History: Stan

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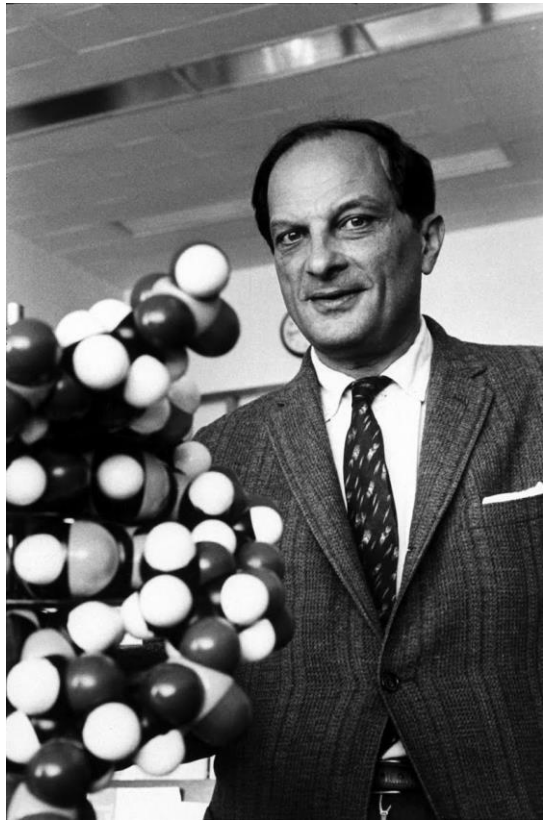
Stanislaw Marcin Ulam

- 1909-1984
- Measure theory, topology, logic
- 1943: Manhattan Project
- Monte-Carlo-Method



Stan - Development

Andrew Gelman

Bob Carpenter

Daniel Lee

Matt Hoffman

Stan - Example

$$Y \sim \mathcal{N}(\mu = 3, \sigma^2 = 100)$$

```
Y <- rnorm(n = 100, mean = 3, sd = 10)                  # Simulate normal distributed data

data {                                                  # stan code that defines the data
  int<lower = 1> N;   // Total number of trials
  vector[N] y;        // Score in each trial}

parameters {                                            # definition of parameters mu and sigma
  real mu;
  real<lower = 0> sigma;}

model {                                                 # definition of prior and likelihood
   // Priors:
  target += normal_lpdf(mu | 0, 20);                    # target: adds terms to the unnormalized log posterior
  target += lognormal_lpdf(sigma | 3, 1);                 probability
  // Likelihood:
  for(i in 1:N)
    target += normal_lpdf(y[i] | mu, sigma);}
```

normal.stan

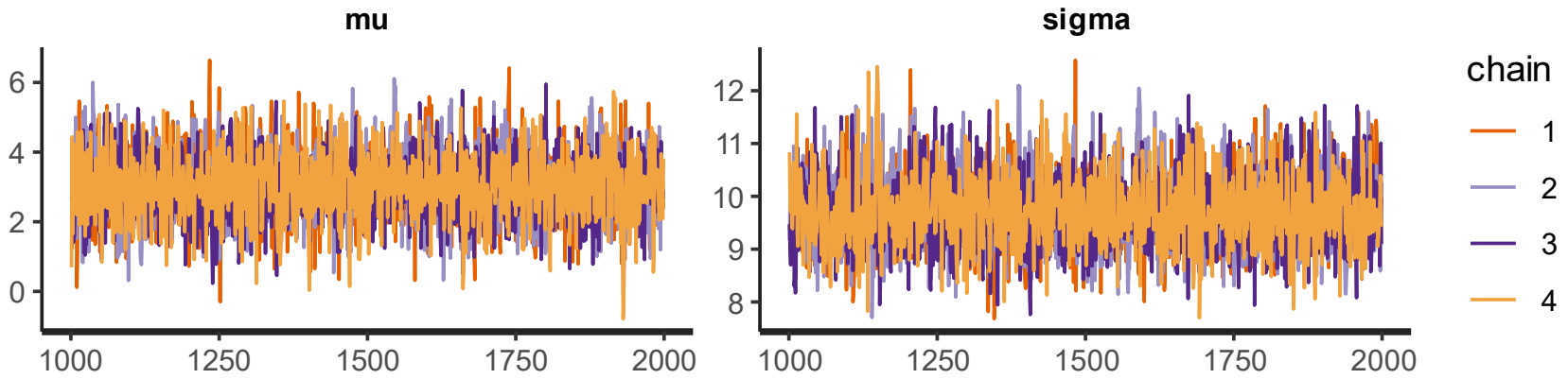
Stan - Example

$$Y \sim \mathcal{N}(\mu = 3, \sigma^2 = 100)$$

```
lst_score_data <- list(y = Y, N = length(Y))          # list object with simulated data

fit_score <- stan(file = "normal.stan", data = lst_score_data)   # fit the model, default: chain=4, iter=2000
                                                      # normal.stan = file that includes
                                                        data/paramaters/model

traceplot(fit_score, pars = c("mu", "sigma"))         # traceplot
print(fit_score, pars = c("mu", "sigma"))             # print results
```



Stan - Example

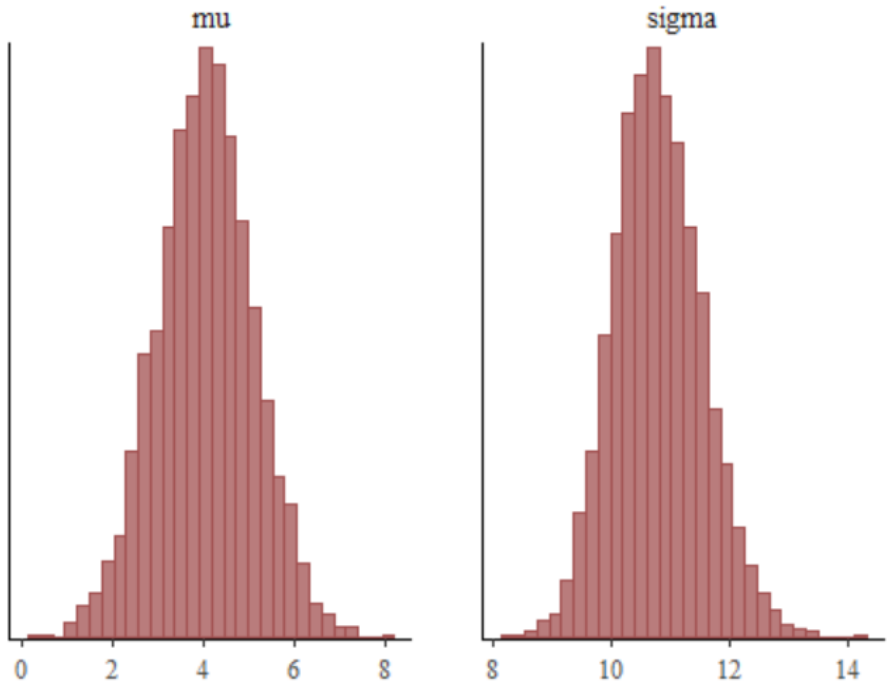
$$Y \sim \mathcal{N}(\mu = 3, \sigma^2 = 100)$$

```
## Inference for Stan model: normal.
## 4 chains, each with iter=2000; warmup=1000; thin=1;
## post-warmup draws per chain=1000, total post-warmup draws=4000.

##       mean   se_mean   sd  2.5% 97.5%  n_eff Rhat
## mu     4.03    0.02 1.05 1.89  6.07   3500    1
## sigma 10.78    0.01 0.75 9.41 12.35   3076    1

# Rhat = 1: at convergence
```

df_fit_score <- as.data.frame(fit_score)
mcmc_hist(df_fit_score, pars = c("mu", "sigma"))



References

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Additional Material – Code I: normal.stan

```
data {
  int<lower = 1> N;  // Total number of trials
  vector[N] y;  // Score in each trial
}
parameters {
  real mu;
  real<lower = 0> sigma;
}
model {
  // Priors:
    target += normal_lpdf(mu | 0, 20);
    target += lognormal_lpdf(sigma | 3, 1);
    // Likelihood:
      target += normal_lpdf(y | mu, sigma);
}
```

Additional Material – Code II

```
## load packages:
library(rstan)
library(bayesplot)

## Sample data from normal distribution with mu =3 and sigma^2 = 1000
Y <- rnorm(n = 100, mean = 3, sd = 10)

## make list object out of sample data:
lst_score_data <- list(y = Y, N = length(Y))

## Note please setwd(), the normal.stan file needs to be in the same place as this R file.
fit_score <- stan(file = "normal.stan", data = lst_score_data)

traceplot(fit_score, pars = c("mu", "sigma"))              # Make Traceplot:
print(fit_score, pars = c("mu", "sigma"))                  # Print Summary result
```

Additional Material – Complete Summary Output

```
## Inference for Stan model: normal.
## 4 chains, each with iter=2000; warmup=1000; thin=1;
## post-warmup draws per chain=1000, total post-warmup draws=4000.

##       mean se_mean   sd 2.5%   25%   50%   75% 97.5% n_eff Rhat
## mu     4.03    0.02 1.05 1.89  3.32  4.04  4.72  6.07  3500    1
## sigma 10.78    0.01 0.75 9.41 10.27 10.74 11.26 12.35  3076    1

## Samples were drawn using NUTS(diag_e) at Fri Apr 15 18:01:50 2022.
## For each parameter, n_eff is a crude measure of effective sample size,
## and Rhat is the potential scale reduction factor on split chains (at
## convergence, Rhat=1).
```

Additional Material – Code III

```
# generate data frame from model fit:
df_fit_score <- as.data.frame(fit_score)

## color scheme:
color_scheme_set("red")

# plot posterior distributions:
mcmc_hist(df_fit_score, pars = c("mu", "sigma"))
```