Infer.NET and CSOFT

A framework and language for Machine Learning

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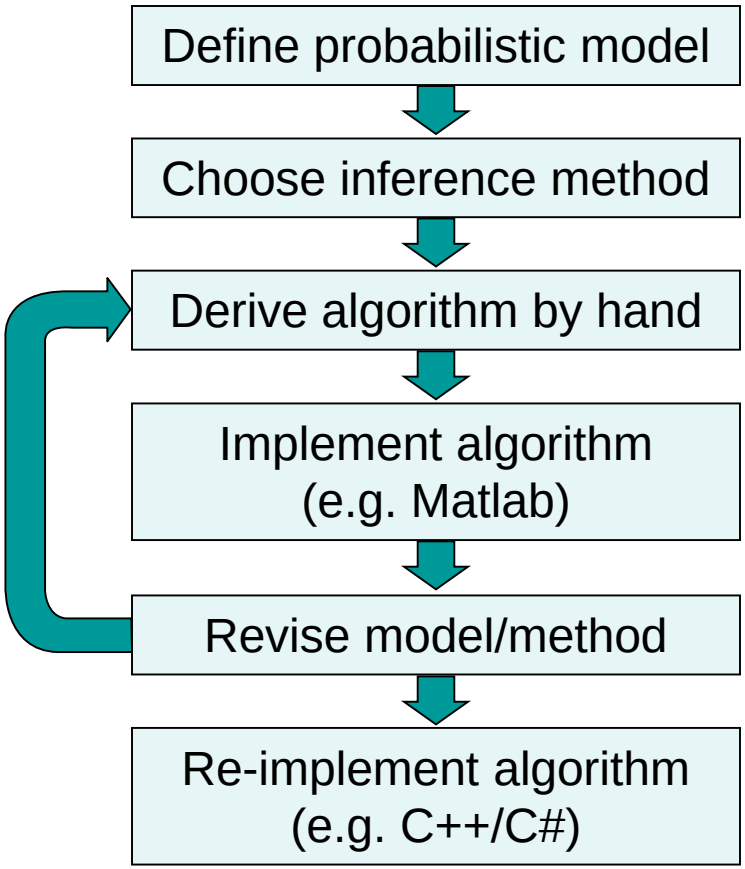
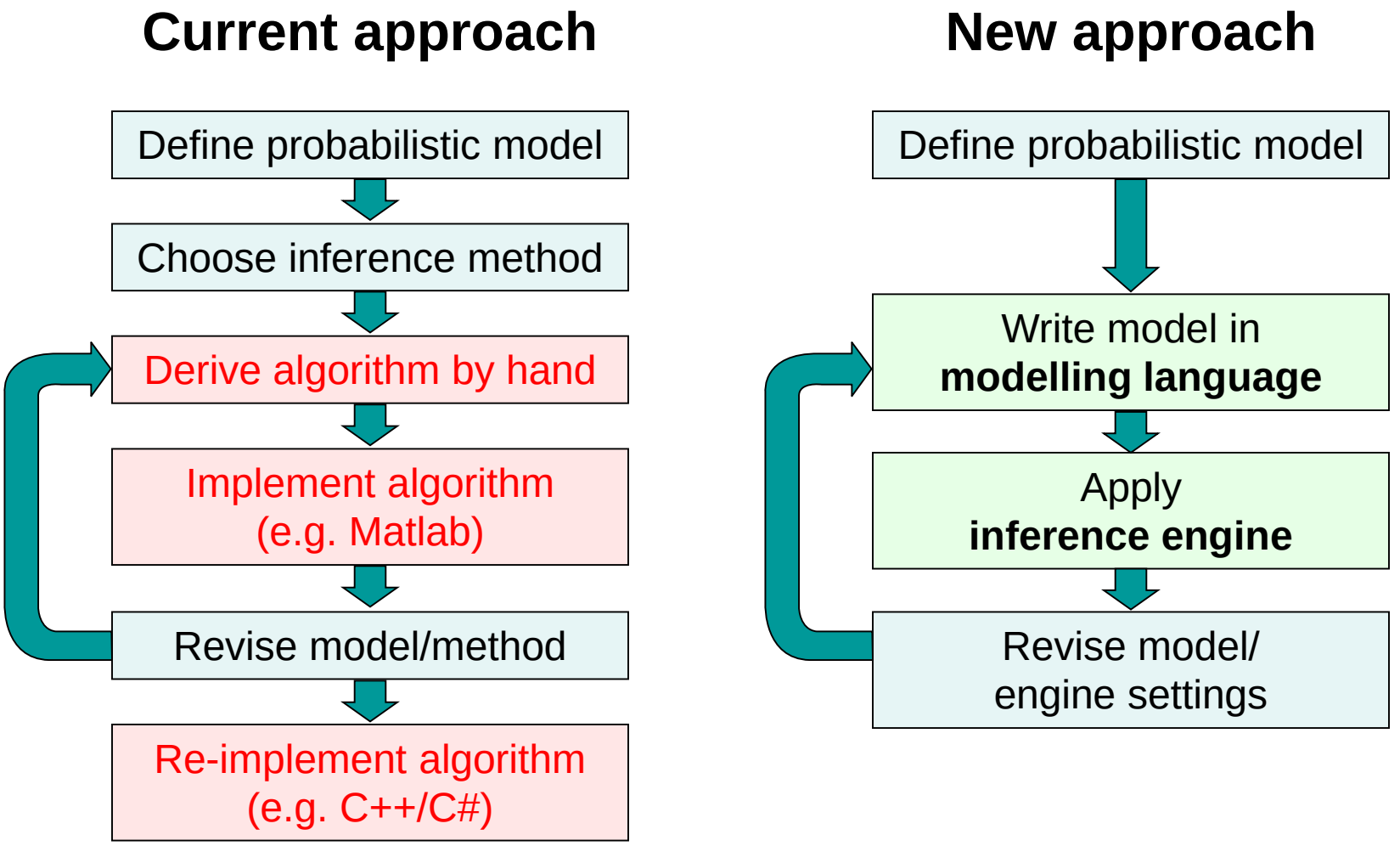
How machine learning is applied

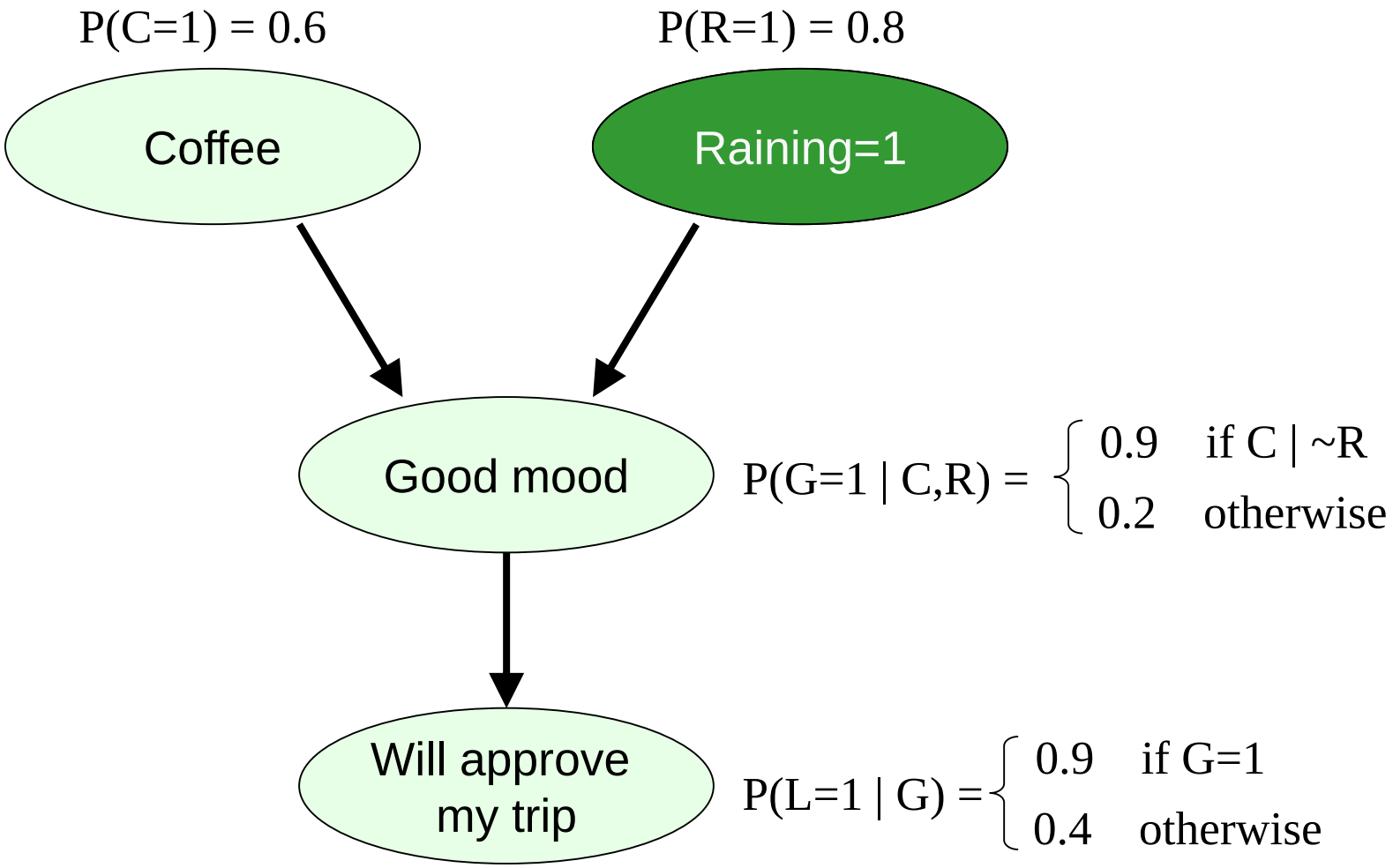
Current approach



How machine learning is applied



Example: BossPredictor



Hand-coded solution (Matlab)

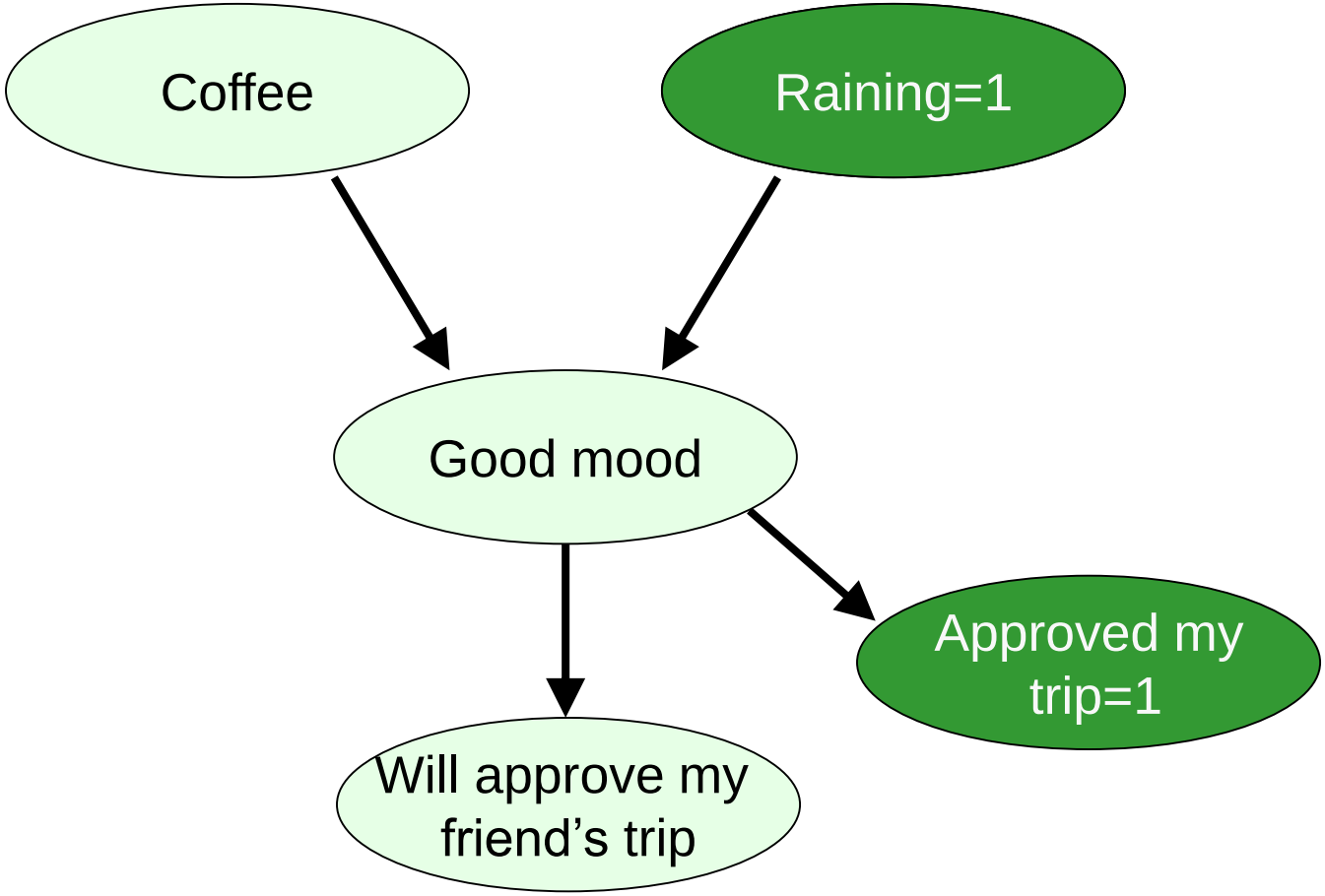
```
% Perform variable elimination on BossPredictor model
% Model specification
PCoffee  = [0.4 0.6];
PRaining = [0.2 0.8];

PGoodMood(2,:,:) = [0.9 0.2;0.9 0.9];
PGoodMood(1,:,:) = 1 - PGoodMood(2,:,:);

PLikesIdea(2,:) = [0.4 0.9];
PLikesIdea(1,:) = 1 - PLikesIdea(2,:);

% Add observation
PRaining = [0 1];

%%% Perform variable elimination
% Eliminate coffee
PGoodMood2 = zeros(2,2);
for coffee=1:2
    PGoodMood2 = PGoodMood2 + squeeze(PGoodMood(:,coffee,:)*PCoffee(coffee));
end

% Eliminate raining
PGoodMood3 = zeros(2,1);
for raining = 1:2
    PGoodMood3 = PGoodMood3 + PGoodMood2(:,raining)*PRaining(raining);
end

% Eliminate good mood
PLikesIdea2 = zeros(2,1);
for goodMood = 1:2
    PLikesIdea2 = PLikesIdea2 + PLikesIdea(:,goodMood)*PGoodMood3(goodMood);
end
PLikesIdea2(2)
```

P(likes idea)=

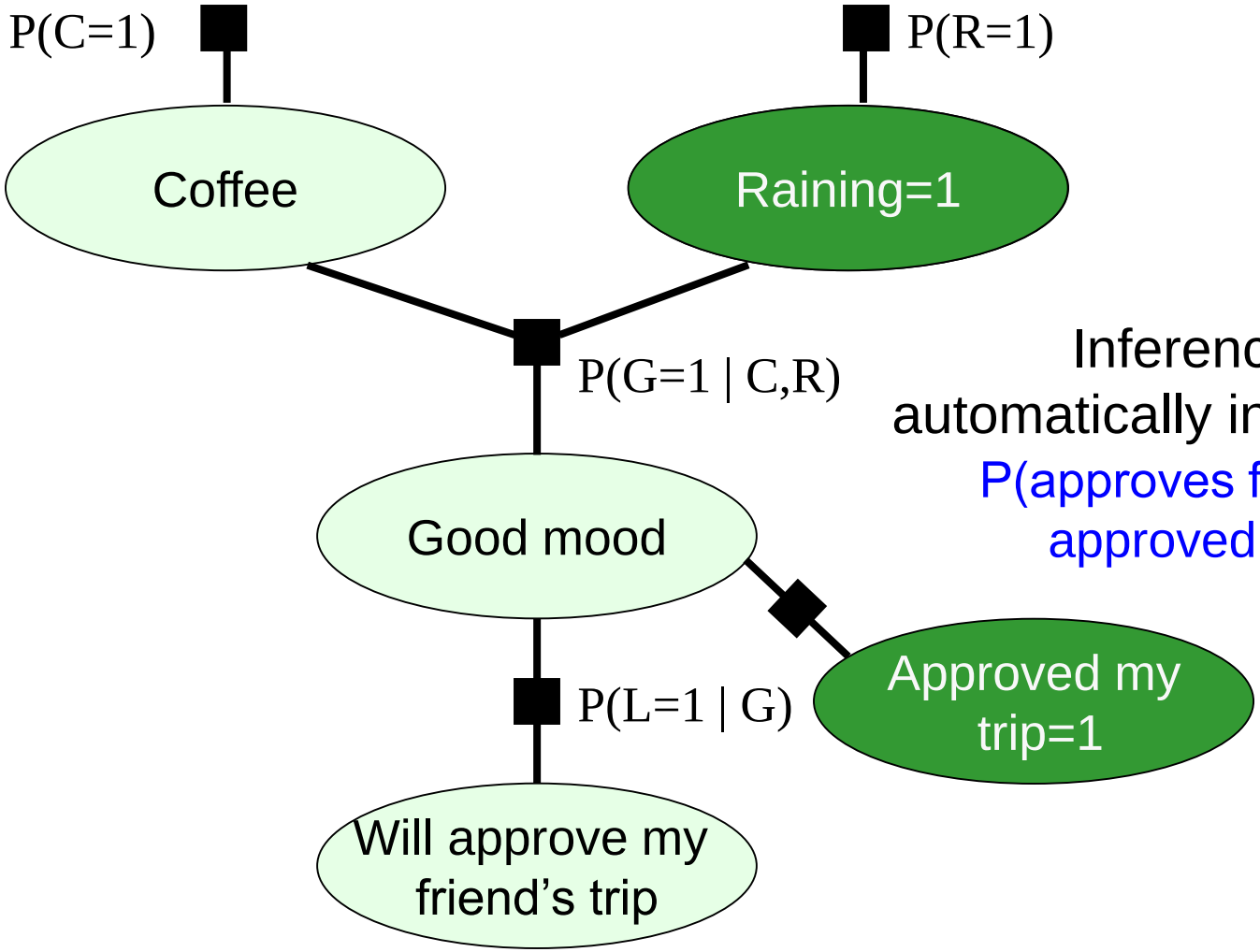
Is raining: 71%

Not raining: 85%

Example: BossPredictor



BossPredictor with Inference Engine



Inference runs automatically in new model:

P(approves friend's trip | approved my trip) = 79%

Existing modelling methods

- Graphical editors/factor graphs
  - Easy to use
  - Hard to develop and maintain large models
  - Hard to integrate with other code
  - Limited scope
- XML
  - Awkward syntax
  - Hard to integrate with other code
  - Limited toolset

CSOFT modelling language

- A representation language for probabilistic models.
- Takes C# and adds support for:
  - random variables
  - constraints on variables
  - inference
- Can be embedded in ordinary C# to allow integration of deterministic + stochastic code

CSOFT – random variables

- Normal variables have a fixed single value.
  e.g. `int length=6,`
  `bool visible=true.`

- Random variables have uncertain value specified by a probability distribution.
  e.g. `int length = random(Uniform(0,10))`
  `bool visible = random(Bernoulli(0.8)).`

- Introduce random operator which means ‘is distributed as’.

CSOFT –constraints

- We can define constraints on random variables, e.g.

```
constrain(visible==true)
constrain(length==4)
constrain(length>0)
constrain(i==j)
```

- The constrain(b) operator means ‘we constrain b to be true’.

CSOFT – inference

- The infer() operator gives the posterior distribution of one or more random variables.
- Example:

```
int i = random(Uniform(1,10));
bool b = (i*i>50);
Dist bdist = infer(b);//Bernoulli(0.3)
```

- Output of infer() is always *deterministic* even when input is *random*.

BossPredictor in CSOFT

Model definition

```
bool coffee = random(Bernoulli(0.6));
bool raining = random(Bernoulli (0.8));
bool goodMood =
        random(Bernoulli((coffee||!raining)?0.9:0.2));
bool approvesTrip = random(Bernoulli(goodMood?0.9:0.4));
```

Constraints and inference

```
constrain(raining==true);
return infer(approvesTrip);
```

TrueSkill™ in CSOFT

TrueSkill model (without draws)

```
double[] skill=new double[nPlayers];
double[] performance=new double[nPlayers];
for (int j=0; j<nPlayers; j++) {
  skill[j]=random(Gaussian(mu[j],sigma[j]));
  double x=random(Gaussian(0, beta));
  performance[j] = skill[j] + x;
  if (j>0) constrain(performance[j-1] >
                     performance[j]);
}
return infer(skill);
```

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CSOFT for analysing existing code

```
int i=random(Uniform(-100,100));
bool b = false;
try {
  Read(i);
} catch (Exception ex) {
  b = true;
```

Existing code called with *random* parameter

```
public byte[] Read(int numBytes) {
    if (numBytes<0) throw new
        ArgumentOutOfRangeException();
                …
}
```

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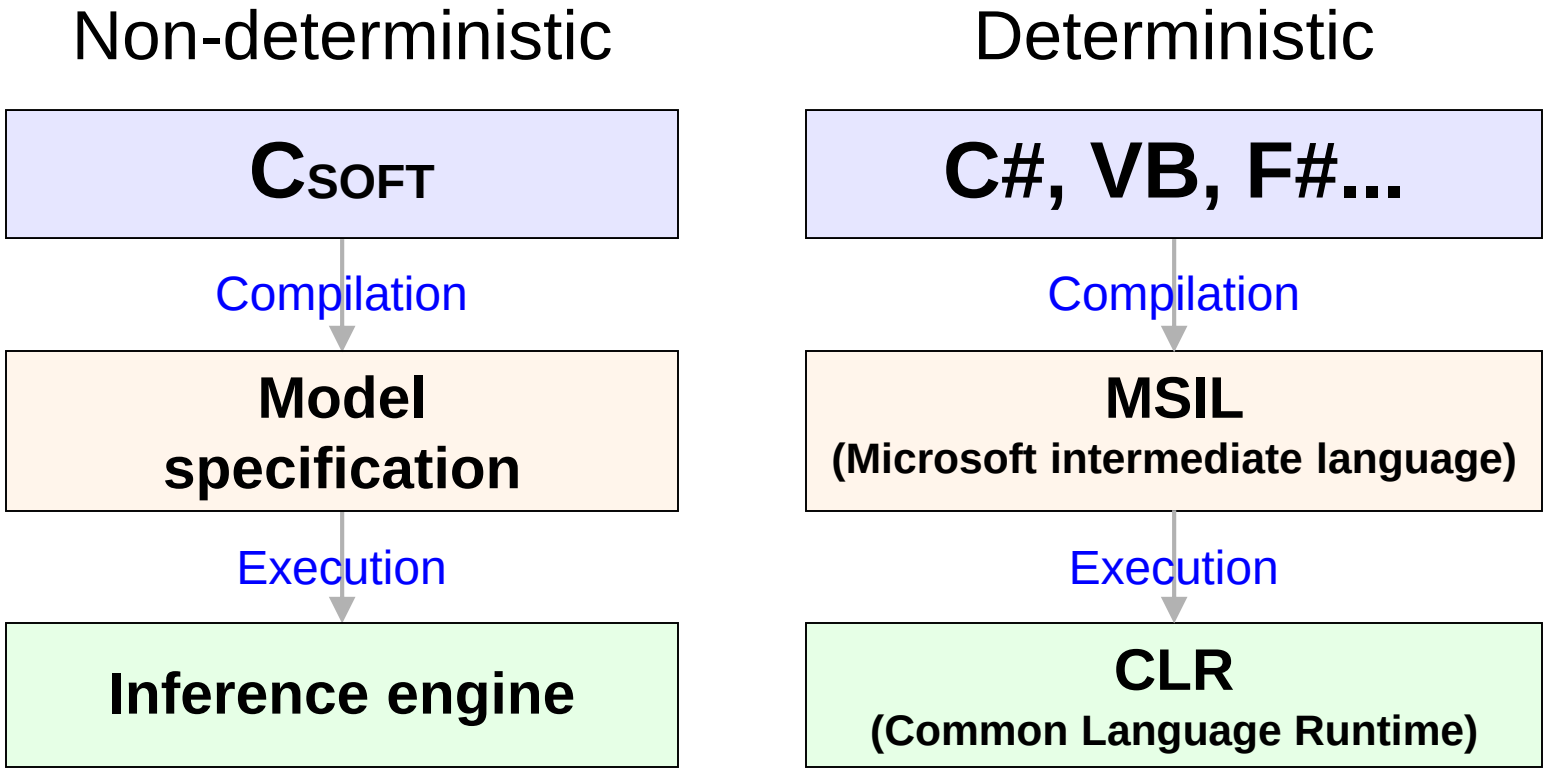
Random objects

- CSOFT is object-oriented. Random objects are objects whose members are random variables.
- Useful for domain-specific inference: can provide a library of random objects relevant to a domain e.g. `Image`, `ImageOperation`, `Texture`.
- For example: machine vision models can be specified as a series of graphics operations which generate an image.

Implementing CSOFT

CSOFT is implemented as a .NET library. The operators appear as static methods e.g. `Csoft.random()`



Inference engine requirements

To support CSOFT, engine must be:

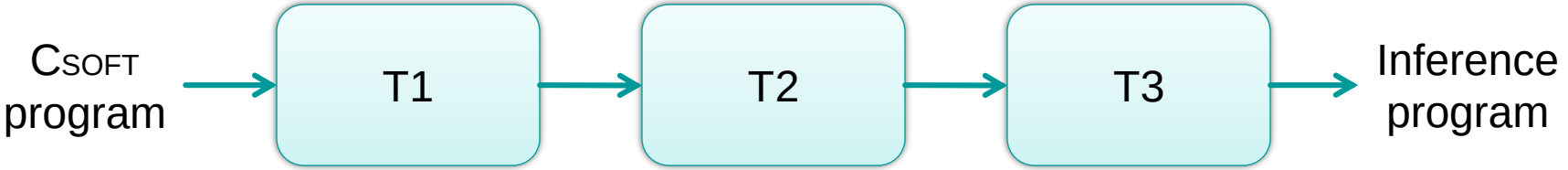
- Flexible: capable of handling very broad range of model specifications
- Accurate: must give appropriately accurate inference results so must use an appropriate inference algorithm
- Efficient: must scale to run on large models with large data sets

Infer.NET version 1

- Flexible: Yes - general purpose architecture for discrete/continuous variables and a large variety of factors
- Accurate: Yes – supported multiple inference algorithms: VMP/EP/Gibbs
- Efficient: No – constructed in-memory factor graphs and traversed them during inference, introducing considerable overhead. Also, made the code very difficult to maintain as more features were added.

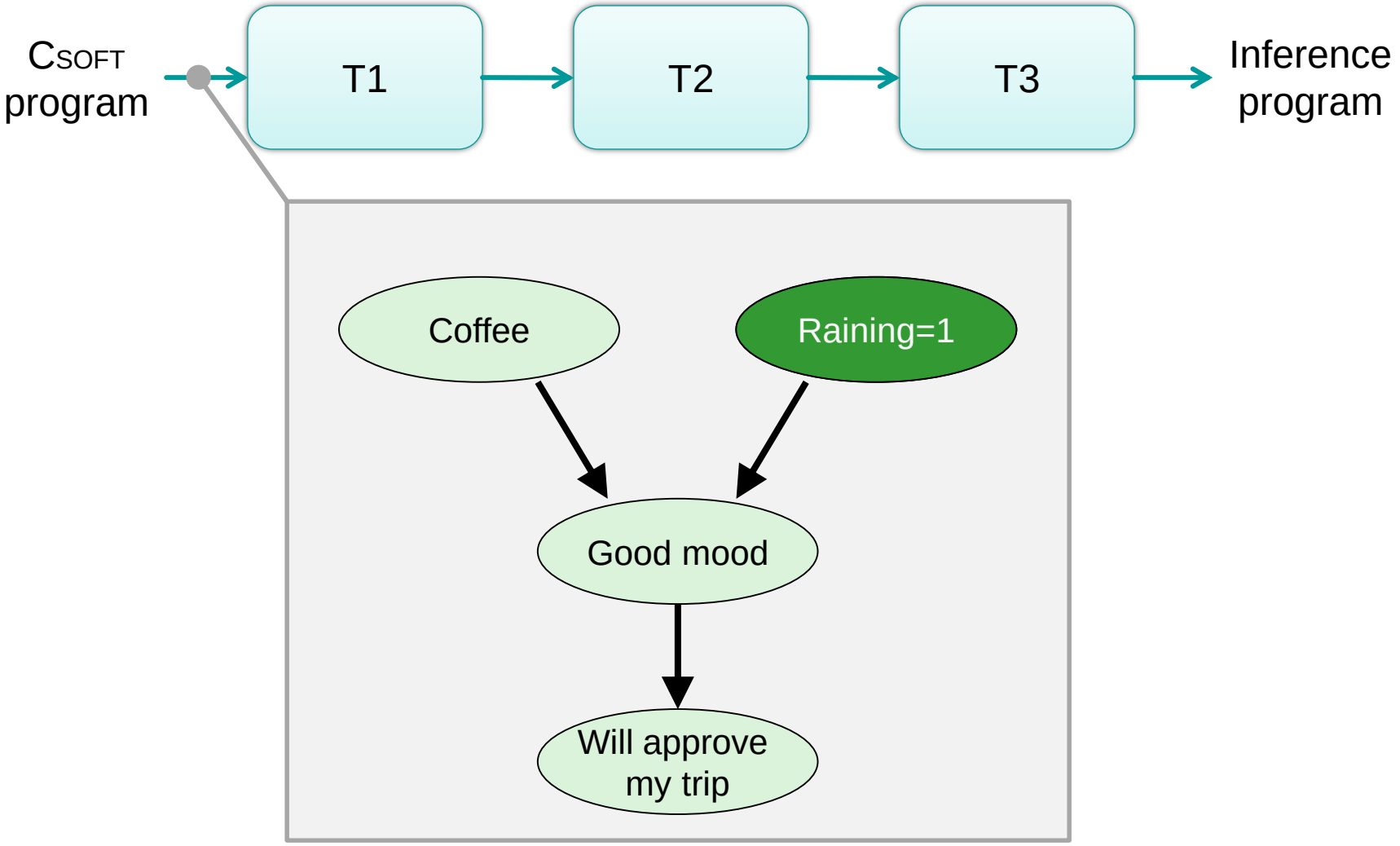
Infer.NET version 2

- Version 2 *compiles* modelling code into inference code.
- No in-memory factor graphs = no overhead
- Consists of a chain of code transformations:

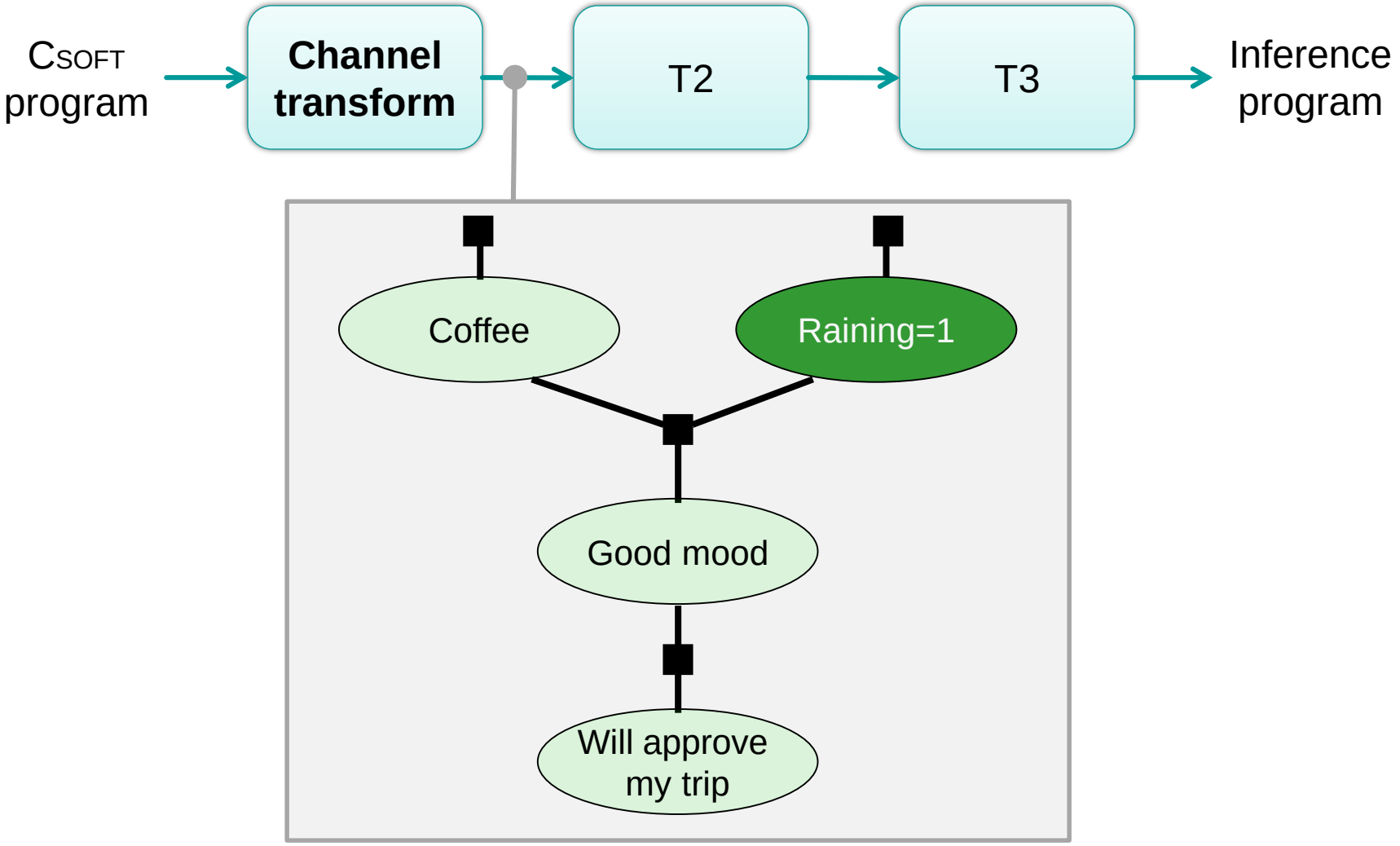


- Each intermediate program is a valid C# program.

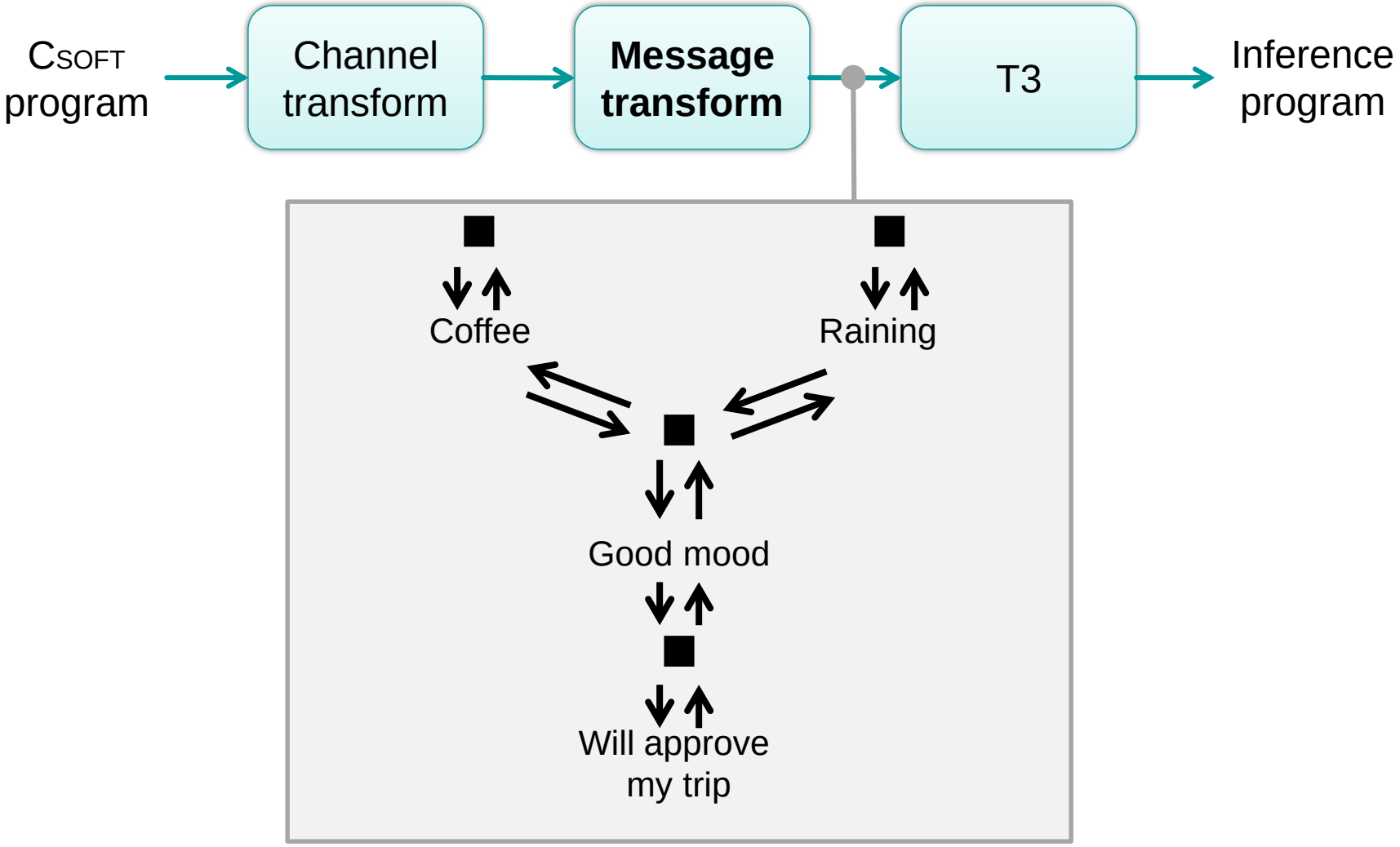
Infer.NET inference engine



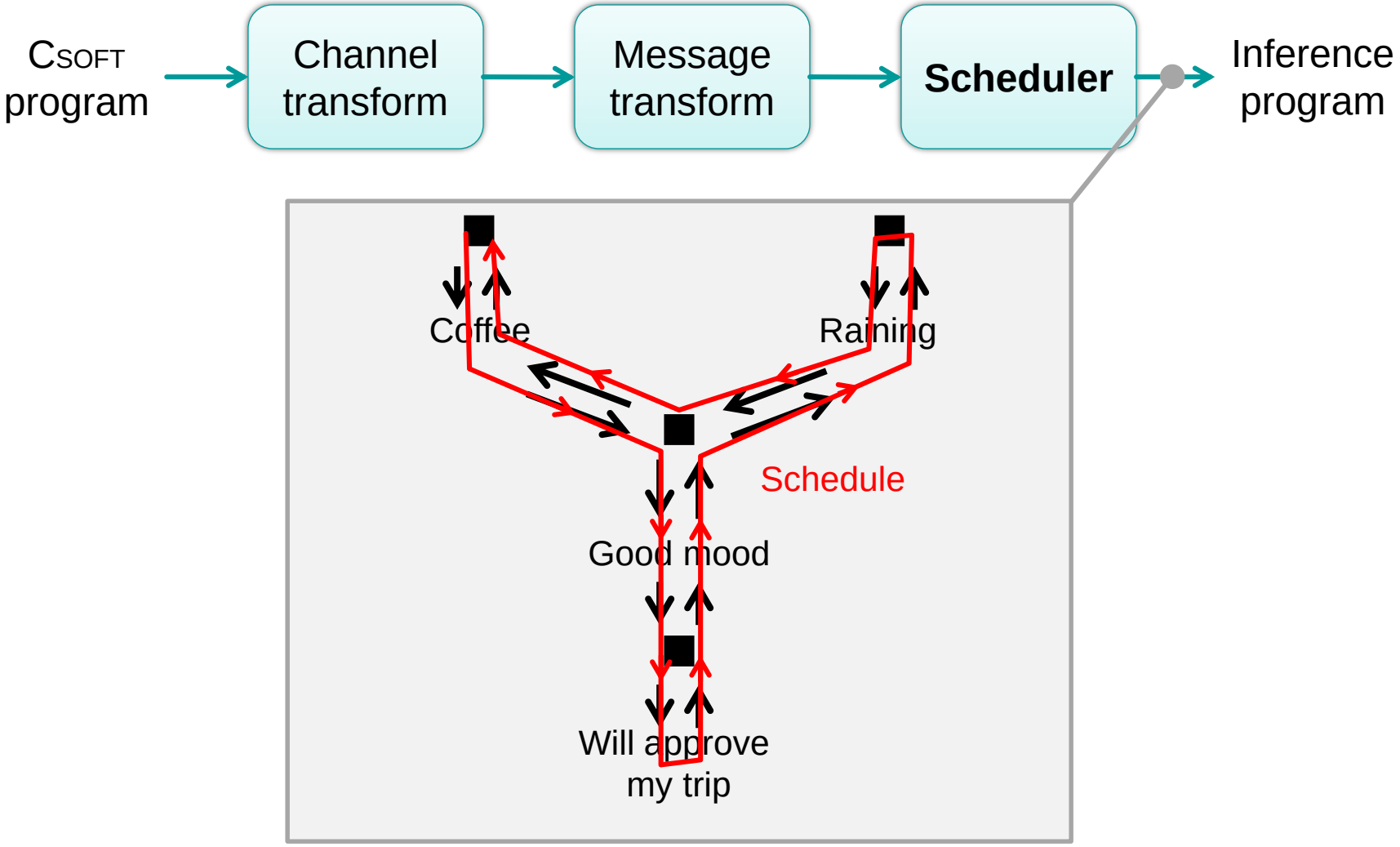
Infer.NET compiler



Infer.NET compiler



Infer.NET compiler



Infer.NET Demo

Advantages of CSOFT + Infer.NET

- **Rich and compact modelling language**
  Wide range of complex models can be represented succinctly.
- **Powerful inference framework**
  Supports multiple inference algorithms, highly customisable.
- **Efficient inference**
  Compilation means almost no overhead.
- **Easy integration**
  Inference can be invoked from .NET with minimal effort.
- **Easy to learn**
  Just the three new operators added to the language

Thanks!

http://research.microsoft.com/infernet

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