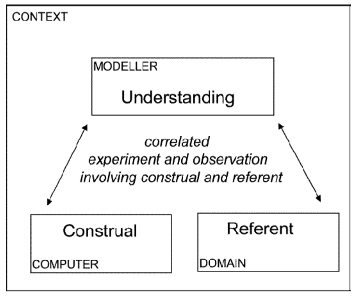
Empirical Modelling ("EM") is a body of principles and tools concerned with computing activity based on observation and experiment (hence '**empirical**') ...

... the principal theme of CS405 is alternative ways to think about "computing-in-the-wild"

… with special attention to computer **programming** and computer **science**

Empirical Modelling as *Construction*



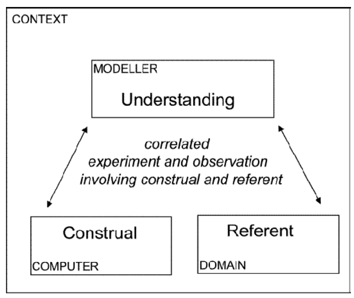
Agenda suggested by Lab 1 …

Making a multi-paradigm programming environment coherent is a fundamental unresolved research problem.

Dealing with the relationship between the operational state-based semantics and the declarative denotational semantics is a challenge for classical programming.

The emphasis in classical computer science is on how meanings can be made formal and non-negotiable ... in contrast modern practices demand ways of thinking about computing that acknowledge its dependence on specific environments and human interpreters.

Empirical Modelling as *Construction*



… contrast this with ….

"The classical answer“ to ***What is a program?***

A program is a recipe for action that computes an input-output relationship

Turing’s machine model

Machine models of a computer always have

- means to store data
  - e.g objects in Java, files and variables in UNIX
- means to manipulate data
  - e.g. methods in Java, processes in UNIX
- ways to program data manipulation
  - e.g. JAVA programs, UNIX shell scripts

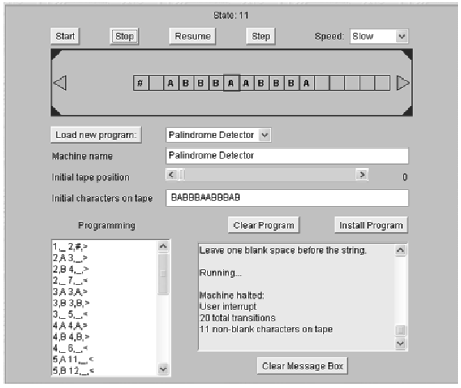
The Turing Machine model (1936)

- store is represented by an unbounded tape
- processor is represented by a read/write head
- program is represented by a set of rules

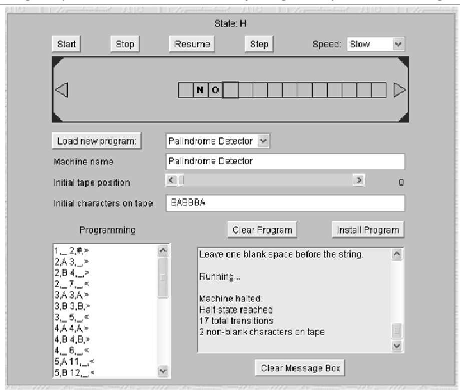
Suzanne Skinner (1996) Java applet simulator at:

http://ironphoenix.org/tril/tm/

A Turing computation in progress … recognising a odd length palindromes



A Turing computation in the halt state … rejecting a non-palindromic string



The Church-Turing thesis

There is no computational model that is in principle more powerful than the Turing machine …

… all algorithmic data processing is equivalent to Turing computation

… by this criterion, very simple notations can define “a full programming language”

A **procedural** program explicitly expresses a recipe as a sequence of actions ...

A problem with procedural programs …

Procedural variable

- has a value that can be elusive e.g. when debugging

- always changing, possibly in ways that are hard to track

Procedural version of isprime

```
func factors {
    para n;
    auto r, result;
    result = [];
    for (r=1; r<=n/2; r++)
        if (n % r == 0) result = result // [r];
    return result;
}

func isprime {
    para n;
    return ((factors[n])# == 1);
}
```

Program (e.g.) by specifying the required input-output relation in a mathematical form:

`out = f(in)`

This is called **functional programming ("FP")**.

FP exploits a special-purpose interpreter that can compute the function f

FP uses very powerful operators ("λ - calculus") in order to frame the function f

Functional programming (FP)

A “functional” program to compute prime numbers:

```
factors n = [r | r<-[1..n div 2]; n mod r = 0]
isprime q = (# factors q) = 1
```

functional ≡ based on specifying functions
The functions in this context are
factors() and *isprime()*

The programming language is **Miranda**

Procedural version of isprime

```
func factors {                    factors n = [r | r<-[1..n div 2]; n mod r = 0]
    para n;
    auto r, result;
    result = [];
    for (r=1; r<=n/2; r++)
        if (n % r == 0) result = result // [r];
    return result;
}

func isprime {                    isprime q = (# factors q) = 1
    para n;
    return ((factors[n])# == 1);
}
```

Key virtues of declarative programming …

it hides internal states of the computation

have **referential transparency**

frame computational problems in terms of the external domain, not the computer

BUT issues for declarative programming …

Makes interaction tricky

‘lazy evaluation’ / dataflow as potential solutions

Supporting rich input-output challenging

Legacy of the TM concept of computation:
a highly abstract conception of programming

Not well-suited to “emerging computing”

- diverse and rich contexts for computer use
  - non-standard devices, modes of interaction
  - reactive systems
  - real-time, distributed computing, concurrency

- new challenges for software development …

Legacy of the TM concept of computation:
a highly abstract conception of programming

Not well-suited to "emerging computing"

- new challenges for software development …
  - computer + devices + human
  - team work, user participation in design
  - computer as instrument

  Need software that is comprehensible and manipulable even by the non-specialist / even whilst its being constructed

Techniques to help address these goals …

object-orientation
agent-based analysis and conception of systems
design patterns
service-oriented architecture
spreadsheet principles

CADENCE as reflecting many programming paradigms ….

Prototype-based object-oriented code:

```
this sgobjects puddle

        primitive = cube
        width = 3.3
        height = 3.3
        depth = 0.1
        visible = true

        position = (new x=0.0 y=0.0 z=-3.0
                z is { @stargate position z }
        )

        orientation = (new x=0.0 y=2.5 z=0.0
                y is { @stargate orientation y }
        )
;
```

Data-flow

```
#How fast the hole appears
holespeed = 0.8

#The hole animation definition
hole = 1.0
hole := {
    if (.ready) {
          if (..active) -1.0 else {
               ..hole - (..holespeed * (@root itime))
          }
    } else 1.0
}

active = false
active is { .hole < -0.9999 }
```

A "real-time" ingredient:

```
match = false
ready = false
locked = false
rotspeed = -0.3
rotation = 0.0
rotation := {
     if (.dial and (.match not or (.locked))
                    and (.ready not)) {
       ..rotation + (..rotspeed * (@root itime))
     } else {
                  ..rotation
            }
}
```

Spreadsheet-style dependencies

```
position = (new x=0.0 y=0.0 z=-3.0
        z is { @stargate position z }
)

orientation = (new x=0.0 y=2.5 z=0.0
        y is { @stargate orientation y }
)
```

Going beyond classical programming ….

*Characteristics of tools to be introduced in the module ...
they are concerned with modelling in which we*

- *observe meaningful things*
- *adopt a **constructivist** stance*
- *exploit an **empirical** approach*

that we wish to reconcile / can be reconciled with the more abstract, rationalist, theoretical framework that characterises classical computer science

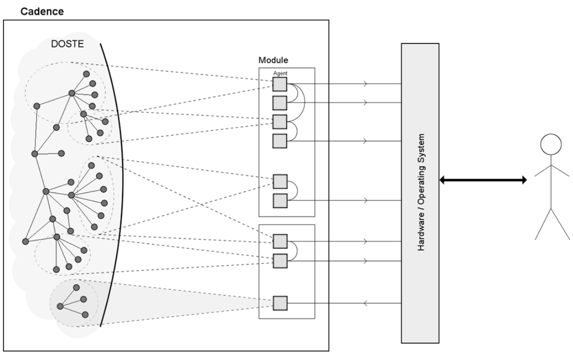
Reconceptualise by **introducing the human dimension** ... key shift in emphasis towards questions such as:

*? what is the **experience** of the people engaging with Turing computation, procedural programs, functional programs etc.*

Consider people's experience ('programmers', 'users', 'modellers' or 'analysts' etc.) with reference to

* What are the significant things that they observe?
* How are they able to interact and manipulate?
* What is the context for their interaction and interpretation?

when they are engaged in some variety of programming / model-building activity.



The CADENCE environment and the DOSTE engine