Package ‘usl’

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Description The Universal Scalability Law is a model to predict hardware and software scalability. It uses system capacity as a function of load to forecast the scalability for the system.

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usl-package

Analyze system scalability with the Universal Scalability Law

Description

The Universal Scalability Law is a model to predict hardware and software scalability. It uses system capacity as a function of load to forecast the scalability for the system.

Details

Use the function `usl` to create a model from a formula and a data frame.

The USL model produces two coefficients as result: `sigma` models the contention and `kappa` the coherency delay of the system.

The Universal Scalability Law has been created by Dr. Neil J. Gunther.

References


See Also

`usl`
**Description**

Estimate confidence intervals for one or more parameters in a USL model. The intervals are calculated from the parameter standard error using the Student t distribution at the given level.

**Usage**

```r
## S4 method for signature 'USL'
confint(object, parm, level = 0.95)
```

**Arguments**

- `object` A USL object.
- `parm` A specification of which parameters are to be given confidence intervals, either a vector of numbers or a vector of names. If missing, all parameters are considered.
- `level` The confidence level required.

**Details**

Bootstrapping is no longer used to estimate confidence intervals.

**Value**

A matrix (or vector) with columns giving lower and upper confidence limits for each parameter. These will be labelled as (1-level)/2 and 1 - (1-level)/2 in % (by default 2.5% and 97.5%).

**See Also**

- `usl`  

**Examples**

```r
require(usl)
data(specsdm91)

## Create USL model
crl = usl(throughput ~ load, specsdm91)

## Print confidence intervals
confint(crl)
```
efficiency, USL-method  Efficiency of the system

Description
The efficiency of a system expressed in terms of the deviation from linear scalability.

Usage

```r
## S4 method for signature 'USL'
efficiency(object)
```

Arguments

- `object` A USL object.

Details
The function returns a vector which contains the deviation from linearity for every measurement of the model input. A value of 1 indicates linear scalability while values less than 1 correspond to the fraction of the measurement compared to linear scalability.

Value
A vector of numeric values.

References

See Also
usl

Examples

```r
require(usl)
data(raytracer)

## Show the efficiency
efficiency(usl(throughput ~ processors, raytracer))
```
Description

A dataset containing performance data for an Oracle OLTP database measured between 8:00am and 8:00pm on January, 19th 2012. The measurements were recorded for two minute intervals during this time and a timestamp indicates the end of the measurement interval. The performance metrics were taken from the v$symetric family of system performance views.

Format

A data frame with 360 rows on 8 variables

Details

The Oracle database was running on a 4-way server.

The data frame contains different types of measurements:

- Variables of the "time" type are expressed in seconds per second.
- Variables of the "rate" type are expressed in events per second.
- Variables of the "util" type are expressed as a percentage.

The data frame contains the following variables:

- timestamp The end of the two minute interval for which the remaining variables contain the measurements.
- db_time The time spent inside the database either working on a CPU or waiting (I/O, locks, buffer waits ...). This time is expressed as seconds per second, so two sessions working for exactly one second each will contribute a total of two seconds per second of db_time. In Oracle this value is also known as Average Active Sessions (AAS).
- cpu_time The CPU time used during the interval. This is also expressed as seconds per second. A 4-way machine has a theoretical capacity of four CPU seconds per second.
- call_rate The number of user calls (logins, parses, or execute calls) per second.
- exec_rate The number of statement executions per second.
- lio_rate The number of logical I/Os per second. A logical I/O is the Oracle term for a cache hit in the database buffer cache. This metric does not indicate if an additional physical I/O was necessary to load the buffer from disk.
- txn_rate The number of database transactions per second.
- cpu_util The CPU utilization of the database server in percent. This was also measured from within the database.
overhead, USL-method

**Description**

overhead calculates the overhead in processing time for a system modeled with the Universal Scalability Law. It evaluates the regression function in the frame `newdata` (which defaults to `model.frame(object)`). The result contains the ideal processing time and the additional overhead caused by contention and coherency delays.

**Usage**

```r
## S4 method for signature 'USL'
overhead(object, newdata)
```

**Arguments**

- `object` A USL model object for which the overhead will be calculated.
- `newdata` An optional data frame in which to look for variables with which to calculate the overhead. If omitted, the fitted values are used.

**Details**

The calculated processing times are given as percentages of a non-parallelized workload. So for a non-parallelized workload the ideal processing time will always be given as 100% while the overhead for contention and coherency will always be zero.

Doubling the capacity will cut the ideal processing time in half but increase the overhead percentages. The increase of the overhead depends on the values of the parameters `sigma` and `kappa` estimated by `usl`.

The calculation is based on *A General Theory of Computational Scalability Based on Rational Functions*, equation 26.

**Value**

overhead produces a matrix of overhead percentages based on a non-parallelized workload. The column `ideal` contains the ideal percentage of execution time. The columns `contention` and `coherency` give the additional overhead percentage caused by the respective effects.

**References**


peak.scalability.USL-method

See Also

usl, USL-class

Examples

```R
require(usl)
data(raytracer)

## Print overhead in processing time for demo dataset
overhead(usl(throughput ~ processors, raytracer))
```

Description

Calculate the point of peak scalability for a specific model.

Usage

```R
## S4 method for signature 'USL'
peak.scalability(object, sigma, kappa)
```

Arguments

- **object**: A USL object.
- **sigma**: Optional parameter to be used for evaluation instead of the parameter computed for the model.
- **kappa**: Optional parameter to be used for evaluation instead of the parameter computed for the model.

Details

The peak scalability is the point where the throughput of the system starts to go retrograde, i.e., starts to decrease with increasing load.

The parameters sigma or kappa are useful to do a what-if analysis. Setting these parameters override the model parameters and show how the system would behave with a different contention or coherency delay parameter.

See formula (4.33) in *Guerilla Capacity Planning*.

Value

A numeric value for the point where peak scalability will be reached.
References

See Also
usl, scalability, USL-method

Examples
require(usl)
data(raytracer)

peak.scalability(usl(throughput ~ processors, raytracer))
## Peak scalability will be reached just below 450 processors

plot,USL-method

**Plot the scalability function from a USL model**

Description
Create a line plot for the scalability function of a Universal Scalability Law model.

Usage
```
## S4 method for signature 'USL'
plot(x, from = NULL, to = NULL, xlab = NULL,
ylab = NULL, bounds = FALSE, sigma, kappa, ...)
```

Arguments
- `x` The USL object to plot.
- `from` The start of the range over which the scalability function will be plotted.
- `to` The end of the range over which the scalability function will be plotted.
- `xlab` A title for the x axis: see `title`.
- `ylab` A title for the y axis: see `title`.
- `bounds` Add the bounds of scalability to the plot.
- `sigma` Optional parameter to be used for evaluation instead of the parameter computed for the model.
- `kappa` Optional parameter to be used for evaluation instead of the parameter computed for the model.
- `...` Other graphical parameters passed to `plot` (see `par`, `plot.function`).
Details

plot creates a plot of the scalability function for the model represented by the argument x.

If from is not specified then the range starts at the minimum value given to define the model. An unspecified value for to will lead to plot ending at the maximum value from the model. For add = TRUE the defaults are taken from the limits of the previous plot.

xlab and ylab can be used to set the axis titles. The defaults are the names of the regressor and response variables used in the model.

If the parameter bounds is set to TRUE then the plot also shows dotted lines for the theoretical bounds of scalability. These are the linear scalability for small loads and Amdahl’s asymptote for the limit of scalability as load approaches infinity.

The parameters sigma or kappa are useful to do a what-if analysis. Setting these parameters override the model parameters and show how the system would behave with a different contention or coherency delay parameter.

See Also

usl.plot.function

Examples

require(usl)
data(raytracer)

## Plot result from USL model for demo dataset
plot(usl(throughput ~ processors, raytracer))

predict,USL-method  Predict method for Universal Scalability Law models

Description

predict is a function for predictions of the scalability of a system modeled with the Universal Scalability Law. It evaluates the regression function in the frame newdata (which defaults to model.frame(object)). Setting interval to "confidence" requests the computation of confidence intervals at the specified level.

Usage

## S4 method for signature 'USL'
predict(object, newdata, sigma, kappa, interval = c("none", "confidence"), level = 0.95)
Arguments

- **object**: A USL model object for which prediction is desired.
- **newdata**: An optional data frame in which to look for variables with which to predict. If omitted, the fitted values are used.
- **sigma**: Optional parameter to be used for evaluation instead of the parameter computed for the model.
- **kappa**: Optional parameter to be used for evaluation instead of the parameter computed for the model.
- **interval**: Type of interval calculation. Default is to calculate no confidence interval.
- **level**: Confidence level. Default is 0.95.

Details

The parameters sigma or kappa are useful to do a what-if analysis. Setting these parameters over-ride the model parameters and show how the system would behave with a different contention or coherency delay parameter.

`predict` internally uses the function returned by `scalability,USL-method` to calculate the result.

Value

`predict` produces a vector of predictions or a matrix of predictions and bounds with column names `fit`, `lwr`, and `upr` if `interval` is set to "confidence".

References


See Also

- `usl`, `scalability,USL-method`, `USL-class`

Examples

```r
require(usl)

data(raytracer)

## Print predicted result from USL model for demo dataset
predict(usl(throughput ~ processors, raytracer))

## The same prediction with confidence intervals at the 99% level
predict(usl(throughput ~ processors, raytracer),
       interval = "confidence", level = 0.99)
```
**print.USL-method**  

*Print objects of class "USL"*

---

**Description**

print prints its argument and returns it invisibly (via `invisible(x)`).

**Usage**

```r
## S4 method for signature 'USL'
print(x, digits = max(3L,getOption("digits") - 3L), ...)  
```

**Arguments**

- **x**: An object from class USL.
- **digits**: Minimal number of significant digits, see `print.default`.
- **...**: Other arguments passed to other methods.

**Value**

print returns the object `x` invisibly.

**See Also**

usl.USL-class

**Examples**

```r
require(usl)
data(raytracer)  

## Print result from USL model for demo dataset
print(usl(throughput ~ processors, raytracer))  
```

---

**raytracer**  

*Performance of a ray-tracing software on different hardware configurations*

---

**Description**

A dataset containing performance data for a ray-tracing benchmark.

**Format**

A data frame with 11 rows on 2 variables
Details
The benchmark measured the number of ray-geometry intersections per second. The data was
gathered on an SGI Origin 2000 with 64 R12000 processors running at 300 MHz.
The data frame contains the following variables:
  • processors The number of CPUs used for the benchmark (1–64).
  • throughput The number of operations per second.

Source
http://sourceforge.net/projects/brlcad/

 scalability,USL-method

Description
scalability is a higher order function and returns a function to calculate the scalability for the
specific USL model.

Usage
## S4 method for signature 'USL'
scalability(object, sigma, kappa)

Arguments
object A USL object.
sigma Optional parameter to be used for evaluation instead of the parameter computed
  for the model.
kappa Optional parameter to be used for evaluation instead of the parameter computed
  for the model.

Details
The returned function can be used to calculate specific values once the model for a system has been
created.
The parameters sigma or kappa are useful to do a what-if analysis. Setting these parameters over-
ride the model parameters and show how the system would behave with a different contention or
coherency delay parameter.

Value
A function with parameter x that calculates the scalability value of the specific model.
References


See Also

usl, peak.scalability, USL-method

Examples

```r
require(usl)
data(raytracer)

## Compute the scalability function
s <- scalability(usl(throughput ~ processors, raytracer))

## Print scalability for 32 CPUs for the demo dataset
print(s(32))

## Plot scalability for the range from 1 to 64 CPUs
plot(s, from=1, to=64)
```

---

show, USL-method

Show objects of class "USL."

Description

Display the object by printing it.

Usage

```r
## S4 method for signature 'USL'
show(object)
```

Arguments

- **object**: The object to be printed.

Value

- show returns an invisible NULL.

See Also

usl, USL-class
**Examples**

```r
require(usl)

data(raytracer)

## Show USL model
show(usl(throughput ~ processors, raytracer))
```

---

**Description**

A dataset containing performance data for a Sun SPARCcenter 2000 (16 CPUs)

**Format**

A data frame with 7 rows on 2 variables

**Details**

A Sun SPARCcenter 2000 with 16 CPUs was used for the SPEC SDM91 benchmark in October 1994. The benchmark simulates a number of users working on the UNIX server and measures the number of script executions per hour.

The data frame contains the following variables:

- `load` The number of simulated users (1–216).
- `throughput` The achieved throughput in scripts per hour.

**Source**

**Description**

summary method for class "USL".

**Usage**

```r
## S4 method for signature 'USL'
summary(object, ...)
```

**Arguments**

- `object`: A USL object.
- `...`: Other arguments passed to other methods.

**See Also**

- `usl.USL-class`

**Examples**

```r
require(usl)
data(raytracer)

## Show summary for demo dataset
summary(usl(throughput ~ processors, raytracer))

## Extract model coefficients
summary(usl(throughput ~ processors, raytracer))$coefficients
```

---

**usl**

Create a model for the Universal Scalability Law

**Description**

`usl` is used to create a model for the Universal Scalability Law.

**Usage**

```r
usl(formula, data, method = "default")
```
Arguments

**formula**
An object of class "formula" (or one that can be coerced to that class): a symbolic description of the model to be analyzed. The details of model specification are given under 'Details'.

**data**
A data frame, list or environment (or object coercible by as.data.frame to a data frame) containing the variables in the model. If not found in data, the variables are taken from `environment(formula)`, typically the environment from which `usl` is called.

**method**
Character value specifying the method to use. The possible values are described under 'Details'.

Details

The Universal Scalability Law is used to forecast the scalability of either a hardware or a software system.

The USL model works with one independent variable (e.g. virtual users, processes, threads, ...) and one dependent variable (e.g. throughput, ...). Therefore the model formula must be in the simple "response ~ predictor" format.

The model produces two coefficients as result: sigma models the contention and kappa the coherency delay of the system. The function `coef` extracts the coefficients from the model object.

The argument method selects which solver is used to solve the model:

- "default" for the default method using a transformation into a 2nd degree polynom. It can only be used if the model frame contains a value for the normalization where the predictor equals "1" for one measurement. This is the algorithm introduced by Dr. Neil J. Gunther in the book *Guerrilla Capacity Planning*.
- "nls" for a nonlinear regression model. This method estimates not only the coefficients sigma and kappa but also the scale factor for the normalization. `nls` with the "port" algorithm is used internally to solve the model. So all restrictions of the "port" algorithm apply.
- "nlxb" for a nonliner regression model using the function `nlxb` from the `nlsr` package. This method also estimates both coefficients and the normalization factor. It is expected to be more robust than the nls method.

The "nlxb" solver is used as fallback if the "default" method is selected and a predictor equal "1" is missing. A warning message will be printed in this case.

The Universal Scalability Law can be expressed with following formula. $C(N)$ predicts the relative capacity of the system for a given load $N$:

$$C(N) = \frac{N}{1 + \sigma(N - 1) + \kappa N(N - 1)}$$

Value

An object of class USL.
References


See Also


Examples

```
require(usl)

data(raytracer)

## Create USL model for "throughput" by "processors"
usl.model <- usl(throughput ~ processors, raytracer)

## Show summary of model parameters
summary(usl.model)

## Show complete list of efficiency parameters
efficiency(usl.model)

## Extract coefficients for model
coef(usl.model)

## Calculate point of peak scalability
peak.scalability(usl.model)

## Plot original data and scalability function
plot(raytracer)
plot(usl.model, add=TRUE)
```

---

**USL-class**

*Class “USL” for Universal Scalability Law models*

**Description**

This class encapsulates the Universal Scalability Law. Use the function `usl` to create new objects from this class.
Slots

frame The model frame.
call The call used to create the model.
regr The name of the regressor variable.
resp The name of the response variable.
scale.factor The scale factor used to create the model.
coefficients The coefficients sigma and kappa of the model.
coef.std.err The standard errors for the coefficients sigma and kappa.
coef.names A vector with the names of the coefficients.
fitted The fitted values of the model. This is a vector.
residuals The residuals of the model. This is a vector.
df.residual The degrees of freedom of the model.
r.squared Coefficient of determination of the model.
adj.r.squared Adjusted coefficient of determination.
efficiency The efficiency, e.g. speedup per processor.
na.action The na.action used by the model.

See Also

usl
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