Enabling Grids for E-sciencE

Towards a statistical model of the EGEE load

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Grid Observatory

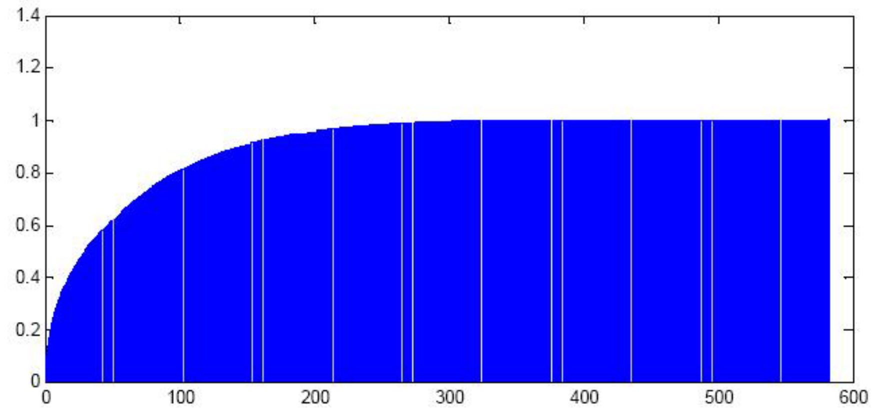
Information Society and Media

Overview

- **General goal: contribute to resource dimensioning, providing differentiated Quality of Service (QoS), middleware-level and user-level scheduling**
- **Through statistical modeling of the EGEE workload. Classical observables are inter-arrival time, service i.e. execution times, load i.e. the job backlog**
  - Intrinsic behavior: users requirement, aggregated
  - Middleware impact: at the computing elements
  - A further difficulty: background activity
- **Through autonomic strategies. Utility-based reinforcement learning is emerging.**
- **gLite provides a unique opportunity for such kind of analysis due to extensive logging (L&B)**
- **The Real Time Monitor developed by GridPP gives easy acces to WMS-integrated traces**

The Data

- **More than 18 million jobs**
- **Timestamps of the major events in the job lifecycle**
- 1st CE : 626K jobs
  ce03-lcg.cr.cnaf.infn.it
- 2nd CE : 579K jobs
  lcgce01.gridpp.rl.ac.uk
- 4th CE : 384K jobs
  ce101.cern.ch
- 33th CE : 107K jobs
  ce2.egee.cesga.es



CE

Statistics workplan

- **Descriptive statistics**
  - The EGEE job traffic may share some properties with the Internet traffic: many small jobs,and a significant number of large ones, at all scales
  - Method: parametric modeling of the nominal behavior as well as the tail behavior of the distributions
- **Time-dependent structures in the time series**
  - Long-range correlation: Poisson processes, with a possibly non homogeneous or stochastic intensity; and self-similar stochastic models such as fractional Gaussian noises (FGN) and fractional ARIMA processes (ARFIMA).

Distribution tails

- **Tail: restrict to values larger than u –**

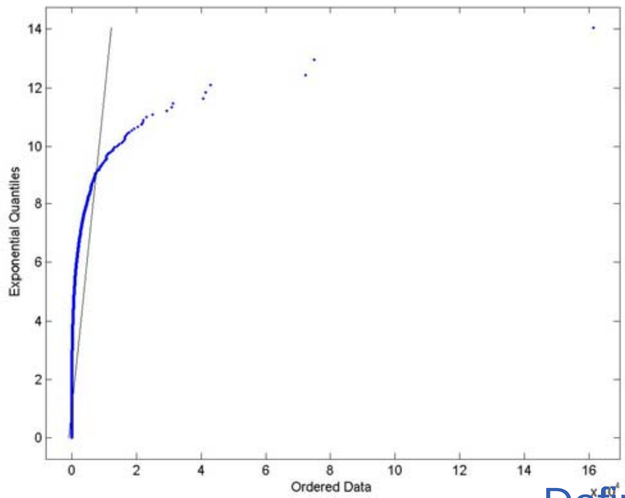
$$f(x) = P(X > u + x \mid X > u)$$

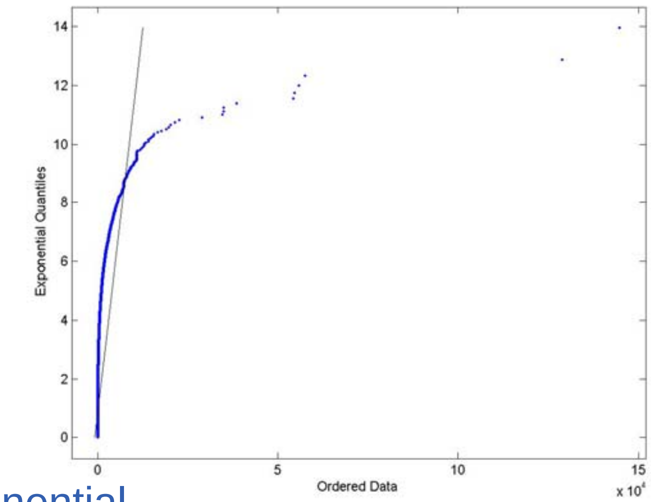
- **Large u for load is related to extreme (catastophic) events**
- **Large u for inter-arrival is related to QoS**
- **Theoretical answer: generalized Pareto distribution**
  - $\xi = 0$: exponential
  - $\xi > 0$: heavy tailed
  - If $\xi > 1/k$, the k-th order moment does not exist

$$H(y) = \begin{cases} 1 - \left(1 + \frac{\xi y}{\sigma}\right)^{-1/\xi} & \text{if } y > 0 \quad 1 + \frac{\xi y}{\tilde{\sigma}} > 0 \\ 0 & \text{else} \end{cases}$$

With $\tilde{\sigma} = \sigma + \xi (u - \mu)$.

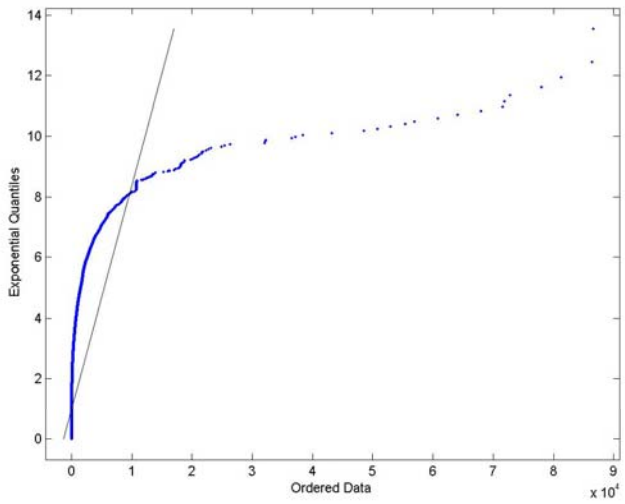
Inter-arrival time

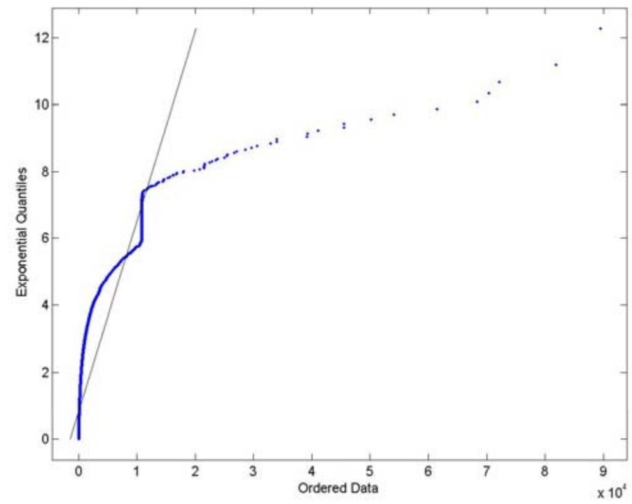




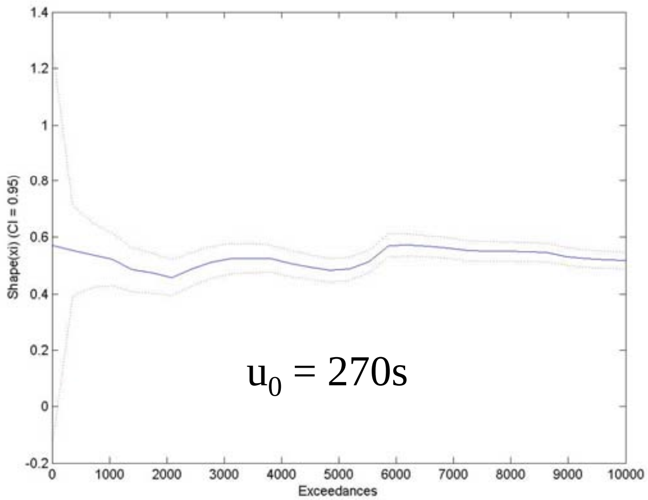
Definitely not exponential

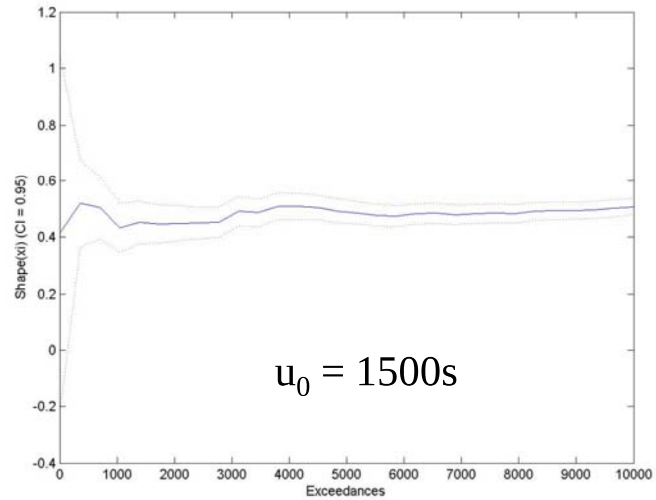
Probably heavy tailed



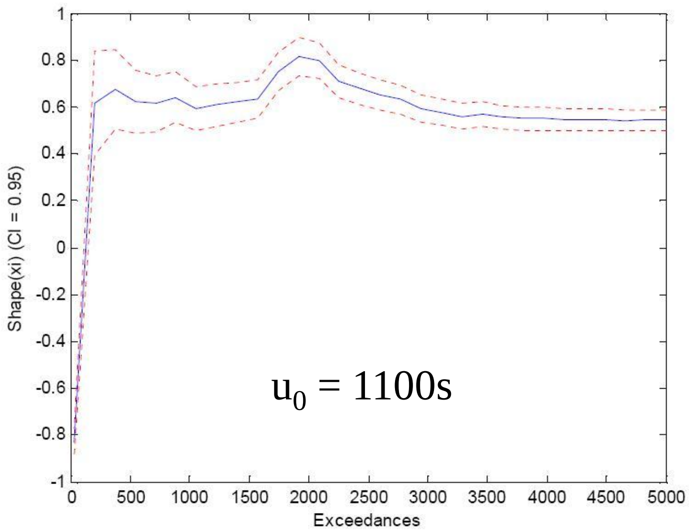


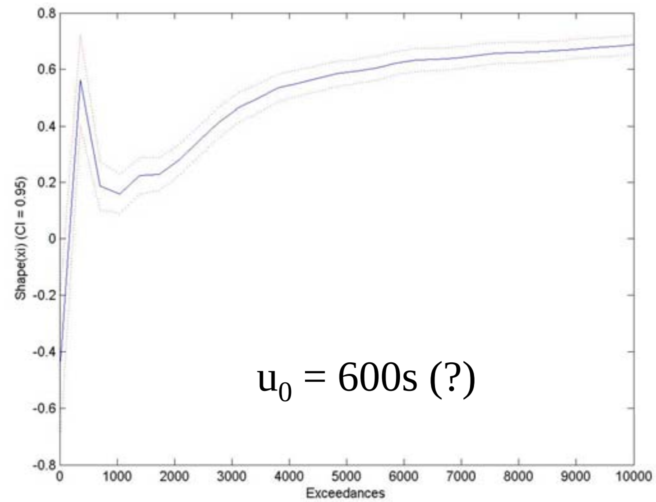
Fitting a Pareto distribution



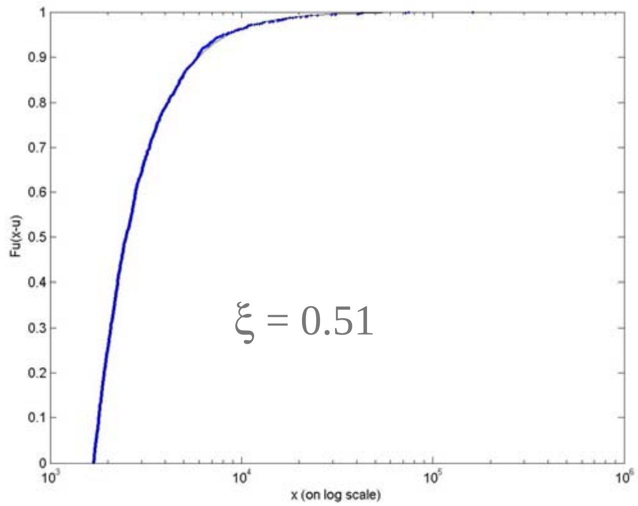


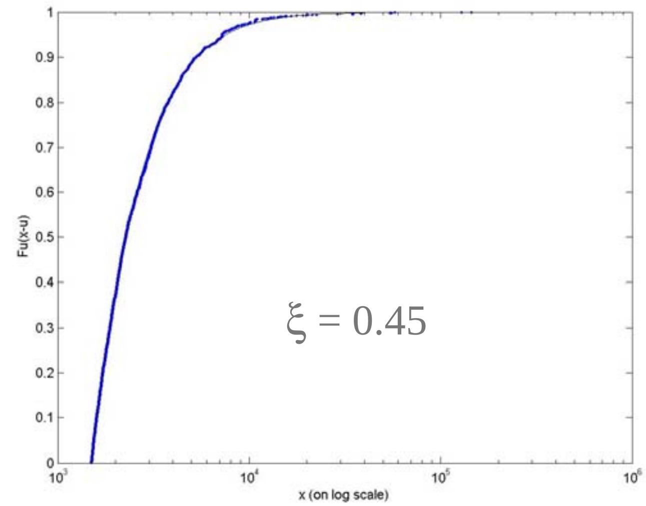
The estimation of K should be constant

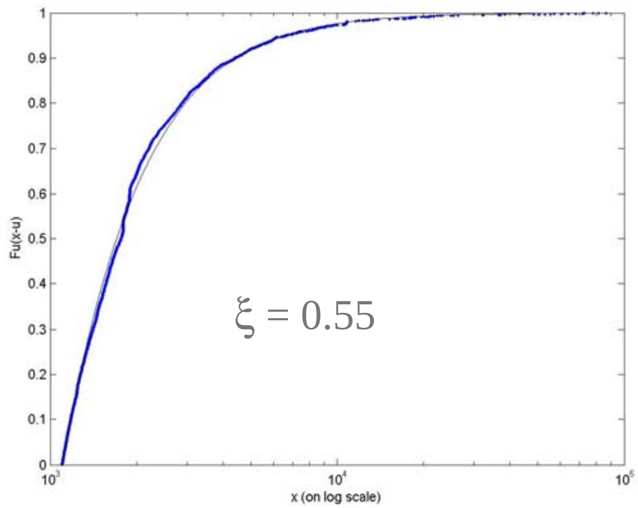


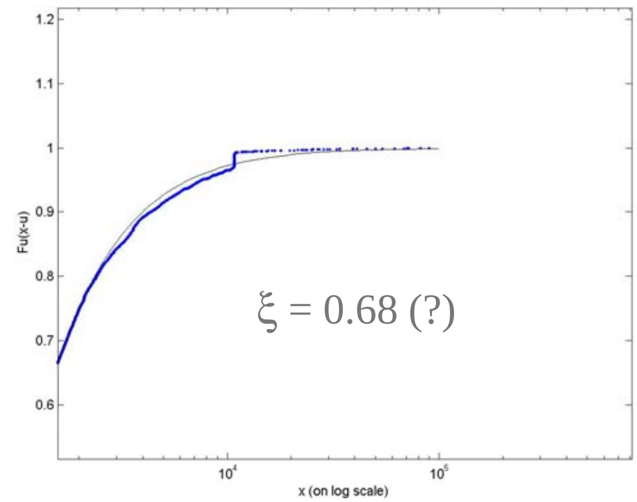


Pareto fit

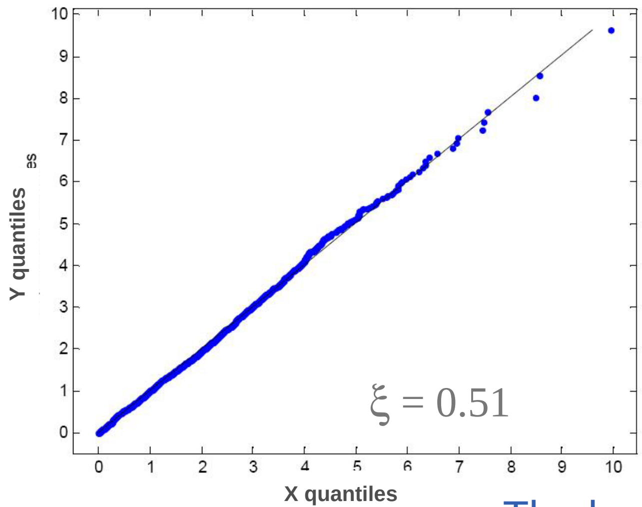

Fu(x-u)
x (on log scale)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10^3
10^4
10^5
10^6
ξ = 0.51

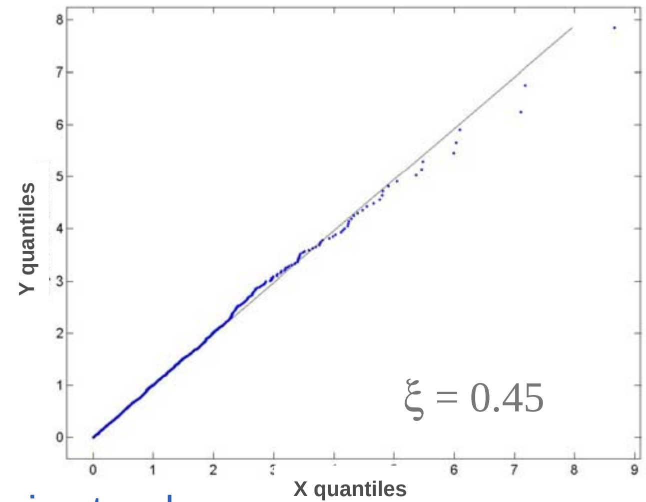

Fu(x-u)
x (on log scale)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10^3
10^4
10^5
10^6
ξ = 0.45


Fu(x-u)
x (on log scale)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10^3
10^4
10^5
ξ = 0.55


Fu(x-u)
x (on log scale)
0.6
0.7
0.8
0.9
1
1.1
1.2
10^4
10^5
ξ = 0.68 (?)

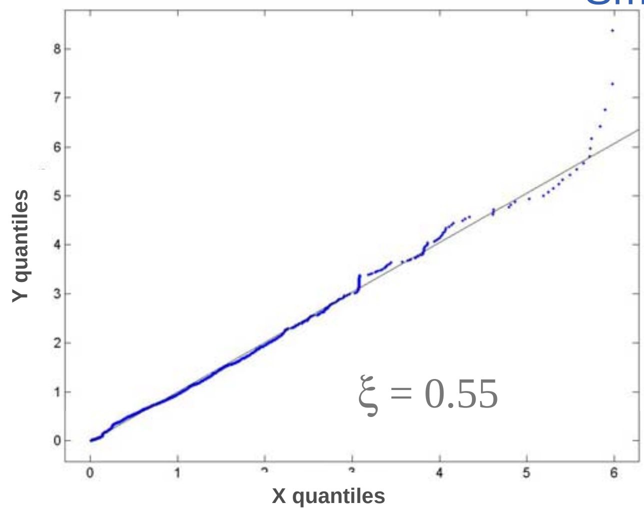
Pareto fit

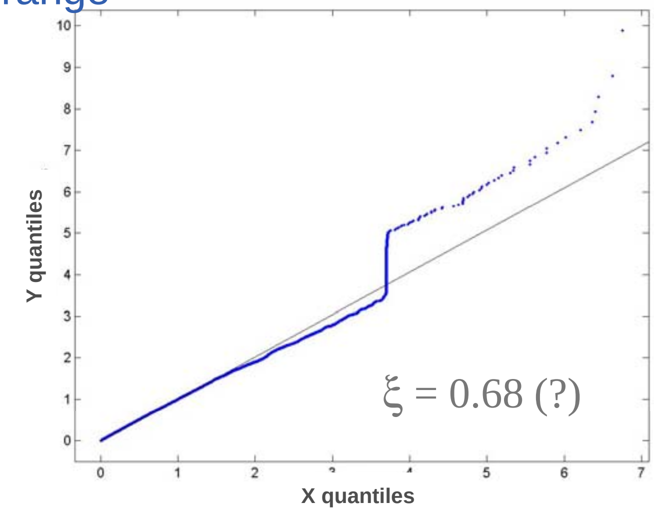




The heavy-tail hypothesis stands

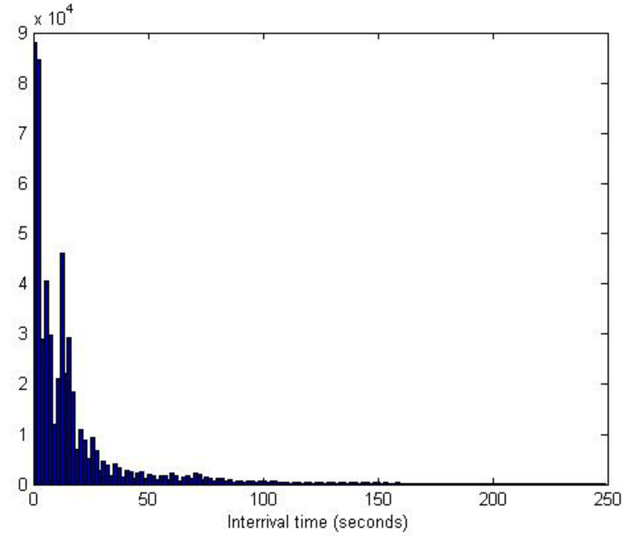
Small parameter range



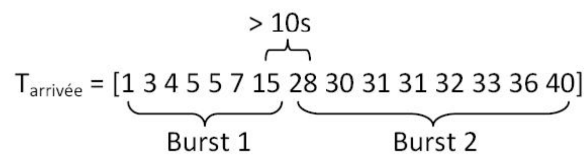


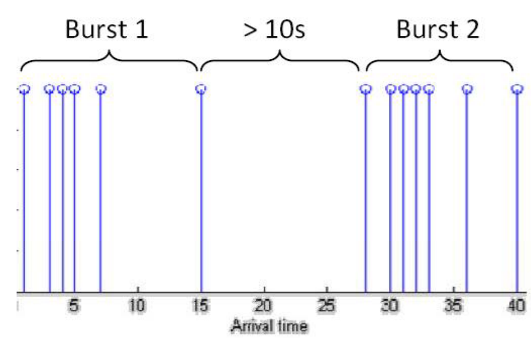
Bursts

- **Observation :**
  - Inter-arrival times (i.e. times between arrival of two jobs) show evidence of *bursty behaviour*
  - Problem : find an appropriate representation of this behaviour



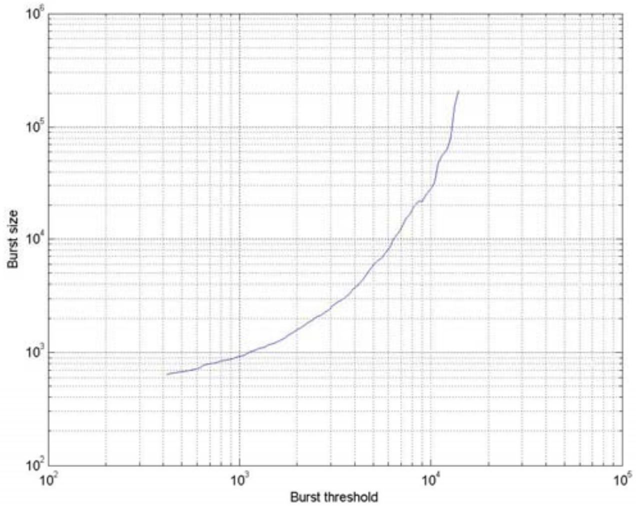
- **Given a threshold, a burst gathers all those jobs separated one from another by a time shorter than the threshold**
- **For each burst,**
  - Size=number of jobs
  - Length=duration

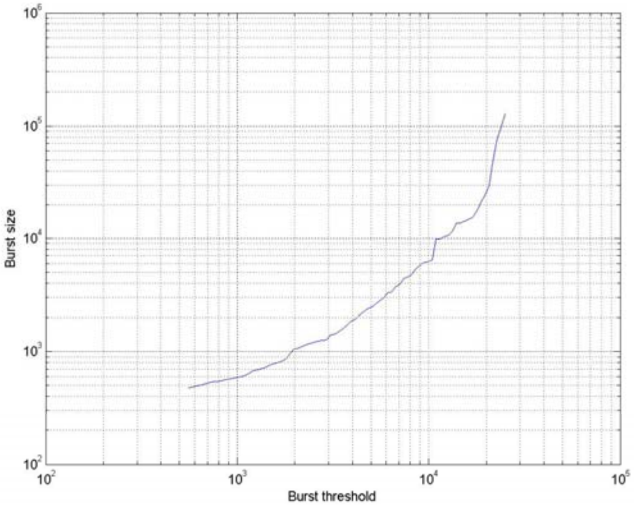


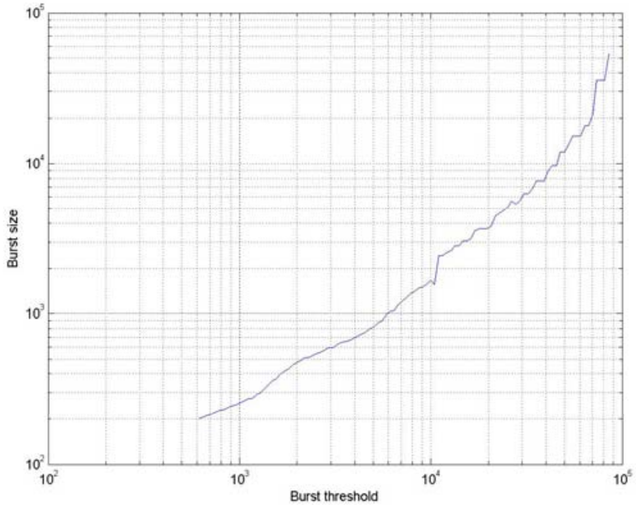


Inter-arrival bursts

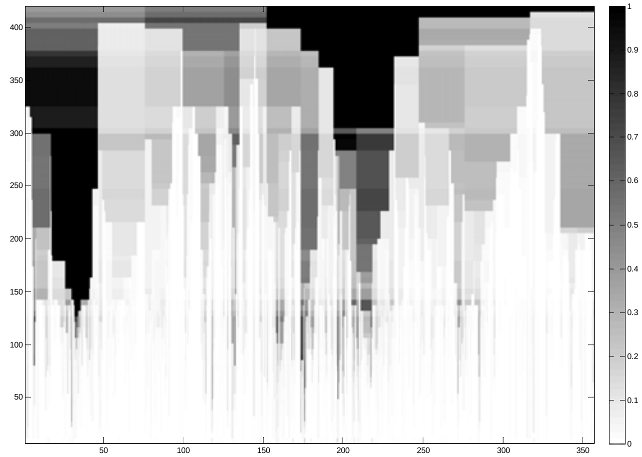
- **The shape of the average burst size as a function of a threshold does is very similar across the CEs**







Stalactite diagrams

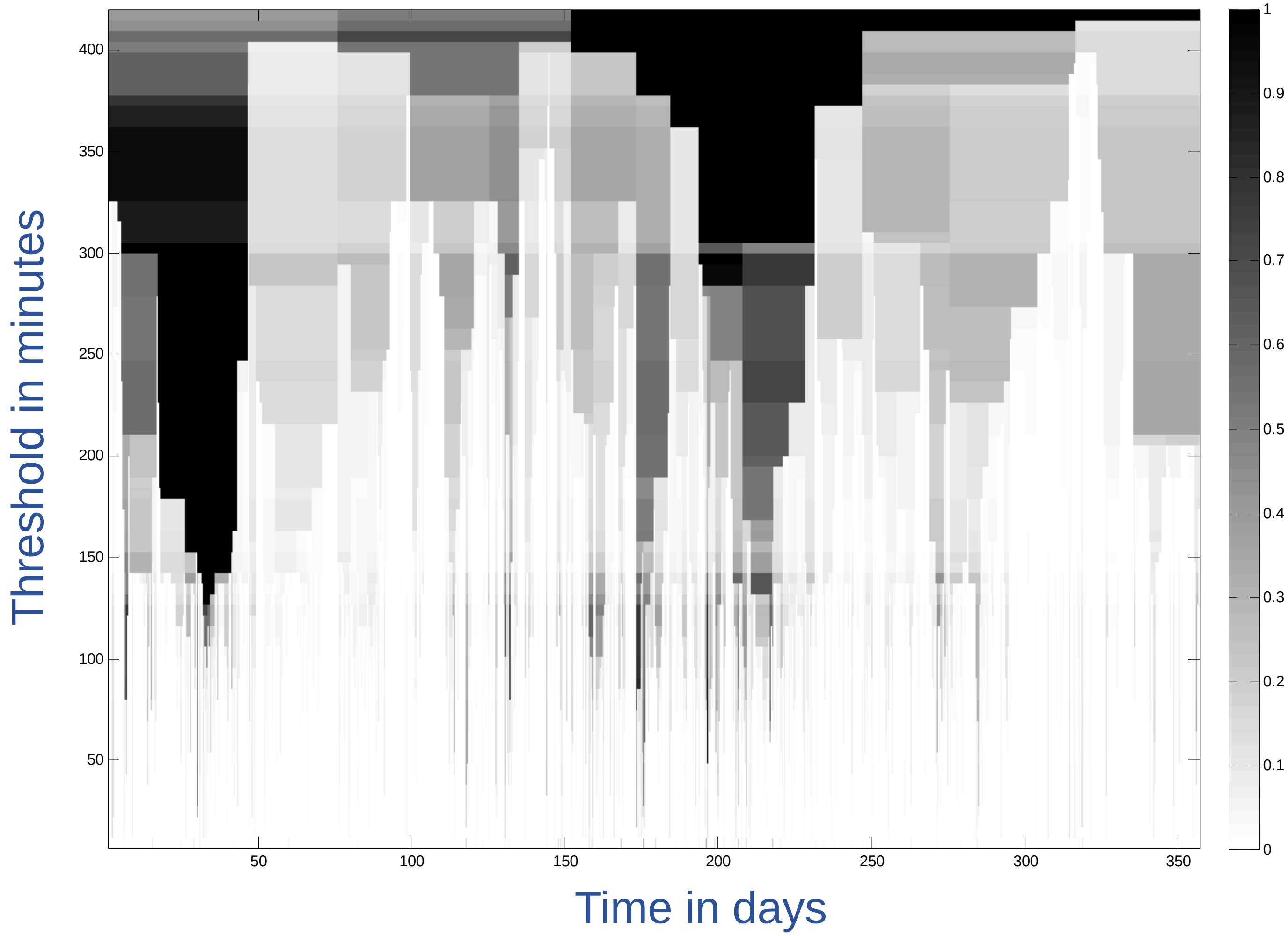


- **X-Axis : time in days**
- **Y-Axis : threshold in minutes**
- **Color : mean burst size**

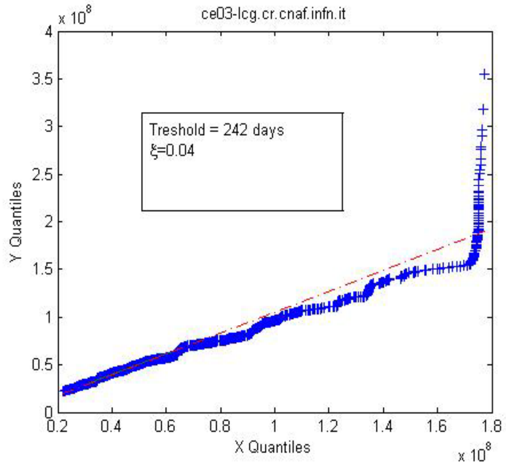
Note : color is normalized on each row

- **How to read a stalactite diagram:**
  – On a single row, clear areas indicate smaller-sized bursts while darker areas stand for bursts gathering more jobs
  – Dark vertical areas reveal bursts left undivided by progressive threshold reduction
- **Interpretation: the more the threshold is reduced, the more jobs are dispatched between shorter bursts EXCEPT for some “stalactites”**
- **Possible use:**
  – Offline detection of *exceptional density* in inter-arrival times
  – Model for arrival times
  – Ongoing work: benchmarking with Cox models

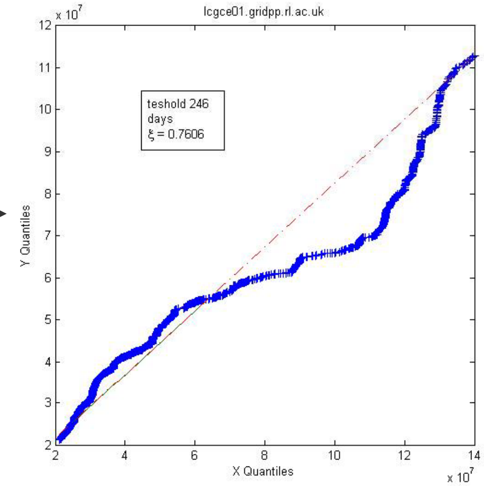
Stalactite diagrams : example



Load tails

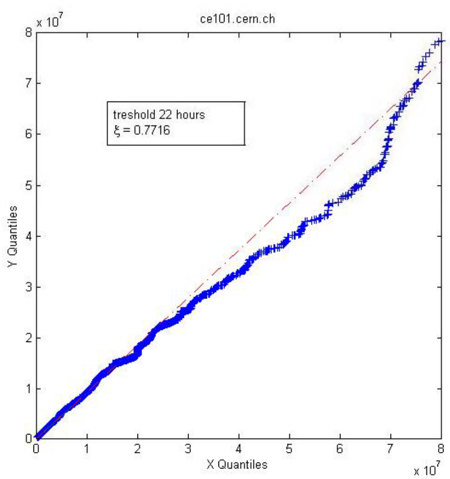


90% percentile



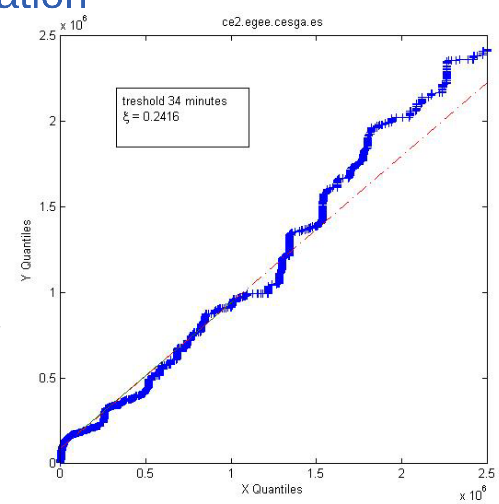
Very contrasted behaviors

Ongoing work: classification



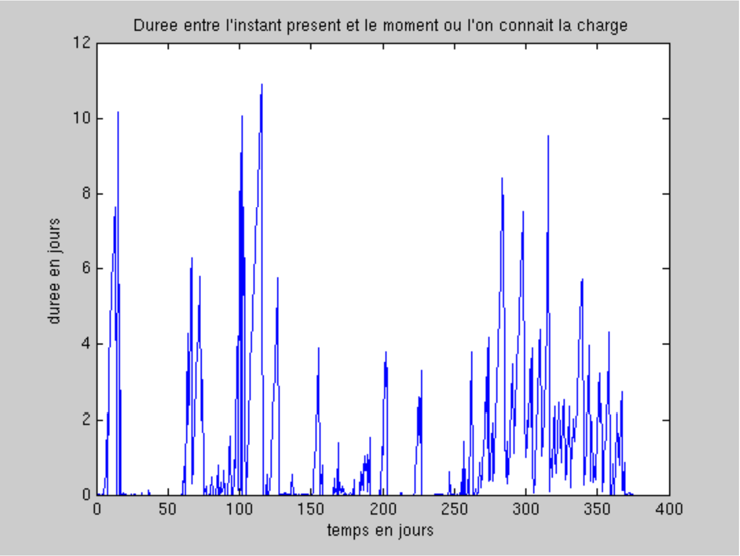
20% percentile

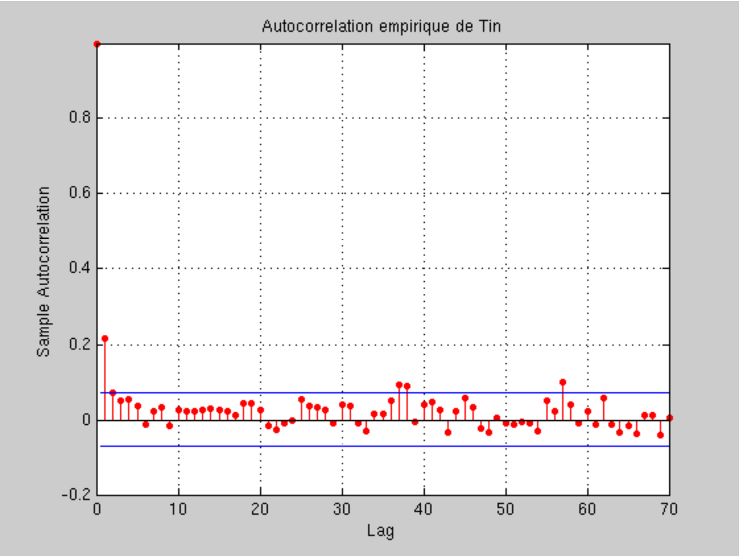
60% percentile



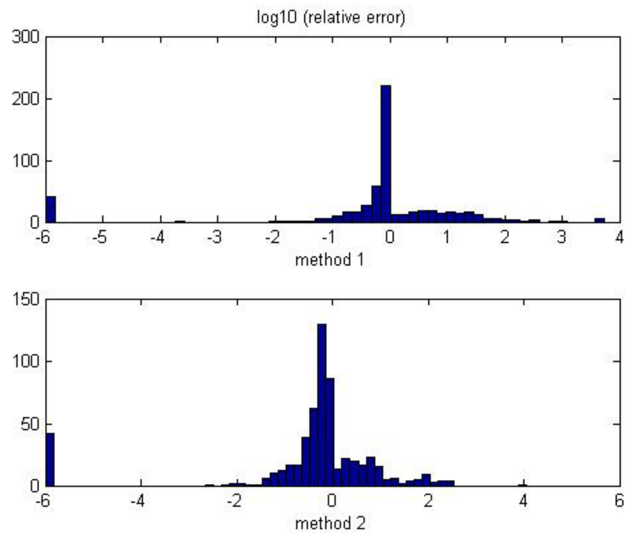
Predicting the load

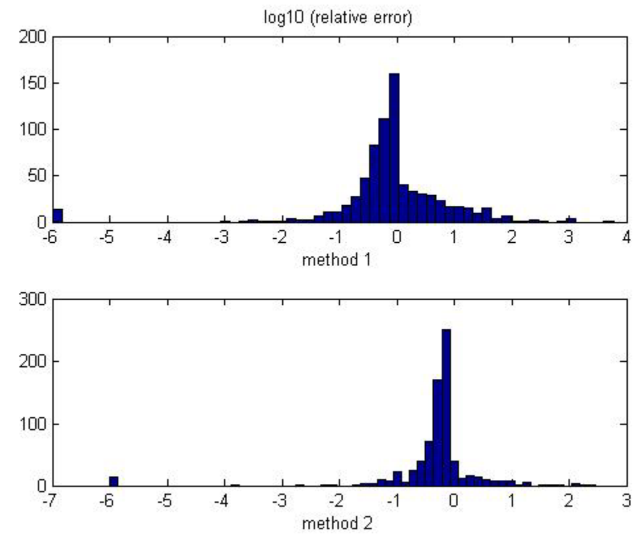
- **Two naive prediction strategies**
  - Linear from the load history
  - As the mean of the past executions x number of jobs in the queue
- **From the load history**
  - We must use only the known load
  - If t_0 is the present date, and t_1 the last date where the load was known, t_0 - t_1 is typically of the order of a few days in active periods
  - Thus we must extrapolate the load with a horizon of a few days
- **From the past executions**
  - The correlation of the series of averaged execution times decreases very fast
  - The horizon for a linear prediction of the execution times is one day at best

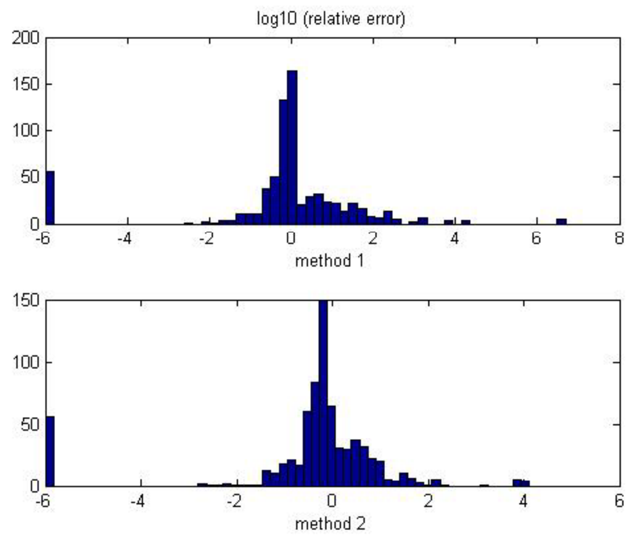


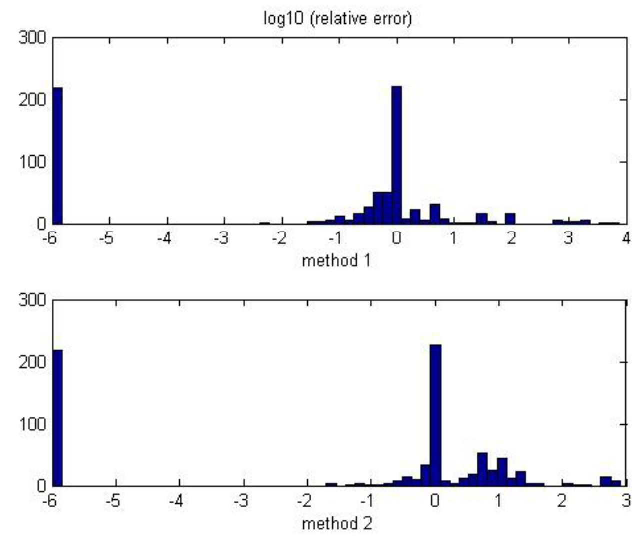


Predicting the load



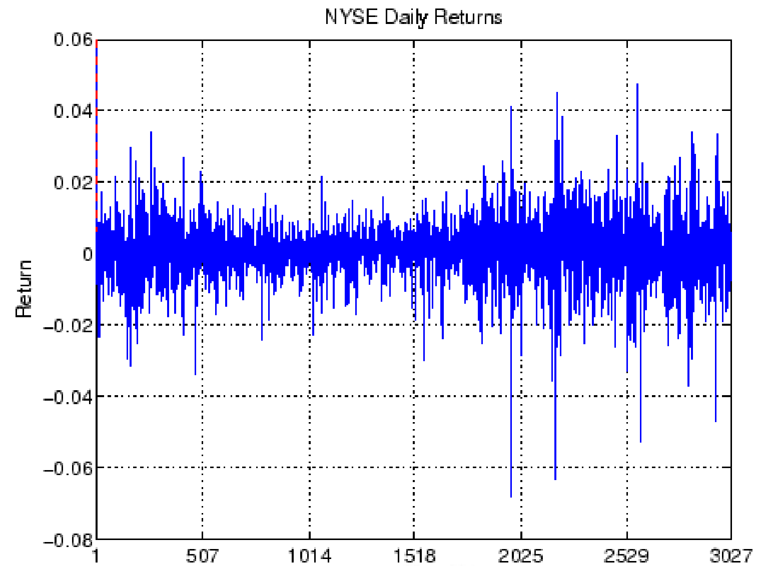


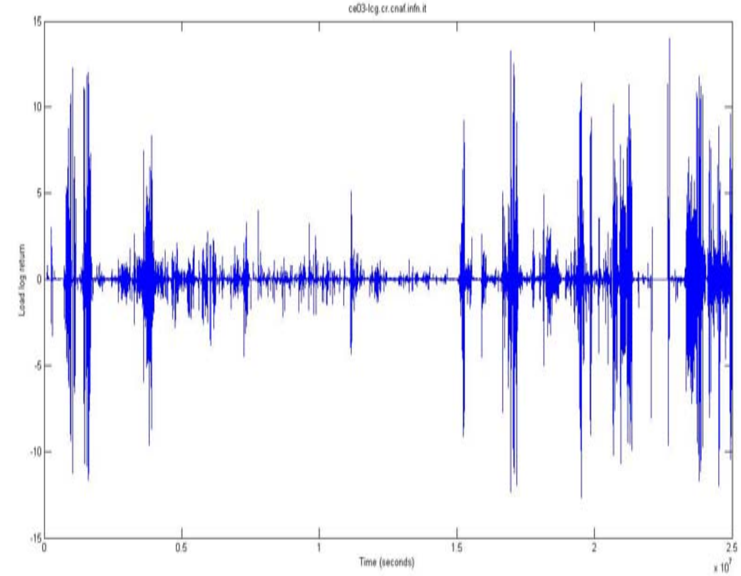




On going work: ARCH models

- **Autoregressive conditional heteroskedasticity (Engle, 1982) Widely used in finance modeling**
  - Fat tails
  - Time-varying volatility clustering:changes of the same magnitude tend to follow; here the goal is forecasting the variance of the next shock
  - Leverage effects: volatility negatively correlated with magnitude in change
- **The one-step-ahead forecast error are zero-mean random disturbances uncorrelated from one period to the next, but not independent**



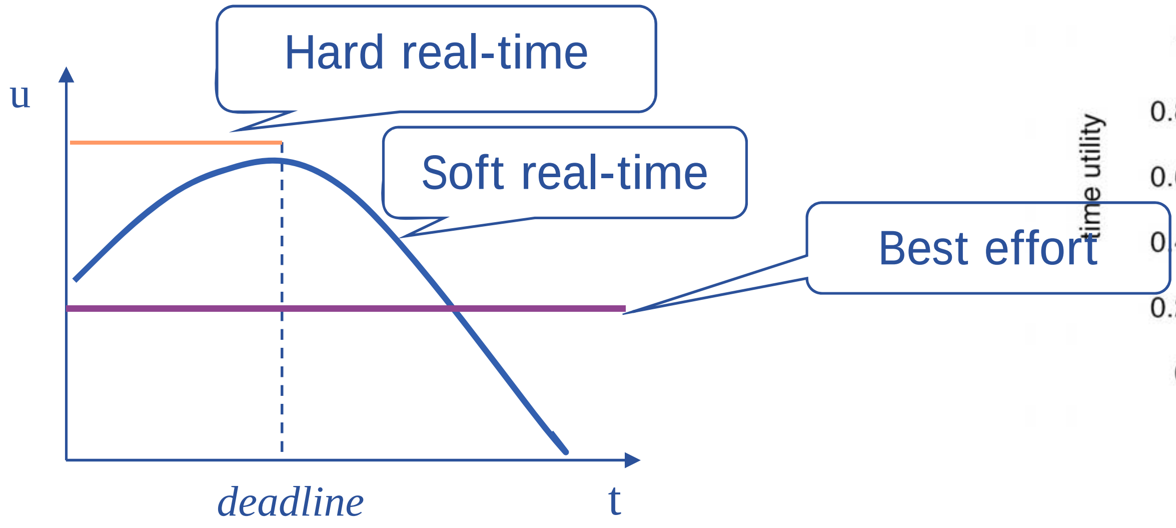


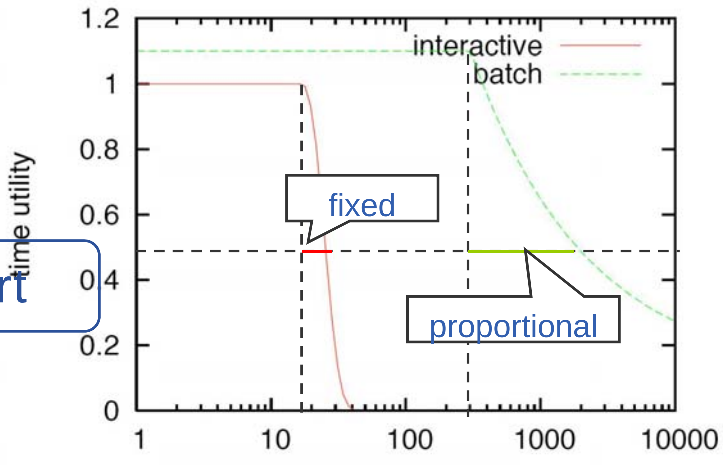
Policy design

- Model-based approaches
  - Predict the performance of the ressources from on-line history and off-line analysis of traces
- Model-free approaches
  - Build a relationship between state of the environment (e.g. grid), available actions, (e.g. jobs to schedule), immediate benefit, and expected long term benefits
  - Empirical approximation of a value function that gives the expected long-term benefit as a function of the current state
  - If the dynamics of the system is known, a classical optimization problem
  - If the dynamic is unknown, reinforcement learning learns the value function by actual actions; a good RL algorithm efficiently samples the (action, value) space

Utility criteria

- **Time/Utility functions (TUF) – [Jensen, Locke, Tokuda 85]**
  - Utility is a function of the execution delay
  - Service classes are associated to functions
- **Other requirements can be included in the utility framework**
  - Weighted fairness is mandatory
  - Productivity if the scheduling policy is not work-conserving





Experiment

- **At the CE level - Data: Torque logs LAL 17-26 May 2006**
- **« Interactive » jobs: execution time less than 15 minutes**
- **Details in CCGRID'08 paper**
- **Further work: evaluate RL at the WMS level**