Building A Crystal Ball:

Forecasting Future Values For Multi-cyclic Time Series Metrics In Splunk

Mike Fisher

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About Me

- Splunk user/administrator for 7 years
- Work for a Fortune 100 financial firm
- Currently leading a Monitoring and Operational Intelligence team
- I was **not** a Statistics major in college!

Agenda

- The Problem
- Existing Tools
- Finding A Better Way
- Implementation
- Results
- Caveats
- Questions

The Problem

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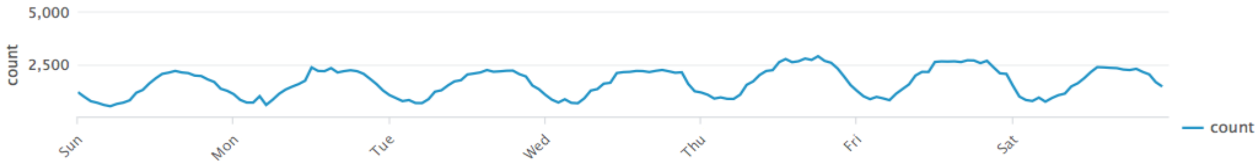
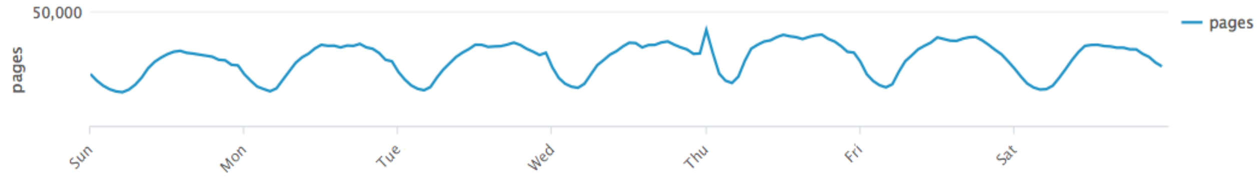
Many Time Series Contain Cyclic Patterns

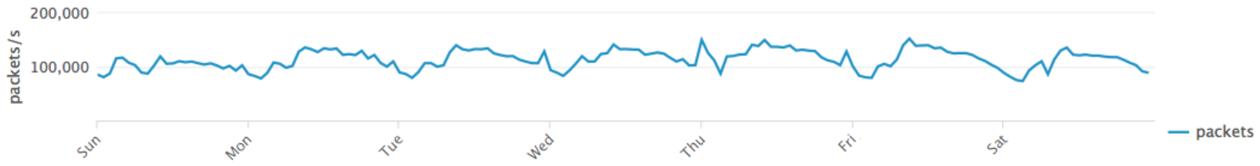
- Sales per hour



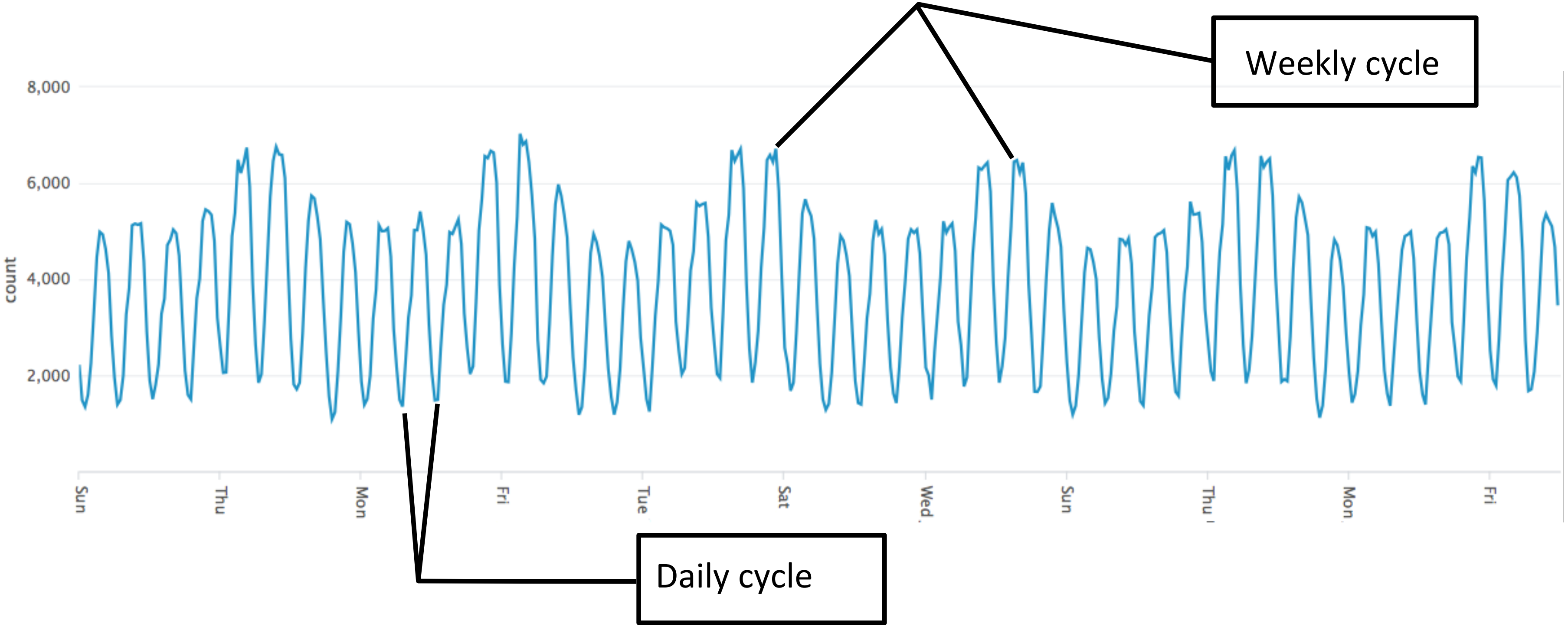
- Web page hits



- Network traffic



Some Have Multiple Concurrent Cycles



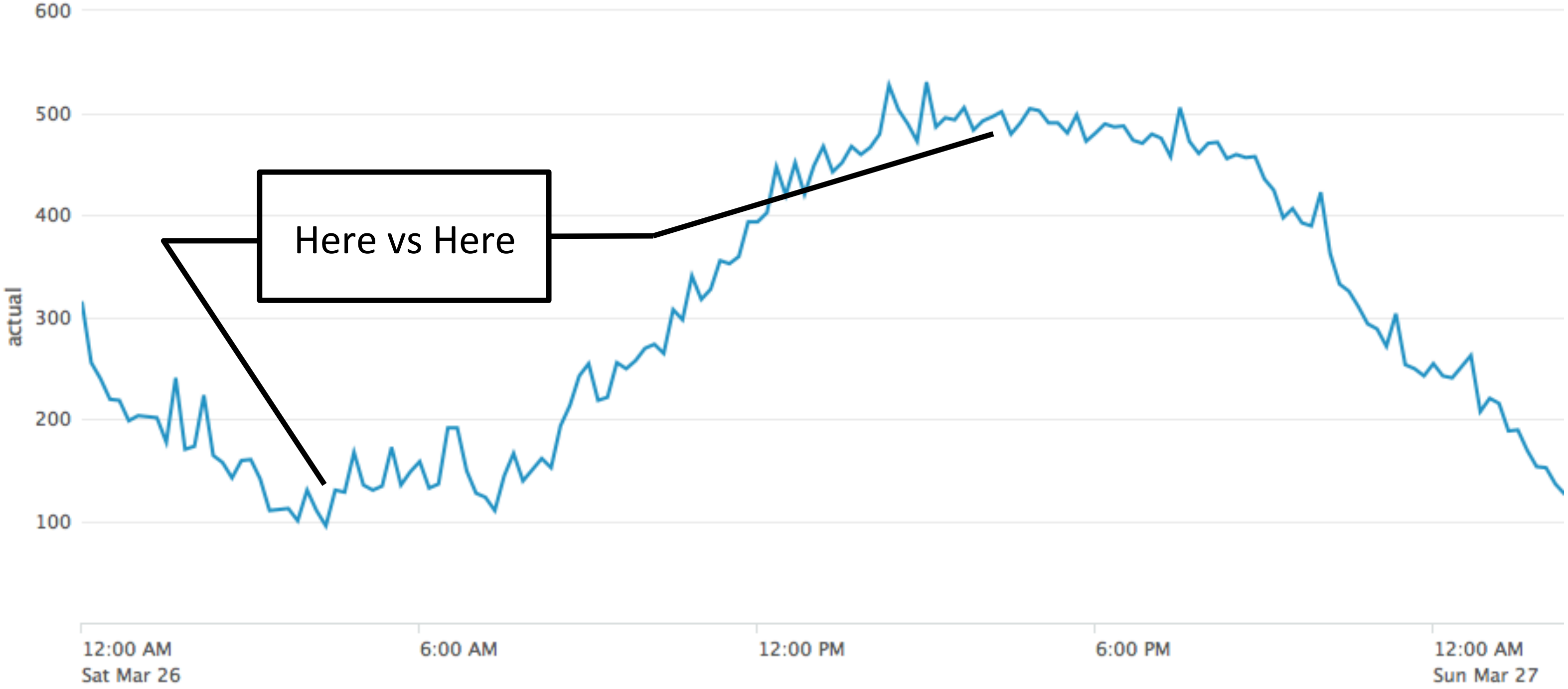
Weekly cycle

Daily cycle

How Do We Know What’s Normal?

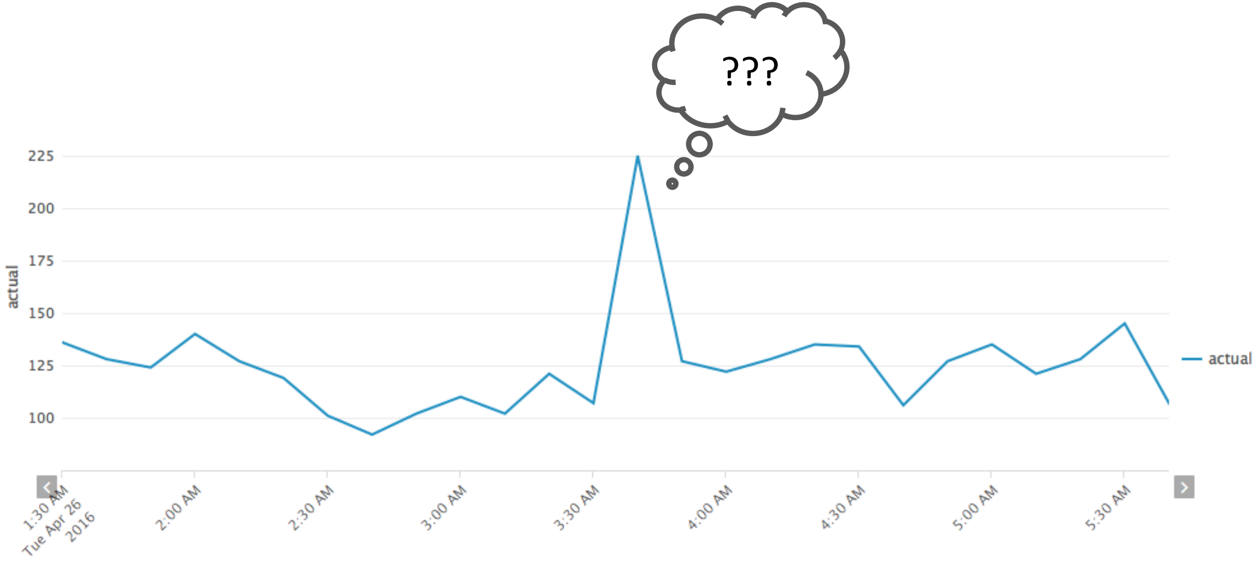
- **Sales per minute** - Are sales abnormally low right now?
- **Web page hits** - Is my web site experiencing high traffic?
- **Network traffic** - Is that spike in network traffic expected?

How Do We Set Alert Thresholds?



Here vs Here

How Do We Alert?



… if we don’t know what’s normal at any given time?

Existing Tools

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Splunk's predict() Command

- The `predict` command forecasts values for one or more sets of time-series data.

- Two algorithms that deal with seasonal data:

  LLP – Seasonal local level

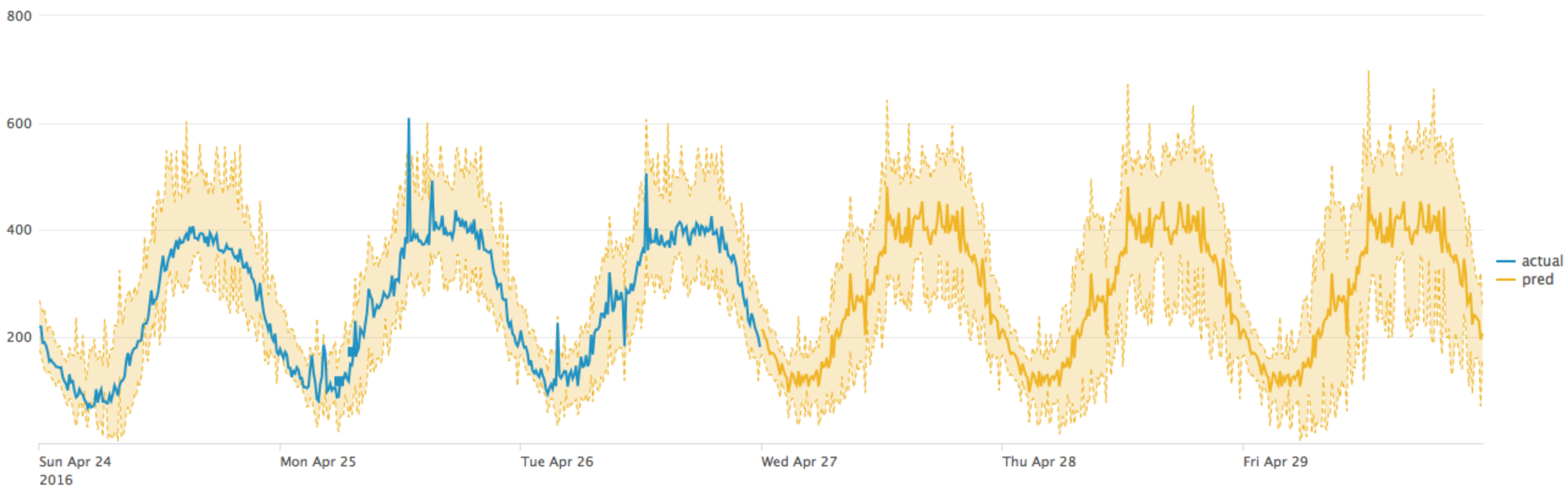
  LLP5 - Combines local level trend and seasonal local level

Al’s Online Toy Barn Sales

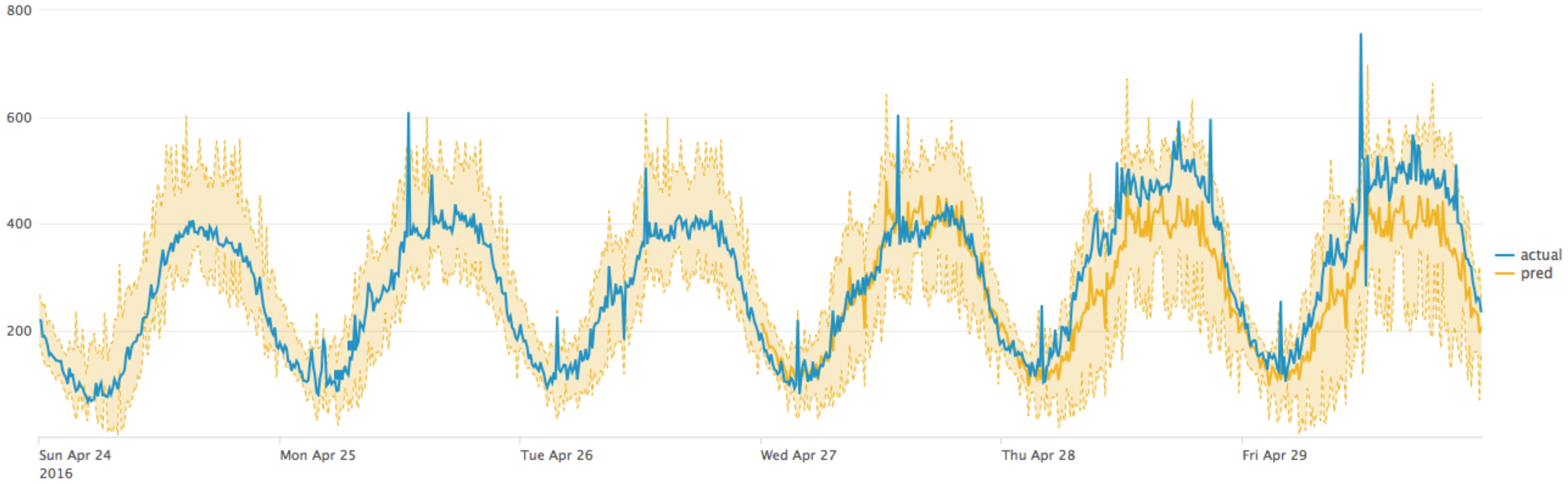
```
index=summary search_name= "Sales - Summary - 10 min count"
| timechart span=10m sum(count) as actual
| predict actual as pred algorithm=LLP upper90=high
  lower90=low future_timespan=432
```

Forecast Using LPP

5 weeks of data, 3 days of forecast, 90% confidence intervals

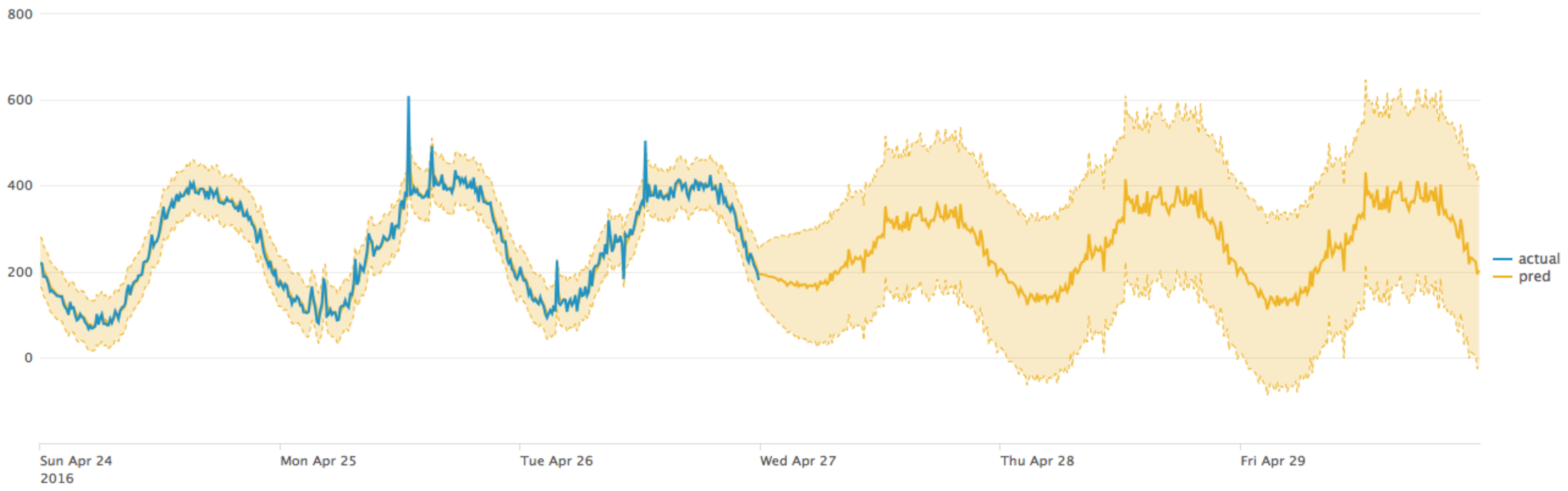


LLP Forecast vs Reality

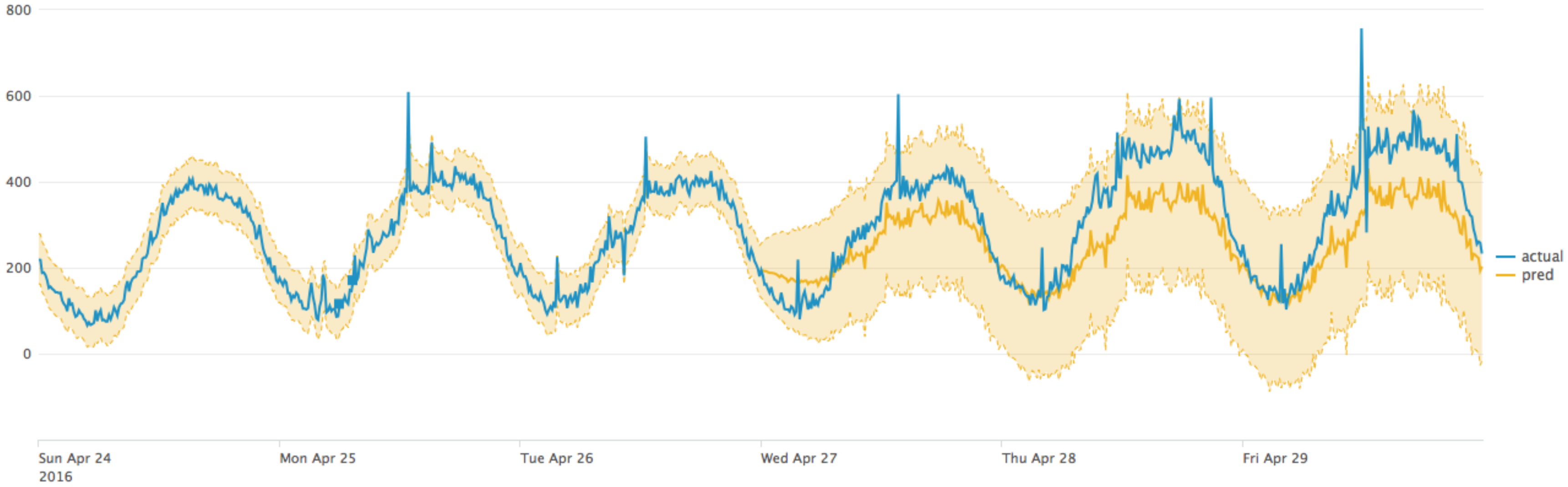


Forecast Using LPP5

5 weeks of data, 3 days of forecast, 90% confidence intervals



LLP Forecast vs Reality



The Future Is Fuzzy…

Finding A Better Way

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Requirements

Handle multi-cyclic time series

Fast

Efficient

Accurate

Reusable

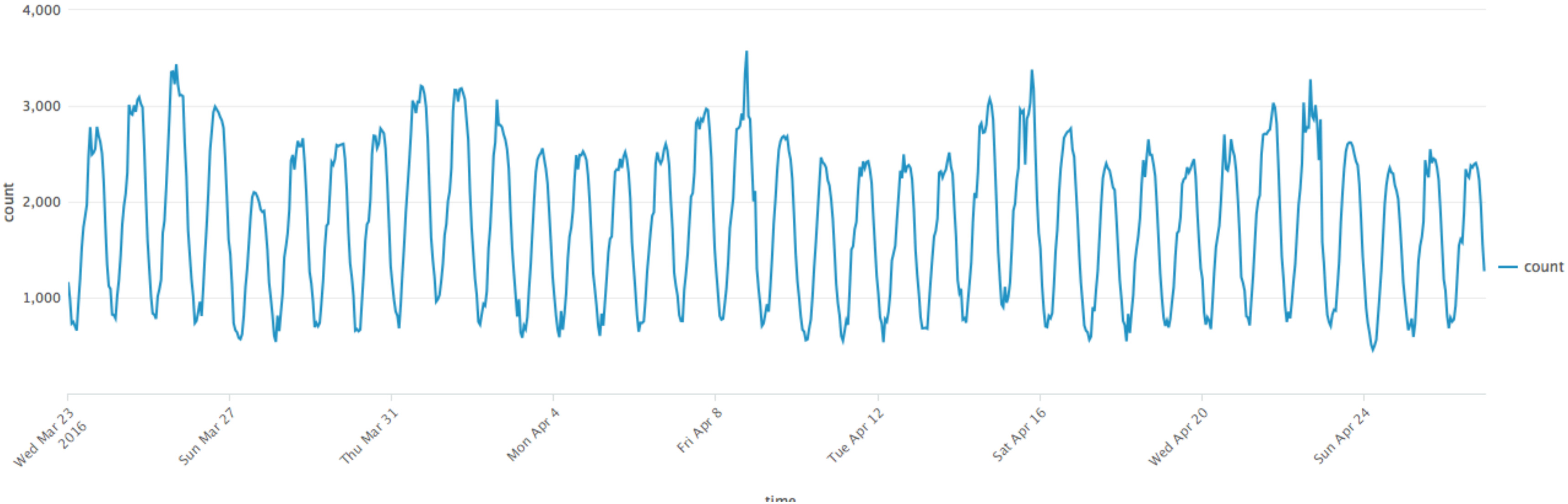
Predict The Future

…without hiring this guy

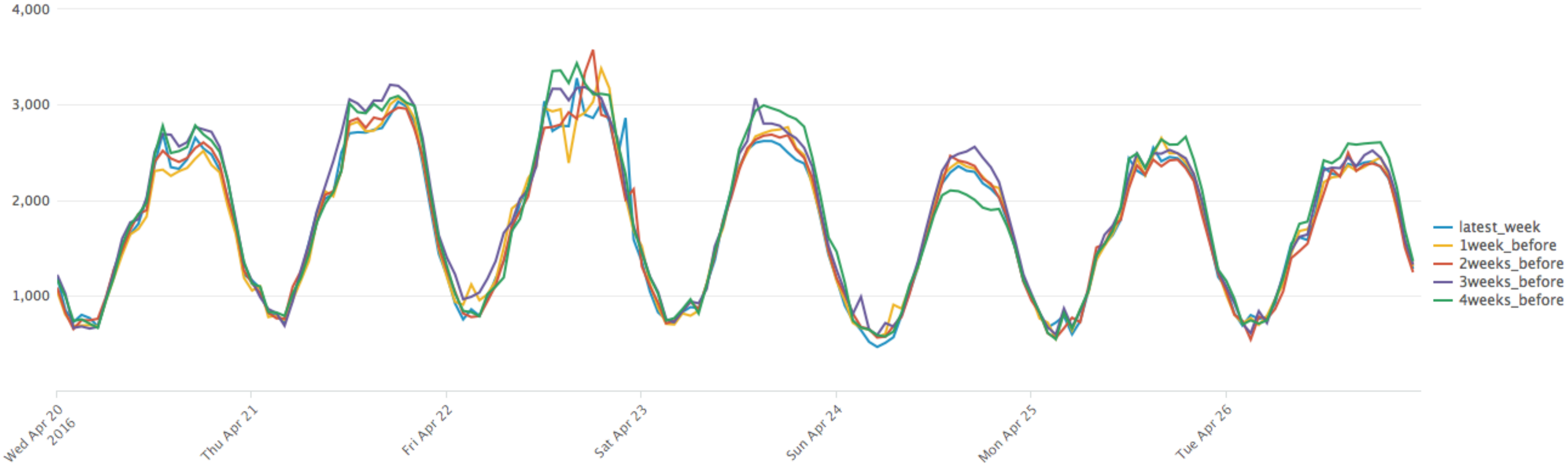
The Data

```
index=summary
search_name="Sales - Summary - 10 min count"
| timechart span=1h sum(count) as actual
```

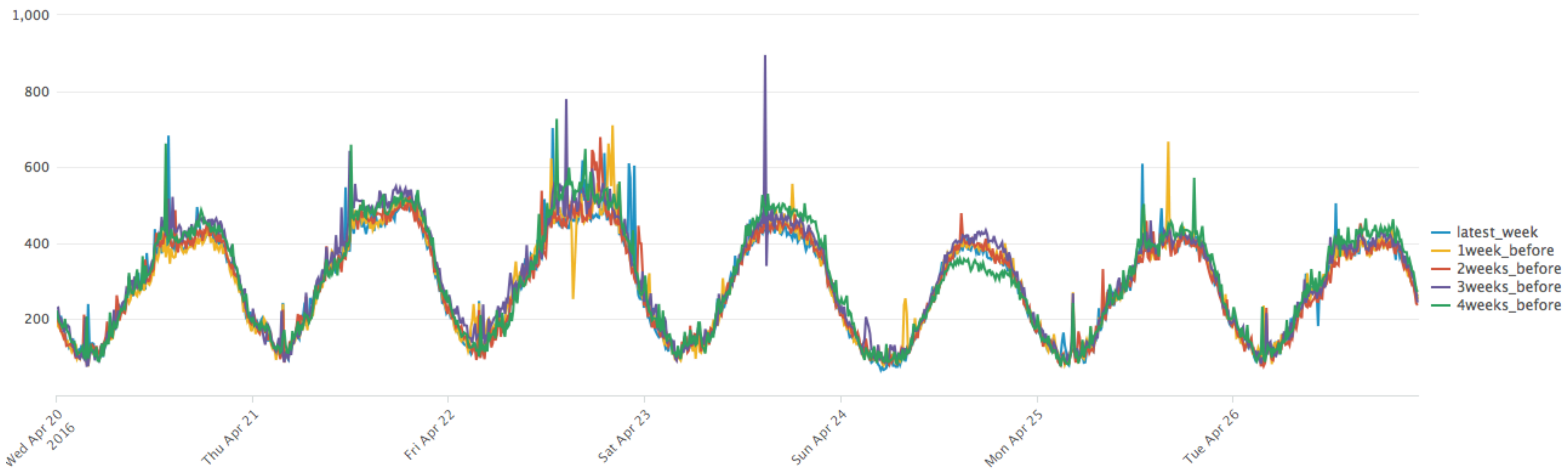
Al’s Online Toy Barn Sales



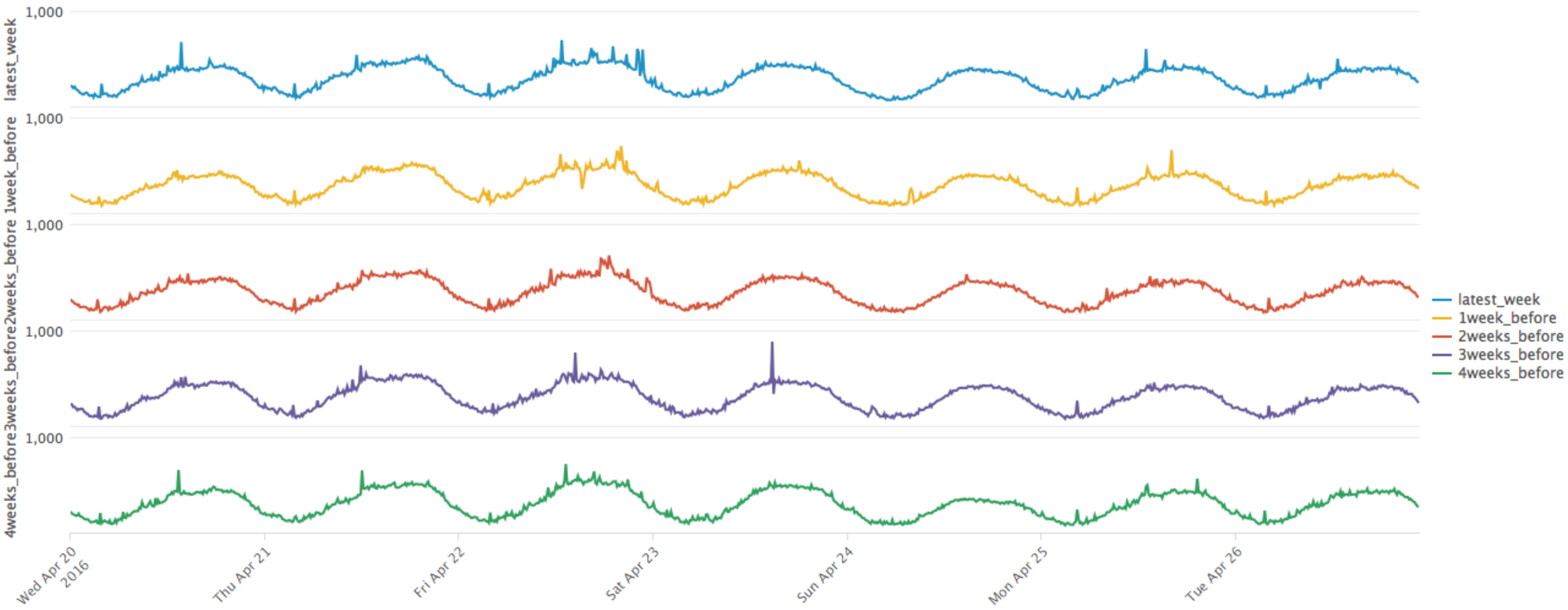
Week-over-week View



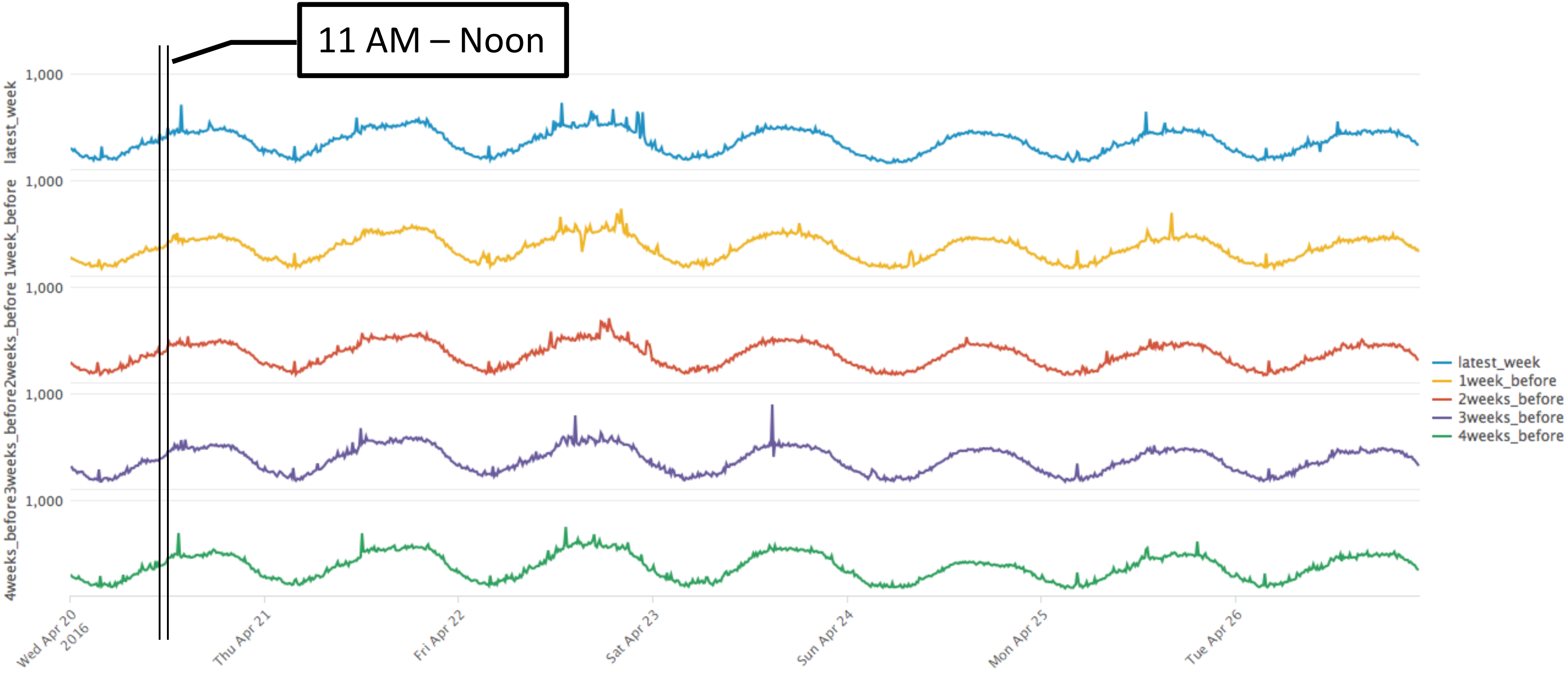
Week Over Week 10 Minute Resolution



Multi-Series View



Take A Slice of Time



The Slice in Numbers

	11:00	11:10	11:20	11:30	11:40	11:50	12:00
04/20/16	374	327	313	337	330	331	437
04/13/16	304	295	291	300	318	317	358
04/06/16	311	300	301	323	325	331	376
03/30/16	319	323	328	339	353	357	395
03/23/16	312	318	319	329	335	355	394

The Target

	11:00	11:10	11:20	11:30	11:40	11:50	12:00
04/27/16				???			
04/20/16	374	327	313	337	330	331	437
04/13/16	304	295	291	300	318	317	358
04/06/16	311	300	301	323	325	331	376
03/30/16	319	323	328	339	353	357	395
03/23/16	312	318	319	329	335	355	394

Average

	11:00	11:10	11:20	11:30	11:40	11:50	12:00
04/27/16				???			
04/20/16	374	327	313	337	330	331	437
04/13/16	304	295	291	300	318	317	358
04/06/16	311	300	301	323	325	331	376
03/30/16	319	323	328	339	353	357	395
03/23/16	312	318	319	329	335	355	394

Average = 333.57

Standard Deviation = 31.66

High and Low Bounds

$$prediction = average$$

$$bounds = prediction \pm stdev * \sqrt{1}/1 - confidence/100$$

High and Low Bounds

Average = 333.57
Standard deviation = 31.65

predicted = average

bounds = predicted +/- stdev * (sqrt(1/(1-confidence/100)))

low = 333.57 – 31.65 * (sqrt(1/(1-90/100))) = 233.46
high = 333.57 + 31.65 * (sqrt(1/(1-90/100))) = 433.68

How’d We Do?

Predicted = 333.57

Low bound = 233.46

High bound = 433.68

Apr 27 11:30 actual = 318

Implementation

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So….. How Do We Do That In Splunk?

Simple.

Just build a macro.

forecast5w(val,confidence,reltime,days)

```
eval w=case(
  (_time>relative_time(now(), "$reltime$@d-5w-30m") AND _time<=relative_time(now(), "$reltime$@d-5w+$days$d+30m")), 5,
  (_time>relative_time(now(), "$reltime$@d-4w-30m") AND _time<=relative_time(now(), "$reltime$@d-4w+$days$d+30m")), 4,
  (_time>relative_time(now(), "$reltime$@d-3w-30m") AND _time<=relative_time(now(), "$reltime$@d-3w+$days$d+30m")), 3,
  (_time>relative_time(now(), "$reltime$@d-2w-30m") AND _time<=relative_time(now(), "$reltime$@d-2w+$days$d+30m")), 2,
  (_time>relative_time(now(), "$reltime$@d-1w-30m") AND _time<=relative_time(now(), "$reltime$@d-1w+$days$d+30m")), 1 )
| eval shift=case(isnotnull(w), "+"+w+"w-30m +"+w+"w-20m +"+w+"w-10m +"+w+"w-0m +"+w+"w+10m +"+w+"w+20m +"+w+"w+30m")
| where isnotnull(shift)
| makemv shift
| mvexpand shift
| eval time=relative_time(_time, shift)
| eventstats avg($val$) as pred by time
| eval upper=if($val$>pred,$val$,pred)
| eval lower=if($val$<pred,$val$,pred)
| stats avg($val$) as pred, stdev(upper) as ustdev, stdev(lower) as lstdev by time
| eval low=pred-lstdev*(sqrt(1/(1-$confidence$/100)))
| eval low=if(low<0, 0, low)
| eval high=pred+ustdev*(sqrt(1/(1-$confidence$/100)))
| eval _time=time
| timechart span=10m min(pred) as pred, min(low) as low, min(high) as high
| where _time>relative_time(now(), "$reltime$@d") AND _time<=relative_time(now(), "$reltime$+$days$d@d")
```

Any Questions?

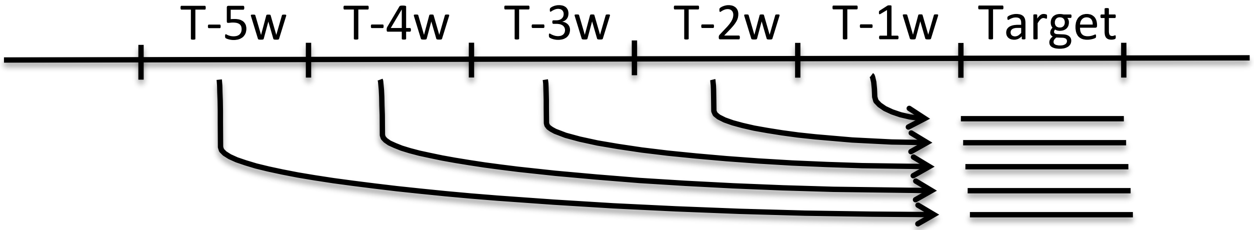
How Do We Do That In Splunk, Really?

Short answer:

Time travel and cloning

Time Travel

Shift data points from prior weeks forward in time to where they are needed.



Cloning

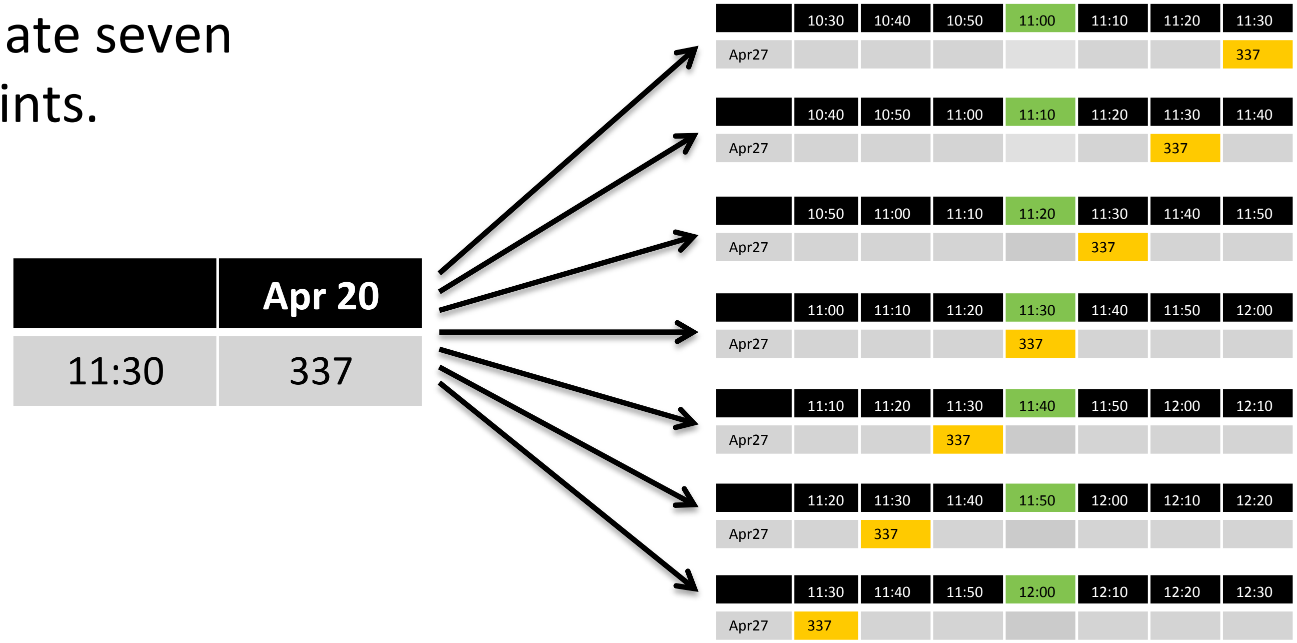
Each data point will be used seven times as the forecast window slides by.

Forecast window

	10:30	10:40	10:50	11:00	11:10	11:20	11:30	11:40	11:50	12:00	12:10	12:20	12:30
Apr20							337						

Cloning

Duplicate each data point so it can be used to calculate seven different forecast points.



	Apr 20
11:30	337

	10:30	10:40	10:50	11:00	11:10	11:20	11:30
Apr27							337

	10:40	10:50	11:00	11:10	11:20	11:30	11:40
Apr27						337	

	10:50	11:00	11:10	11:20	11:30	11:40	11:50
Apr27					337		

	11:00	11:10	11:20	11:30	11:40	11:50	12:00
Apr27				337			

	11:10	11:20	11:30	11:40	11:50	12:00	12:10
Apr27			337				

	11:20	11:30	11:40	11:50	12:00	12:10	12:20
Apr27		337					

	11:30	11:40	11:50	12:00	12:10	12:20	12:30
Apr27	337						

But How Do We Do That In Splunk?

- Use relative_time() to calculate the time shifts.

- Use makemv and mvexpand to duplicate data.

Take Timechart Output As Our Input

```
index=summary search_name="Sales - Summary - 10 min count"
| timechart span=10m sum(count) as actual
| `forecast5w(actual,90,+1d,1)`
```

Arguments To The Macro

val - The name of the field to forecast

$confidence$ - A number, 0 < N < 100, that determines the width of the bounds

$reltime$ - Start time of the forecast relative to current time

$days$ - How many days to forecast

Only Shift The Data We Need

Example, for five weeks ago:

```
_time  >relative_time(now(), "$reltime$@d-5w-30m")
AND
_time <= relative_time(now(), "$reltime$@d-5w+$days$d+30m")
```

Computing the Time Jump

For each week of data:

Compute shifts needed to move the data to seven locations needed for the forecast.

For example: to shift from five weeks ago to the target week

```
$reltime$+5w-30m,
$reltime$+5w-20m,
$reltime$+5w-10m,
$reltime$+5w-0m,
$reltime$+5w+10m,
$reltime$+5w+20m,
$reltime$+5w+30m
```

The Full Shift

```
eval w=case(
        (_time>relative_time(now(), "$reltime$@d-5w-30m") AND _time<=relative_time(now(), "$reltime$@d-5w+$days$d+30m")), 5,
        (_time>relative_time(now(), "$reltime$@d-4w-30m") AND _time<=relative_time(now(), "$reltime$@d-4w+$days$d+30m")), 4,
        (_time>relative_time(now(), "$reltime$@d-3w-30m") AND _time<=relative_time(now(), "$reltime$@d-3w+$days$d+30m")), 3,
        (_time>relative_time(now(), "$reltime$@d-2w-30m") AND _time<=relative_time(now(), "$reltime$@d-2w+$days$d+30m")), 2,
        (_time>relative_time(now(), "$reltime$@d-1w-30m") AND _time<=relative_time(now(), "$reltime$@d-1w+$days$d+30m")), 1 )

| eval shift=case(isnotnull(w), "+"+w+"w-30m +"+w+"w-20m +"+w+"w-10m +"+w+"w-0m +"+w+"w+10m +"+w+"w+20m +"+w+"w+30m")
```

Drop What We Don’t Need

```
| where isnotnull(shift)
```

Clone The Data And Compute New Time For Each Event

```
| makemv shift
| mvexpand shift
| eval time=relative_time(_time, shift)
```

Do The Math

```
| eventstats avg($val$) as pred by time
| eval upper=if($val$>pred,$val$,pred)
| eval lower=if($val$<pred,$val$,pred)

| stats avg($val$) as pred, stdev(upper) as ustdev, stdev(lower) as lstdev by time

| eval low=pred-lstdev*(sqrt(1/(1-$confidence$/100)))
| eval low=if(low<0, 0, low)
| eval high=pred+ustdev*(sqrt(1/(1-$confidence$/100)))
```

_time Travel!

```
| eval _time=time
```

* This doesn’t work reliably in Splunk versions prior to 5.4.3.

Post Jump Cleanup

```
| timechart span=10m min(pred) as pred,
   min(low) as low, min(high) as high
| where _time>relative_time(now(), "$reltime$@d")
  AND _time<=relative_time(now(), "$reltime$+$days$d@d")
```

forecast5w(val,confidence,reltime,days)

```
eval w=case(
  (_time>relative_time(now(), "$reltime$@d-5w-30m") AND _time<=relative_time(now(), "$reltime$@d-5w+$days$d+30m")), 5,
  (_time>relative_time(now(), "$reltime$@d-4w-30m") AND _time<=relative_time(now(), "$reltime$@d-4w+$days$d+30m")), 4,
  (_time>relative_time(now(), "$reltime$@d-3w-30m") AND _time<=relative_time(now(), "$reltime$@d-3w+$days$d+30m")), 3,
  (_time>relative_time(now(), "$reltime$@d-2w-30m") AND _time<=relative_time(now(), "$reltime$@d-2w+$days$d+30m")), 2,
  (_time>relative_time(now(), "$reltime$@d-1w-30m") AND _time<=relative_time(now(), "$reltime$@d-1w+$days$d+30m")), 1 )
| eval shift=case(isnotnull(w), "+"+w+"w-30m +"+w+"w-20m +"+w+"w-10m +"+w+"w-0m +"+w+"w+10m +"+w+"w+20m +"+w+"w+30m")
| where isnotnull(shift)
| makemv shift
| mvexpand shift
| eval time=relative_time(_time, shift)
| eventstats avg($val$) as pred by time
| eval upper=if($val$>pred,$val$,pred)
| eval lower=if($val$<pred,$val$,pred)
| stats avg($val$) as pred, stdev(upper) as ustdev, stdev(lower) as lstdev by time
| eval low=pred-lstdev*(sqrt(1/(1-$confidence$/100)))
| eval low=if(low<0, 0, low)
| eval high=pred+ustdev*(sqrt(1/(1-$confidence$/100)))
| eval _time=time
| timechart span=10m min(pred) as pred, min(low) as low, min(high) as high
| where _time>relative_time(now(), "$reltime$@d") AND _time<=relative_time(now(), "$reltime$+$days$d@d")
```

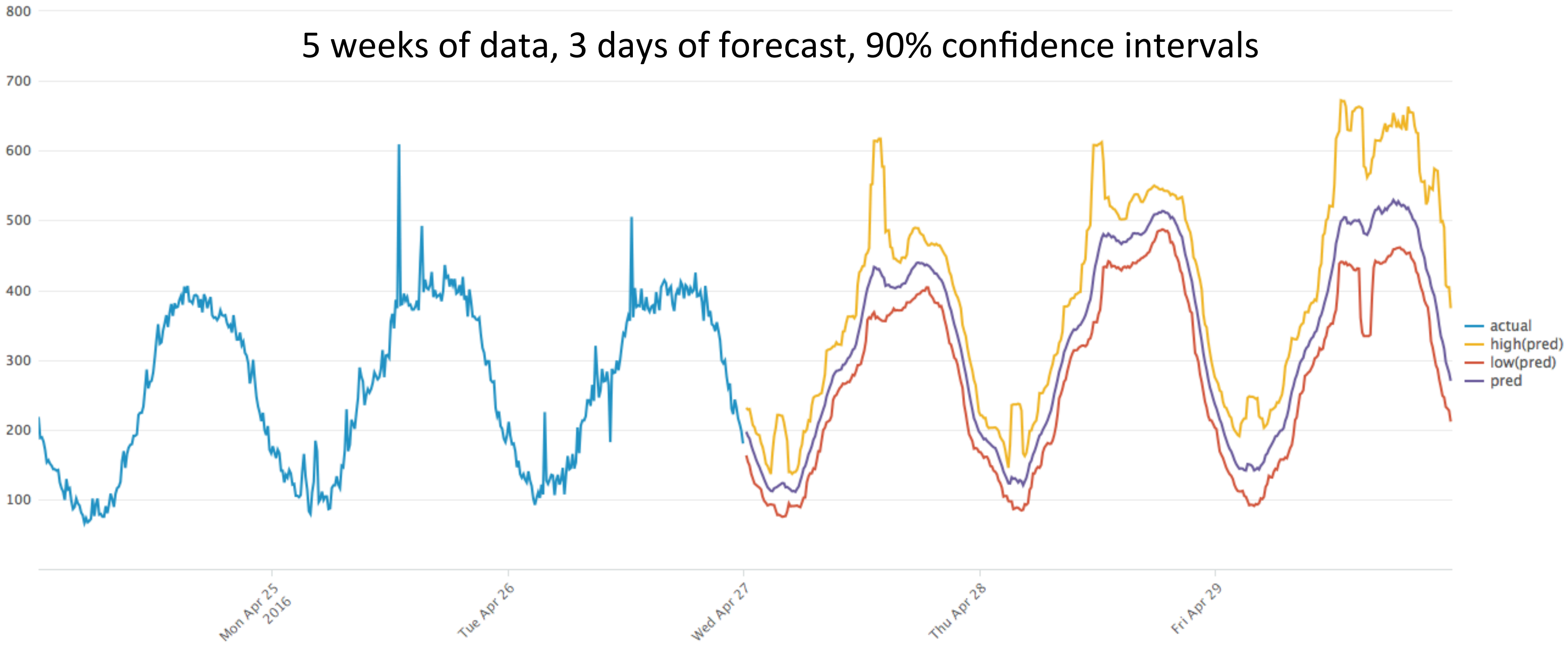
Results

Generate A Forecast

```
index=summary search_name="Sales - Summary - 10 min count"
| timechart span=10m sum(count) as actual
| `forecast5w(actual, 90.0, +1d, 3)`
```

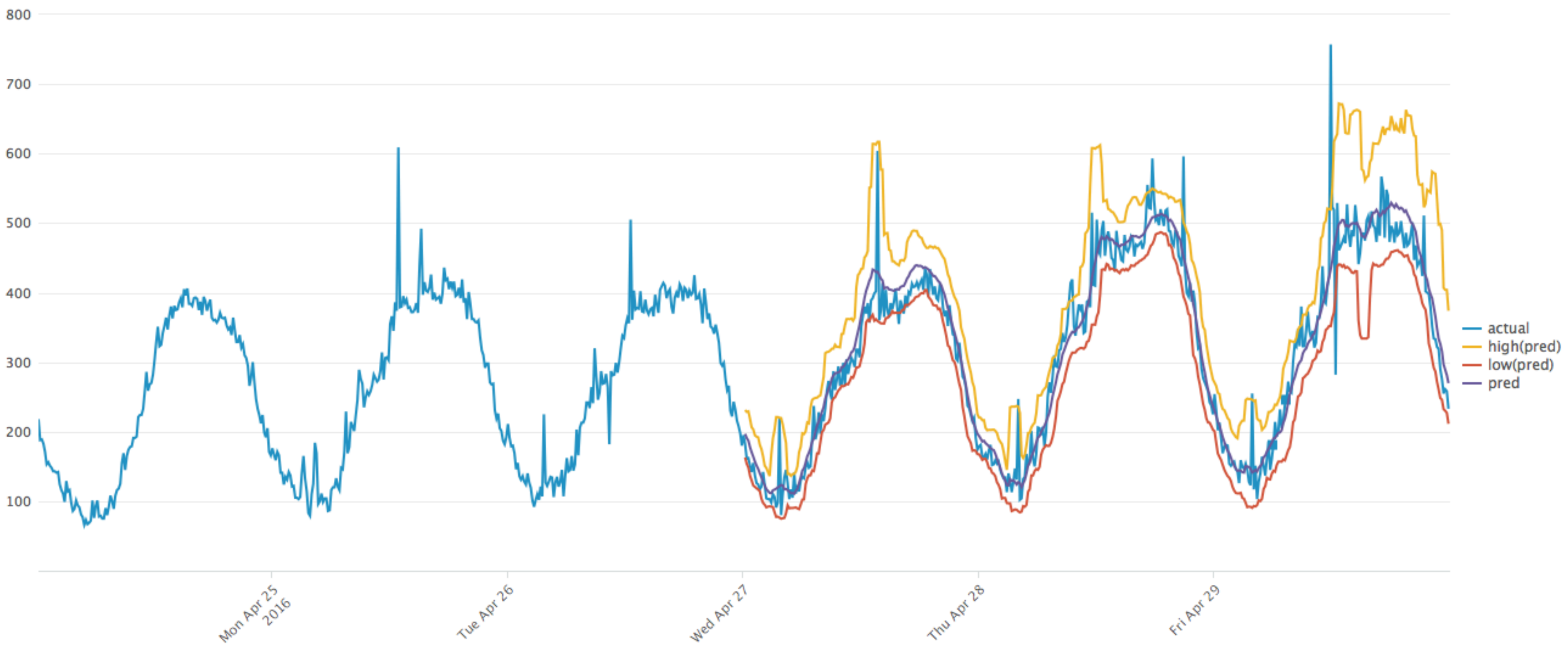
Run over the last 5 weeks.

Forecast Using forecast5w()



5 weeks of data, 3 days of forecast, 90% confidence intervals

forecast5w() vs Reality



Automatic Forecasting

Save search as “Sales Volume Forecast” and schedule to run every day over the previous 5 weeks.

```
index=summary search_name="Sales - Summary - 10 min count"
| timechart span=10m sum(count) as actual
| `forecast(actual, 90.0, +1d, 1)`
```

Alert

```
index=summary
        search_name="Sales - Summary - 10 min count" OR
        search_name="Sales Volume Forecast"
| where count<low
```

Test The Alert Based On History

- Backfill the forecast for the last month or so:

```
splunk cmd python fill_summary_index.py -app search \
        -name "Sales Volume Forecast" -et -1mon -lt now -j 8
```

- Use timechart to find out when your alert would have fired:

```
index=summary
        search_name="Sales - Summary - 10 min count" OR
        search_name="Sales Volume Forecast"
 | timechart sum(count) as count, sum(low) as low
 | where count<low
```

Caveats

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Caveats

- Doesn’t perform well on low volume time series data
- Must adjust the default MAX_DAYS_HENCE in props to create forecast data more than two days in advance
- Needs a feedback loop so that abnormal data can be excluded from future forecast calculations
- Your mileage may vary

Wrap Up

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Go Forth And Predict The Future!

Now that you've seen how to build a crystal ball, the only question is…

What will you forecast?

Questions?

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THANK YOU

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