http://poloclub.gatech.edu/cse6242

CSE6242 / CX4242: Data & Visual Analytics

Time Series

Non-linear Forecasting

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Georgia Tech

Partly based on materials by
Professors Guy Lebanon, Jeffrey Heer, John Stasko, Christos Faloutsos, Parishit Ram (GT PhD alum; SkyTree), Alex Gray

Chaos & non-linear forecasting

Reference:

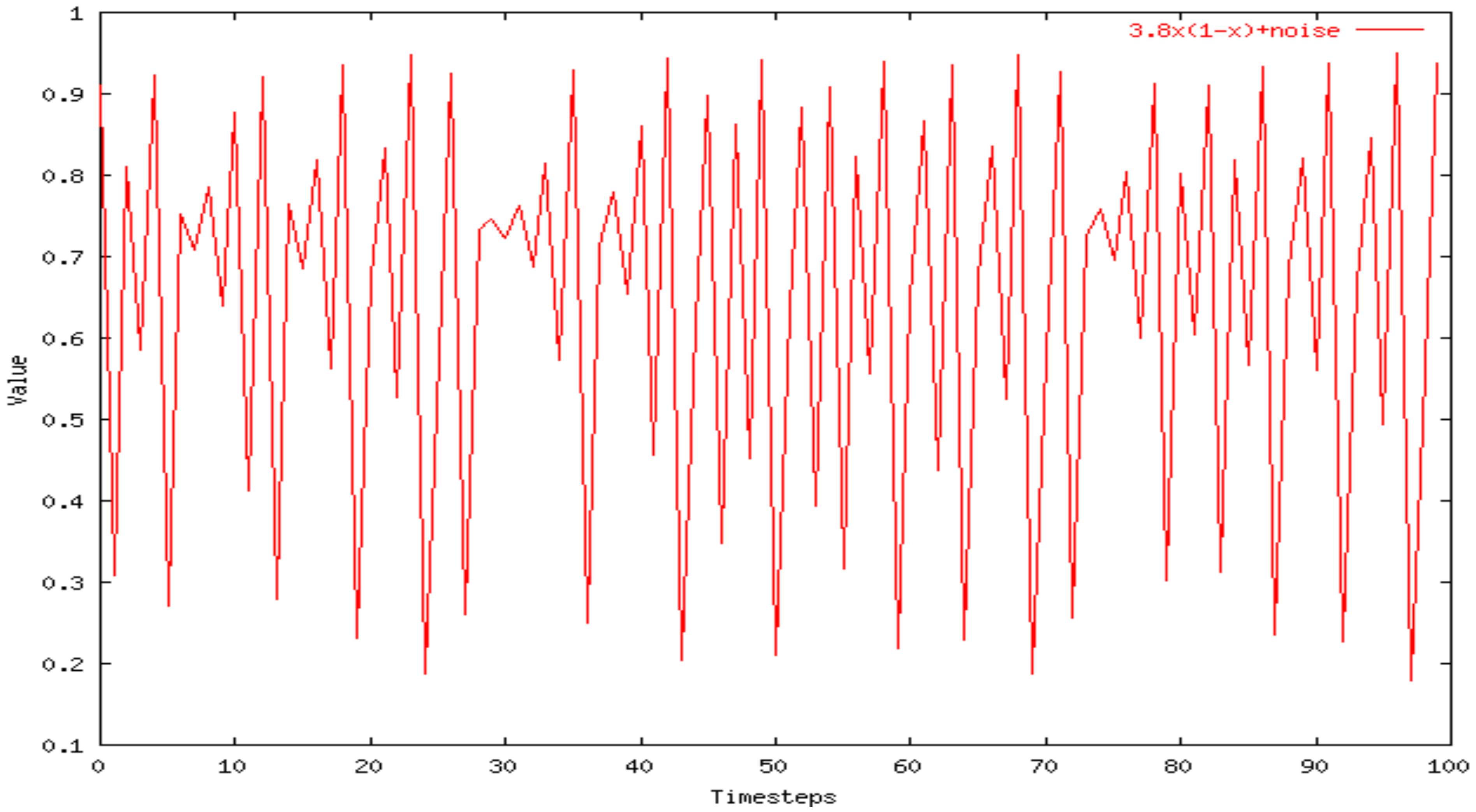
[Deepay Chakrabarti and Christos Faloutsos *F4: Large-Scale Automated Forecasting using Fractals* CIKM 2002, Washington DC, Nov. 2002.]

Detailed Outline

- Non-linear forecasting
  - Problem
  - Idea
  - How-to
  - Experiments
  - Conclusions

Recall: Problem #1

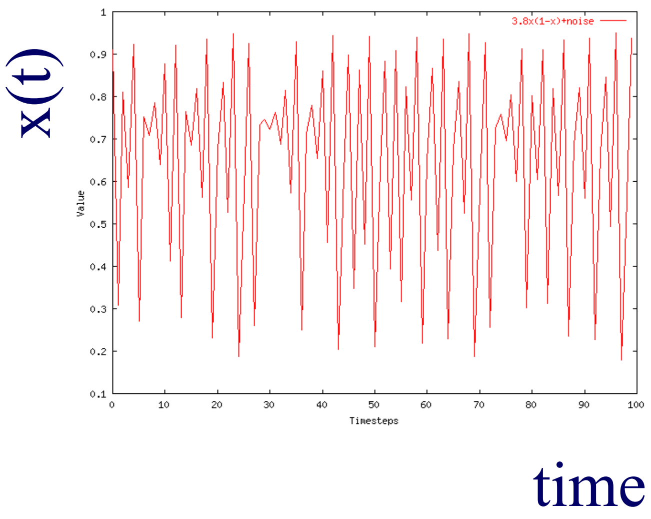
Value



Time

Given a time series $\{x_t\}$, predict its future course, that is, x_{t+1}, x_{t+2}, ...

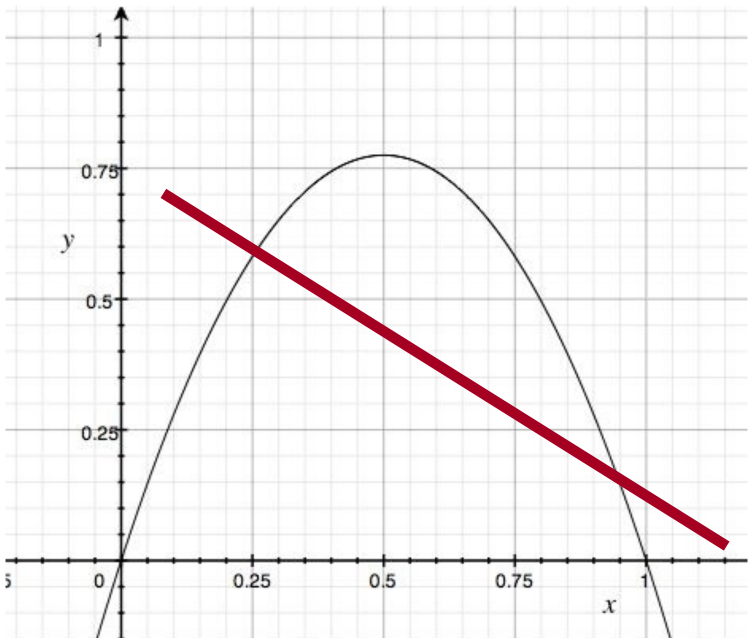
Datasets



Logistic Parabola:

$x_t = ax_{t-1}(1-x_{t-1}) + noise$

Models population of flies [R. May/1976]

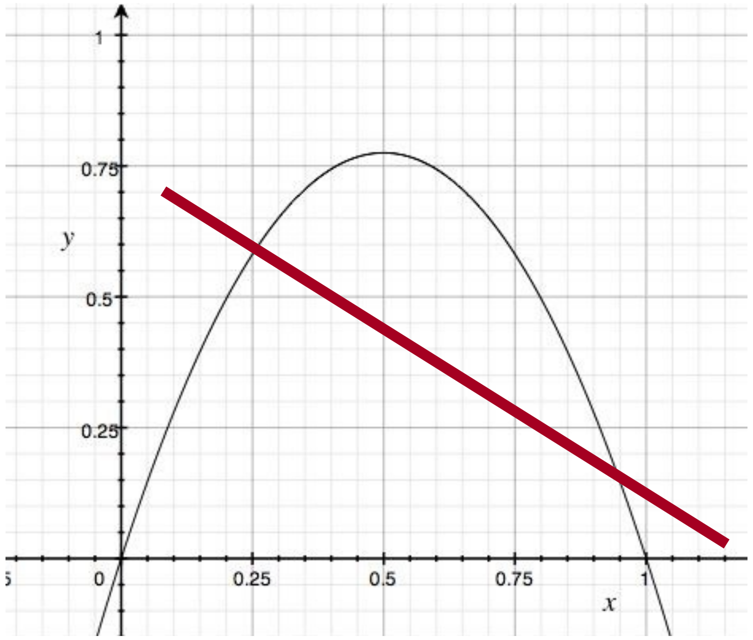


Lag-plot

ARIMA: fails

How to forecast?

- ARIMA - but: linearity assumption



Lag-plot

ARIMA: fails

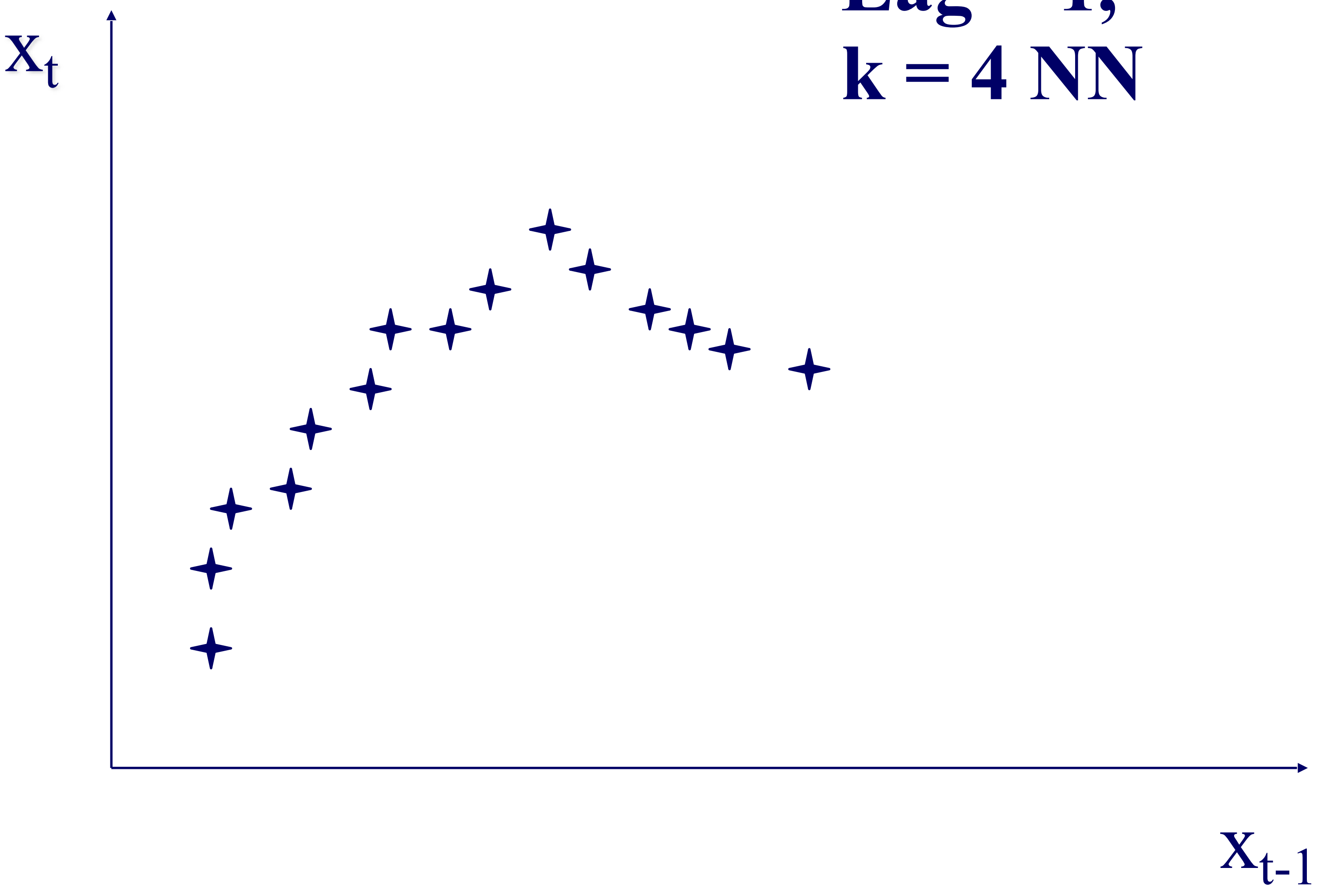
How to forecast?

- ARIMA - but: linearity assumption

- ANSWER: ‘Delayed Coordinate Embedding’ = Lag Plots [Sauer92]

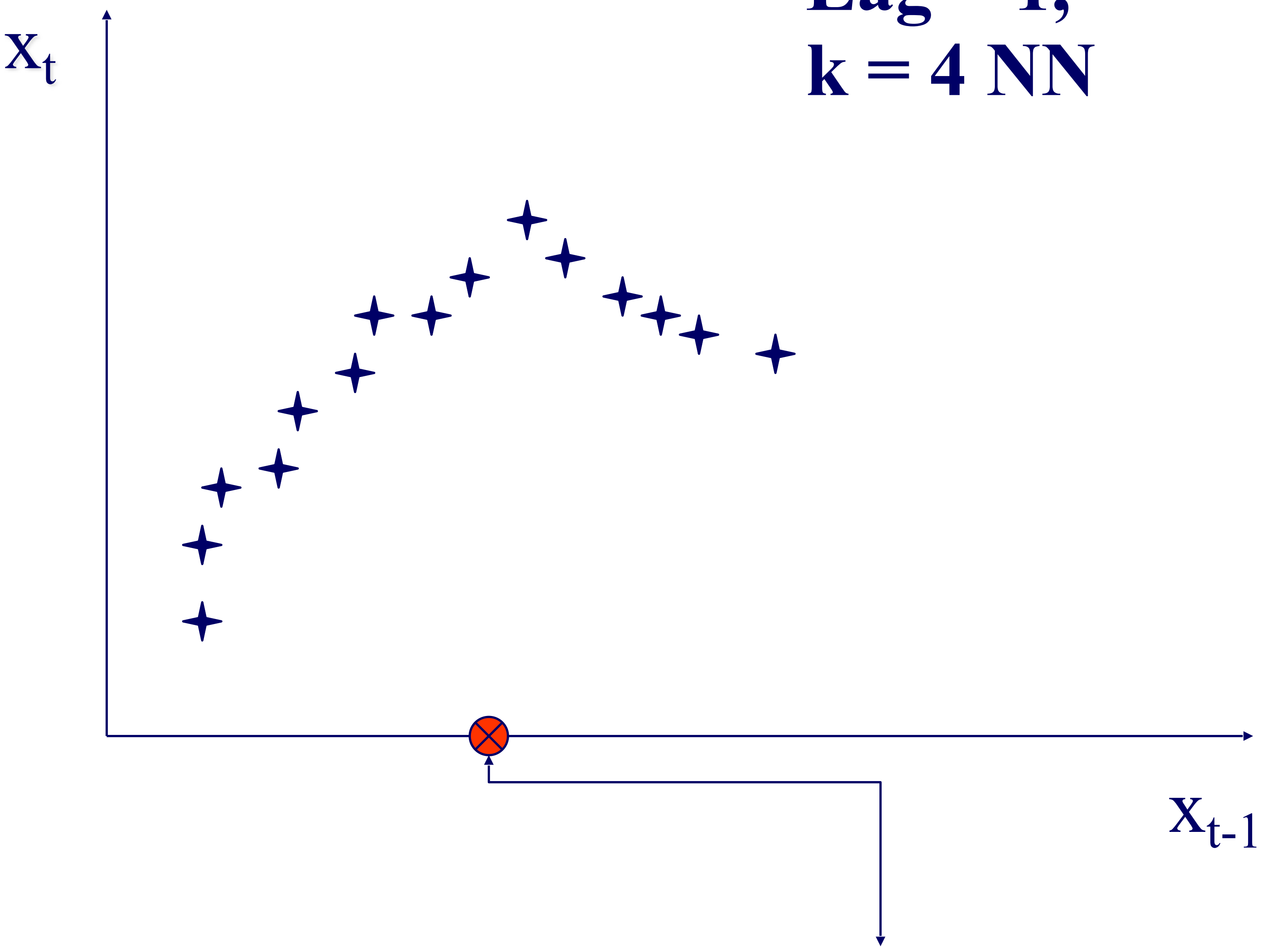
  ~ nearest-neighbor search, for past incidents

General Intuition (Lag Plot)



Lag = 1,
k = 4 NN

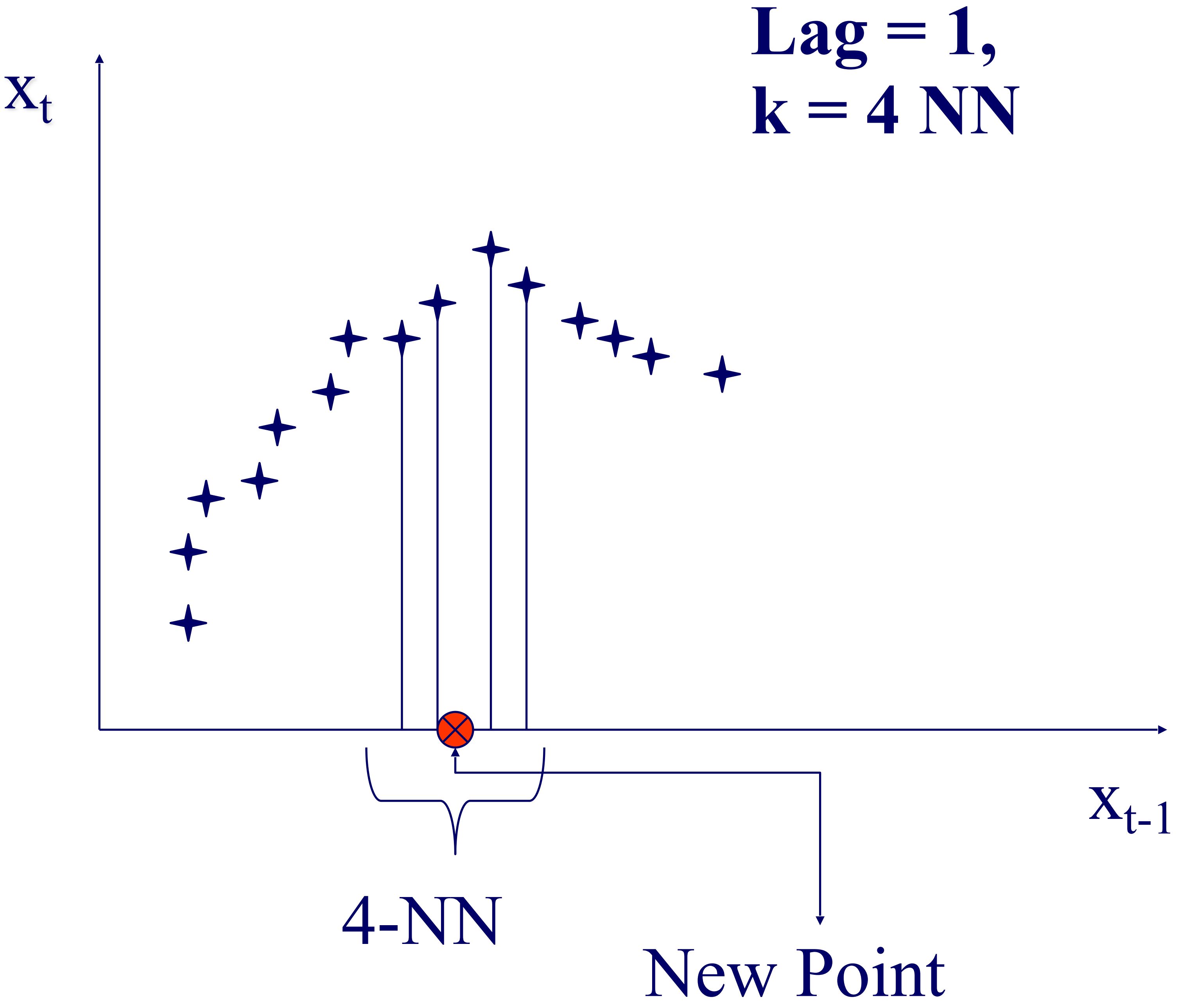
General Intuition (Lag Plot)



Lag = 1,
k = 4 NN

New Point

General Intuition (Lag Plot)



Lag = 1,
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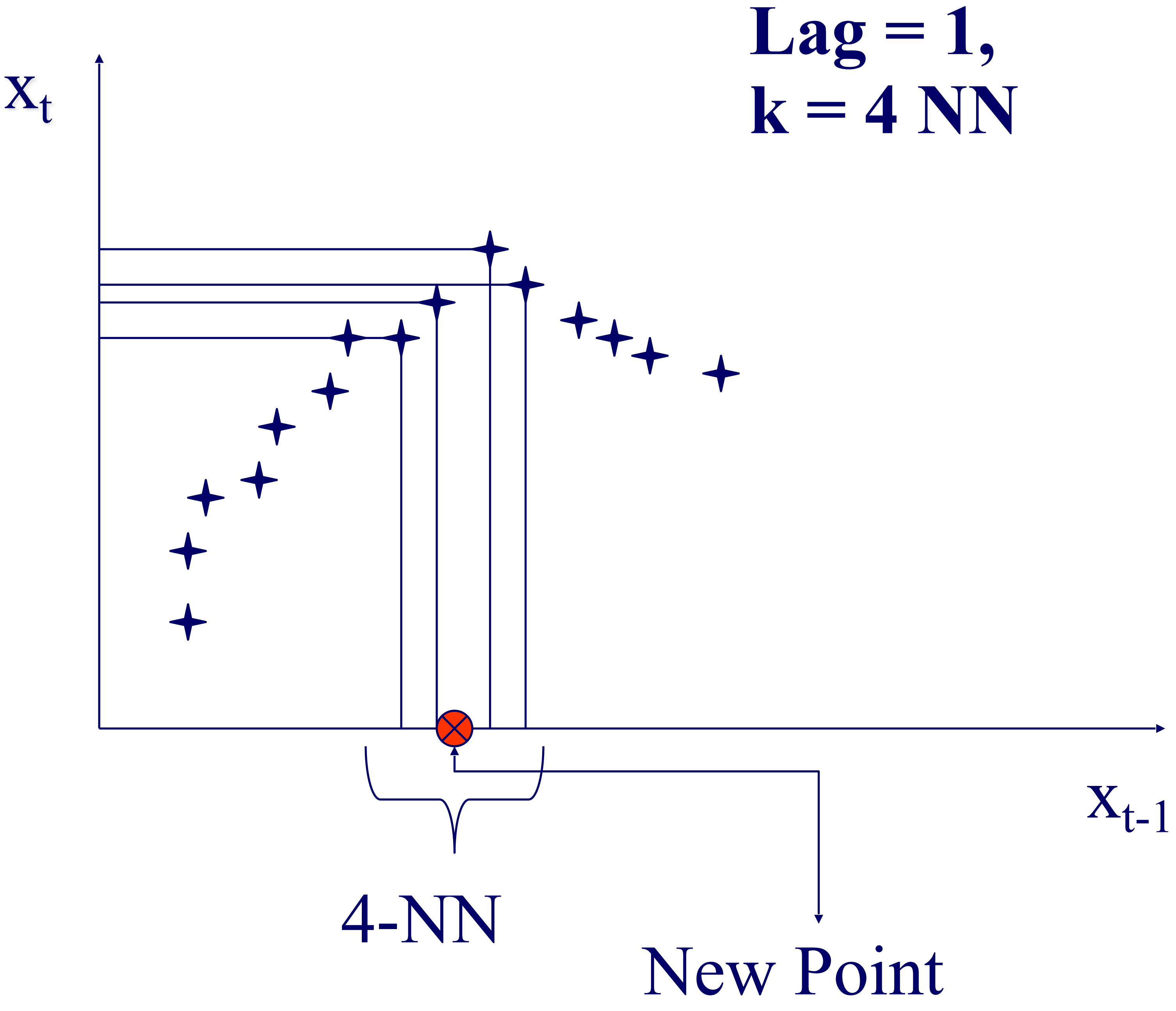
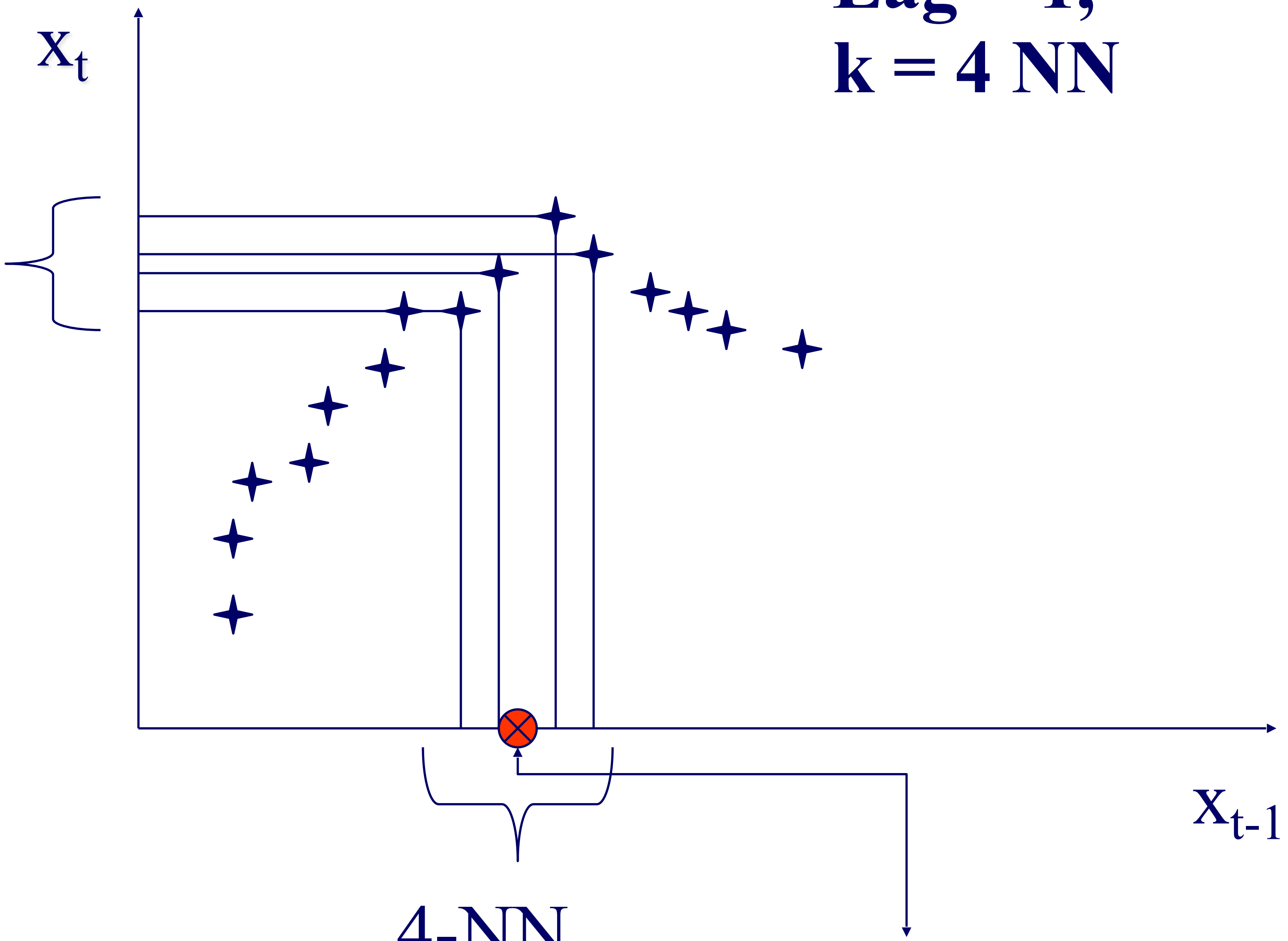
General Intuition (Lag Plot)



General Intuition (Lag Plot)

Lag = 1,
k = 4 NN



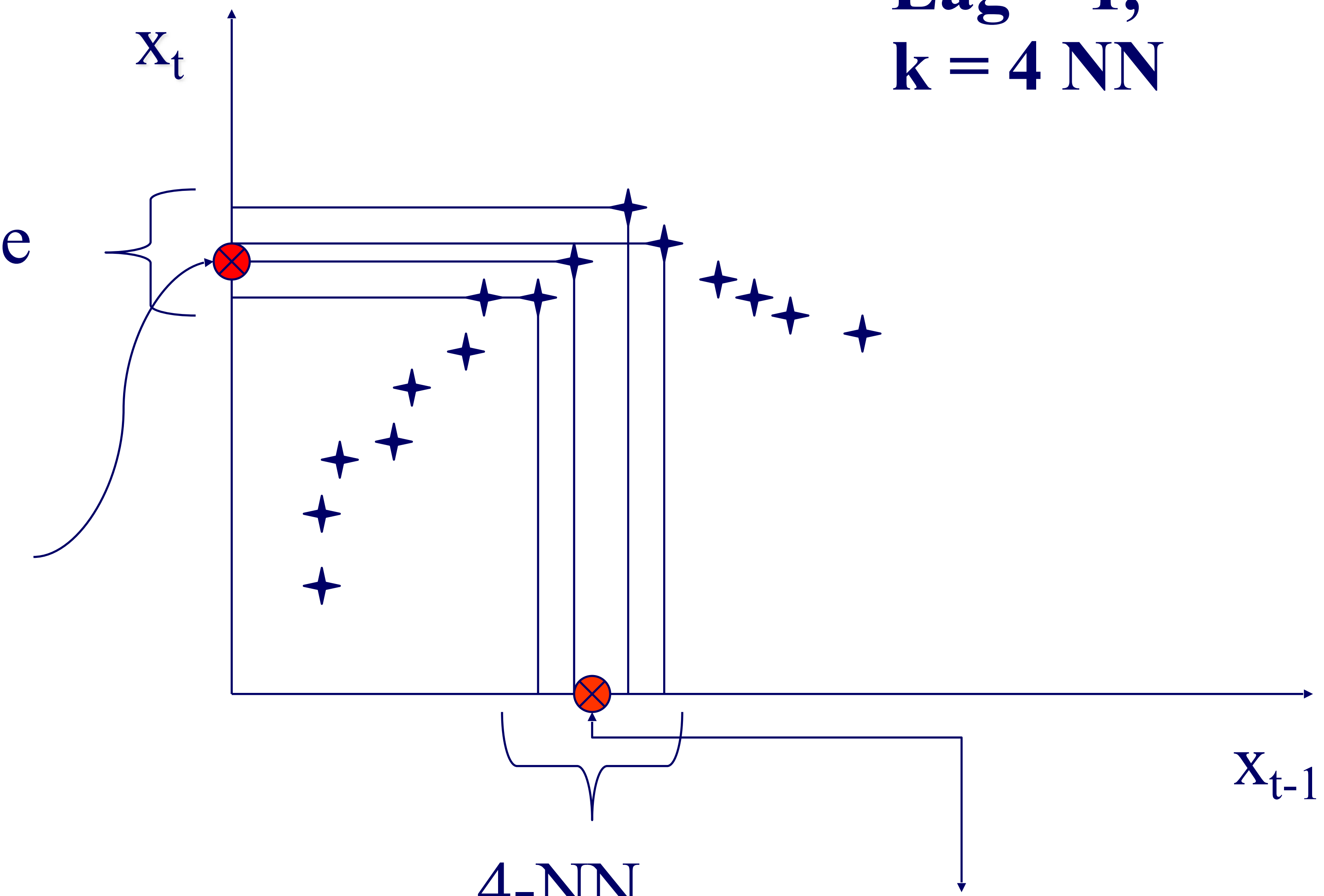
Interpolate these…

4-NN

New Point

General Intuition (Lag Plot)

Lag = 1,
k = 4 NN



Interpolate these…

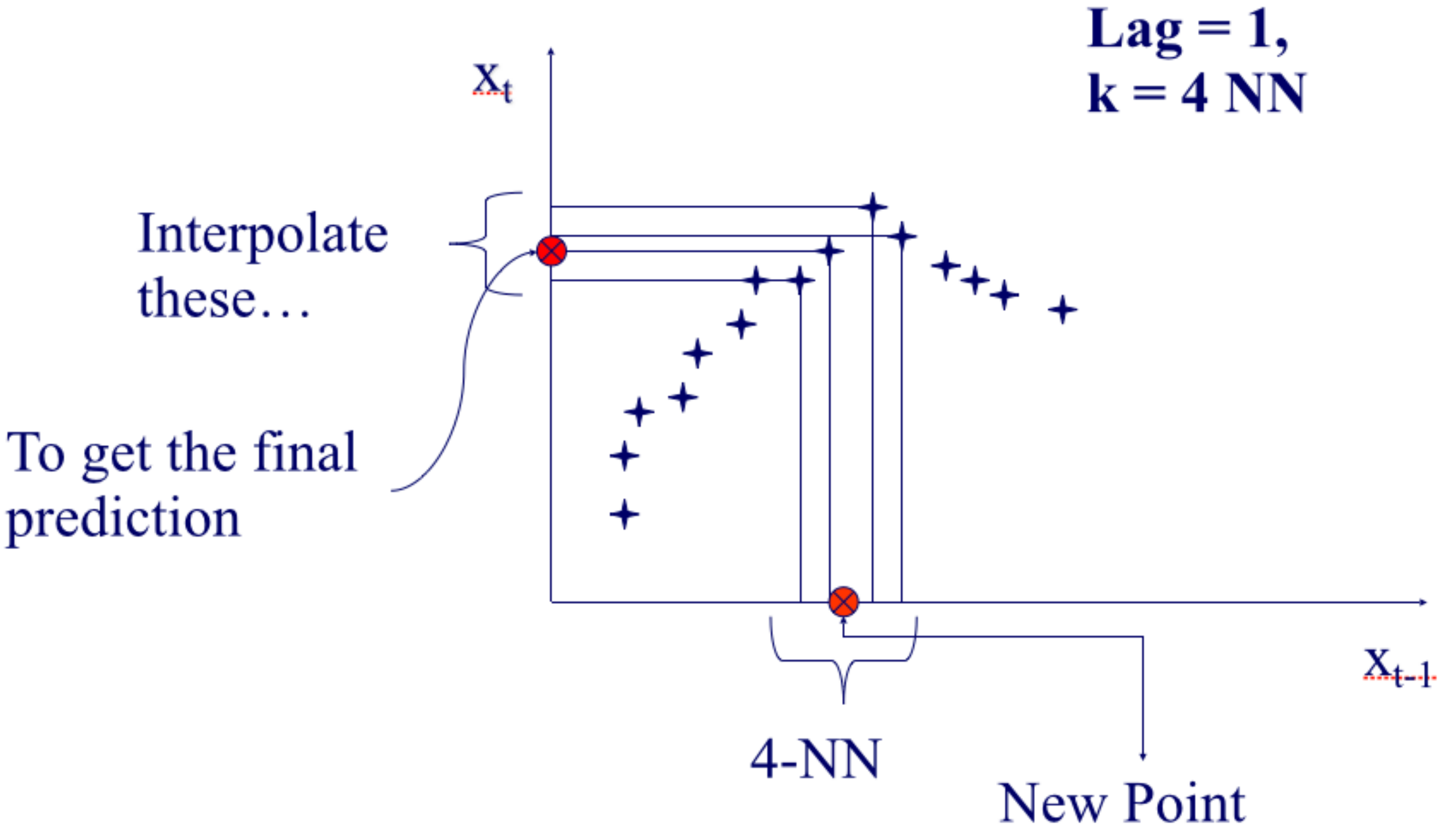
To get the final prediction

4-NN

New Point

Questions:

- Q1: How to choose lag *L*?
- Q2: How to choose *k* (the # of NN)?
- Q3: How to interpolate?
- Q4: why should this work at all?



Lag = 1,
k = 4 NN

Interpolate these…

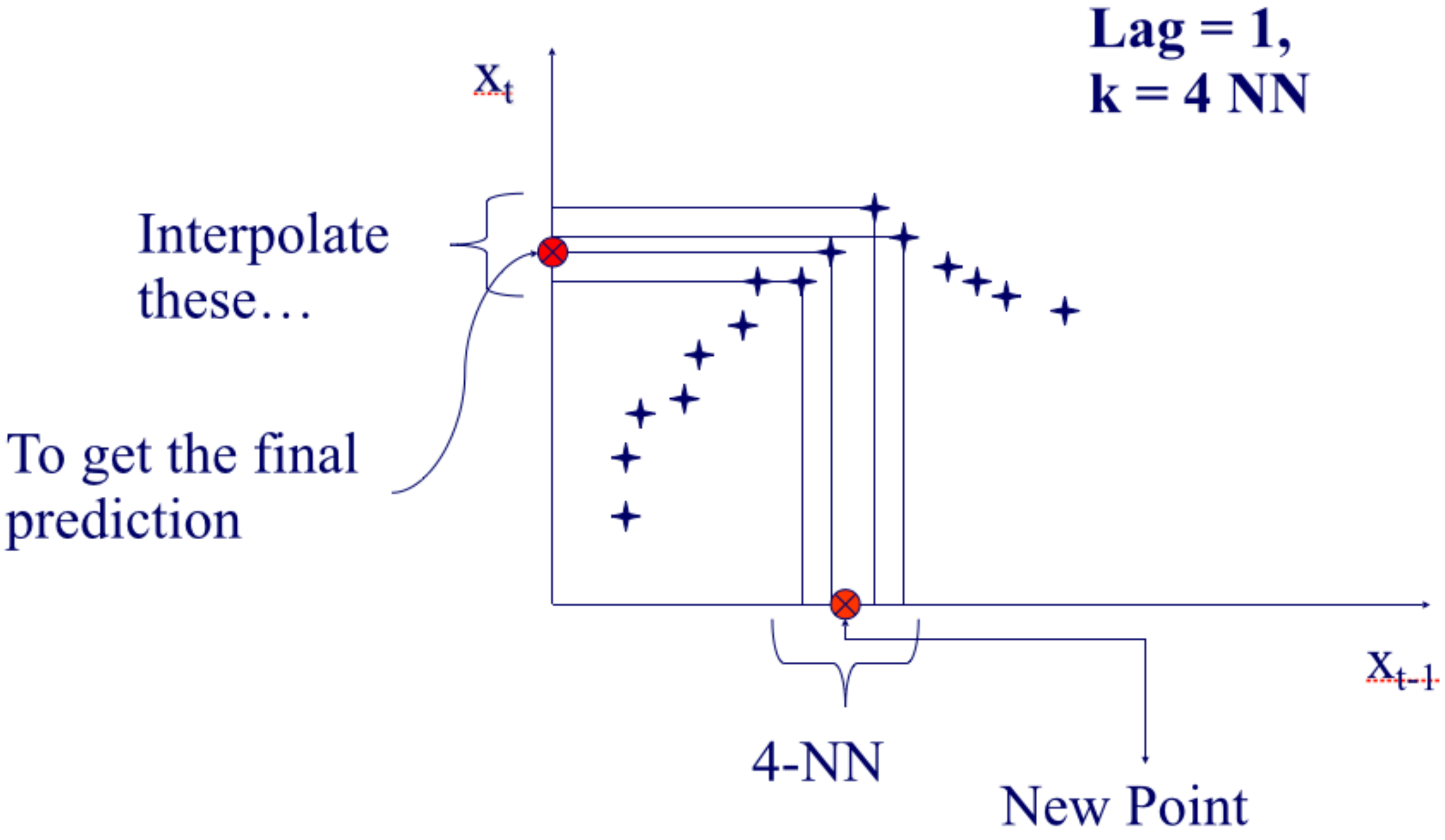
To get the final prediction

4-NN

New Point

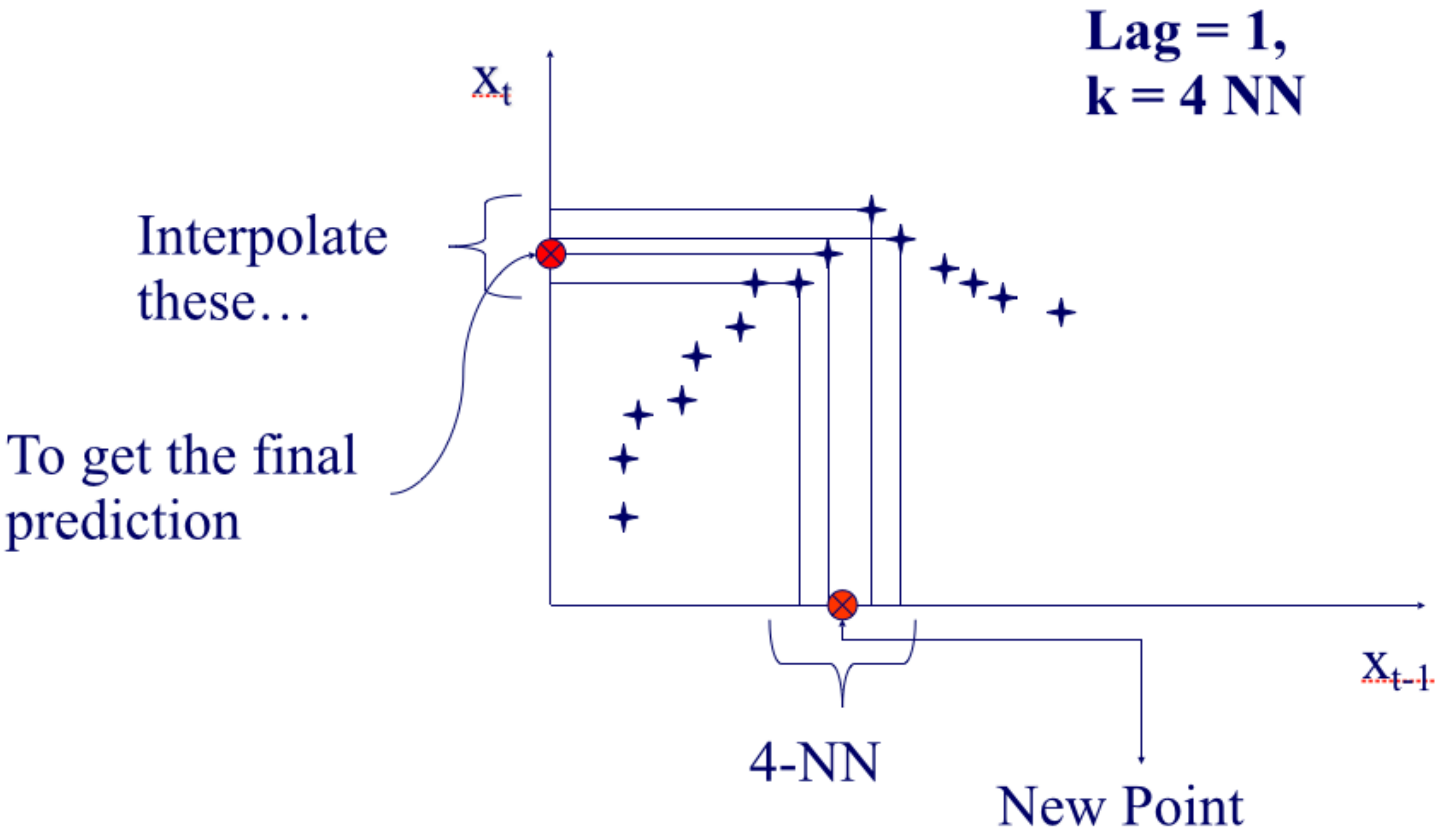
Q1: Choosing lag *L*

- Manually (16, in award winning system by [Sauer94])



Q2: Choosing number of neighbors *k*

- Manually (typically ~ 1-10)

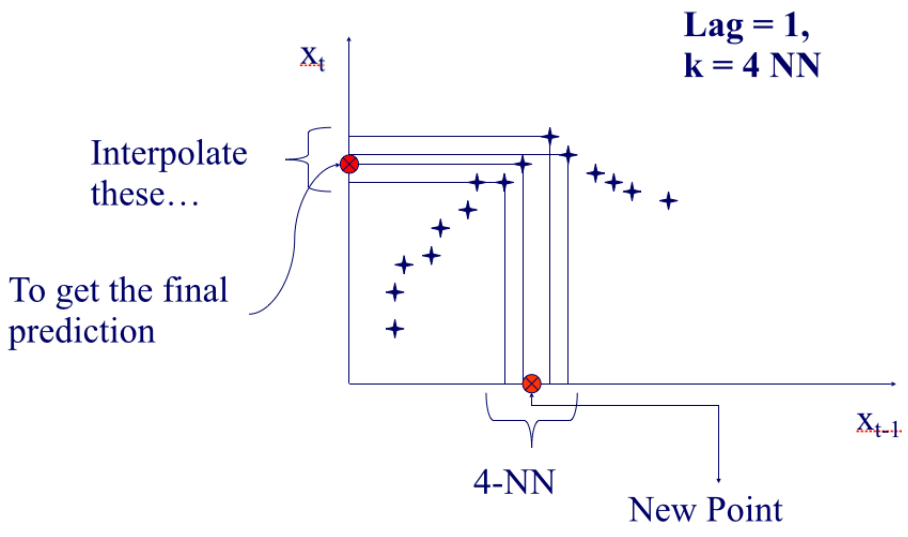


Q3: How to interpolate?

How do we interpolate between the *k* nearest neighbors?

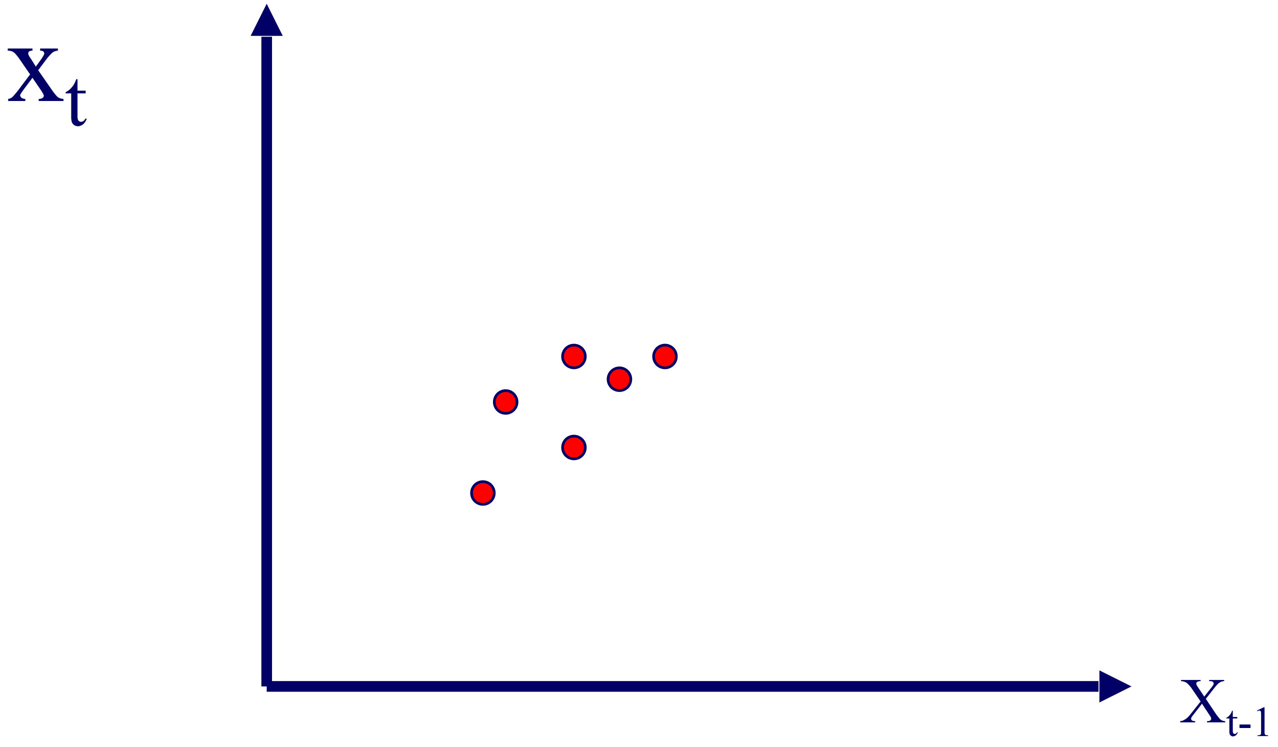
A3.1: Average

A3.2: Weighted average (weights drop with distance - how?)



Q3: How to interpolate?

A3.3: Using SVD - seems to perform best ([Sauer94] - first place in the Santa Fe forecasting competition)



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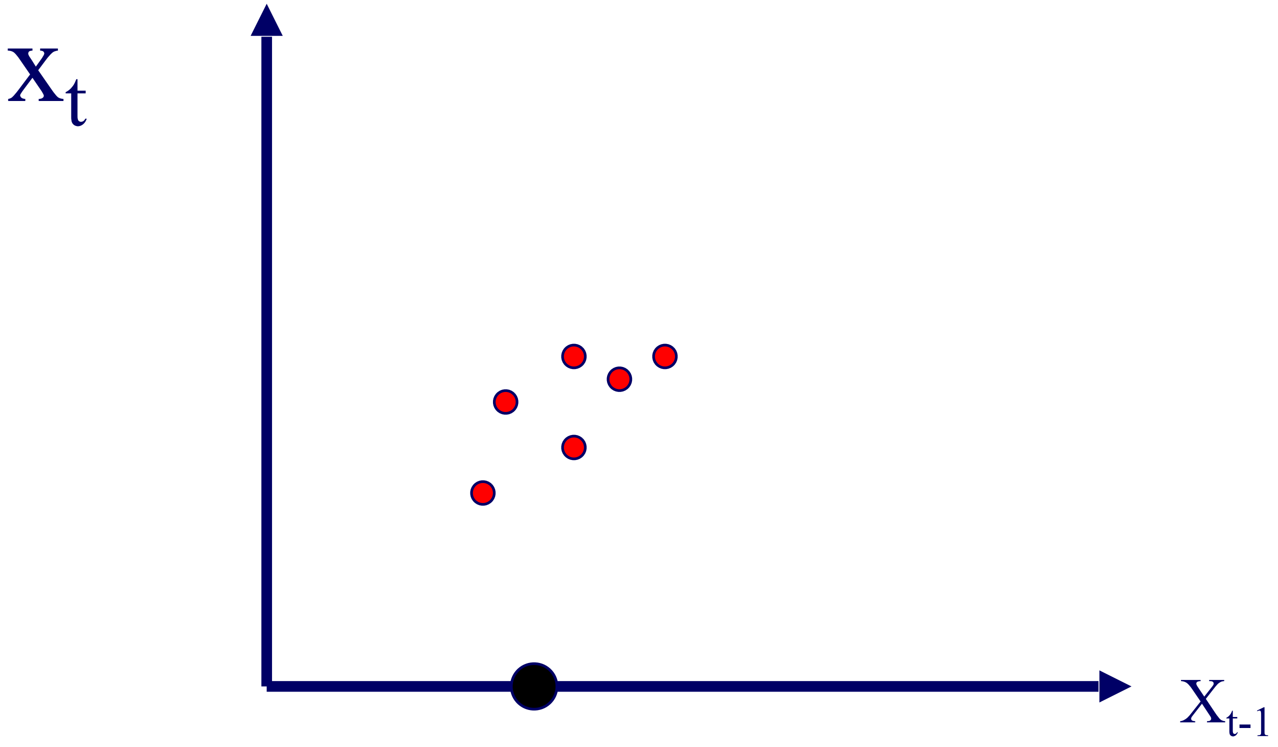

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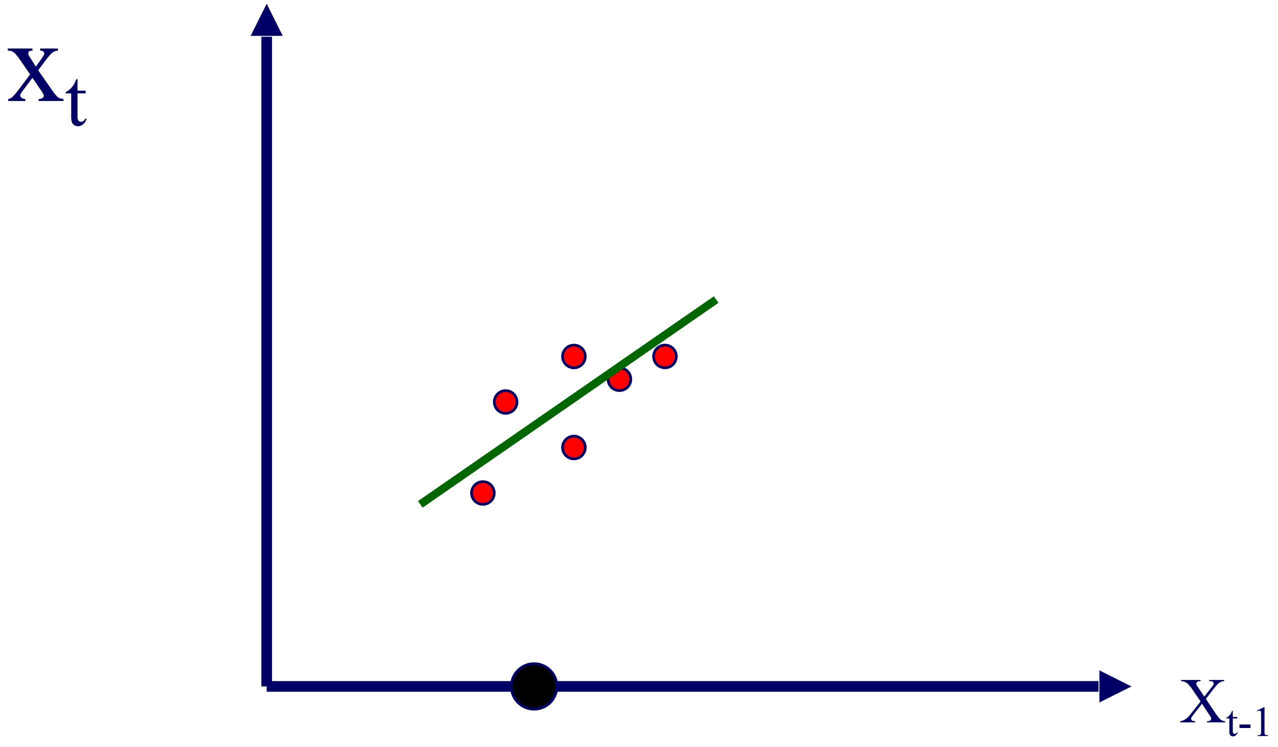

Q3: How to interpolate?

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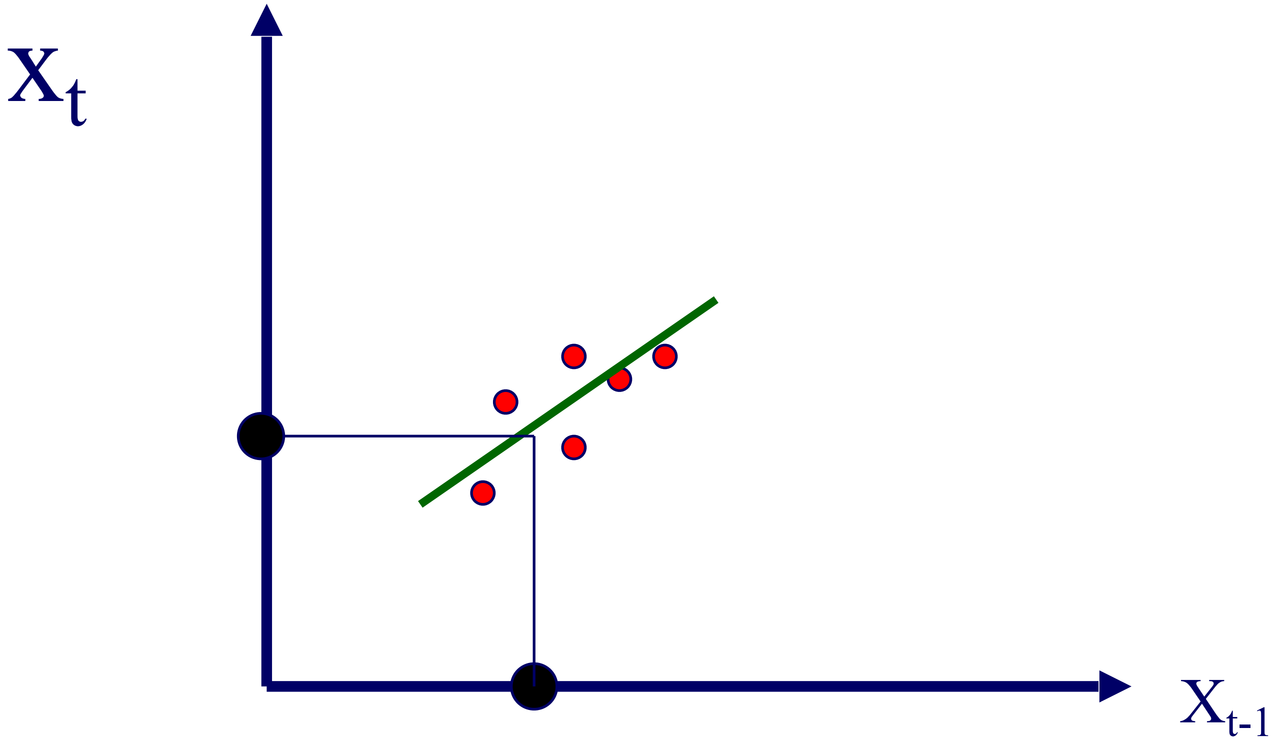

Q4: Any theory behind it?

A4: YES!

Theoretical foundation

- Based on the ‘Takens theorem’ [Takens81]
- which says that long enough delay vectors can do prediction, even if there are unobserved variables in the dynamical system (= diff. equations)

Detailed Outline

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  - Problem
  - Idea
  - How-to
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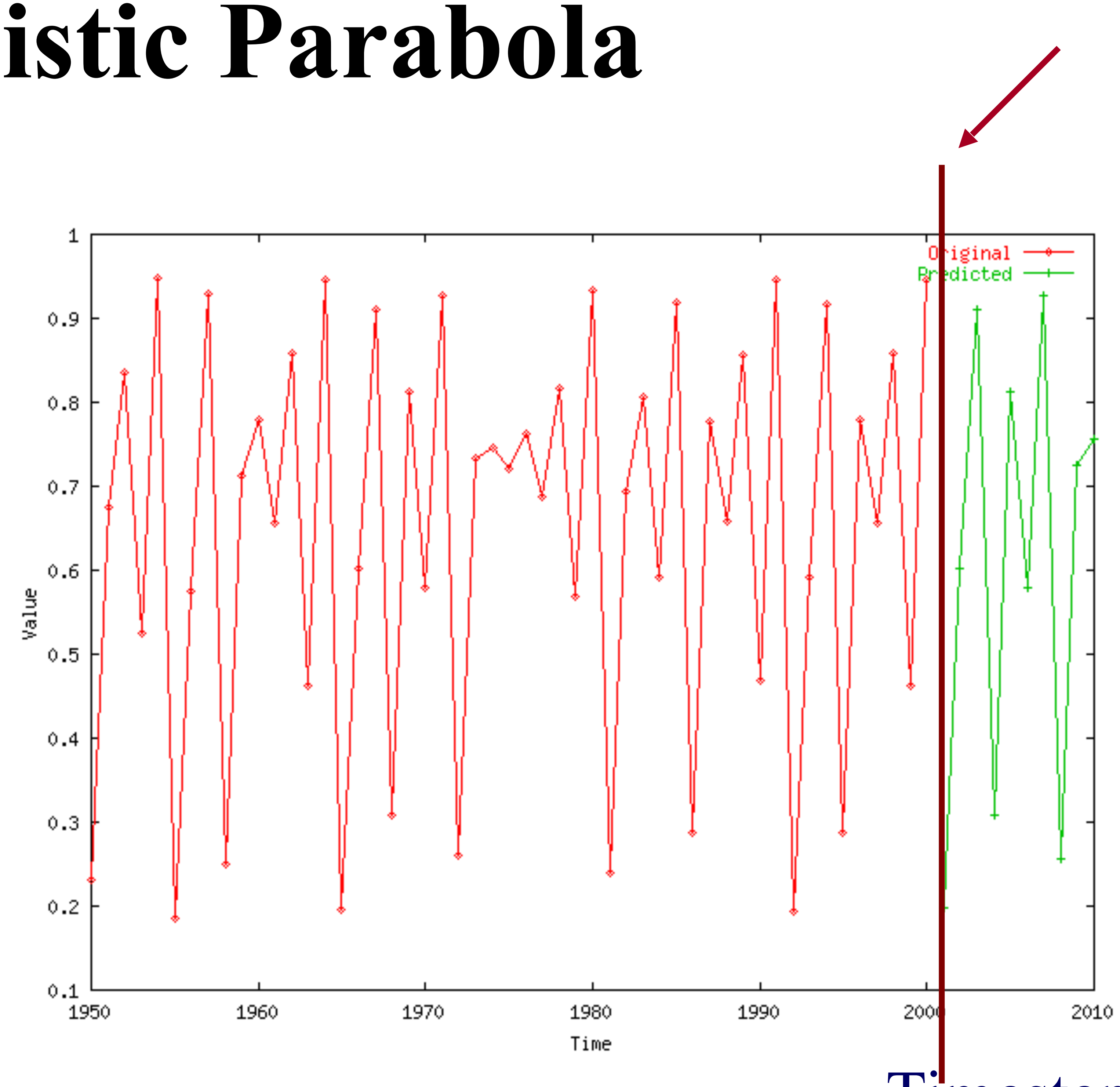
Logistic Parabola

Our Prediction from here

Value

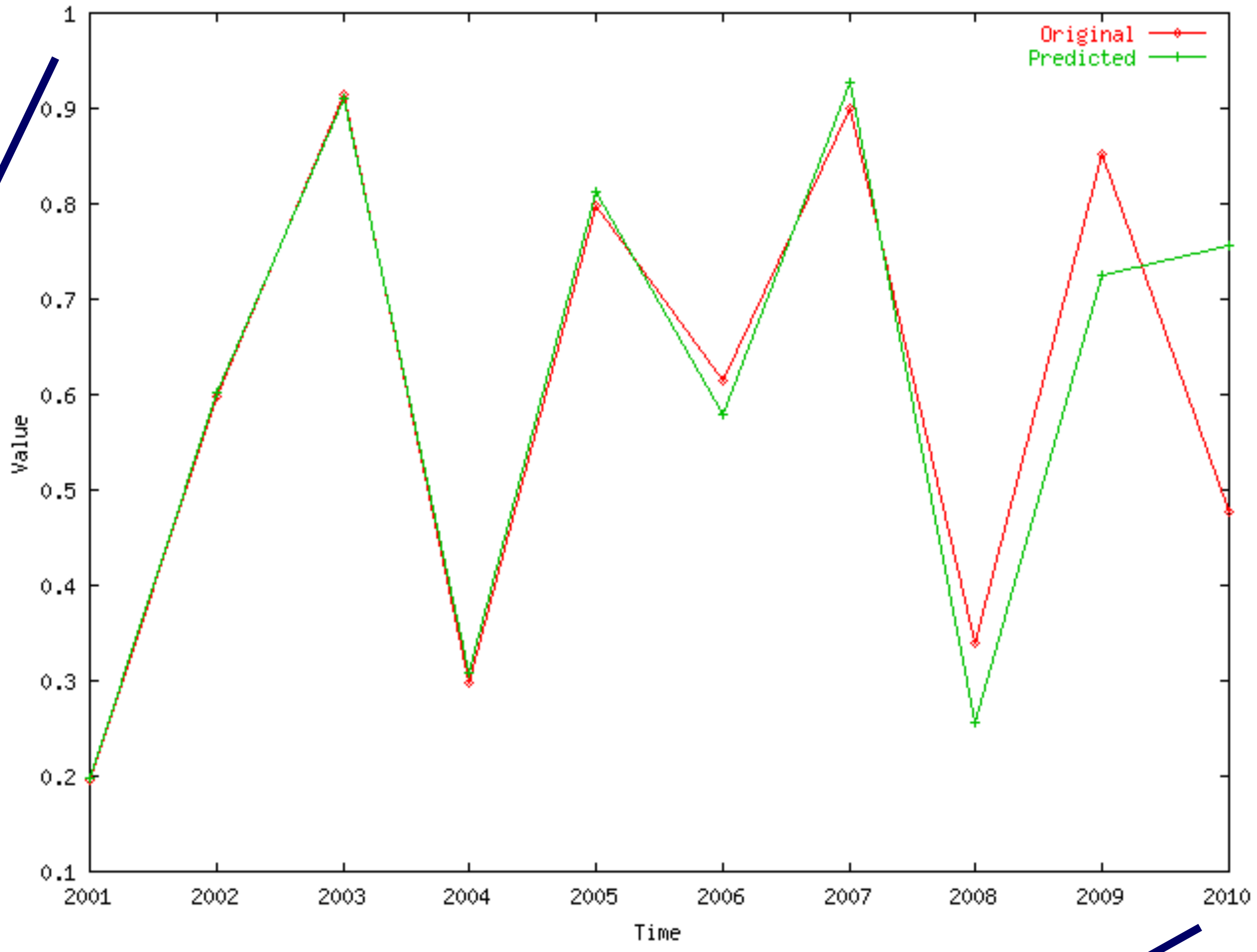


Timesteps

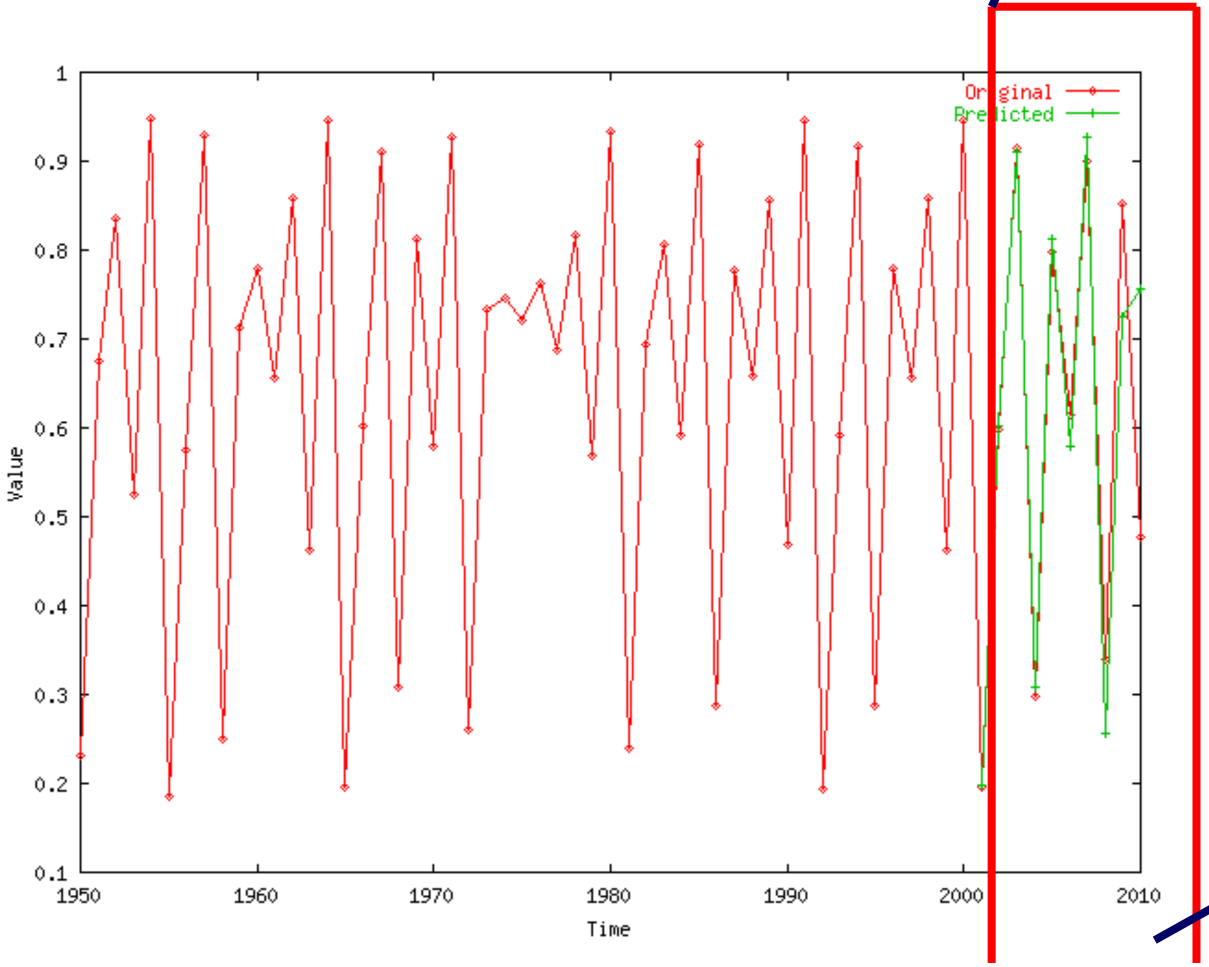
Value

Logistic Parabola

Comparison of prediction to correct values



Timesteps



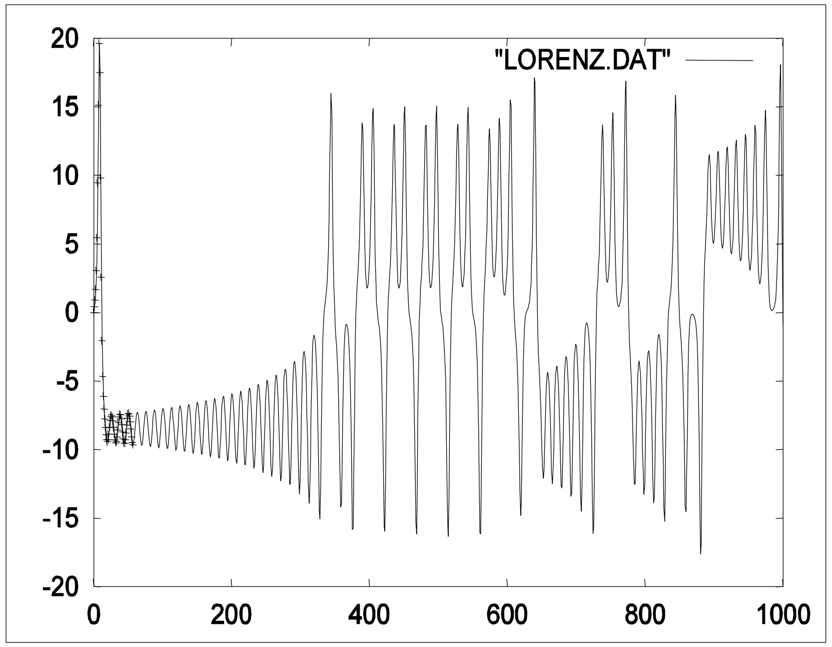
Datasets

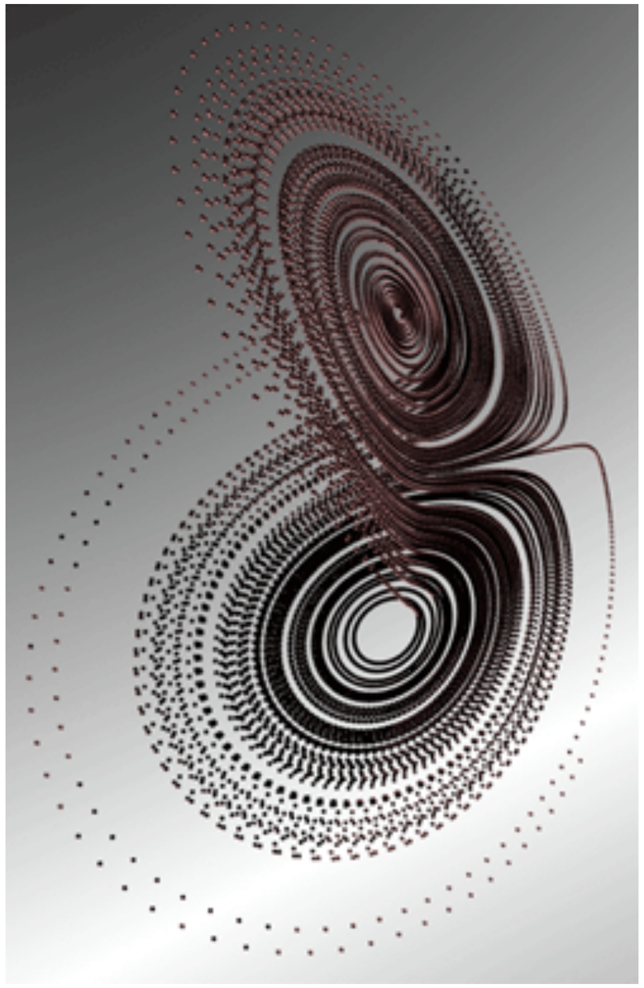
LORENZ: Models convection currents in the air

$dx / dt = a (y - x)$

$dy / dt = x (b - z) - y$

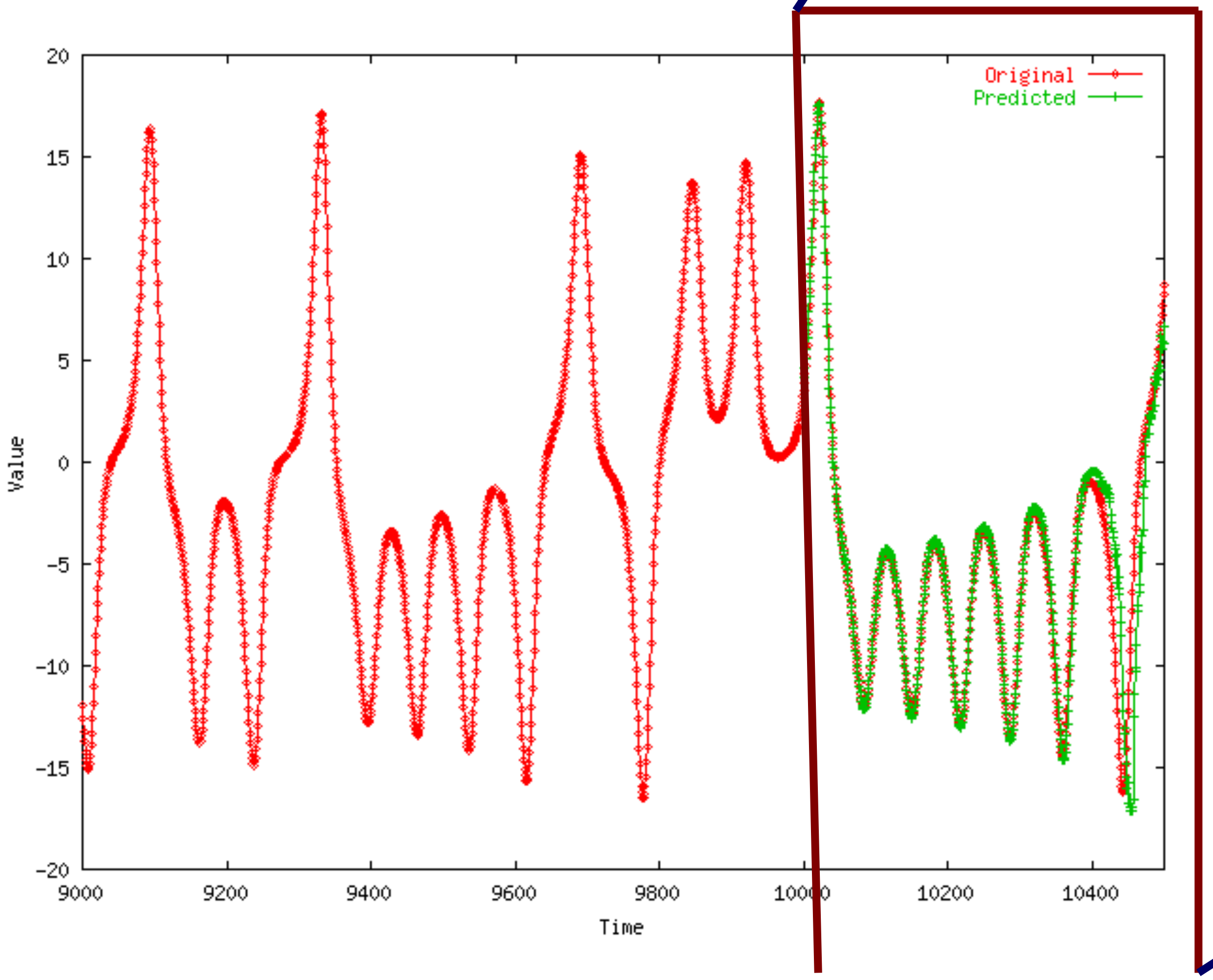
$dz / dt = xy - c z$



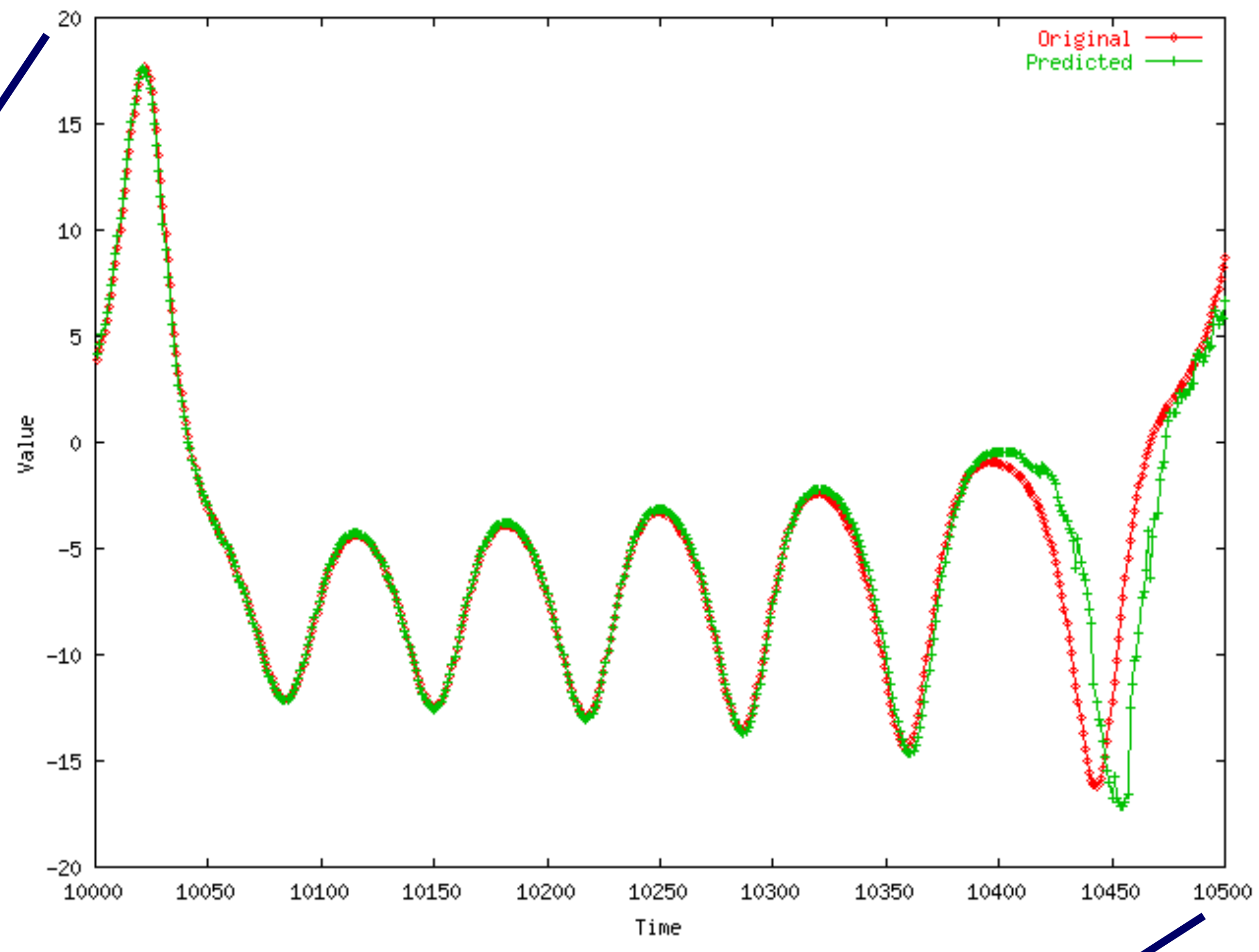


LORENZ

Comparison of prediction to correct values



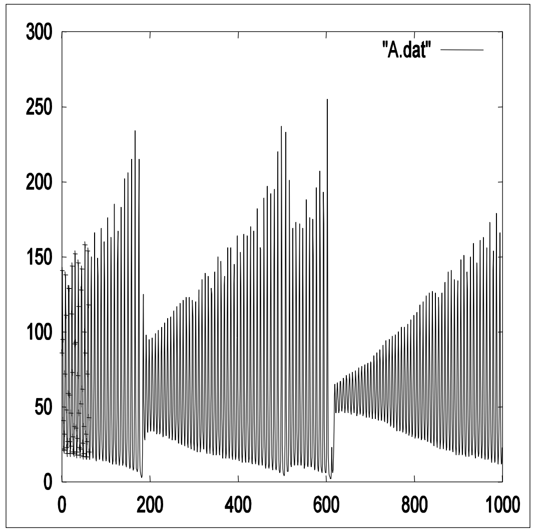
Value



Timesteps

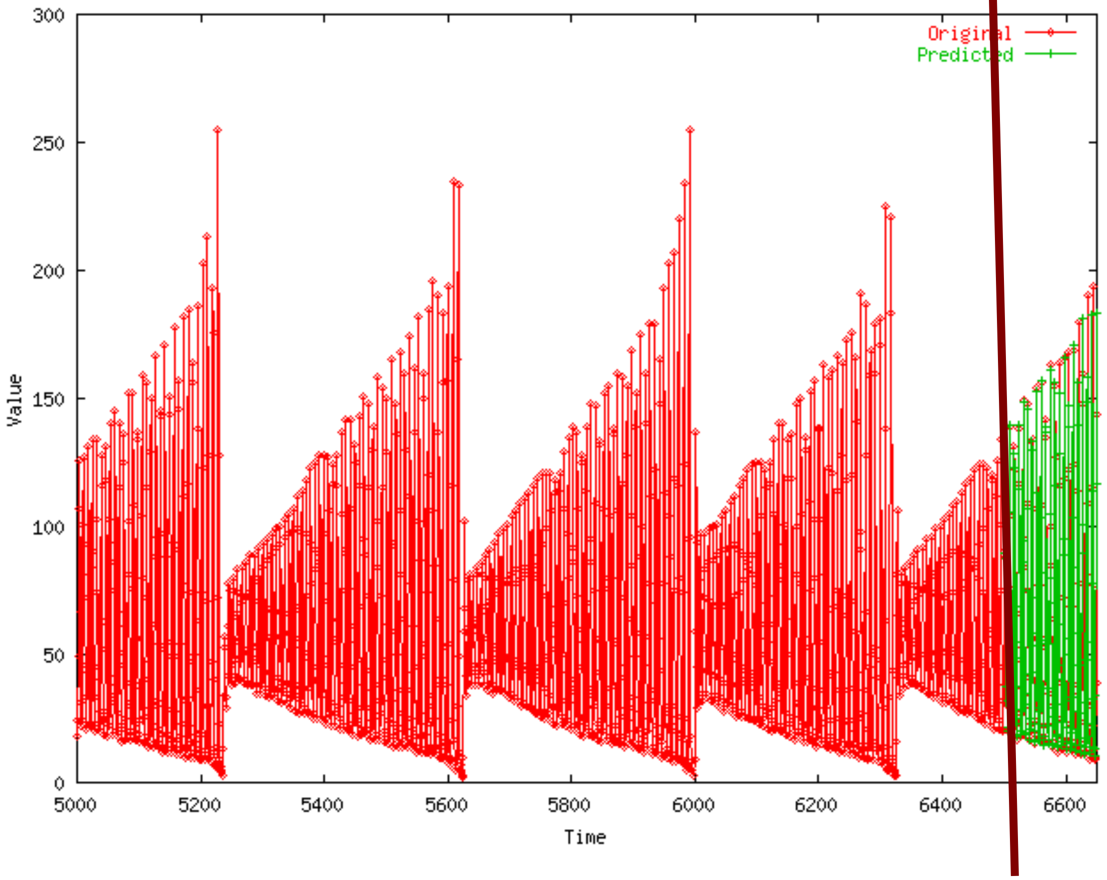
Datasets

- LASER: fluctuations in a Laser over time (used in Santa Fe competition)

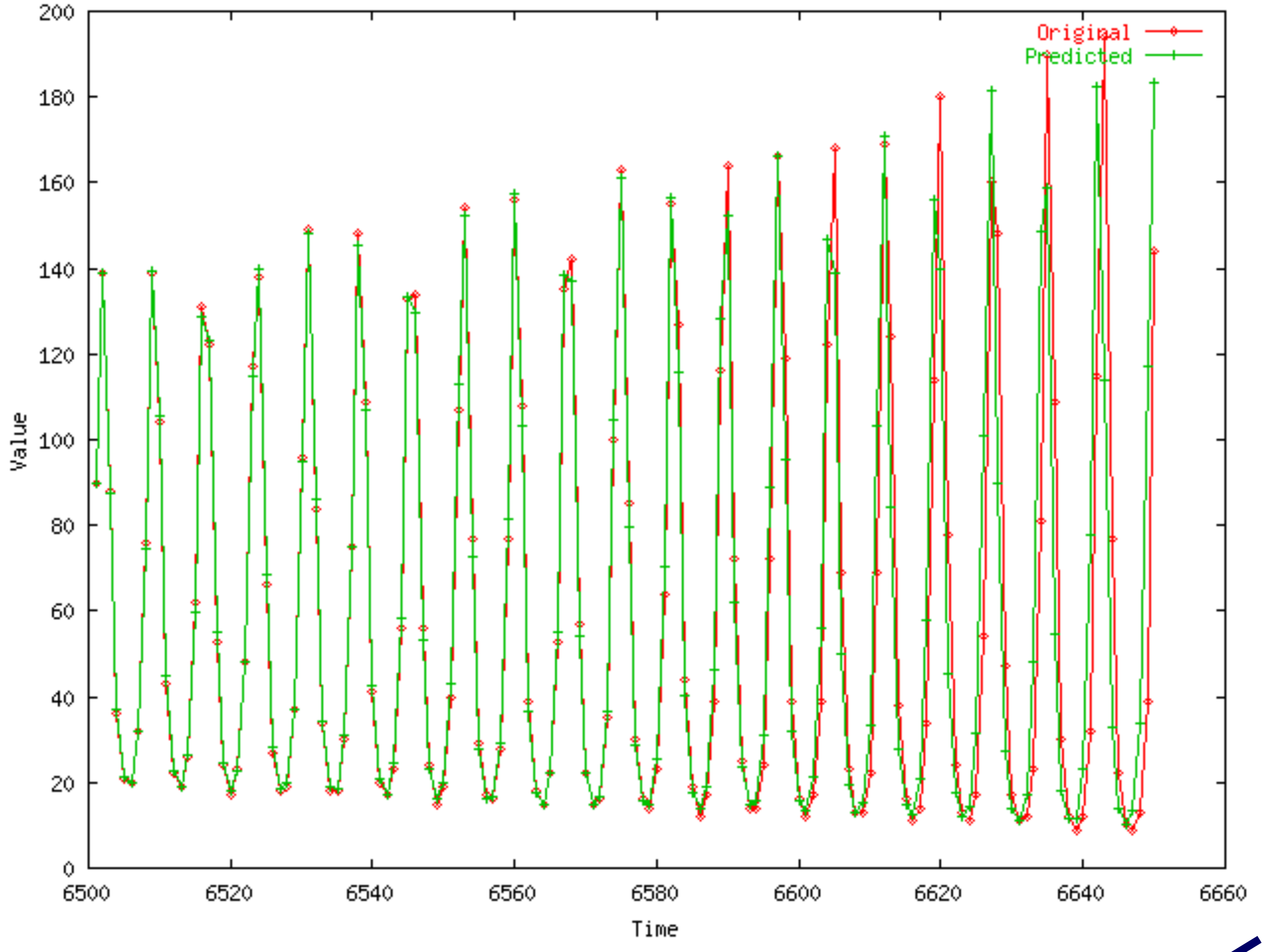


Laser

Comparison of prediction to correct values



Value



Timesteps

Conclusions

- Lag plots for non-linear forecasting (Takens' theorem)
- suitable for 'chaotic' signals

References

- Deepay Chakrabarti and Christos Faloutsos *F4: Large-Scale Automated Forecasting using Fractals* CIKM 2002, Washington DC, Nov. 2002.
- Sauer, T. (1994). *Time series prediction using delay coordinate embedding*. (in book by Weigend and Gershenfeld, below) Addison-Wesley.
- Takens, F. (1981). *Detecting strange attractors in fluid turbulence*. Dynamical Systems and Turbulence. Berlin: Springer-Verlag.

References

- Weigend, A. S. and N. A. Gerschenfeld (1994). *Time Series Prediction: Forecasting the Future and Understanding the Past*, Addison Wesley. (Excellent collection of papers on chaotic/non-linear forecasting, describing the algorithms behind the winners of the Santa Fe competition.)

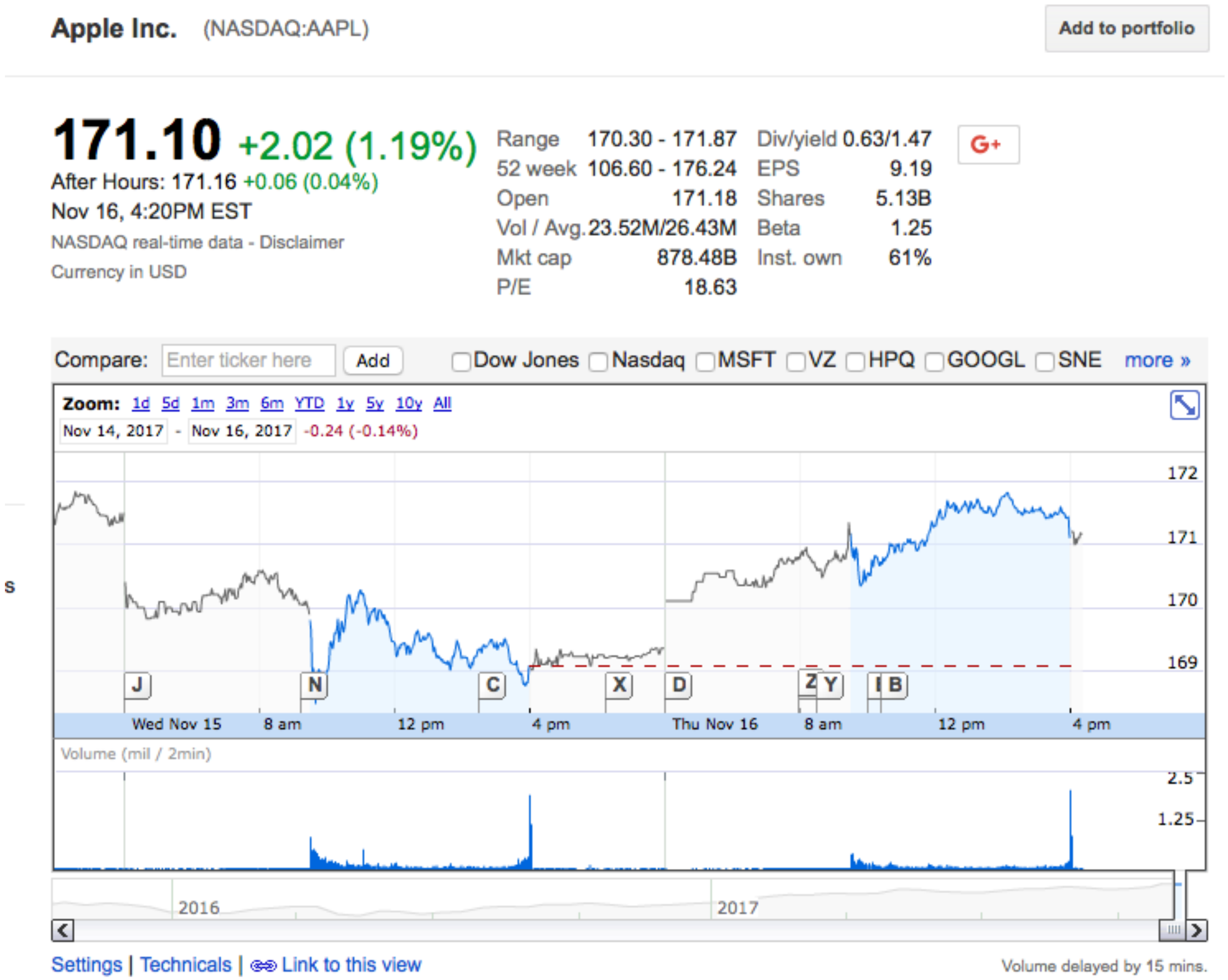
Overall conclusions

- Similarity search: **Euclidean**/time-warping; **feature extraction** and **SAMs**
- Linear Forecasting: **AR** (Box-Jenkins) methodology;
- Non-linear forecasting: **lag-plots** (Takens)

Must-Read Material

- Byong-Kee Yi, Nikolaos D. Sidiropoulos, Theodore Johnson, H.V. Jagadish, Christos Faloutsos and Alex Biliris, *Online Data Mining for Co-Evolving Time Sequences*, ICDE, Feb 2000.
- Chungmin Melvin Chen and Nick Roussopoulos, *Adaptive Selectivity Estimation Using Query Feedbacks*, SIGMOD 1994

Time Series Visualization + Applications



Apple Inc. (NASDAQ:AAPL)

171.10 +2.02 (1.19%)

After Hours: 171.16 +0.06 (0.04%)

Nov 16, 4:20PM EST

NASDAQ real-time data - Disclaimer

Currency in USD

Range	170.30 - 171.87	Div/yield	0.63/1.47
52 week	106.60 - 176.24	EPS	9.19
Open	171.18	Shares	5.13B
Vol / Avg.	23.52M/26.43M	Beta	1.25
Mkt cap	878.48B	Inst. own	61%
P/E	18.63		

Nov 14, 2017 - Nov 16, 2017 -0.24 (-0.14%)

Volume delayed by 15 mins.

How to build time series visualization?

Easy way: use existing tools, libraries

- **Google Public Data Explorer** (Gapminder)
  http://goo.gl/HmrH
- **Google acquired Gapminder**

  http://goo.gl/43avY

  (Hans Rosling's **TED talk** http://goo.gl/tKV7)
- **Google Annotated Time Line**
  http://goo.gl/Upm5W
- **Timeline**, from MIT's SIMILE project
  http://simile-widgets.org/timeline/
- **Timeplot**, also from SIMILE
  http://simile-widgets.org/timeplot/
- **Excel,** of course

How to build time series visualization?

The harder way:

- Cross filter. http://square.github.io/crossfilter/
- R (ggplot2)
- Matlab
- gnuplot
- **seaborn** https://seaborn.pydata.org

The even harder way:

- D3, for web
- JFreeChart (Java)
- ...

Time Series Visualization

Why is it useful?

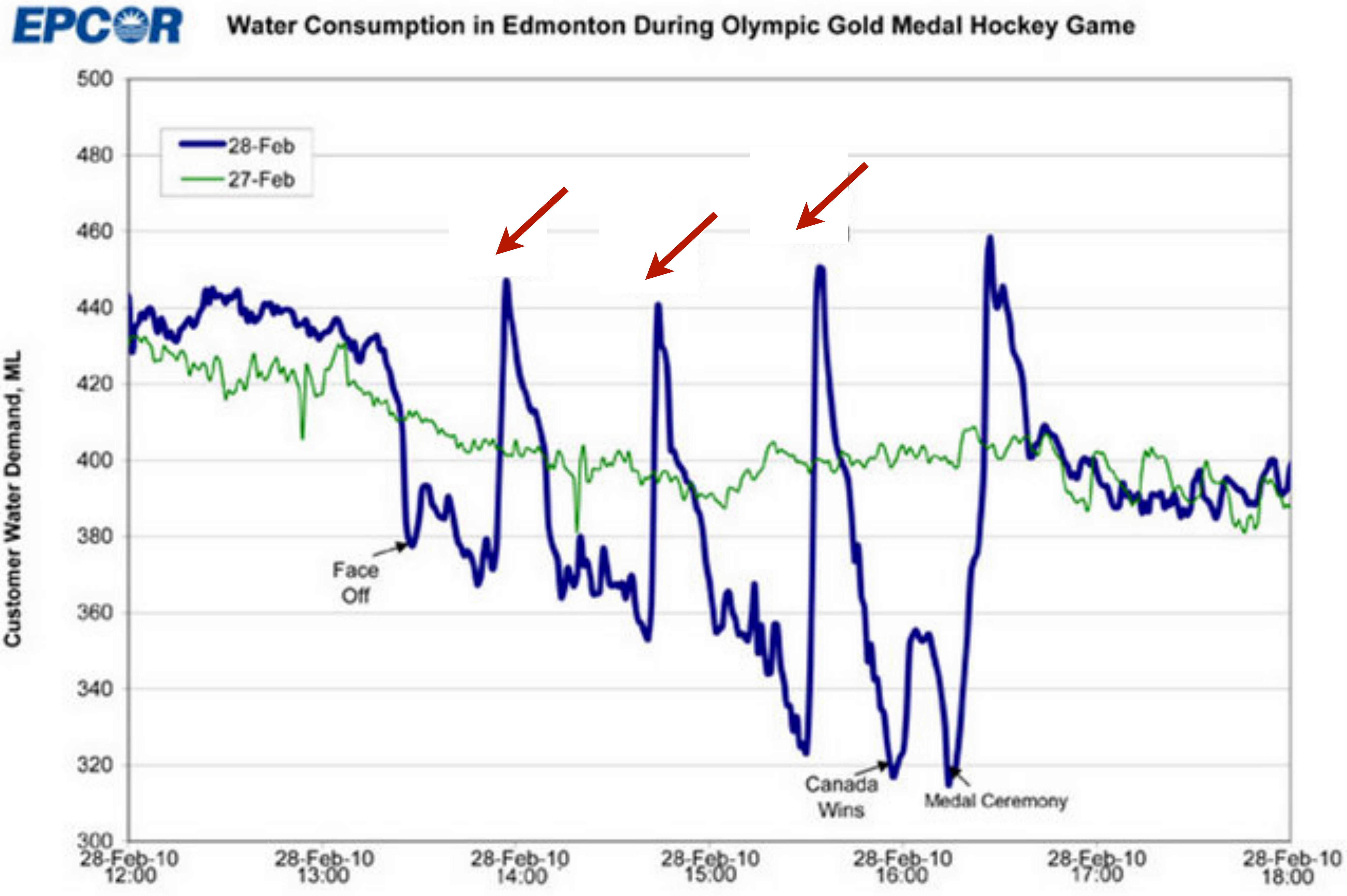
When is visualization useful?

(Why not automate everything? Like using the forecasting techniques you learned last time.)

Time Series User Tasks

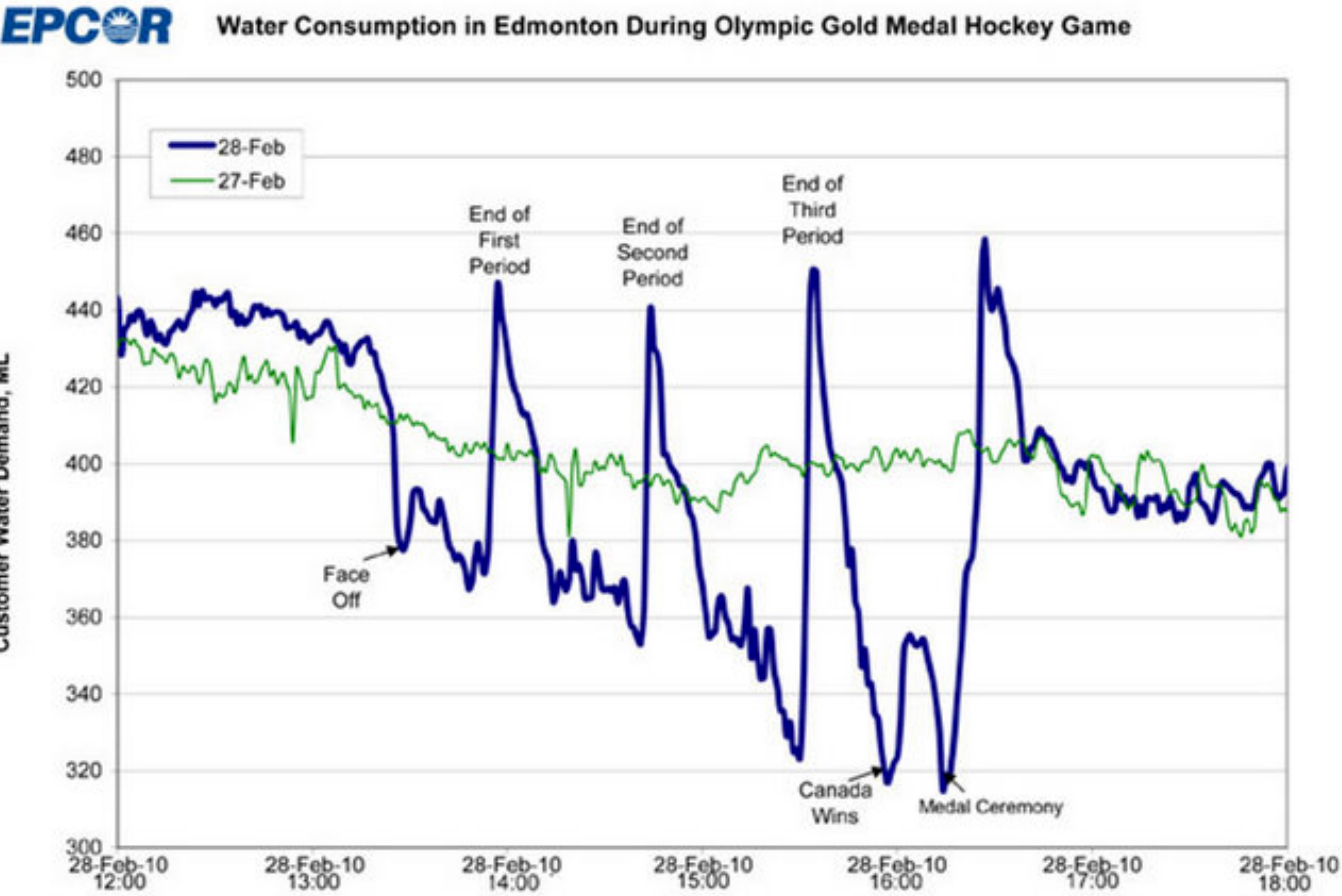
- When was something greatest/least?
- Is there a pattern?
- Are two series similar?
- Do any of the series match a pattern?
- Provide simpler, faster access to the series
- Does data element exist at time t ?
- When does a data element exist?
- How long does a data element exist?
- How often does a data element occur?
- How fast are data elements changing?
- In what order do data elements appear?
- Do data elements exist together?

Muller & Schumann 03
citing MacEachern 95



Water Consumption in Edmonton During Olympic Gold Medal Hockey Game

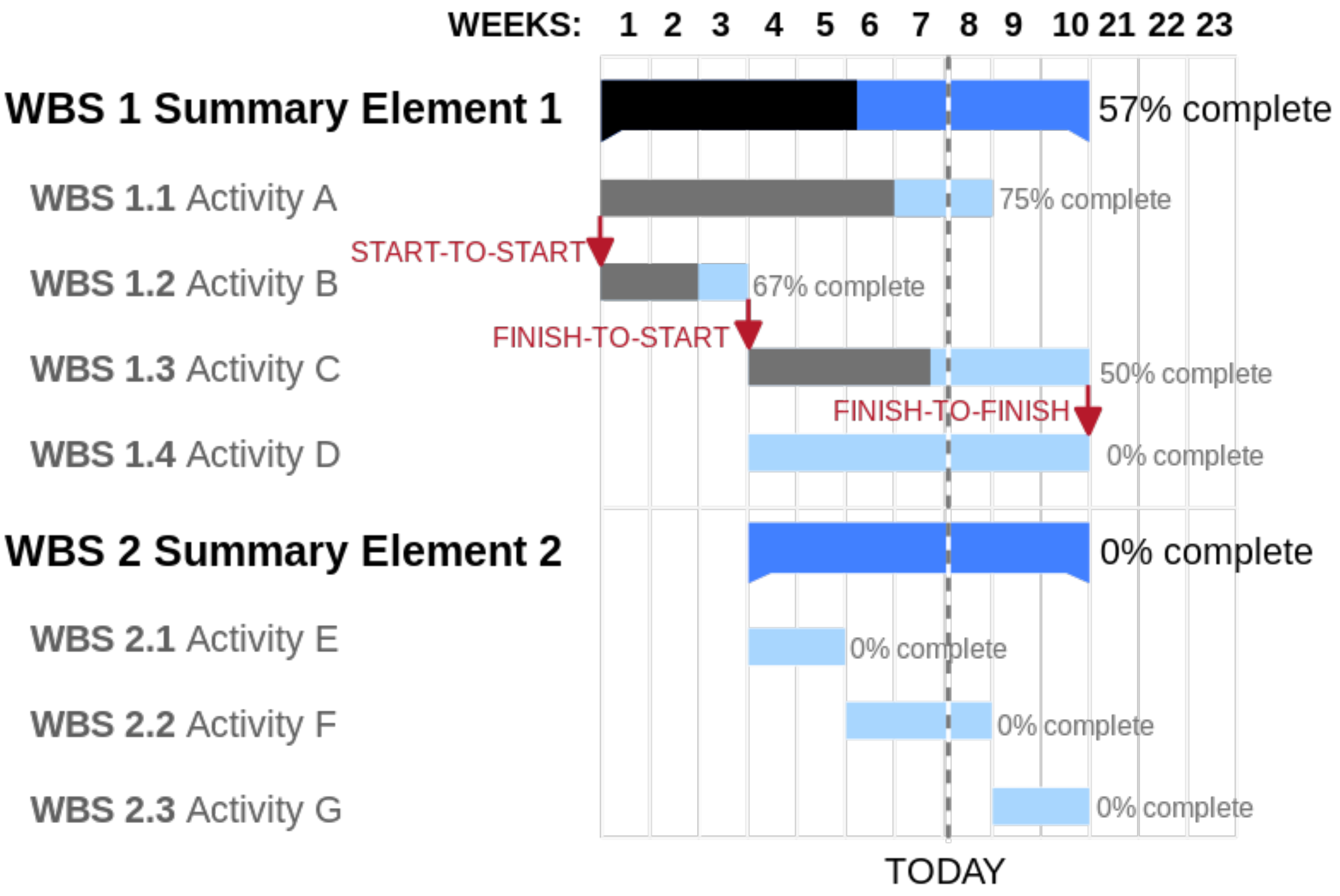
http://www.patspapers.com/blog/item/what_if_everybody_flushed_at_once_Edmonton_water_gold_medal_hockey_game/



http://www.patspapers.com/blog/item/what_if_everybody_flushed_at_once_Edmonton_water_gold_medal_hockey_game/

Gantt Chart

Useful for project



How to create in Excel:

http://www.youtube.com/watch?v=sA67g6zaKOE

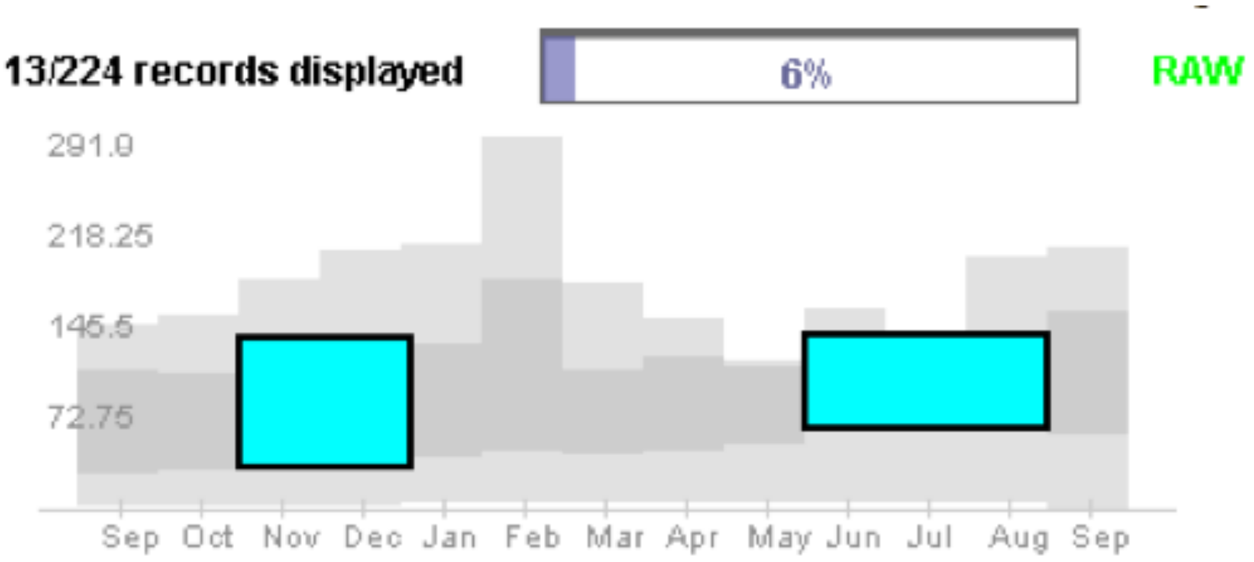
ThemeRiver
Stacked graph
Streamgraph

http://www.nytimes.com/interactive/2008/02/23/movies/20080223_REVENUE_GRAPHIC.html

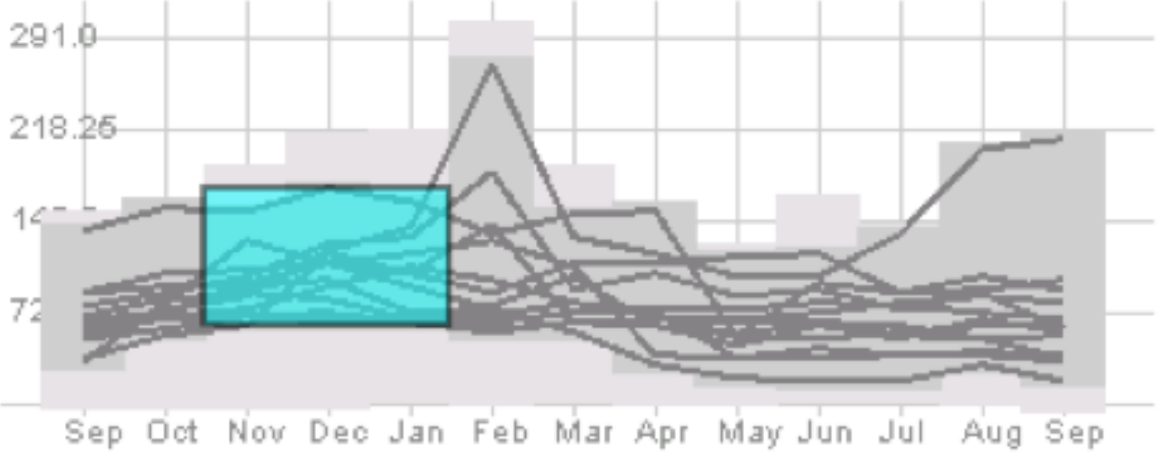
https://github.com/mbostock/d3/wiki/Stack-Layout

TimeSearcher

support queries



Can create rectangles that function as matching regions



Light gray is all data's extent

Darker grayed region is data envelope that shows extreme values of queries matching criteria

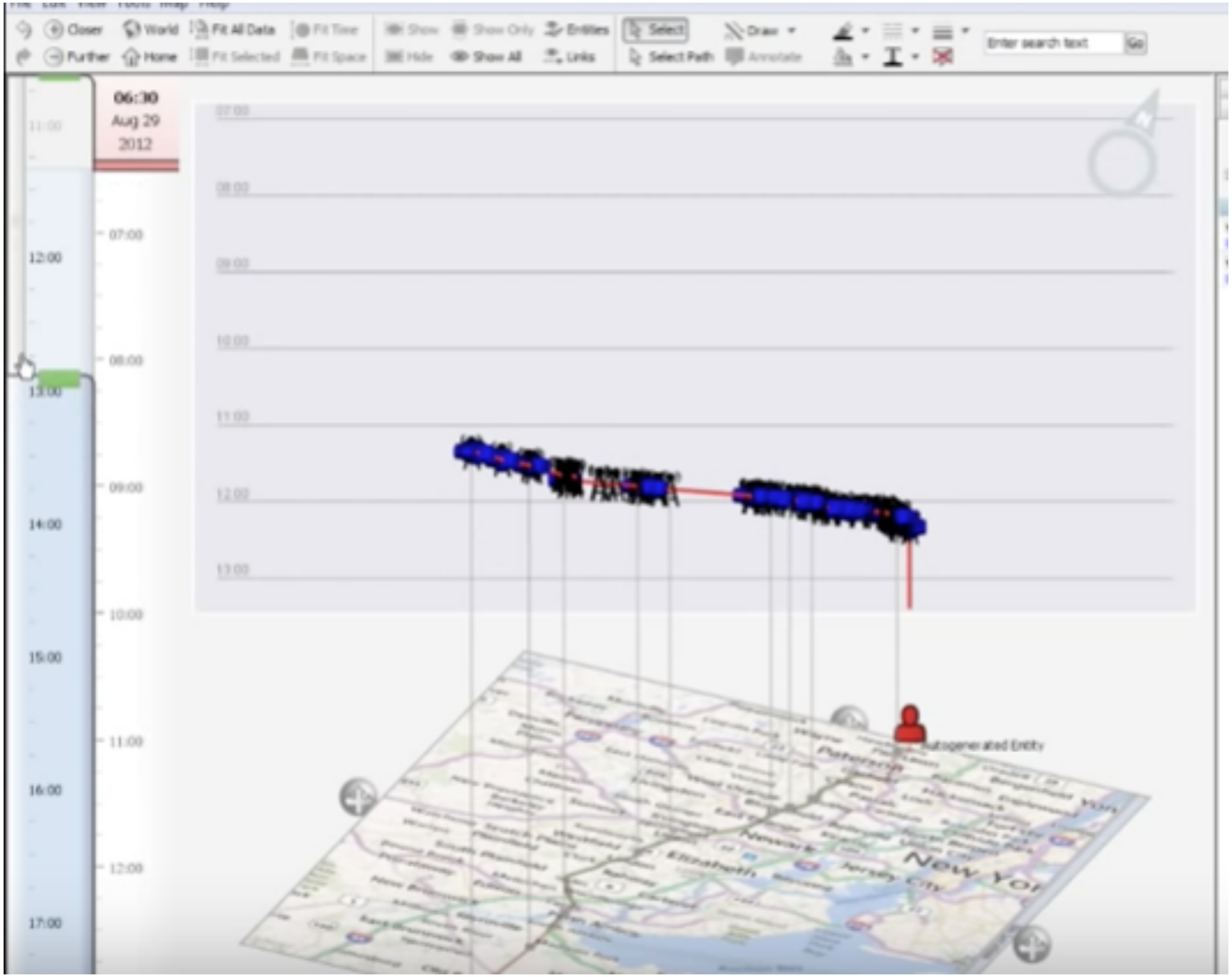
Multiple boxes are "anded"

Hochheiser & Shneiderman
Proc. Discovery Science '01

http://hcil2.cs.umd.edu/video/2005/2005_timesearcher2.mpg

GeoTime

Infovis 2004



https://youtu.be/inkF86QJBdA?t=2m51s

http://vadl.cc.gatech.edu/documents/55_Wright_KaplerWright_GeoTime_InfoViz_Jrnl_05_send.pdf