Modelling with RStan

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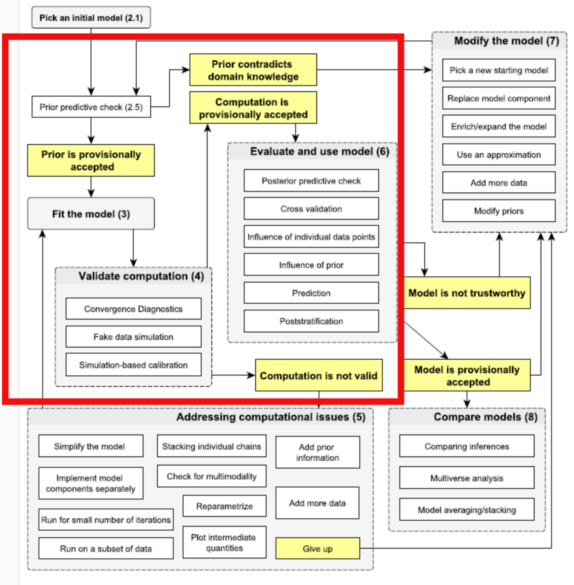
Modelling with Stan

1. Choose an initial model.
2. Construct Stan model.
3. Sample the model.
4. Check for convergence and good sampling quality.
    - Unsuccessful? Try a different parameterisation and review of the prior model!
5. Extract and interpret posterior parameters.

Bayesian Workflow



Adapted from Gelman et al. 2020

Structure of a Stan Model

Stan Example

```
data{
    ...
}
parameters{
    ...
}
transformed parameters{
    ...
}
model{
    ...
}
generated quantities{
    ...
}
```

Data and Model

We have a dataset containing the number of observed head counts for twenty biased coins:

ID	Flips	Heads	P
1	35	20	0.50
2	61	61	0.99
3	72	31	0.46
4	62	51	0.77
5	48	6	0.25
6	41	39	0.95
7	93	29	0.35

... and so on.

Data and Model

We can construct a mathematical model for this data:

$$y_i \sim \text{Binomial}(n_i, \theta_i), \quad i \ldots N$$
$$\theta_i \sim \text{Beta}(\alpha, \beta)$$

How does this translate into a Stan model?

Constructing a Stan Model

Stan Example

```
data{
    int N;
    int y[N];
    int n[N];
}
```

Constructing a Stan Model

Stan Example

```
data{
    int N;
    int y[N];
    int n[N];
}
parameters{
    real<lower=0, upper=1> theta[N];
}
```

Constructing a Stan Model

Stan Example

```
data{
    int N;
    int y[N];
    int n[N];
}
parameters{
    real<lower=0, upper=1> theta[N];
}
model{
    theta ~ beta(2,2);
}
```

Constructing a Stan Model

Stan Example

```
data{
    int N;
    int y[N];
    int n[N];
}
parameters{
    real<lower=0, upper=1> theta[N];
}
model{
    theta ~ beta(2,2);
    y ~ binomial(n, theta);
}
```

Constructing a Stan Model

Stan Example

```
data{
    int N;
    int y[N];
    int n[N];
}
parameters{
    real<lower=0, upper=1> theta[N];
}
model{
    theta ~ beta(2,2);
    y ~ binomial(n, theta);
}
generated quantities{
    int yrep[N];
    for(i in 1:N){
        yrep[i] = binomial_rng(n[i], theta[i]);
    }
}
```

Sampling Statements

The model section is made up of sampling statements:

Stan Example

```
y ~ normal(0,1)
```

Using the distributions are short hands for incrementing the log density:

Stan Example

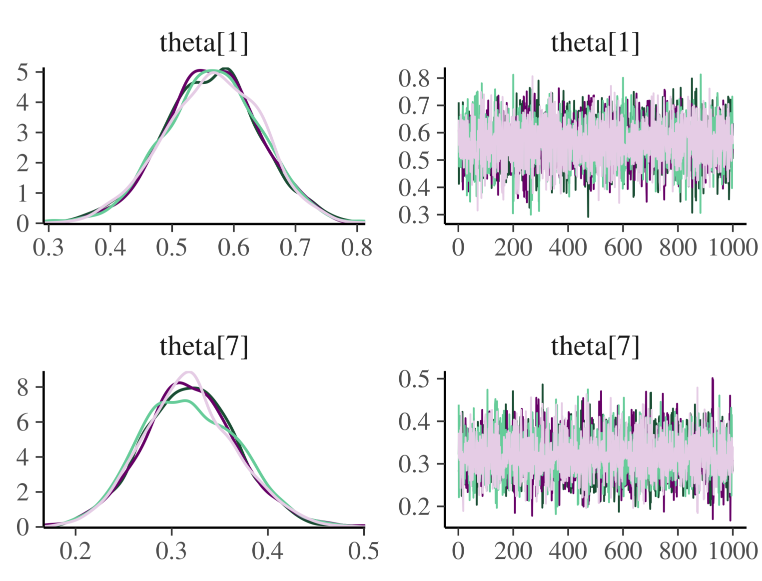
```
target += normal_lpdf( y | 0, 1);
```

This is how you can define your own densities within Stan.

Running the Model from R

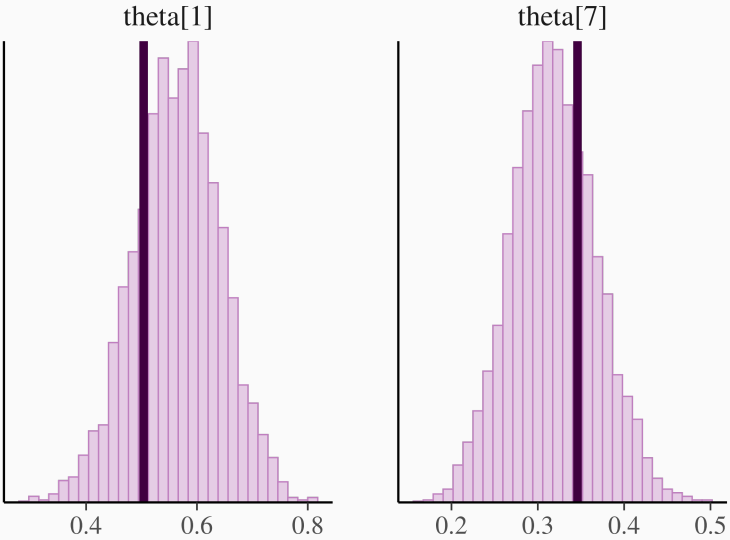
```r
library(rstan)
library(readr)
library(bayesplot)
rstan_options(auto_write = TRUE)
options(mc.cores = parallel::detectCores())

data <- read_csv("data/coin.csv") # Read in the data

# Prepare data for Stan
stan_data <- list(N = nrow(data),
                  y = data$Heads,
                  n = data$Flips)

# Sample the model
fit <- stan(file="models/binom_coin.stan", data=stan_data, chains=4, iter=1000)

# Extract posterior samples
theta <- extract(fit, "theta")$theta
```

Plotting



theta[1]
5
4
3
2
1
0
0.3
0.4
0.5
0.6
0.7
0.8
theta[1]
0.8
0.7
0.6
0.5
0.4
0.3
0
200
400
600
800
1000
theta[7]
8
6
4
2
0
0.2
0.3
0.4
0.5
theta[7]
0.5
0.4
0.3
0.2
0
200
400
600
800
1000

Plotting



Plotting

Visualisations can be created quickly using `bayesplot`.

The syntax is consistent across most of the library functions requiring:

1. Stan fit object
2. Parameters of interest, specified by string or regular expression.

Stan Example

```
mcmc_areas(fit, c('theta[1]','theta[2]'));
```