Students wanted visualizations (pictures, diagrams, tables).
- Students needed examples that are between the Birthday Book and the Kitchen Environment in complexity.

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Findings

- The student performance did not show a huge drop between Kitchen Environment (77.5%) and Birthday Book (88%).
- Students believe that Z and Alloy are similar and can be taught together but that textbooks using toy examples for Z or Alloy are insufficient.
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Final Remarks

- Novice students are able to learn Z and Alloy and answer questions about an intermediate-sized example after only a couple hours of study.
- We recommend educators to focus on the Alloy tool while teaching the Z language.
- It is necessary to provide well-explained and interesting intermediate-level examples for the Z to Alloy transition.

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- *Interactive application of Formal Methods*
  Dean's interactive case e-study [3], Pandora's e-tutor [2]
- *Similar Educational Materials*
  Piaget's genetic epistemology theory [8], Z to SPIN module [9]
- *Content-wise*
  Real-life examples such as a Bluetooth communication protocol, a Eurovision Song Contest [1, 5, 6, 7]


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