Package ‘bandit’

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Title Functions for simple A/B split test and multi-armed bandit analysis
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Imports boot, gam (>= 1.09)
Author Thomas Lotze and Markus Loecher
Maintainer Thomas Lotze <thomaslotze@thomaslotze.com>
Description A set of functions for doing analysis of A/B split test data and web metrics in general.
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Description

A set of functions for doing analysis of A/B split test data and web metrics in general.

Details

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Title: Functions for simple A/B split test and multi-armed bandit analysis
Version: 0.5.0
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Imports: boot, gam (>= 1.09)
Author: Thomas Lotze and Markus Loecher
Maintainer: Thomas Lotze <thomaslotze@thomaslotze.com>
License: GPL-3

Author(s)

Thomas Lotze and Markus Loecher

Description

Compute the Bayesian probabilities for each arm being the best binomial bandit.

Usage

best_binomial_bandit(x, n, alpha=1, beta=1)

Arguments

x as in prop.test, a vector of the number of successes
n as in prop.test, a vector of the number of trials
alpha shape parameter alpha for the prior beta distribution.
beta shape parameter beta for the prior beta distribution.
**Value**

a vector of probabilities for each arm being the best binomial bandit; this can be used for future randomized allocation

**Author(s)**

Thomas Lotze <thomaslotze@thomaslotze.com> and Markus Loecher

**References**


**See Also**

`prop.test`

**Examples**

```r
x = c(10, 20, 30, 50)
n = c(100, 102, 120, 130)
arm_probabilities = best_binomial_bandit(x, n)
print(arm_probabilities)
paste("The best arm is likely ", which.max(arm_probabilities), ",
with ",
round(100*max(arm_probabilities), 2), " percent probability of being the best.", sep="")

best_binomial_bandit(c(2, 20), c(100, 10000))
best_binomial_bandit(c(2, 20), c(100, 10000), alpha = 2, beta = 5)

# quick look at the various shapes of the beta distribution as we change the shape params:
AlphaBeta = cbind(alpha = c(0.5, 5, 1, 2, 2), beta = c(0.5, 1, 3, 2, 5))
M = nrow(AlphaBeta)
y = matrix(0, 100, ncol=M)
x = seq(0, 1, length=100)
for (i in 1:M) y[, i] = dbeta(x, AlphaBeta[i, 1], AlphaBeta[i, 2])
matplot(x, y, type="l", ylim = c(0, 3.5), lty=1, lwd=2)
param_strings = paste("a=", AlphaBeta[, "alpha"], ", b=", AlphaBeta[, "beta"], sep="")
legend("top", legend = param_strings, col=1:M, lty=1)
```

---

**Description**

Compute the Bayesian probabilities for each arm being the best binomial bandit, using simulation.
Usage

best_binomial_bandit_sim(x, n, alpha = 1, beta = 1, ndraws = 5000)

Arguments

x as in prop.test, a vector of the number of successes
n as in prop.test, a vector of the number of trials
alpha shape parameter alpha for the prior beta distribution.
beta shape parameter beta for the prior beta distribution.
ndraws number of random draws from the posterior

Value

a vector of probabilities for each arm being the best binomial bandit; this can be used for future randomized allocation

Author(s)

Thomas Lotze and Markus Loecher

References

(http://www.economics.uci.edu/~ivan/asmb.874.pdf)

See Also

prop.test

Examples

x=c(10,20,30,33)
N=c(100,102,120,130)
best_binomial_bandit_sim(x,N, ndraws=1000)
round(best_binomial_bandit(x,N),3)

best_binomial_bandit_sim(c(2,20),c(100,1000))

best_binomial_bandit_sim(c(2,20),c(100,1000), alpha = 2, beta = 5)

# quick look at the various shapes of the beta distribution as we change the shape params:
AlphaBeta = cbind(alpha=c(0.5,5,1,2,2),beta=c(0.5,1,3,2,5))
M = nrow(AlphaBeta)
y = matrix(0,100,ncol=M)
x = seq(0,1,length=100)
for (i in 1:M) y[,i] = dbeta(x,AlphaBeta[i,1],AlphaBeta[i,2])
matplot(x,y,type="l", ylim = c(0,3.5), lty=1, lwd=2)


```r
param_strings = paste("a=", AlphaBeta["alpha"], ", b=", AlphaBeta["beta"], sep="")
legend("top", legend = param_strings, col=1:M, lty=1)
```

---

**Description**

Compute the Bayesian probabilities for each arm being the best poisson bandit.

**Usage**

```r
best_poisson_bandit(x, n = NULL)
```

**Arguments**

- `x` as in prop.test, a vector of the number of successes; it may alternatively be a list of vectors of the results of each trial, if `n` is not provided
- `n` as in prop.test, a vector of the number of trials; if it is not provided, `x` must be a list of vectors of the results of each trial

**Value**

A vector of probabilities for each arm being the best poisson bandit; this can be used for future randomized allocation

**Author(s)**

Thomas Lotze <thomaslotze@thomaslotze.com>

**References**


**See Also**

- `prop.test`

**Examples**

```r
p1 = rpois(100, lambda=10)
p2 = rpois(100, lambda=9)
x = sapply(list(p1, p2), sum)
n = sapply(list(p1, p2), length)
best_poisson_bandit(x, n)
```
deseasonalized_trend
deseasonalized_trend

Description
A convenience function to analyze a timeseries and return an estimate (via gam, using day of week factors and smoothed timestamp) of whether, after accounting for day-of-week, there is a significant time-based influence and what that influence is.

Usage
deseasonalized_trend(df, w=NULL)

Arguments
- df: a data frame containing timestamp and value entries
- w: number of attempts (n for binomial data)

Value
A list with the following items:
- pval: pval given by anova on gam, to indicate whether s(timestamp) is significant
- smoothed_prediction: a smoothed prediction over time (on Wednesdays), to give a human-understandable idea of what the change over time has been

Author(s)
Thomas Lotze <thomaslotze@thomaslotze.com>

Examples
timestamps = as.numeric(as.POSIXct(seq(as.Date("2012-01-01"),as.Date("2012-05-03"),by=1)))
df=data.frame(timestamp = timestamps, value = rnorm(length(timestamps)))
dt = deseasonalized_trend(df)
if (dt$pval < 0.01) {
  print("Significant time-based factor")
  plot(df$timestamp, dt$smoothed_prediction)
} else {
  print("No significant time-based factor")
}

df=data.frame(timestamp = timestamps,
              value = sapply(timestamps, function(t) {rpois(1, lambda=t-min(timestamps))))
dt = deseasonalized_trend(df)
if (dt$pval < 0.01) {
  print("Significant time-based factor")
  plot(df$timestamp, dt$smoothed_prediction)
} else {
  print("No significant time-based factor")
}
distribution_estimate

} else {
    print("No significant time-based factor")
}

---

distribution_estimate  summarize_metrics

Description

A convenience function to perform overall metric analysis: mean, median, CI.

Usage

distribution_estimate(v, successes=NULL, num_quantiles=101, observed=FALSE)

Arguments

v                  a vector of values to be analyzed (for nonbinary data), or number of trials (for binary data)
successes         number of successes (for binary data)
num_quantiles     number of quantiles to split into
observed           whether to generate the observed distribution (rather than the estimated distribution of the mean); default FALSE

Value

a data frame with the following columns:

quantiles         the estimated quantiles (0,0.01,0.02,...,1) for the mean, using a Beta-binomial estimate of p for binomial data, a bootstrapped quantile distribution for real-valued numbers
x                  x values for plotting a lineplot of the estimated distribution
y                  y values for plotting a lineplot of the estimated distribution
mids               mid values for plotting a barplot of the estimated distribution
lefts              left values for plotting a barplot of the estimated distribution
rights             right values for plotting a barplot of the estimated distribution
widths             width values for plotting a barplot of the estimated distribution
heights            height values for plotting a barplot of the estimated distribution
probabilities      probabilities indicating how much probability is contained in each barplot

Author(s)

Thomas Lotze <thomaslotze@thomaslotze.com>
prob_winner

Examples

```r
c1 = c(10, 20, 30, 50)
n = c(100, 102, 120, 130)
b1 = sim_post(c1, n)
prob_winner(b1)
```

Description

Function to compute probability that each arm is the winner, given simulated posterior results

Usage

```r
prob_winner(post)
```

Arguments

- `post` the simulated results from the posterior, provided by `sim_post`

Author(s)

Thomas Lotze and Markus Loecher

Examples

```r
c1 = c(10, 20, 30, 50)
n = c(100, 102, 120, 130)
b1 = sim_post(c1, n)
prob_winner(b1)
```
Description

A convenience function to perform overall proportion comparison using prop.test, before doing pairwise comparisons, to see what outcomes seem to be better than others.

Usage

significance_analysis(x, n)

Arguments

x as in prop.test, a vector of the number of successes
n as in prop.test, a vector of the number of trials

Value

a data frame with the following columns:
successes x
totals n
estimated_proportion x/n
lower 0.95 confidence interval on the estimated amount by which this alternative outperforms the next-lower alternative
upper 0.95 confidence interval on the estimated amount by which this alternative outperforms the next-lower alternative
significance p-value for the test that this alternative outperforms the next-lower alternative
order order, by highest success proportion
best 1 if it is part of the 'highest performing group' – those groups which were not significantly different from the best group
p_best Bayesian posterior probability that this alternative is the best binomial bandit

Note

This is intended for use in A/B split testing – so sizes of n should be roughly equal. Also, note that alternatives which have the same rank are grouped together for analysis with the 'next-lower' alternative, so you may want to check to see if ranks are equal.

Author(s)

Thomas Lotze <thomaslotze@thomaslotze.com>
Description
Simulate the posterior distribution the Bayesian probabilities for each arm being the best binomial bandit

Usage

```r
sim_post(x, n, alpha = 1, beta = 1, ndraws = 5000)
```

Arguments

- `x`: as in `prop.test`, a vector of the number of successes
- `n`: as in `prop.test`, a vector of the number of trials
- `alpha`: shape parameter alpha for the prior beta distribution.
- `beta`: shape parameter beta for the prior beta distribution.
- `ndraws`: number of random draws from the posterior

Author(s)

Thomas Lotze and Markus Loecher
summarize_metrics

Examples

```r
x = c(10, 20, 30, 50)
n = c(100, 102, 120, 130)
sim_post(x, n)
```

Description

A convenience function to perform overall metric analysis: mean, median, CI.

Usage

```r
summarize_metrics(v, successes=NULL)
```

Arguments

- `v`: a vector of values to be analyzed (for nonbinary data), or number of trials (for binary data)
- `successes`: number of successes (for binary data)

Value

A list with the following items:

- `mean`: mean
- `median`: median
- `lower`: 0.95 confidence interval on the mean
- `upper`: 0.95 confidence interval on the mean
- `num_obs`: number of observations of this metric
- `total`: the sum of all values of this metric (mean*num_obs)

Author(s)

Thomas Lotze <thomaslotze@thomaslotze.com>

Examples

```r
metric_list = list(rbinom(n=100, size=1, prob=.5),
                   rbinom(n=100, size=1, prob=.7),
                   rpois(n=100, lambda=5))
summarize_metrics(length(metric_list[[1]]), sum(metric_list[[1]]))
summarize_metrics(length(metric_list[[2]]), sum(metric_list[[2]]))
summarize_metrics(metric_list[[3]])
```
value_remaining

Description

Compute the "value_remaining" in the binomial bandits

Usage

value_remaining(x, n, alpha = 1, beta = 1, ndraws = 10000)

Arguments

x
  as in prop.test, a vector of the number of successes
n
  as in prop.test, a vector of the number of trials
alpha
  shape parameter alpha for the prior beta distribution.
beta
  shape parameter beta for the prior beta distribution.
ndraws
  number of random draws from the posterior

Value

value_remaining distribution; the distribution of improvement amounts that another arm might have over the current best arm

Author(s)

Thomas Lotze and Markus Loecher

References

https://support.google.com/analytics/answer/2846882?hl=en&topic=2844866&rd=1

Examples

x = c(10, 20, 30, 80)
n = c(100, 102, 120, 240)
vr = value_remaining(x, n)
hist(vr)
best_arm = which.max(best_binomial_bandit(x, n))
# "potential value" remaining in the experiment
potential_value = quantile(vr, 0.95)
paste("Were still unsure about the CvR for the best arm (arm ", best_arm, ", but whatever it is, one of the other arms might beat it by as much as ", round(potential_value*100, 4), ", percent.", sep="")
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