1—Initial Ideas on Formal Methods

UIT2206: The Importance of Being Formal

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1 Preliminaries

2 Hallmarks of a Formal Approach

3 Formal Systems in Information Technology
Structure of the module

- Intro (today)
- Formal reasoning techniques (Weeks 2 to 8)
- Formal methods in other disciplines (Weeks 9 to 12)
Weekly structure

- Lecture: Wednesdays 10–12
- Tutorials: two sessions on Fridays: 8–10 and 10–12 starting next week
Assessment

- Class participation: 10%
- Tutorial participation: 10%
- Assignments: 20%
- Test (Week 9 or 10): 20%
- Presentation (Weeks 10 to 13): 20%
- Essay: 20%
1 Preliminaries

2 Hallmarks of a Formal Approach
   - Discreteness
   - Naming
   - Abstraction
   - Reification
   - Self-reference

3 Formal Systems in Information Technology
Discreteness

Do atoms exist?
Discreteness

Do atoms exist?

Brownian motion
Discreteness

Do atoms exist?
Brownian motion

Fundamental fact
Nature is made up of discrete structures
Discreteness

Do atoms exist?
Brownian motion

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Central dogma of molecular biology
Discreteness

Do atoms exist?
- Brownian motion

Fundamental fact
- Nature is made up of discrete structures

Central dogma of molecular biology
- DNA makes RNA makes protein
Preliminaries
Hallmarks of a Formal Approach
Formal Systems in Information Technology

Discreteness
Naming
Abstraction
Reification
Self-reference

Discreteness in Human Affairs

Language
Natural language is made up of sounds, words, sentences. All of these are discrete structures
Discreteness in Human Affairs

Language
Natural language is made up of sounds, words, sentences. All of these are discrete structures

Politics
States, counties, political parties etc are discrete, not continuous phenomena
Preliminaries
Hallmarks of a Formal Approach
Formal Systems in Information Technology

Naming

John Stuart Mills
Names have denotations, not connotations
Naming

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Frege/Russell
Names are essentially abbreviations for a collection of properties
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A Theory of Naming
Naming is a surprisingly poorly understood concept. 20th century philosophers have made significant progress. Example: Saul Kripke: Naming and Necessity
Abstraction

Definition

Abstraction is a process by which concepts are derived from the usage and classification of other (more “real” or “concrete”) concepts.
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Science
Classification of phenomena into discrete categories lies at the heart of many sciences. Example: taxonomy in biology
Reification refers to making something real, bringing it into being, or making something concrete.
Reification

Definition
Reification refers to making something real, bringing it into being, or making something concrete.

Automated processing
Reification is a prerequisite for automated processing.
Self-reference

The Grelling-Nelson paradox

Is "non-self-descriptive" non-self-descriptive or self-descriptive?

Applications

Sometimes, self-reference has surprising results: Gödel's Theorems, the Halting Problem
Self-reference

Grelling-Nelson paradox

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Preliminaries

Hallmarks of a Formal Approach

Formal Systems in Information Technology

Formal Systems: A Standard Response to Complexity
Formal Systems All Around Us

UIT2206: The Importance of Being Formal

1—Initial Ideas on Formal Methods
Example 1: Books

Problem

How to identify a book uniquely, and world-wide
Example 1: Books

**Problem**
How to identify a book uniquely, and world-wide

**Attempts**
“Library of Congress”, need of fast access to records led to alternatives (publishers J Whitaker & Sons, R R Bowker)
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**Solution**
Example 2: Representing Text

Problem

How to store and transmit text, given that dozens of scripts exist, and hundreds of languages use them.
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ASCII (95 characters), ISO 8859 (one “byte”)
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**Problem**
How to store and transmit text, given that dozens of scripts exist, and hundreds of languages use them.

**Attempts**
ASCII (95 characters), ISO 8859 (one “byte”)

**Solution**
Unicode standardizes more than 109,000 characters, covering 93 scripts, developed by the Unicode Consortium.
Example 3: Text Processing

Problem

In the 1960s, some projects required amounts of documents that exceeded the processing capabilities of traditional administrative procedures.
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GML by IBM: named after inventors Goldfarb, Mosher, Lorie
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Problem
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Attempts
GML by IBM: named after inventors Goldfarb, Mosher, Lorie

Solution: SGML
“SGML was...designed to enable the sharing of machine-readable large-project documents in government, law, and industry. Many such documents must remain readable for several decades—a long time in the information technology field.”
Example 4: Hypertext

Problem

In the late 1980s, it became clear that the Internet could be used to link documents together. For that, software needed to run on the client (browsers), and (web) servers.
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**Solution**

HTML, and application of SGML
Surprised?

Why do we not realize...

Because they work!

We do not need to know that what underlies complex systems is a formal process. The formal systems allow them to work as expected, always!
Surprised?

Why do we not realize...

... that we are surrounded by formal systems?
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The Importance of Being Formal

First Agenda

Find out *in detail* how formal systems work
The Importance of Being Formal

First Agenda
Find out in detail how formal systems work

Goal
Thorough understanding of formal logic as an example par excellence for formal methods
The Importance of Being Formal

First Agenda
Find out *in detail* how formal systems work

Goal
Thorough understanding of formal logic as an example *par excellence* for formal methods

Approach
Study a series of logics: traditional, propositional, predicate logic
The Importance of Being Formal

Second Agenda

Explore fundamental boundaries of formal reasoning
The Importance of Being Formal

Second Agenda
Explore fundamental boundaries of formal reasoning

Goal
Appreciate Undecidability and Gödel’s incompleteness results
The Importance of Being Formal

Second Agenda
Explore fundamental boundaries of formal reasoning

Goal
Appreciate Undecidability and Gödel’s incompleteness results

Approach
Study predicate logic deep enough to understand his formal arguments
The Importance of Being Formal

Third Agenda
Explore formal methods across fields
The Importance of Being Formal

Third Agenda
Explore formal methods across fields

Approach
Students write essays and present their findings
The Importance of Being Formal

Third Agenda
Explore formal methods across fields

Approach
Students write essays and present their findings

Goal
Overview of formal methods and their limitations in our civilization