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MorphingProjections: Interactive Visualization of Electric Power Demand Time Series

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Eurovis 2012, Wien, Austria

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Analysis of power demand time series

Requirements

- **Temporal behavior**
  - Regular periodicities (daily, weekly, yearly...)
  - Social time granularities (months, feasts, exams, holidays,...)

- **Prototypes**
  - Find & classify typical demand profiles
    → exploit prior knowledge → refine → interaction

- **Global view**
  - Find connections in different domains, e.g.:
    daily, weekly, monthly & day-pattern

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Basic idea: multiple views

weekdays

develop

several views
showing different aspects

year

day
hours

months
(calendar)

day
patterns

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Basic idea: multiple views

weekdays

¿how to connect all these views?

¿how to get a global understanding?

year

day
hours

months
(calendar)

day
patterns

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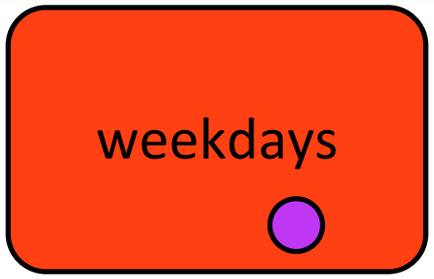
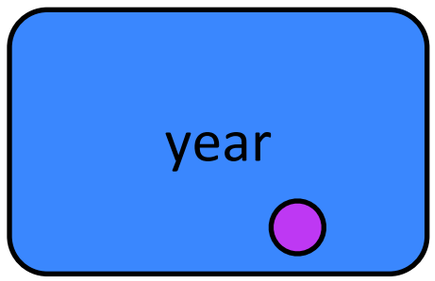
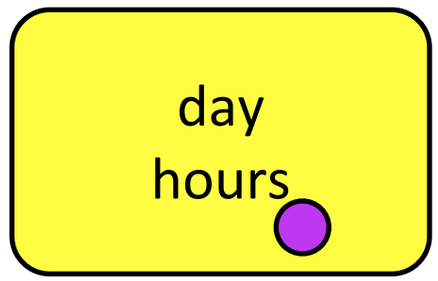
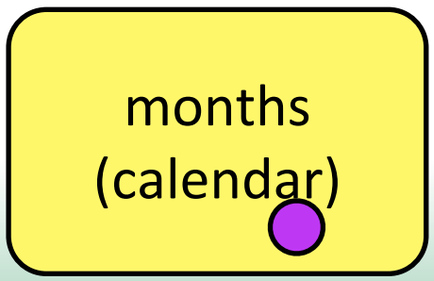
Basic idea: multiple views

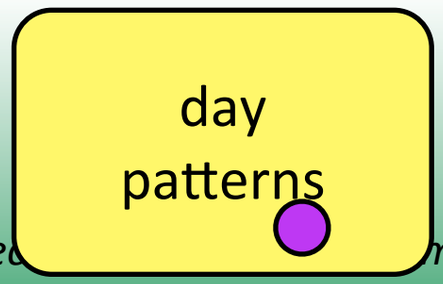


Coordinated views









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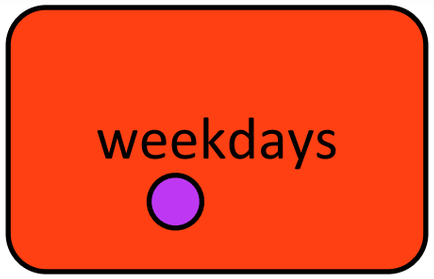
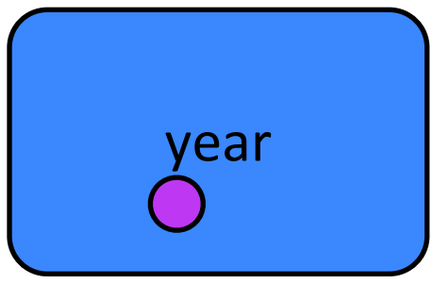
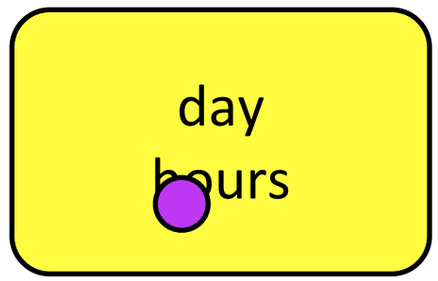
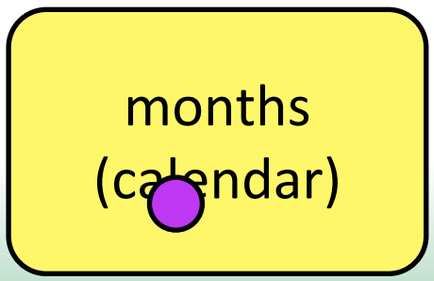
Basic idea: multiple views

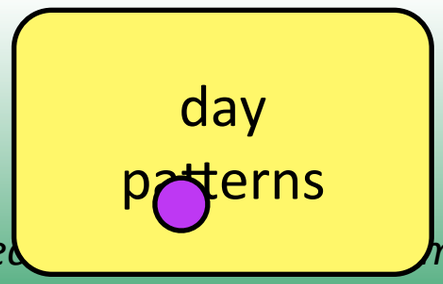


Coordinated views









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Basic idea: multiple views

Animated transitions

view 1

view 2

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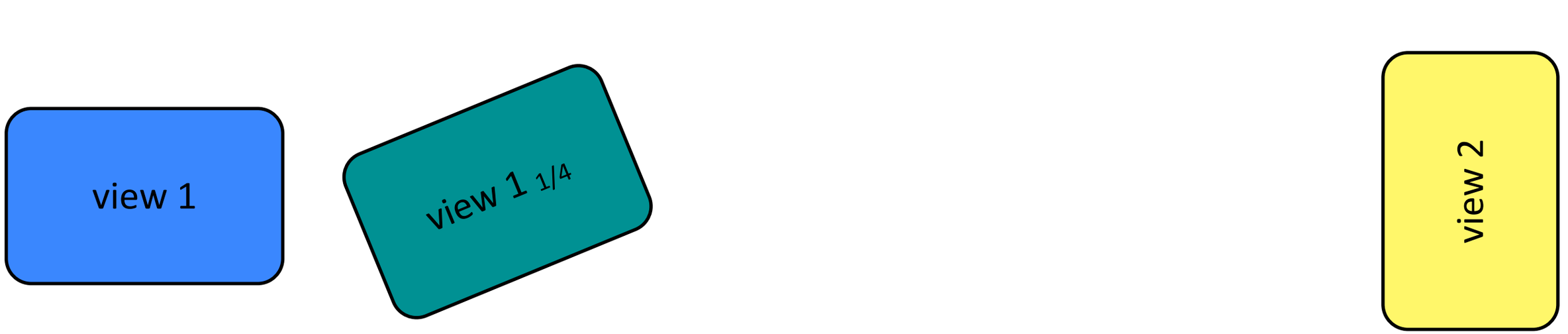
Basic idea: multiple views

Animated transitions



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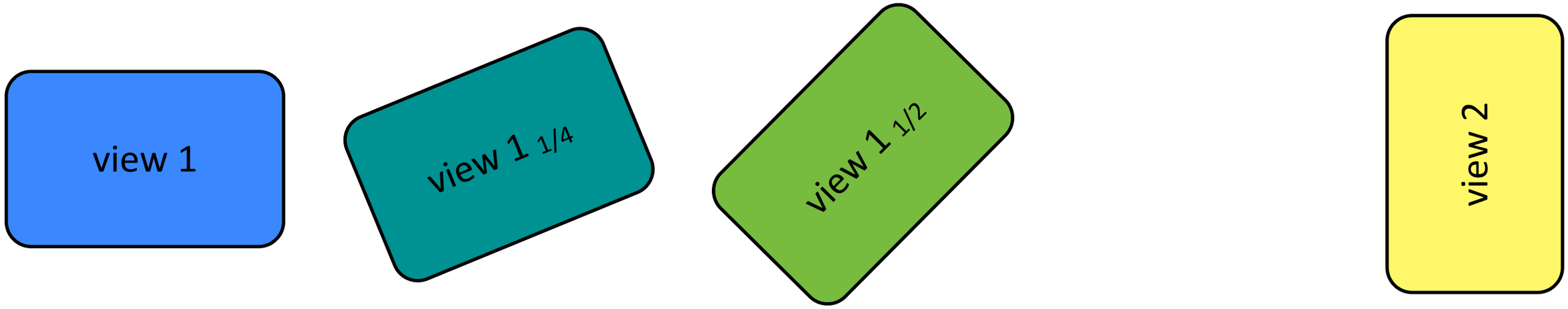
Basic idea: multiple views

Animated transitions



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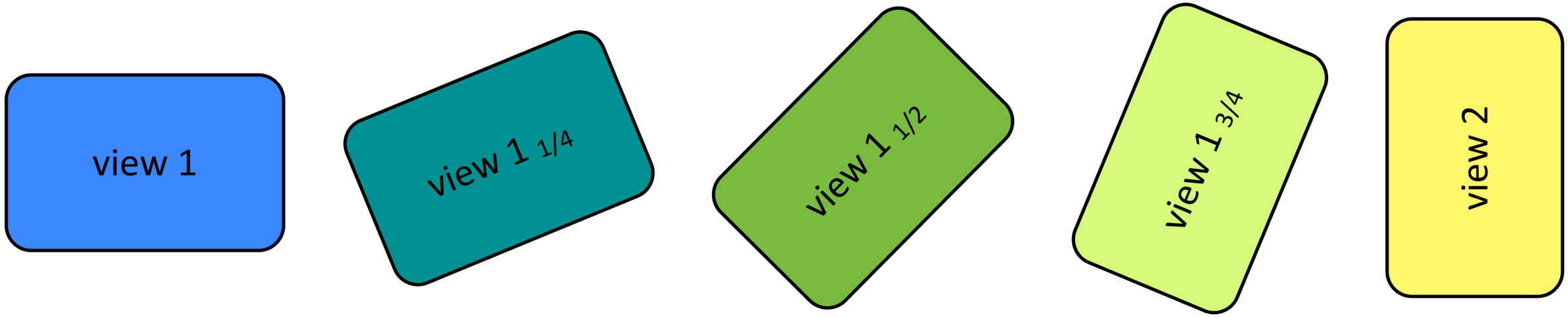
Basic idea: multiple views

Animated transitions



✓ helps to keep a **mental model** of data between views

✗ **intermediate views** are usually meaningless

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Basic idea: multiple views

Animated transitions
on scatterplots
↓
morphingProjections

demand
each weekday

demand
each day hour

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Basic idea: multiple views

Animated transitions
on scatterplots
↓
morphingProjections

demand
each weekday

hourly demand
each weekday

demand
each day hour

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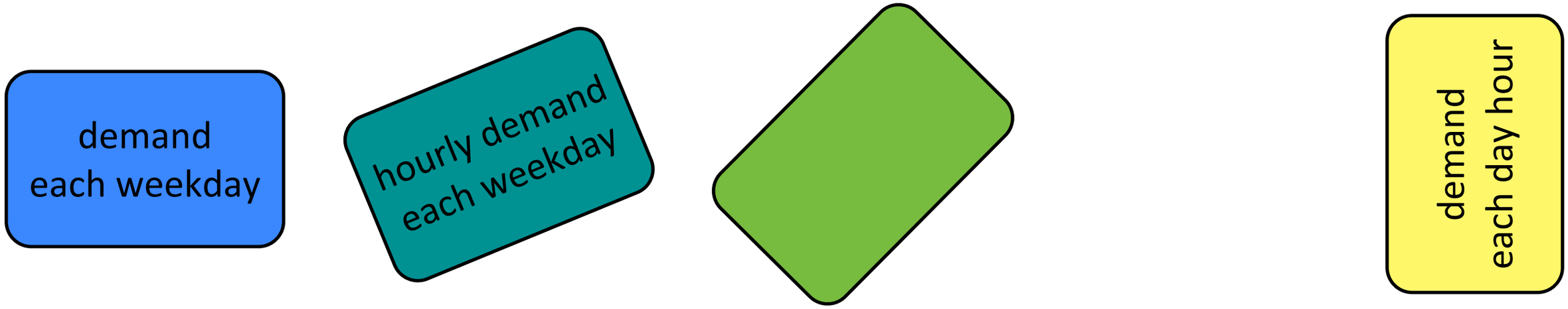
Basic idea: multiple views

Animated transitions
on scatterplots
↓
morphingProjections



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Basic idea: multiple views

Animated transitions
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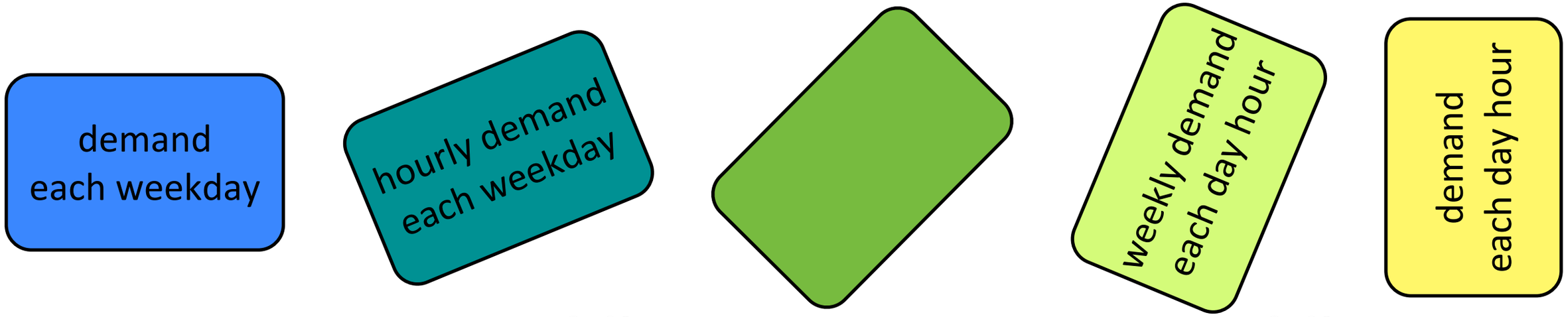
morphingProjections



meaningful! **meaningful!**

- ✓ helps to keep a **mental model** of data between views
- ✓ yields **meaningful intermediate views**!

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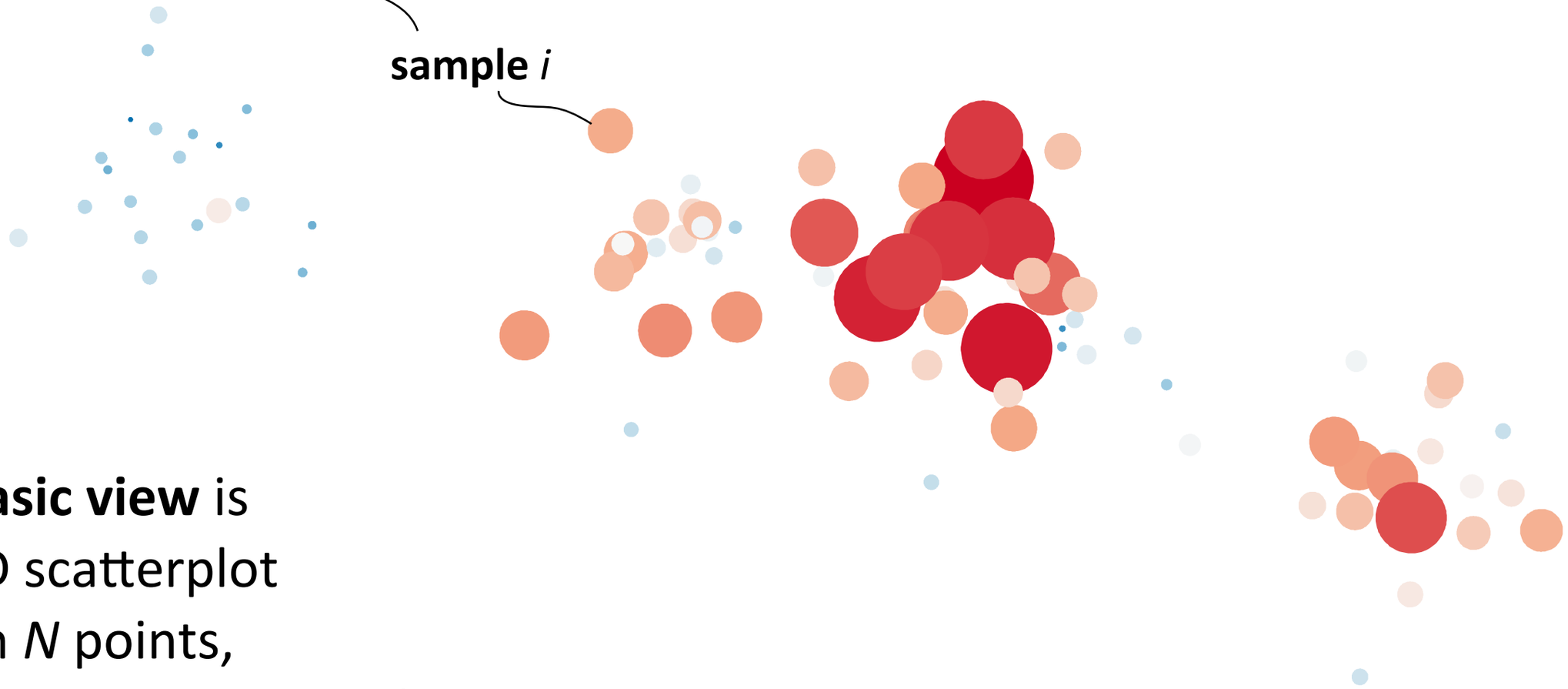
Basic view

elements

		sample *i*-1	sample *i*	sample *i*+1		sample *N*
absolute hour *h(i)*	...	47	48	49	...	8760
absolute day *d(i)*	...	2	2	3	...	365
active power	...	21,232	22,232	22,352	...	55,333
reactive power	...	1,112	1,456	1,234	...	2,444

sample *i*



A **basic view** is
a 2D scatterplot
with *N* points,
representing *N* samples

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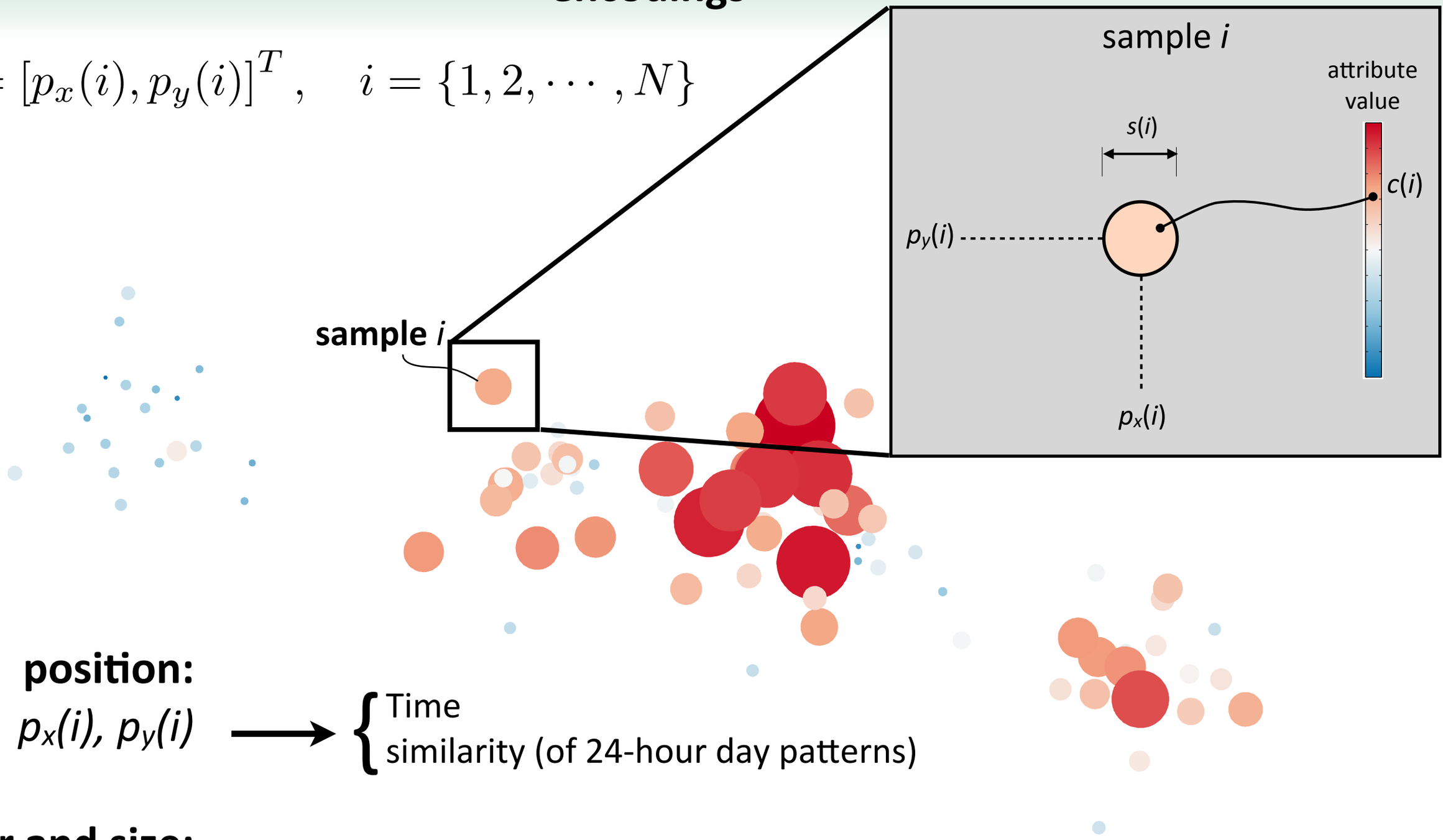
Basic view

encodings

$$\mathbf{p}(i) = [p_x(i), p_y(i)]^T, \quad i = \{1, 2, \cdots, N\}$$



position:

$p_x(i)$, $p_y(i)$ → { Time; similarity (of 24-hour day patterns)

color and size:

c(*i*), *s*(*i*) → { attribute value (e.g. active power demand)

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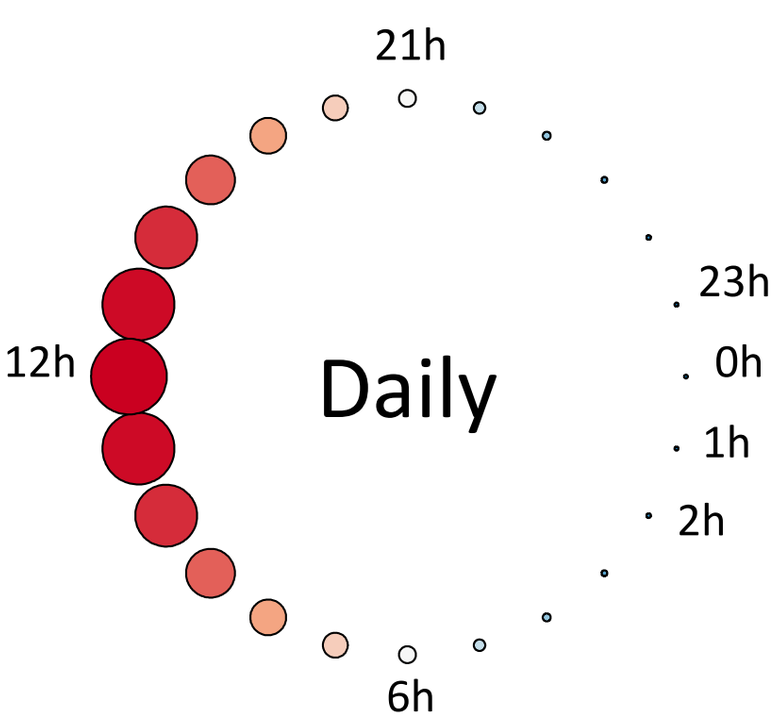
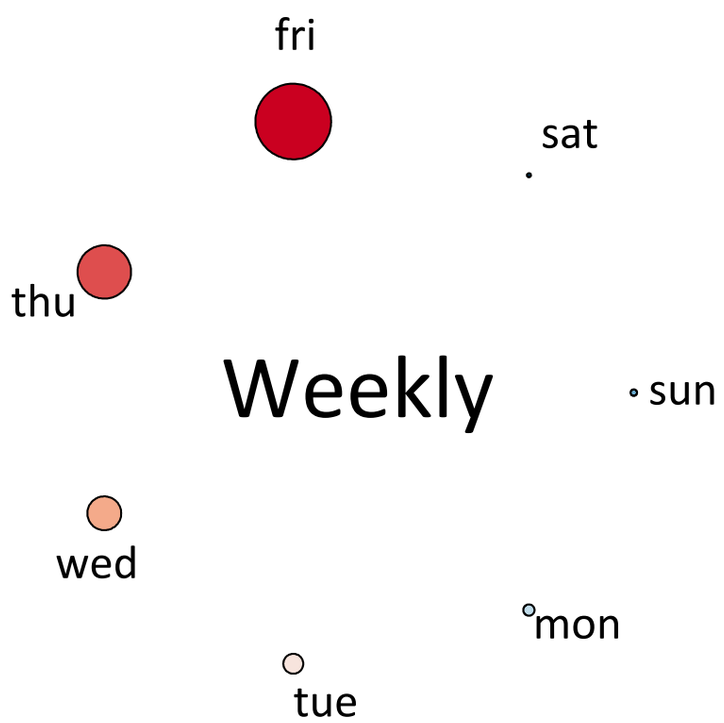
Clock encodings

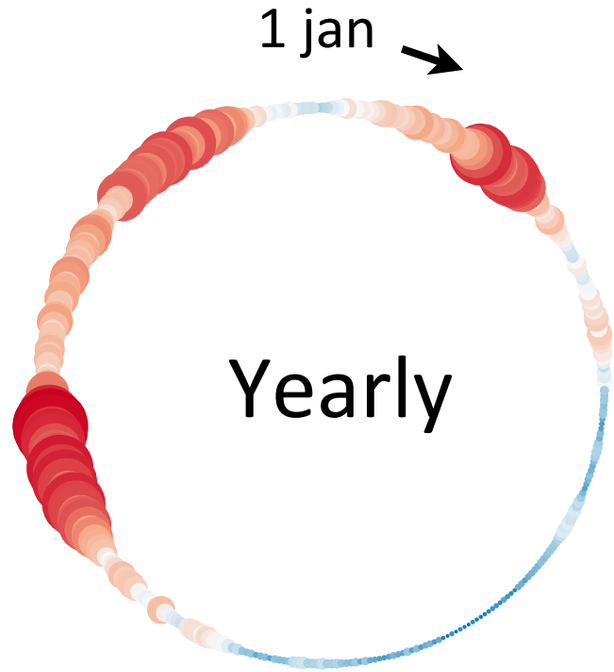
describing regular periodicities

Rationales:

- clocks are widely accepted conventions
- congruence: periodical nature of hours, weekdays and years







$$\mathbf{p}_D(i) = \left[\cos\left(2\pi\frac{h(i)}{24}\right), \sin\left(2\pi\frac{h(i)}{24}\right)\right] \qquad \mathbf{p}_Y(i) = \left[\cos\left(2\pi\frac{h(i)}{365\cdot 24}\right), \sin\left(2\pi\frac{h(i)}{365\cdot 24}\right)\right] \qquad \mathbf{p}_W(i) = \left[\cos\left(2\pi\frac{d(i)}{7}\right), \sin\left(2\pi\frac{d(i)}{7}\right)\right]$$

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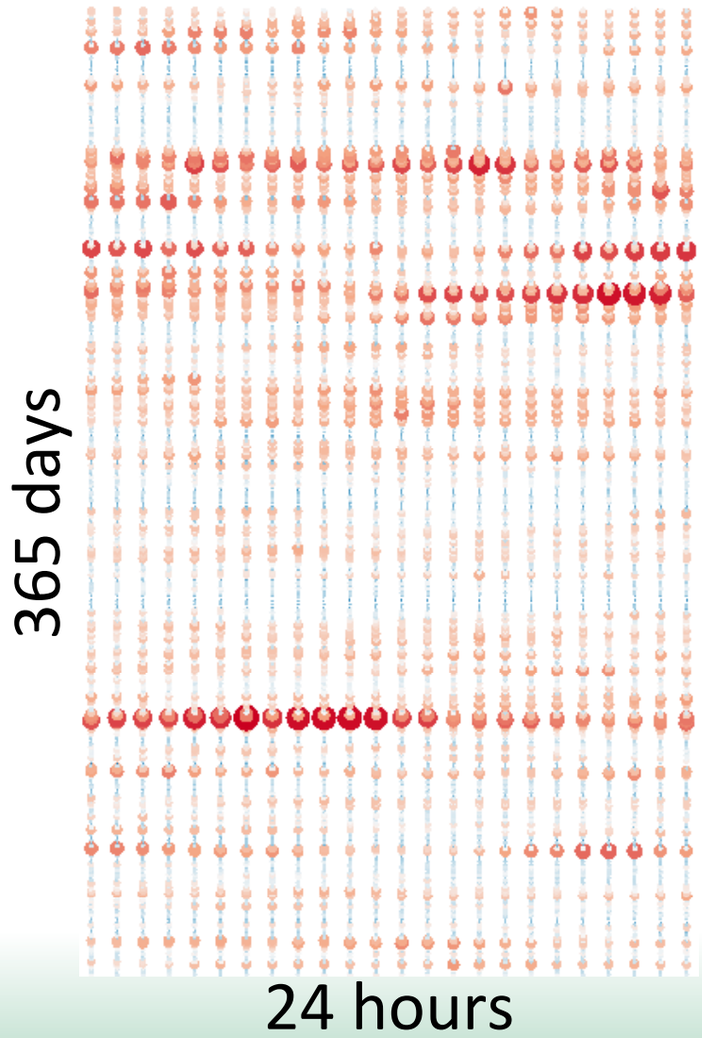
Calendar encodings

seasonal and social time granularities

Rationales:

- seasonal periodicities
- relative position in the year

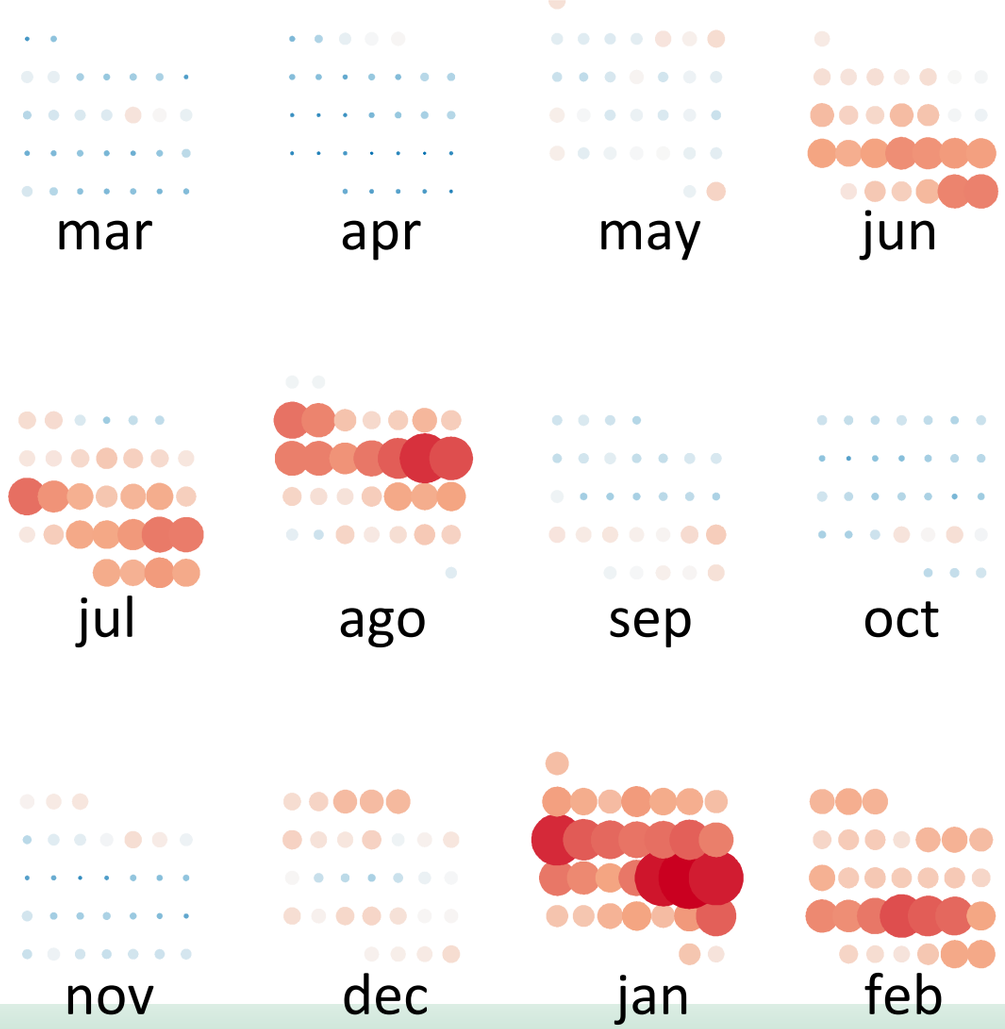
365x24



Rationales:

- social time granularities
- common mental models for time

Calendar



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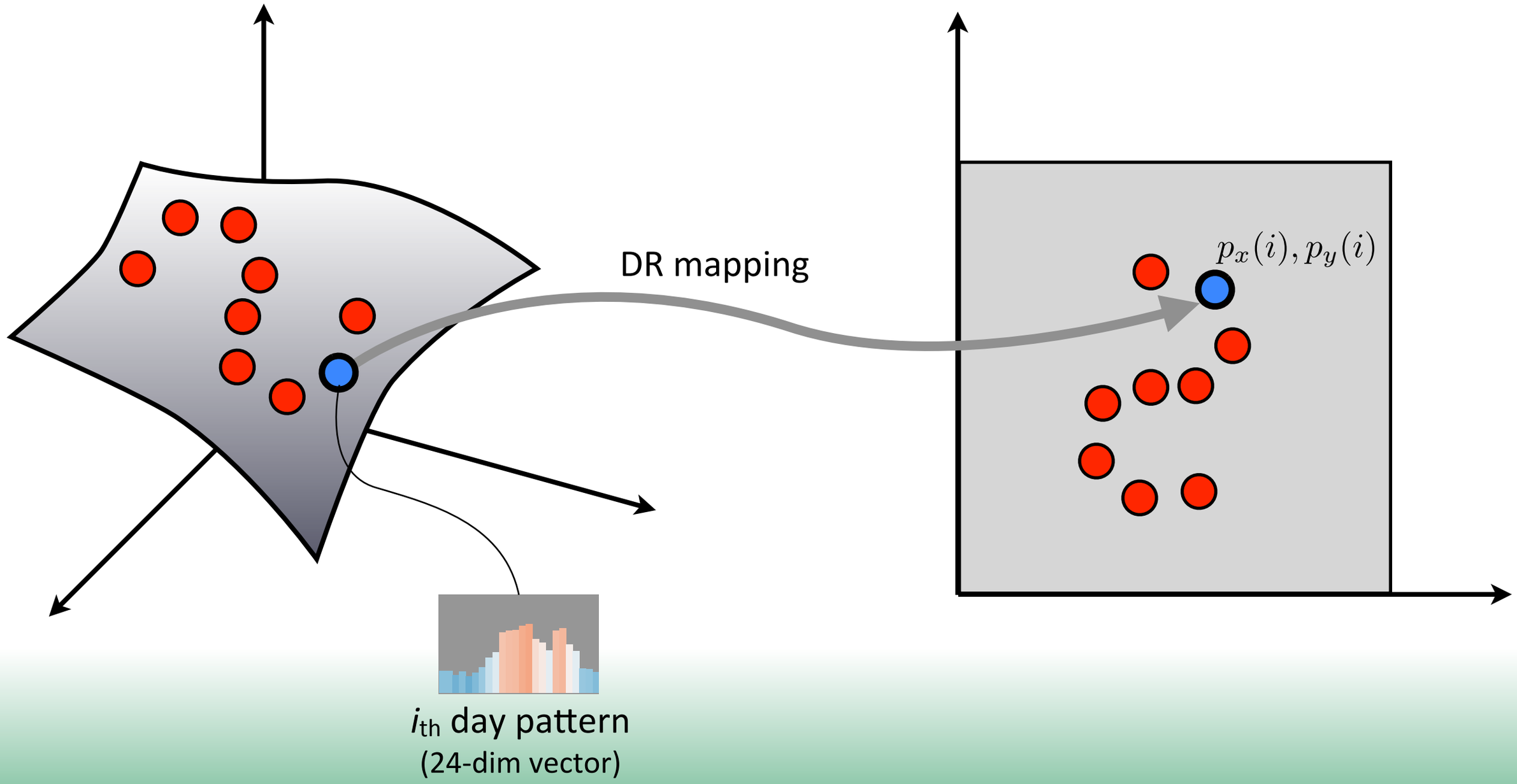
Dimensionality reduction

describing similarity

high dimensional space of Day patterns R^{24}

2D space for visualization



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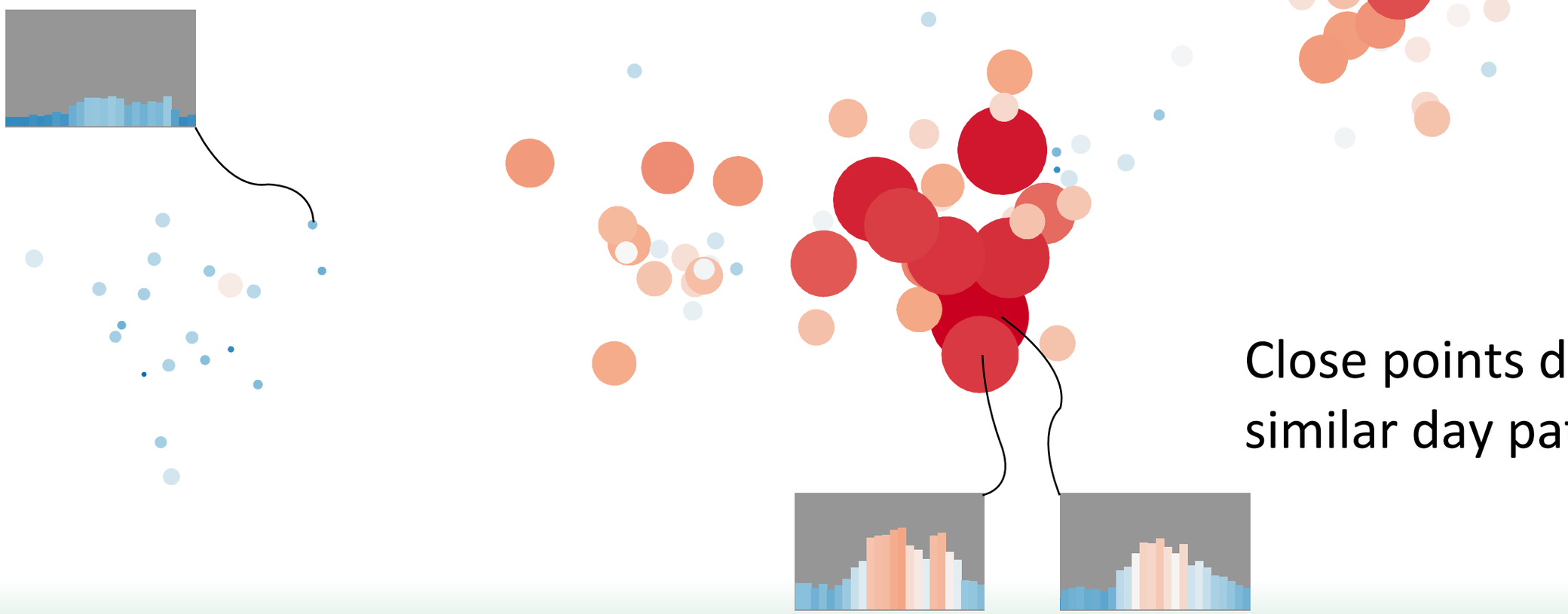
Dimensionality reduction

describing similarity

Rationales:

- associate spatial proximity to similarity
- clusters reveal days with similar demand patterns

t-SNE projection



Close points describe similar day patterns

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Color and size encodings

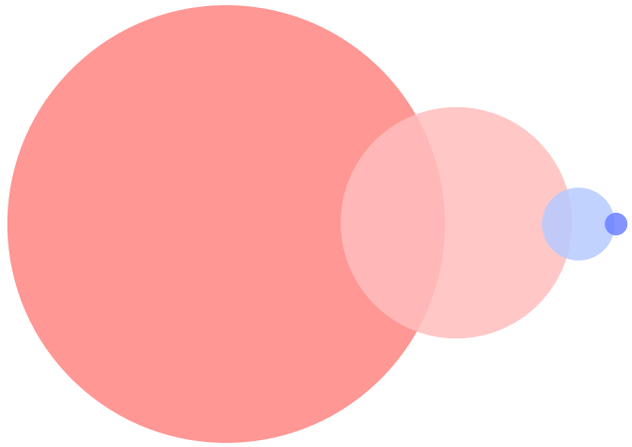
describing attributes

Color

- Scale ColorBrewer 2.0 tool
- Multihue blue/white/red
- divergent
- colorblind safe

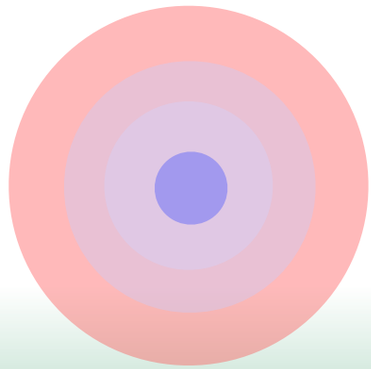
Size

- Exponential w.r.t. attribute value
- Highlight peaks of demand



Transparency

- conveys aggregation info
- concentric circles reveal patterns



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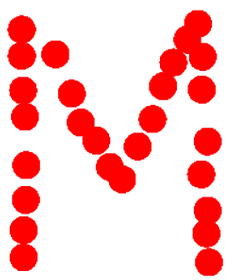
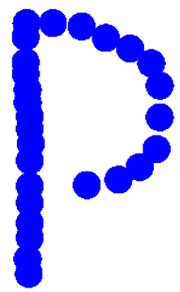
Morphing

basic concept

$$\mathbf{p}(i), \quad i = \{1, 2, \cdots, N\}$$

$$\mathbf{q}(i), \quad i = \{1, 2, \cdots, N\}$$





$$\mathbf{z}(i) = \lambda \mathbf{p}(i) + (1 - \lambda)\mathbf{q}(i)$$

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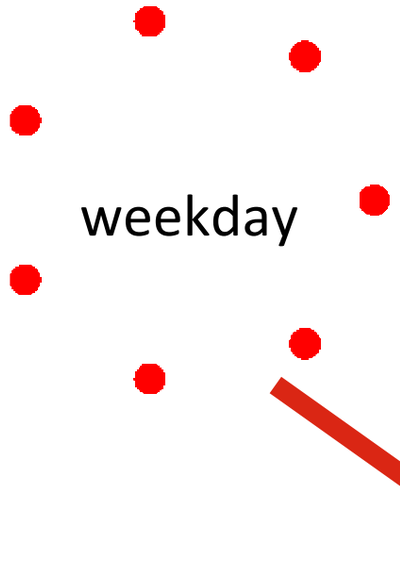
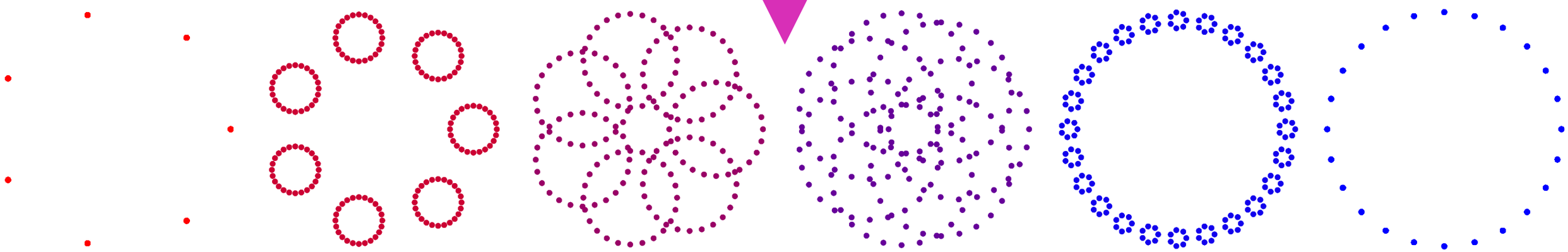
Morphing

meaningful transition views



$$\mathbf{z}(i) = \lambda \mathbf{p}(i) + (1 - \lambda)\mathbf{q}(i)$$



$\lambda = 1$ $\lambda = 0.8$ $\lambda = 0.6$ $\lambda = 0.4$ $\lambda = 0.07$ $\lambda = 0.0$

meaningful **meaningful**

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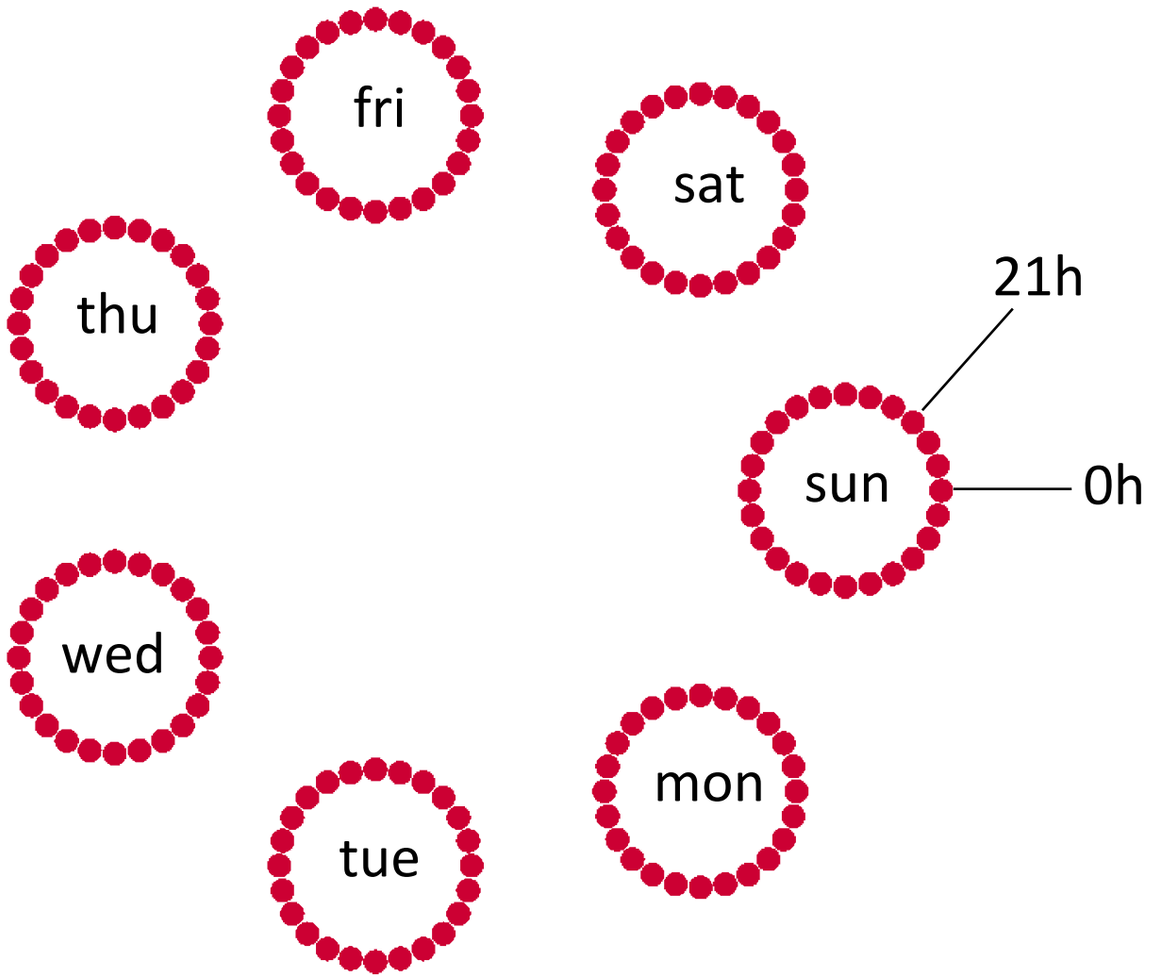
Morphing

meaningful transition views

$\lambda = 0.8$



7 days, 24 hours each

“daily evolving
of the demand
for each weekday”

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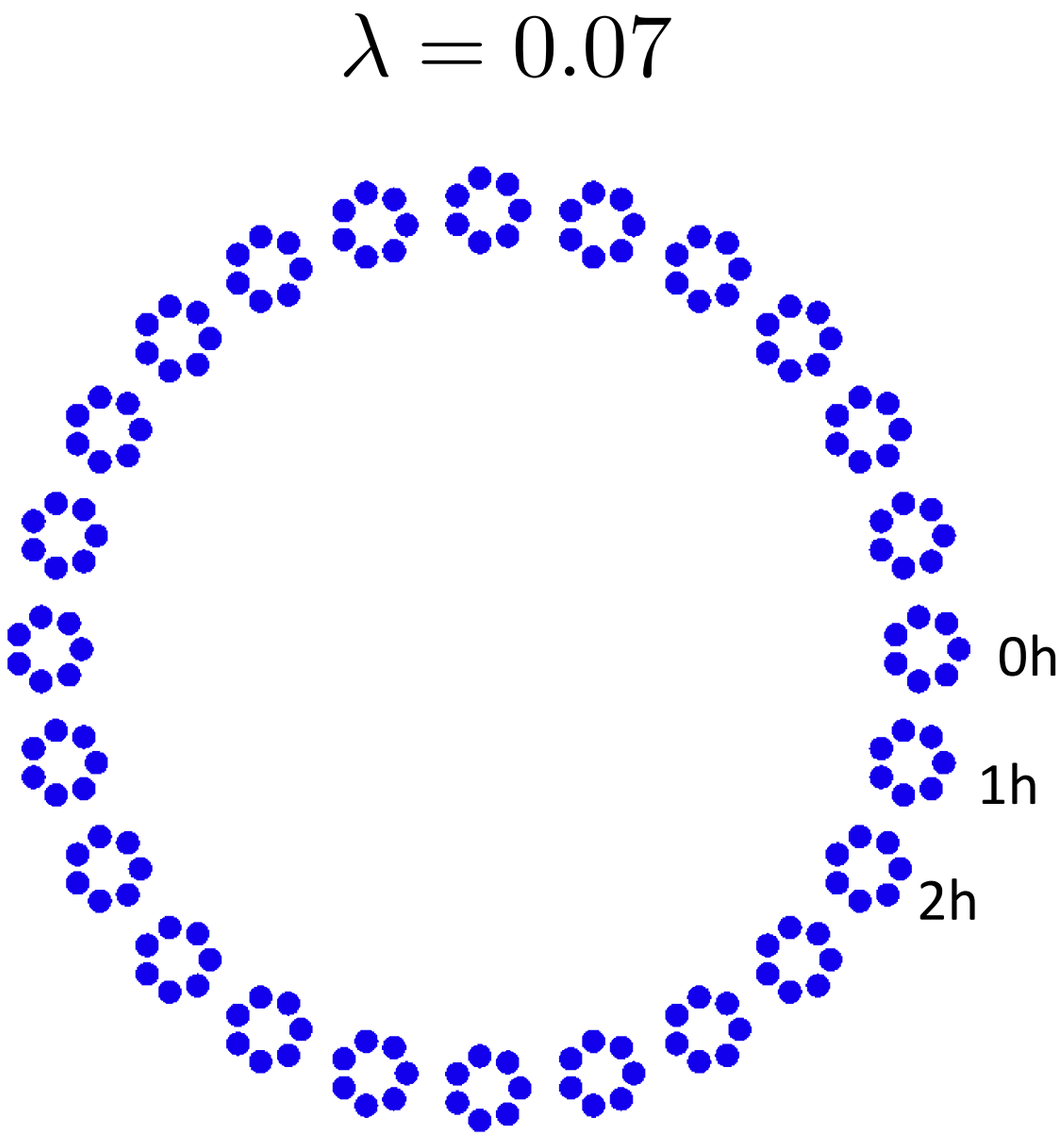
Morphing

meaningful transition views

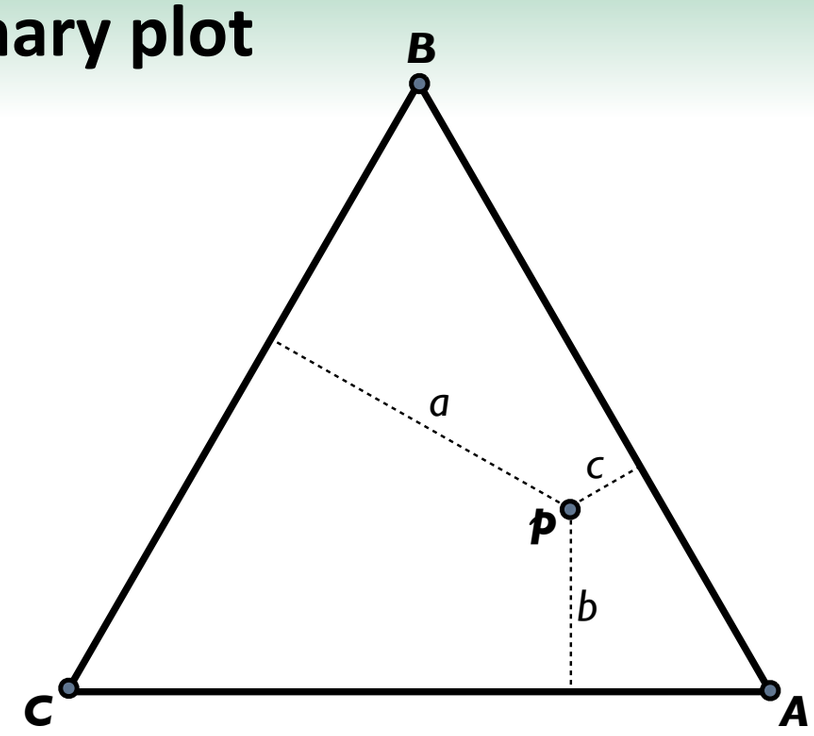


24 hours, 7 days each

weekly distribution
of the demand
for every day hour

Morphing

blending three views: the ternary plot



Mixing coefficient for encoding *A*

coordinates of encoding *A*

$$\mathbf{p}(i,t) = a(t)\mathbf{p}_A(i) + b(t)\mathbf{p}_B(i) + c(t)\mathbf{p}_C(i)$$

The mixture proportions sum up to 1 (100%):

$$a(t) + b(t) + c(t) = 1$$

Interface and Interaction elements

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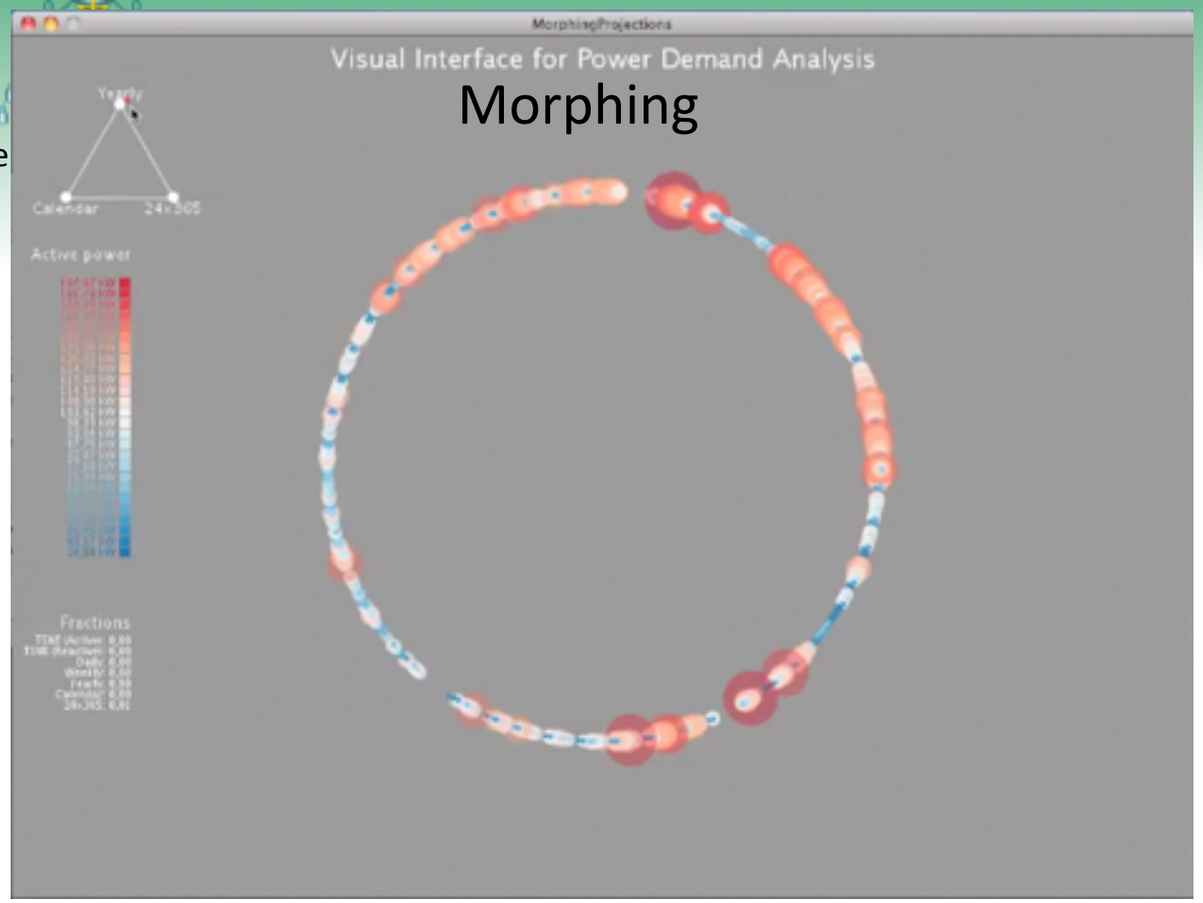
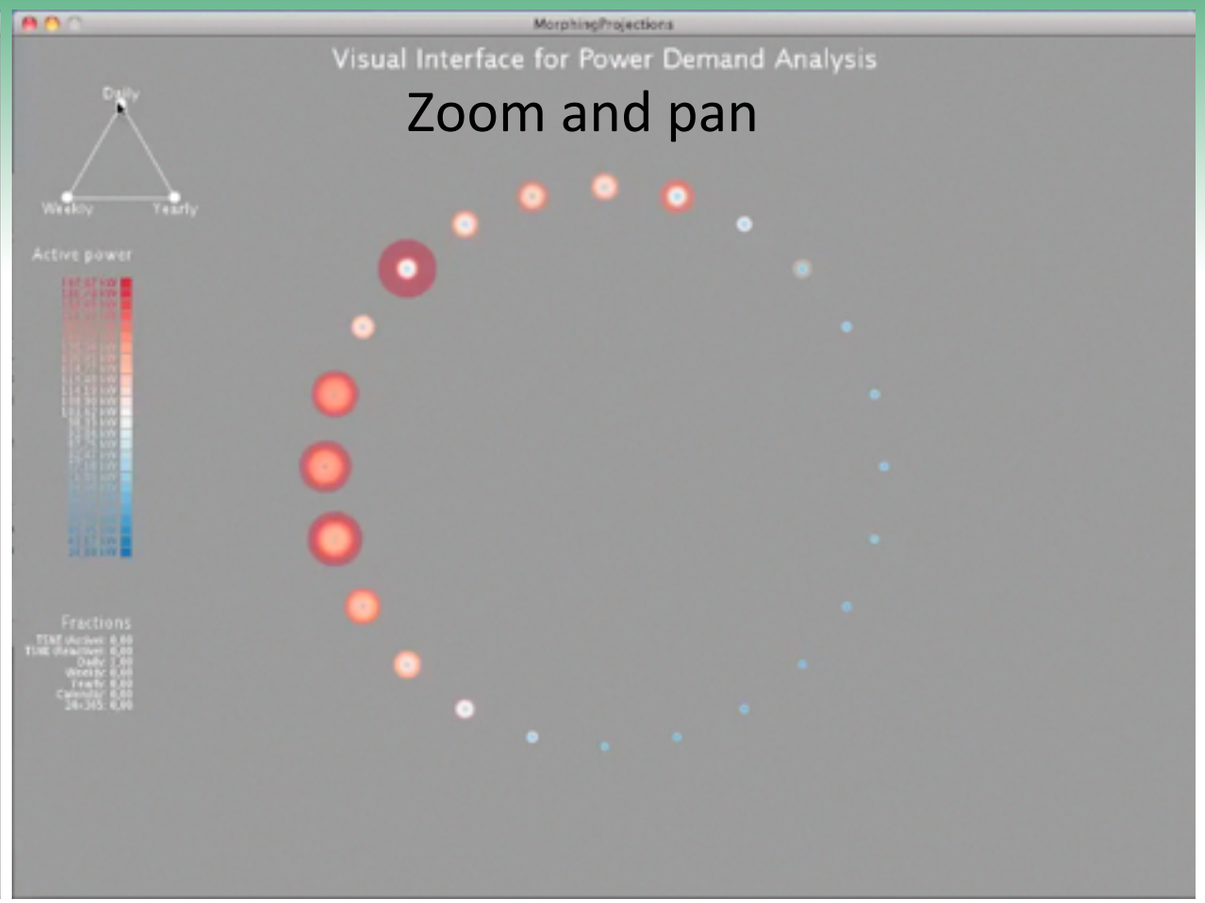
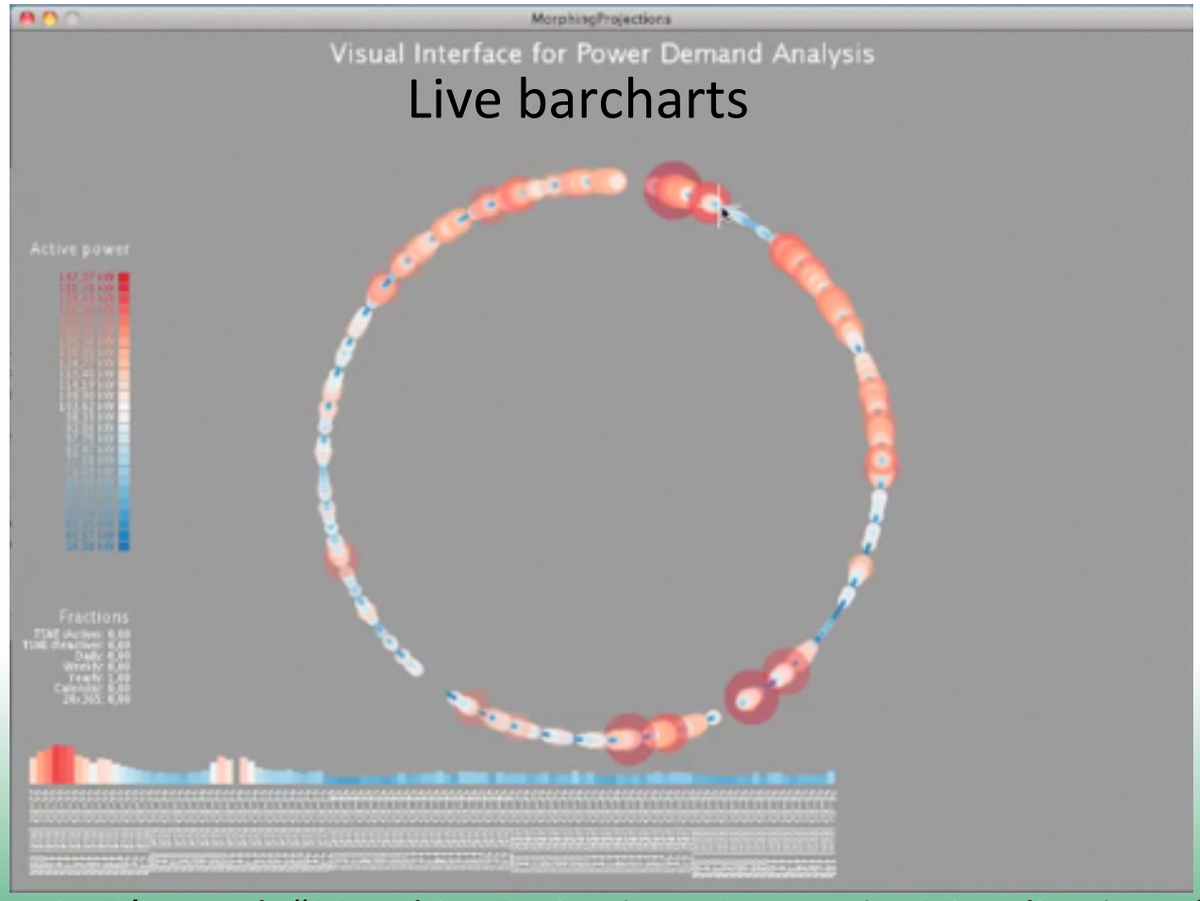
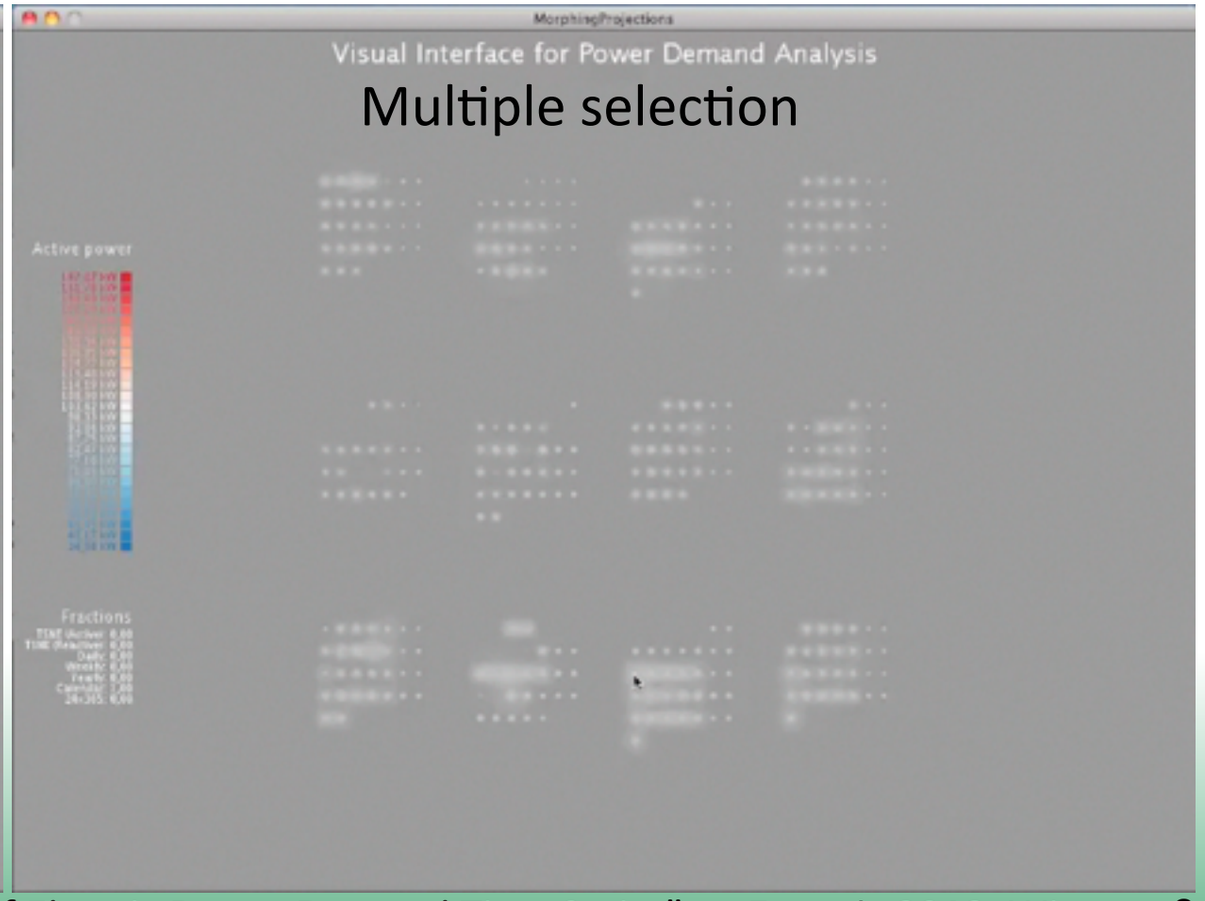

MorphingProjections
Visual Interface for Power Demand Analysis
Morphing
Yearly
Calendar
24x365
Active power
Fractions


MorphingProjections
Visual Interface for Power Demand Analysis
Zoom and pan
Daily
Weekly
Yearly
Active power
Fractions


MorphingProjections
Visual Interface for Power Demand Analysis
Live barcharts
Active power
Fractions


MorphingProjections
Visual Interface for Power Demand Analysis
Multiple selection
Active power
Fractions

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Conclusions

- **Spatial encodings**
  - clocks → regular periodicities
  - calendars → social time granularities
  - dimension reduction → group by similarity → interactive clustering

- **Morphing**
  - advantages of animated transitions → global view
  - meaningful results → combined views

- **Interaction mechanisms**
  - ternary plot, multiple selection, brushing, zoom and pan, context information retrieval

- **Future research**
  - user study
  - morphing: quite general idea
  - spatio-temporal analysis (geo-encodings)
  - Multiway analysis