

Rapid Prototyping for Coordinated Views of Multi-scale Spatial and Abstract Data: A Grammar-based Approach

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Visual Computing for Biology and Medicine (EG VCBM)
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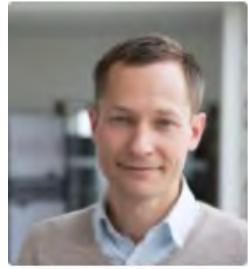
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Visual Computing Group



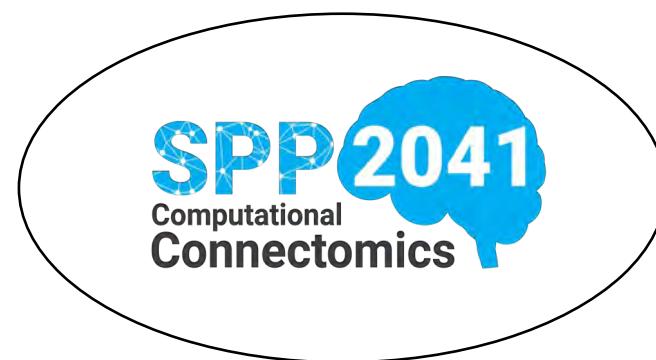
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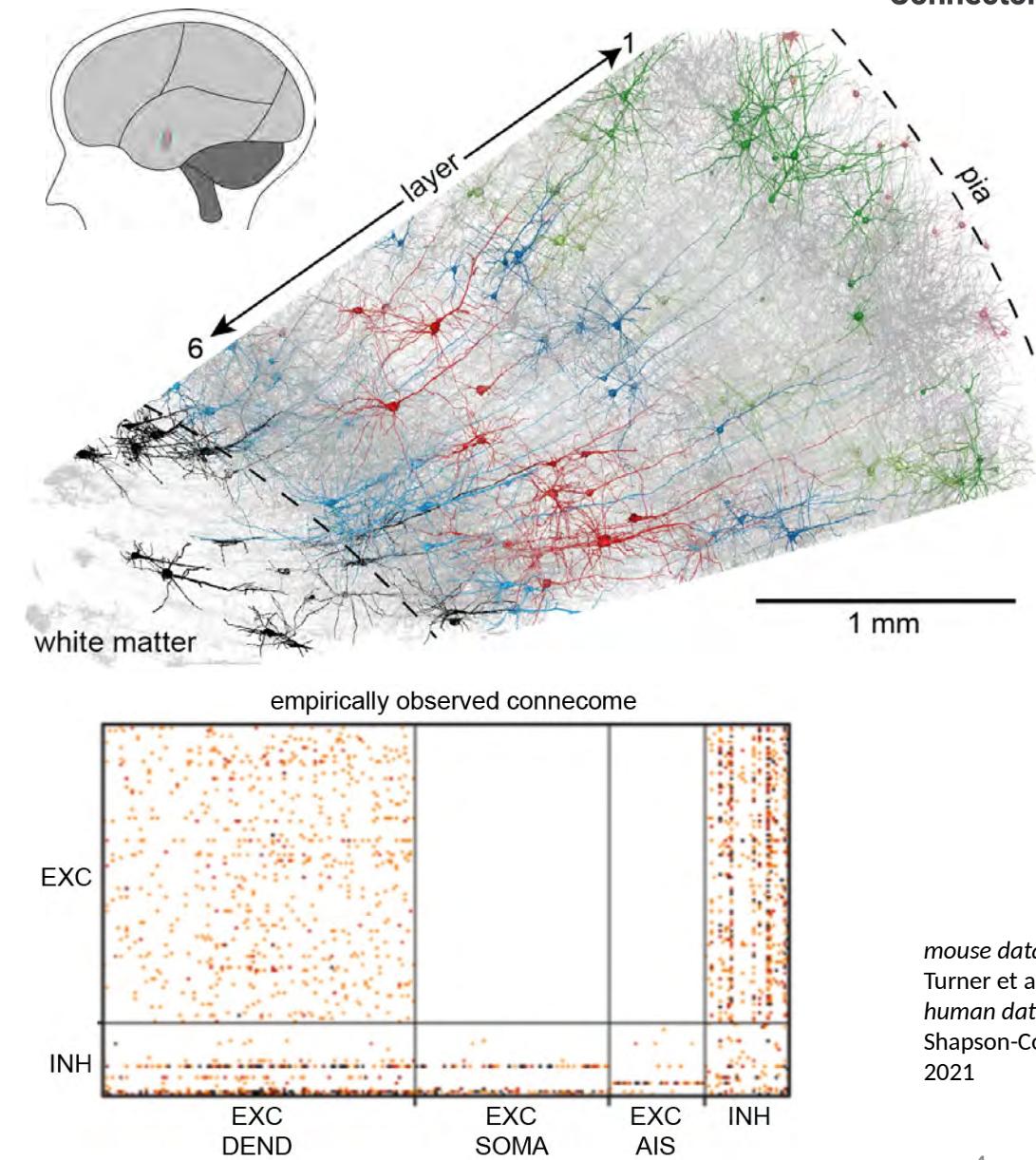
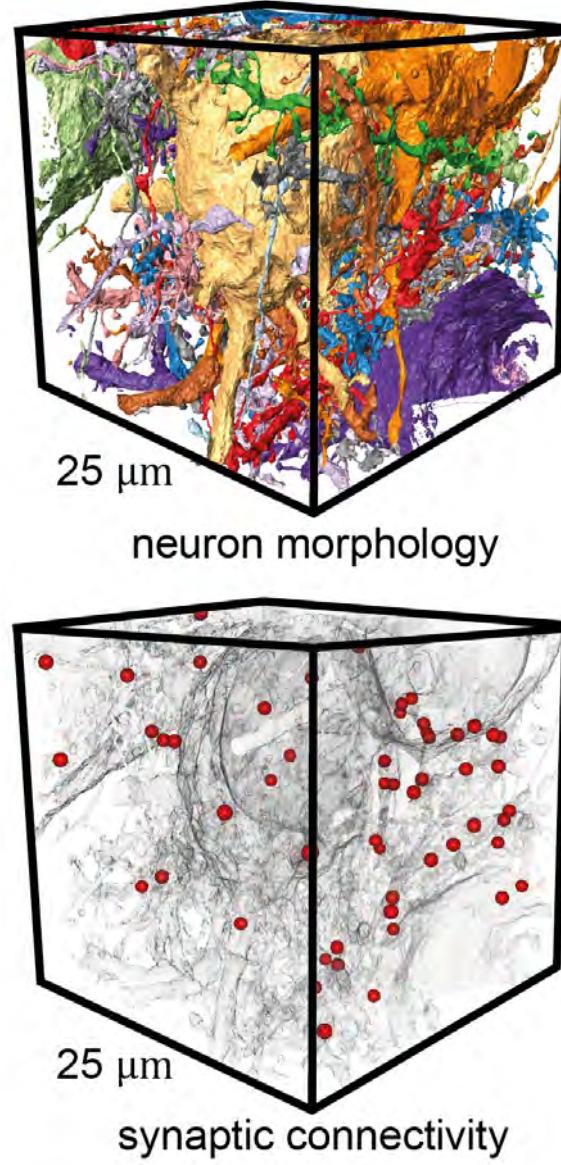
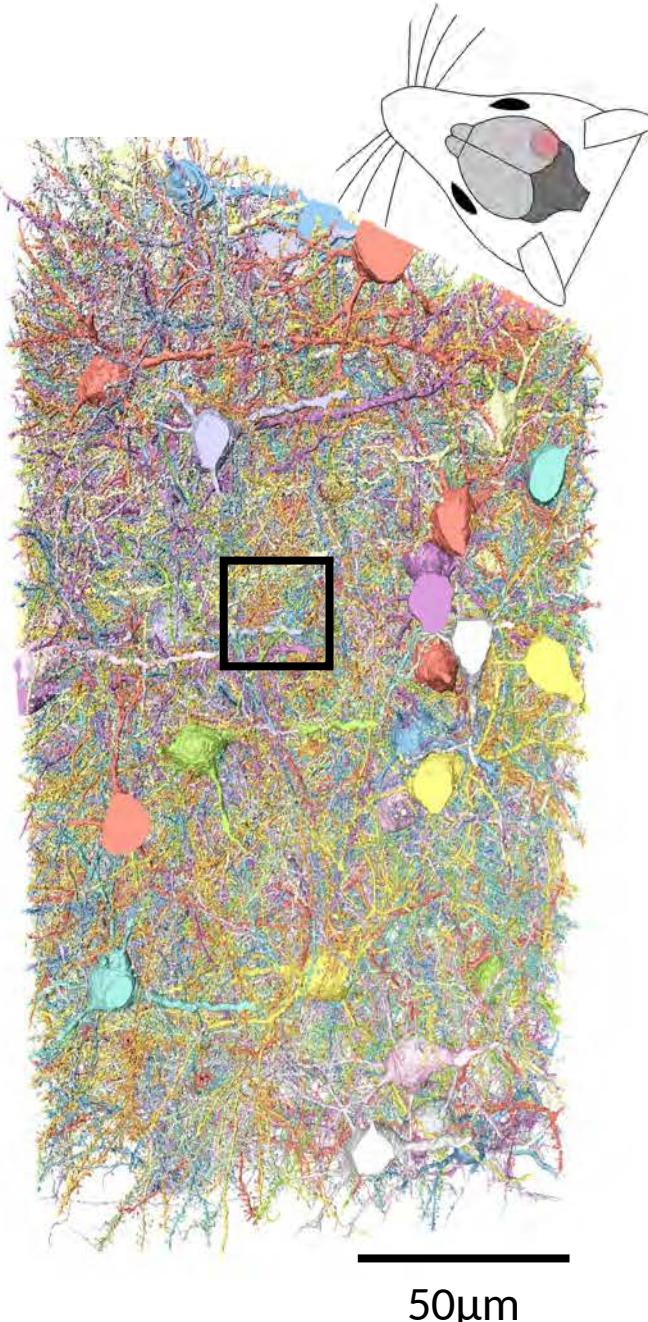
Bjorge
Meulemeester



Rieke
Fruengel

- Visual computing in computational neuroscience
- Design considerations and technical realization
- Application of tool and preliminary results
- Summary and outlook

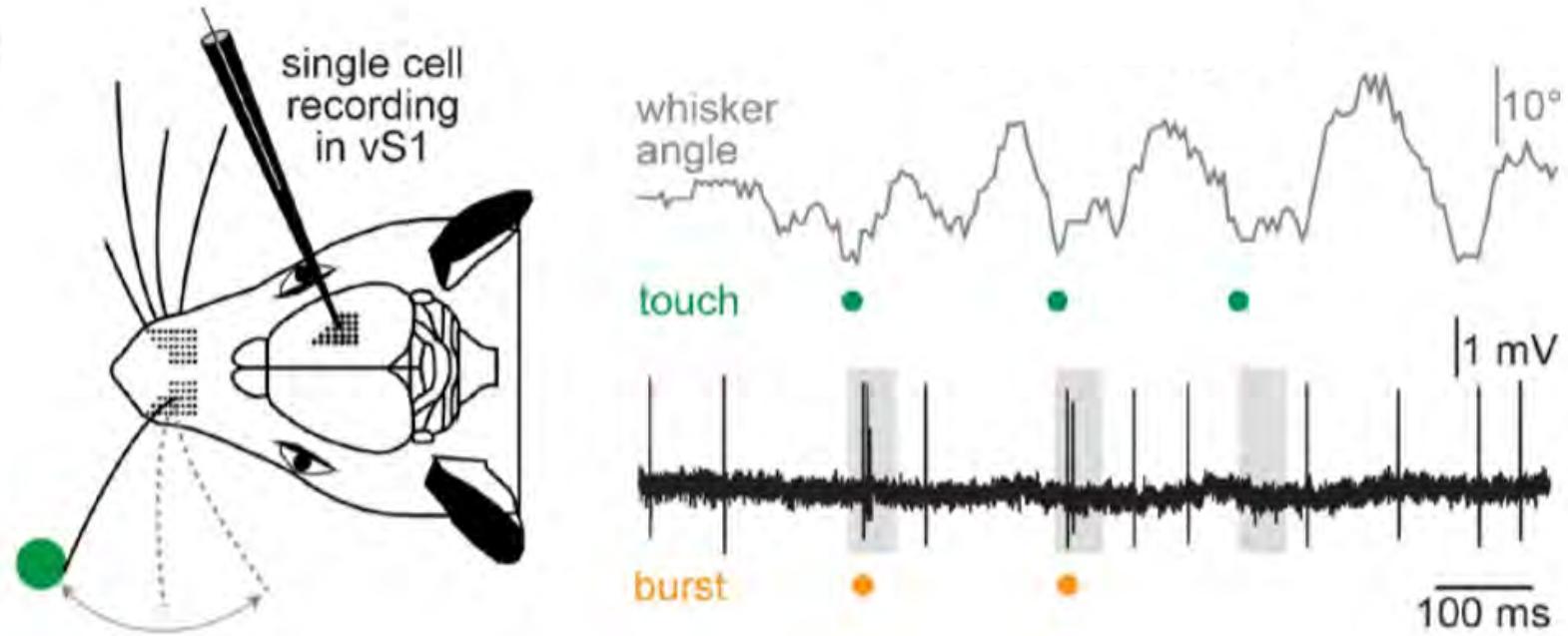
Network structure



mouse dataset
Turner et al., 2022
human dataset
Shapson-Coe et al., 2021

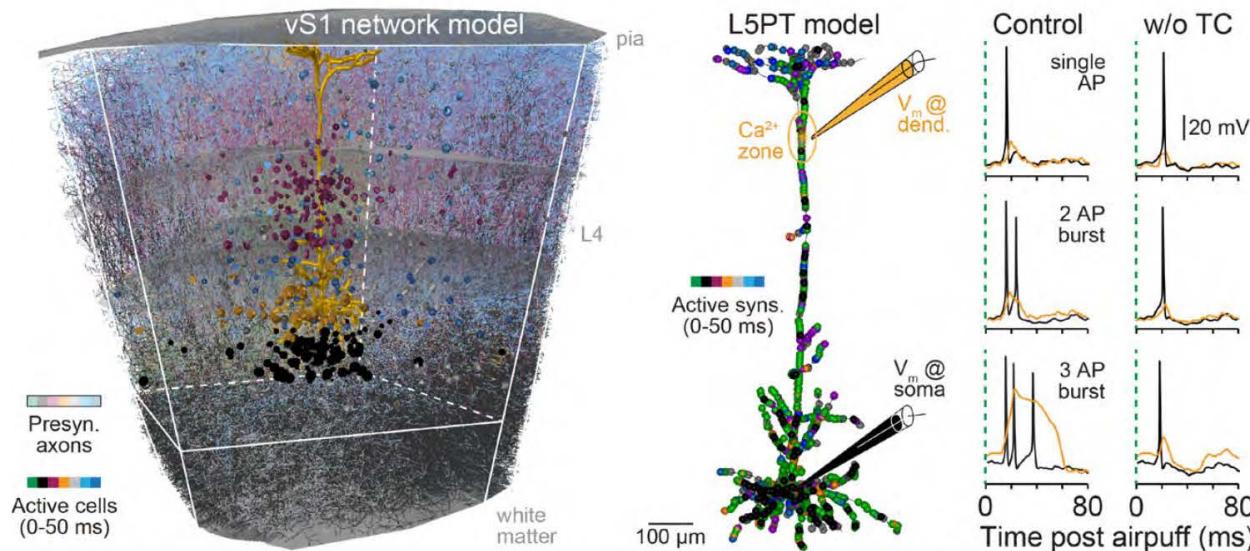
Network function

EXPERIMENT



Bast et al. 2023

MODEL

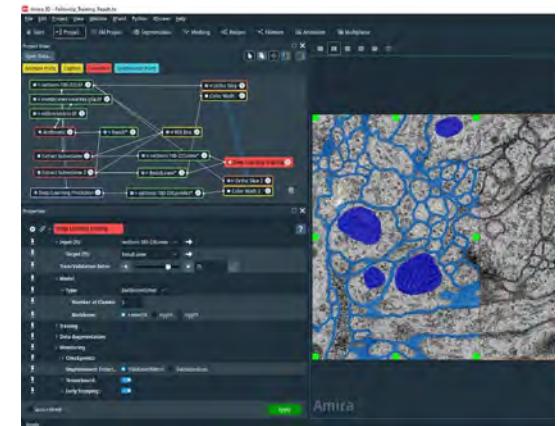
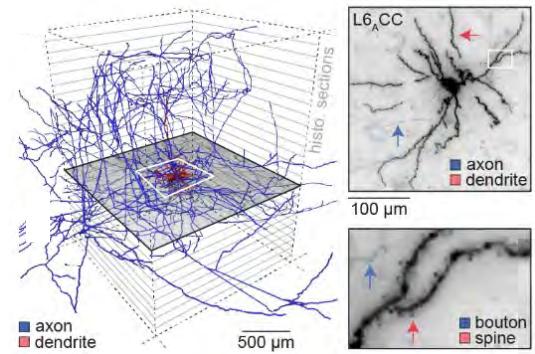


Bast et al. 2023

- High-dimensional parameter/feature space ()
- Spatiotemporal data (voltage traces at different locations)
- million simulation runs

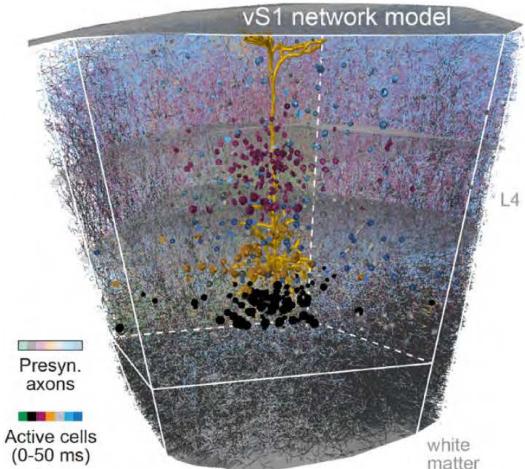
Visual computing in computational neuroscience

model generation



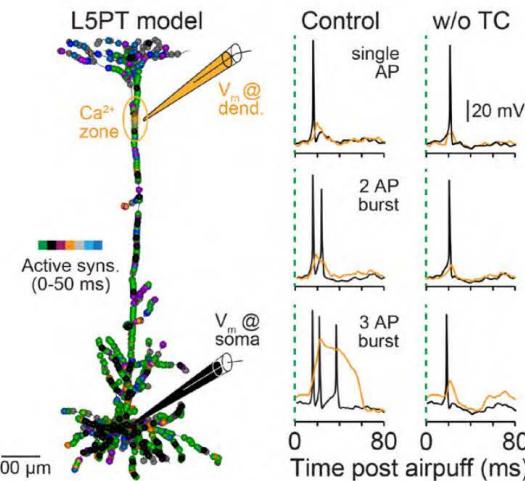
Amira software

structural model

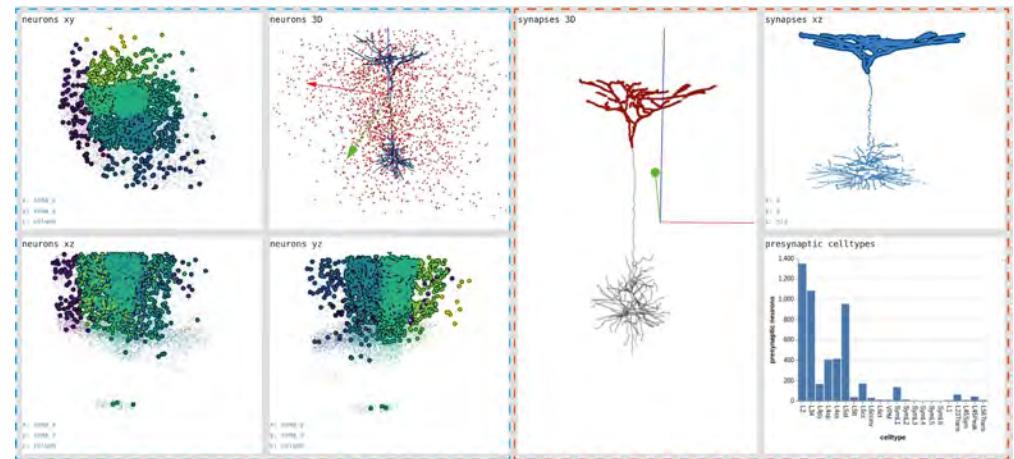


Bast et al. 2023

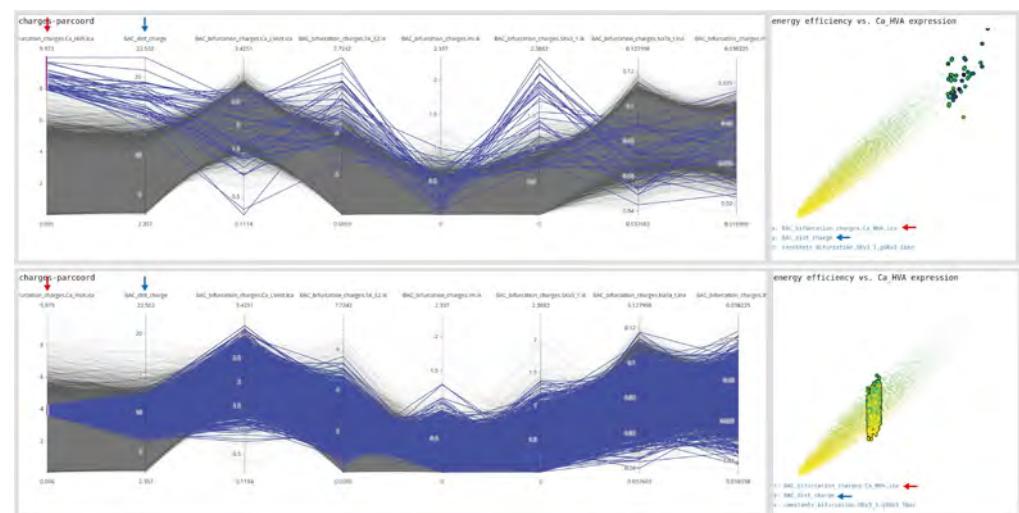
biophysical model



network analysis



model parameter analysis



goal: understand the neural basis of behavior

- Visual computing in computational neuroscience
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Design goals

- G1.** Support the combination of different view types.
- G2.** Integrate existing visualization frameworks and libraries to facilitate code reuse and reduce development time.
- G3.** Enable interactive and iterative refinement of views, workspace layout, and interaction logic.
- G4.** Avoid hard-coded or domain-specific ontologies tied to a priori known analysis questions or workflows.
- G5.** Support dynamic transitions between different workspace configurations.



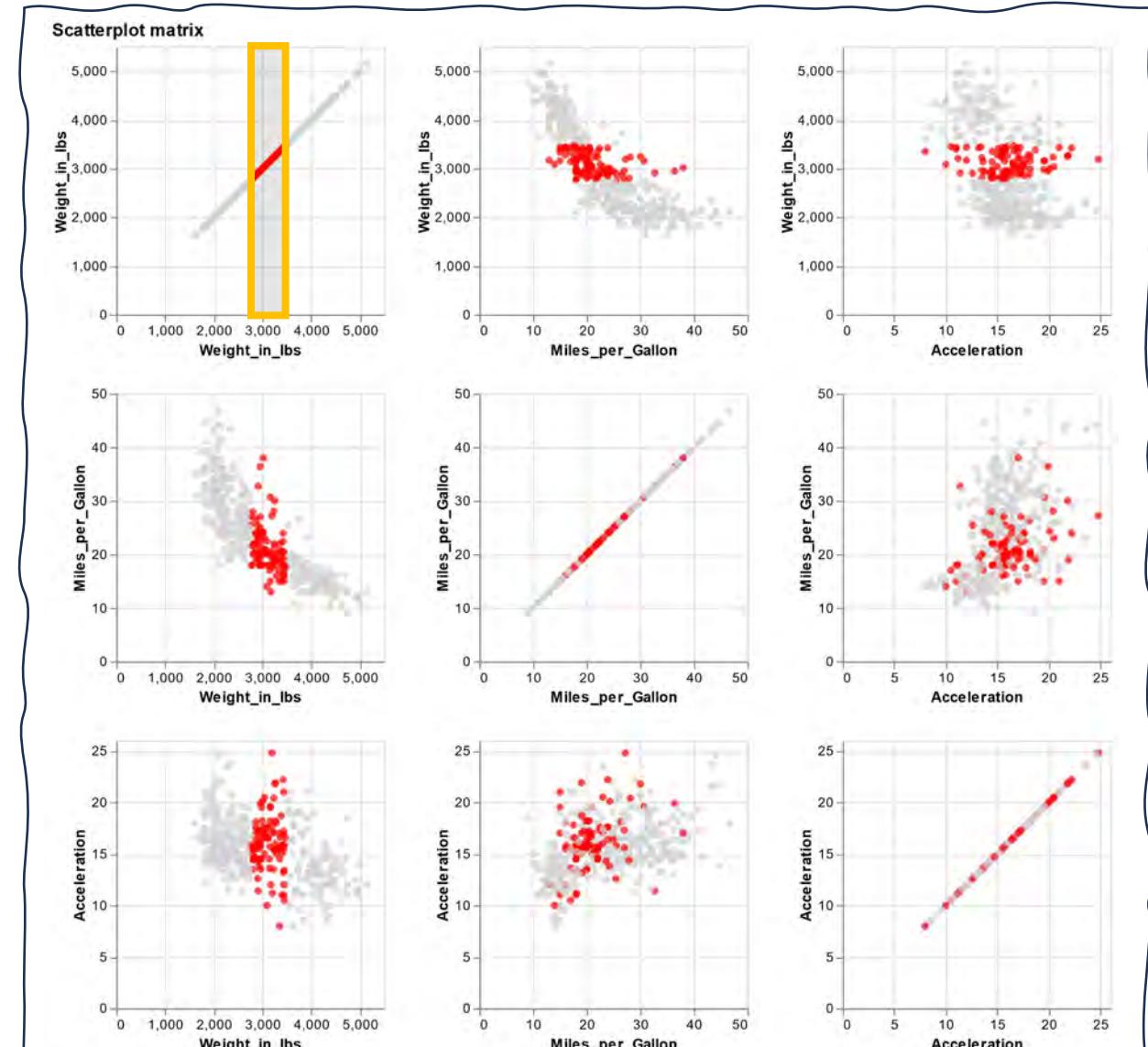
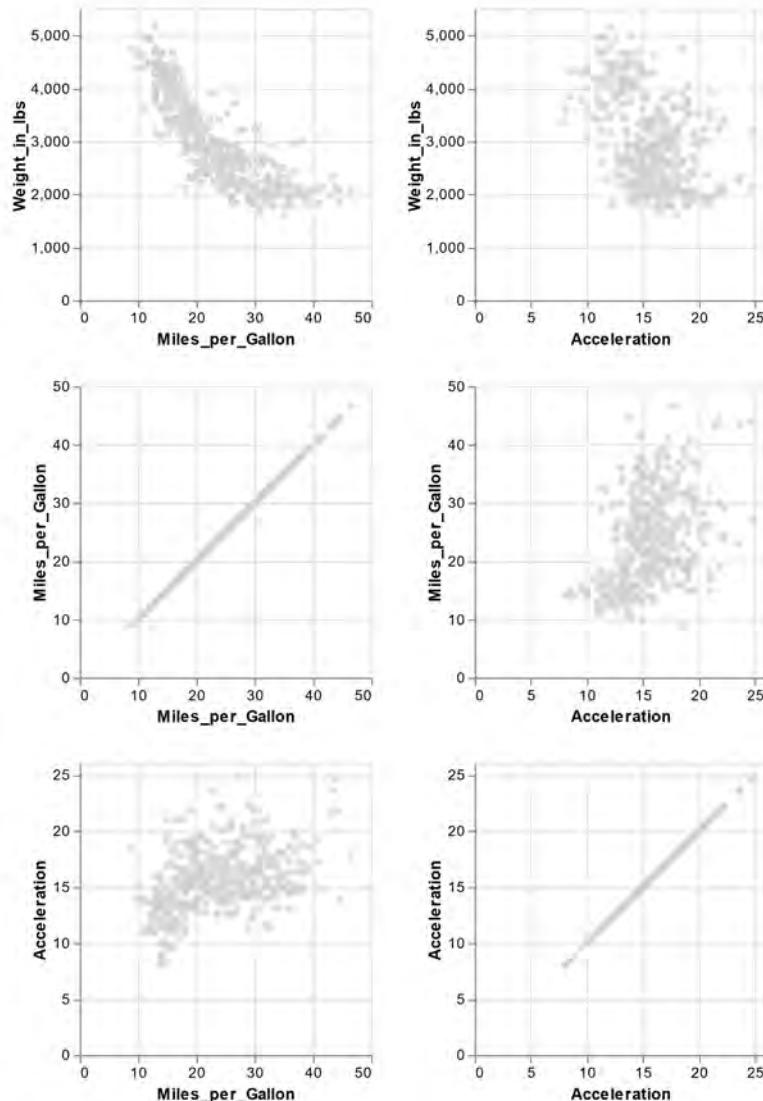
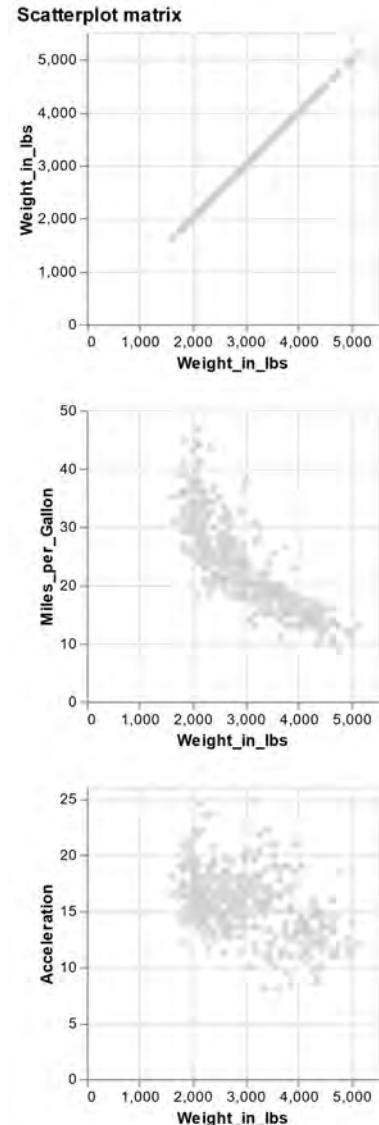
key features of tool

web-based coordinated views

combine InfoVis & SciVis views

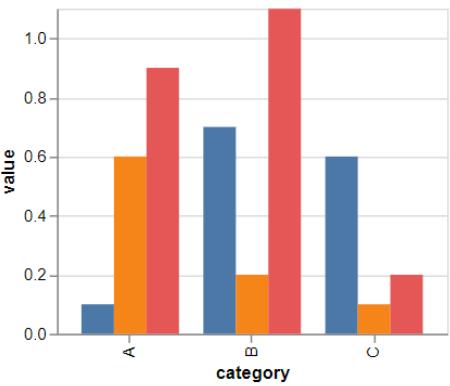
grammar-based specification

Coordinated views – *brushing* & *linking*

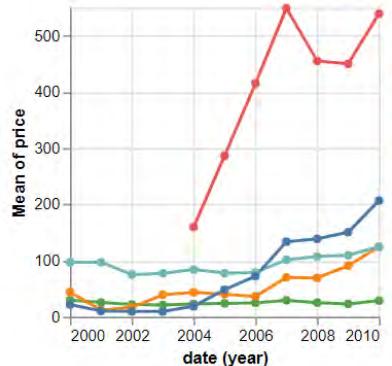


InfoVis & SciVis views

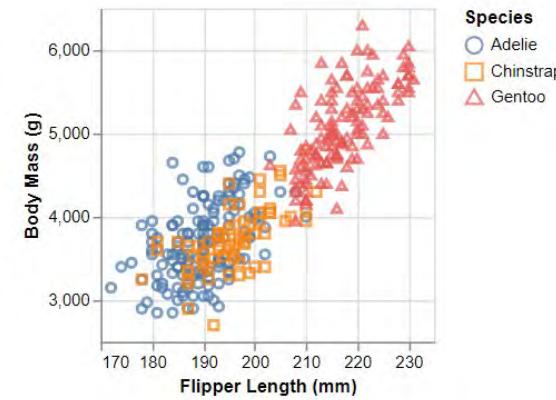
InfoVis: Information Visualization (abstract data)



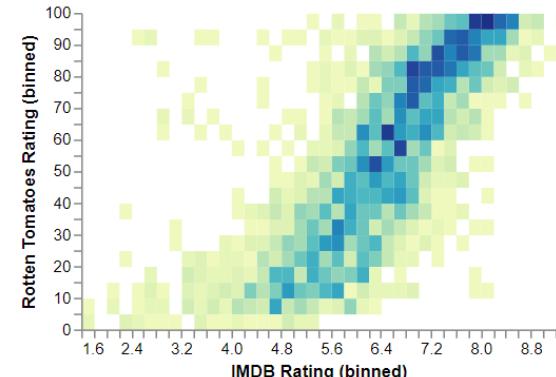
bar chart



line chart

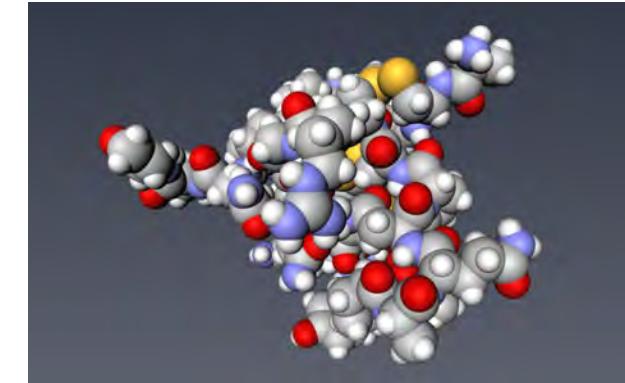


scatter plot

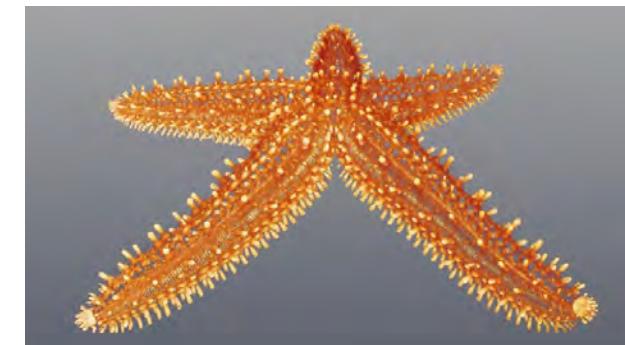


heat map

SciVis: Scientific Visualization (spatial data)



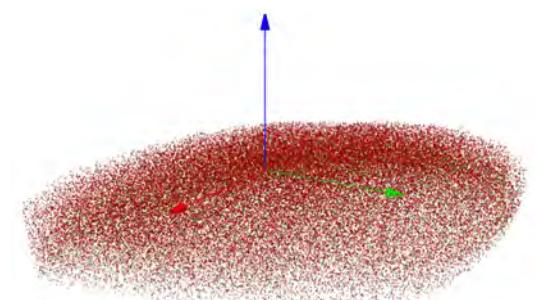
surface rendering



volume rendering



line rendering



point cloud rendering

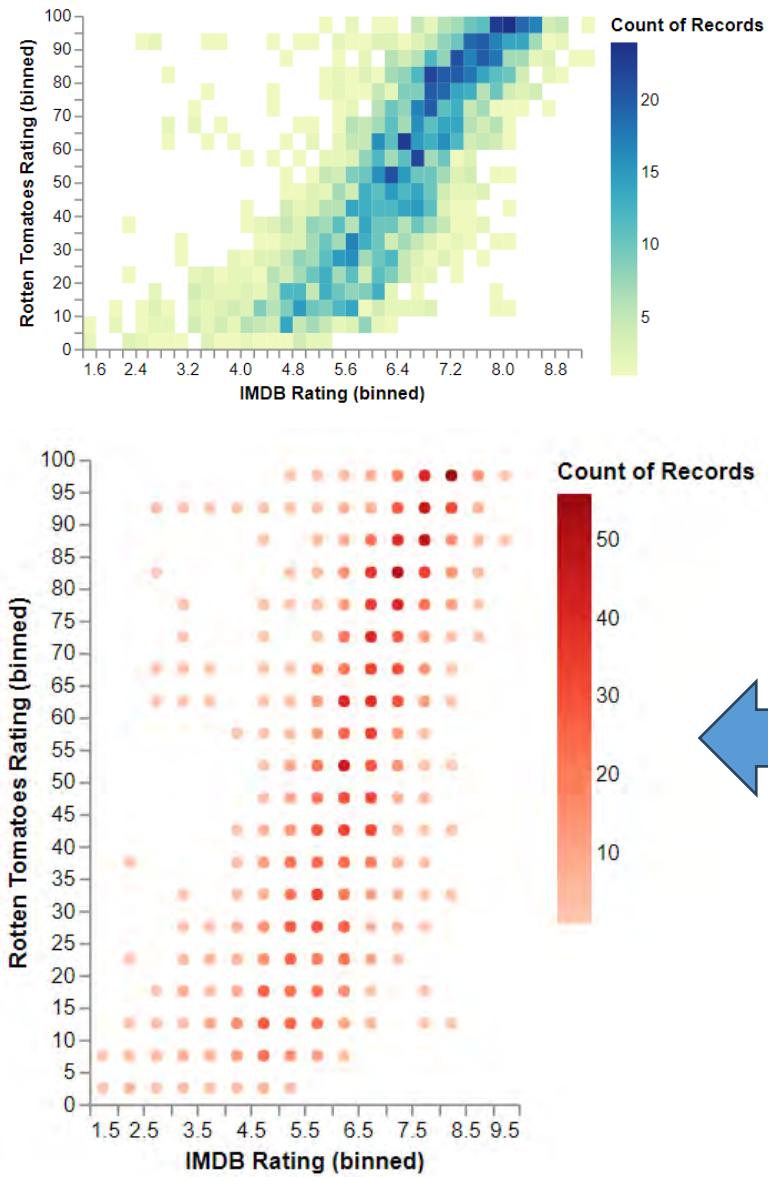
<https://vega.github.io/vega-lite/examples/>

<https://git.zib.de/amira/demos; cortexinsilico.zib.de>

Grammar-based specification – Vega-Lite example

JSON-based specification

```
{  
  "$schema": "https://vega.github.io/schema/vega-lite/v5.json",  
  "data": {"url": "data/movies.json"},  
  "transform": [{  
    "filter": {"and": [  
      {"field": "IMDB Rating", "valid": true},  
      {"field": "Rotten Tomatoes Rating", "valid": true}  
    ]}  
  }],  
  "mark": "rect",  
  "width": 300,  
  "height": 200,  
  "encoding": {  
    "x": {  
      "bin": {"maxbins": 60},  
      "field": "IMDB Rating",  
      "type": "quantitative"  
    },  
    "y": {  
      "bin": {"maxbins": 40},  
      "field": "Rotten Tomatoes Rating",  
      "type": "quantitative"  
    },  
    "color": {  
      "aggregate": "count",  
      "type": "quantitative"  
    }  
  },  
  "config": {  
    "view": {  
      "stroke": "transparent"  
    }  
  }  
}
```



modified specification

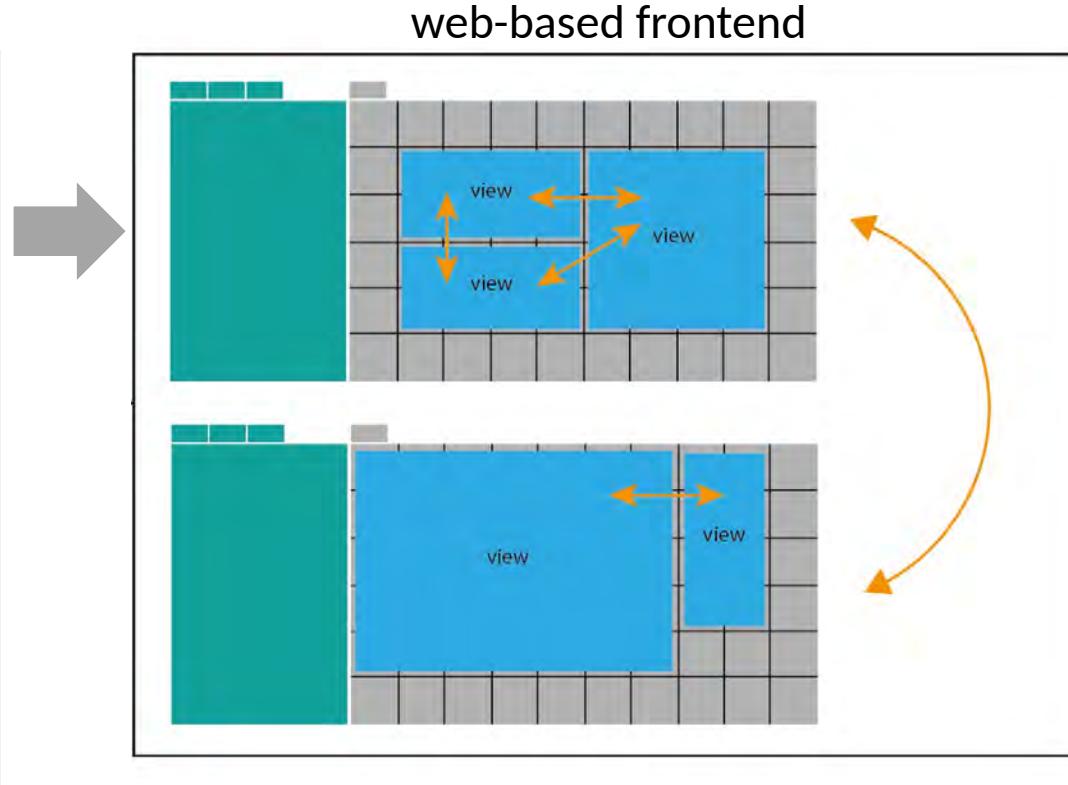
```
{  
  "$schema": "https://vega.github.io/schema/vega-lite/v5.json",  
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  "transform": [{  
    "filter": {"and": [  
      {"field": "IMDB Rating", "valid": true},  
      {"field": "Rotten Tomatoes Rating", "valid": true}  
    ]}  
  }],  
  "mark": "circle",  
  "width": 200,  
  "height": 300,  
  "encoding": {  
    "x": {  
      "bin": {"maxbins": 20},  
      "field": "IMDB Rating",  
      "type": "quantitative"  
    },  
    "y": {  
      "bin": {"maxbins": 40},  
      "field": "Rotten Tomatoes Rating",  
      "type": "quantitative"  
    },  
    "color": {  
      "aggregate": "count",  
      "type": "quantitative",  
      "scale": {  
        "scheme": "reds"  
      }  
    }  
  },  
  "config": {  
    "view": {  
      "stroke": "transparent"  
    }  
  }  
}
```

<https://vega.github.io/>

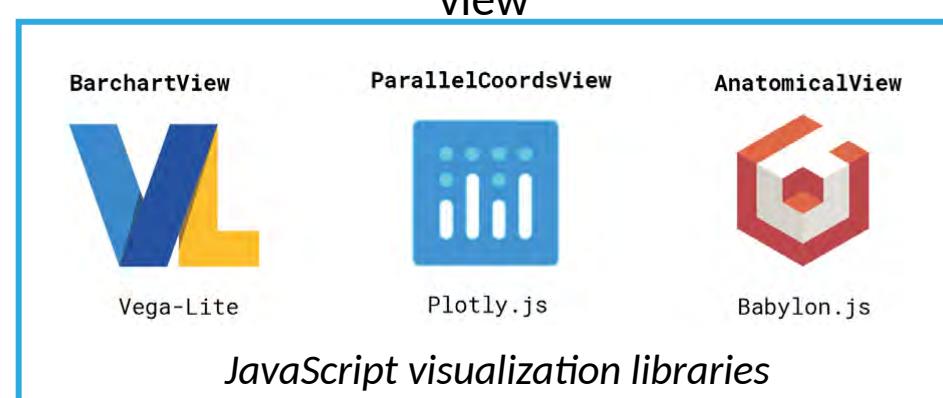
Technical realization

```
{  
  "views" : {  
    <view_name> : {  
      "type" : <view_type>,  
      "dataTable" : <table_name>,  
      "dataColumn" : [<column_name>, ...],  
      "configuration" : {...}  
    }  
  },  
  "grid" : { // partitions workspace  
    "cols" : int, "rowHeight": int, "width" : int  
  },  
  "layouts" : {  
    <layout_name> : {  
      "view" : <view_name>,  
      "x": int, "y": int, "w": int, "h": int  
    }  
  }  
  "initialLayout" : <layout_name>  
  "interactions" : {  
    <source_view_name> : [{ // source of interaction event  
      "filter" : {  
        "currentLayout" : <layout_name>,  
        "interactionType" : <interaction_type>  
        "selectedEntityType" : <type_name>  
        "numSelectedRange" : int | [int, int],  
      }  
      "action" : {  
        "assignData" : [<target_view_name>, ...],  
        "clearData" : [<target_view_name>, ...],  
        "assignSelectionAsData" : [<target_view_name>, ...],  
        "assignSelection" : [<target_view_name>, ...],  
        "intersectSelection" : [<target_view_name>, ...],  
        "unionSelection" : [<target_view_name>, ...],  
        "clearSelection" : [<target_view_name>, ...],  
        "changeLayout" : <layout_name>  
      }  
    }  
  }  
}
```

JSON-based specification



web-based frontend



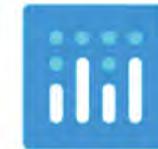
view

BarchartView



Vega-Lite

ParallelCoordsView



Plotly.js

AnatomicalView



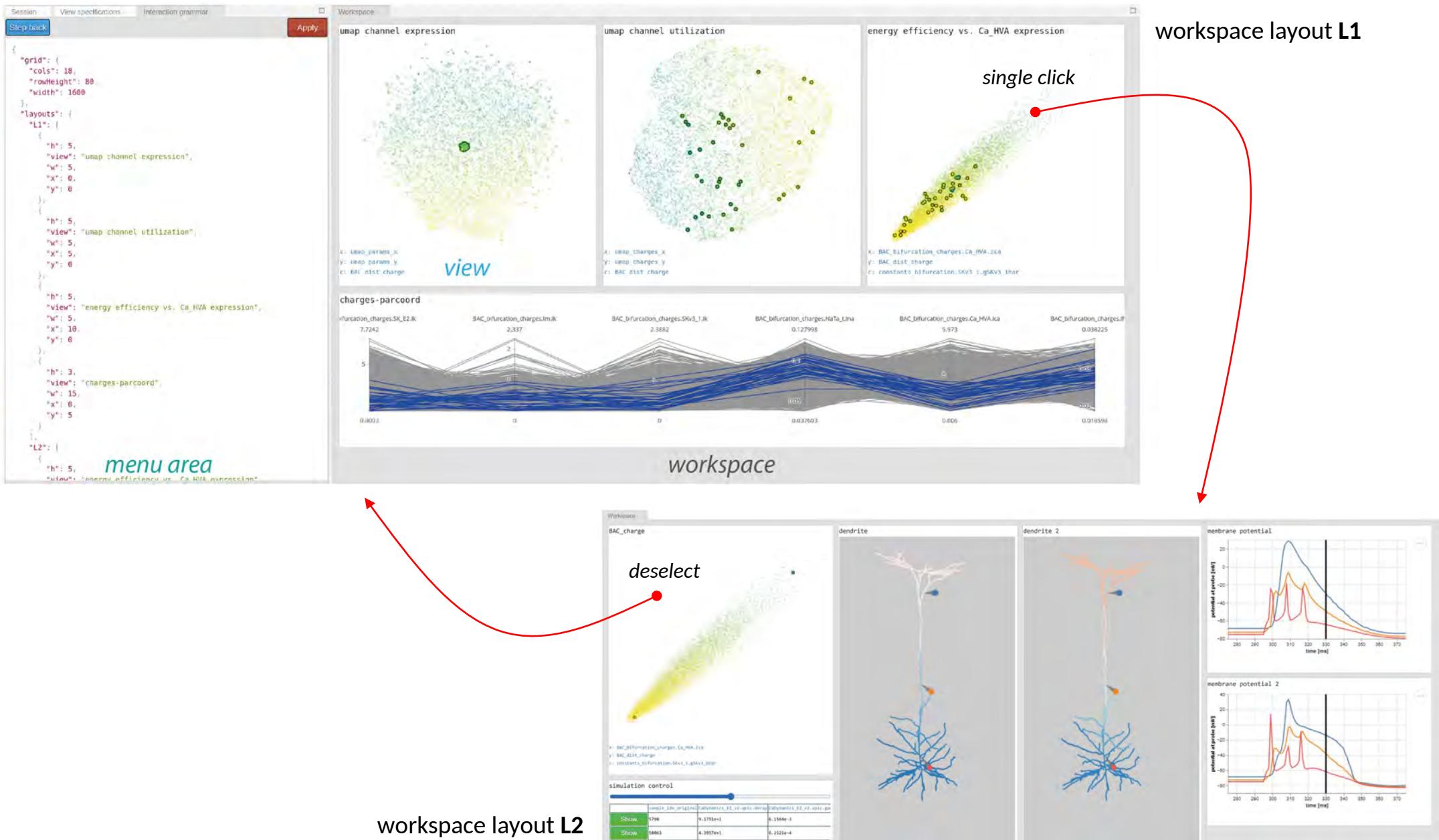
Babylon.js

JavaScript visualization libraries

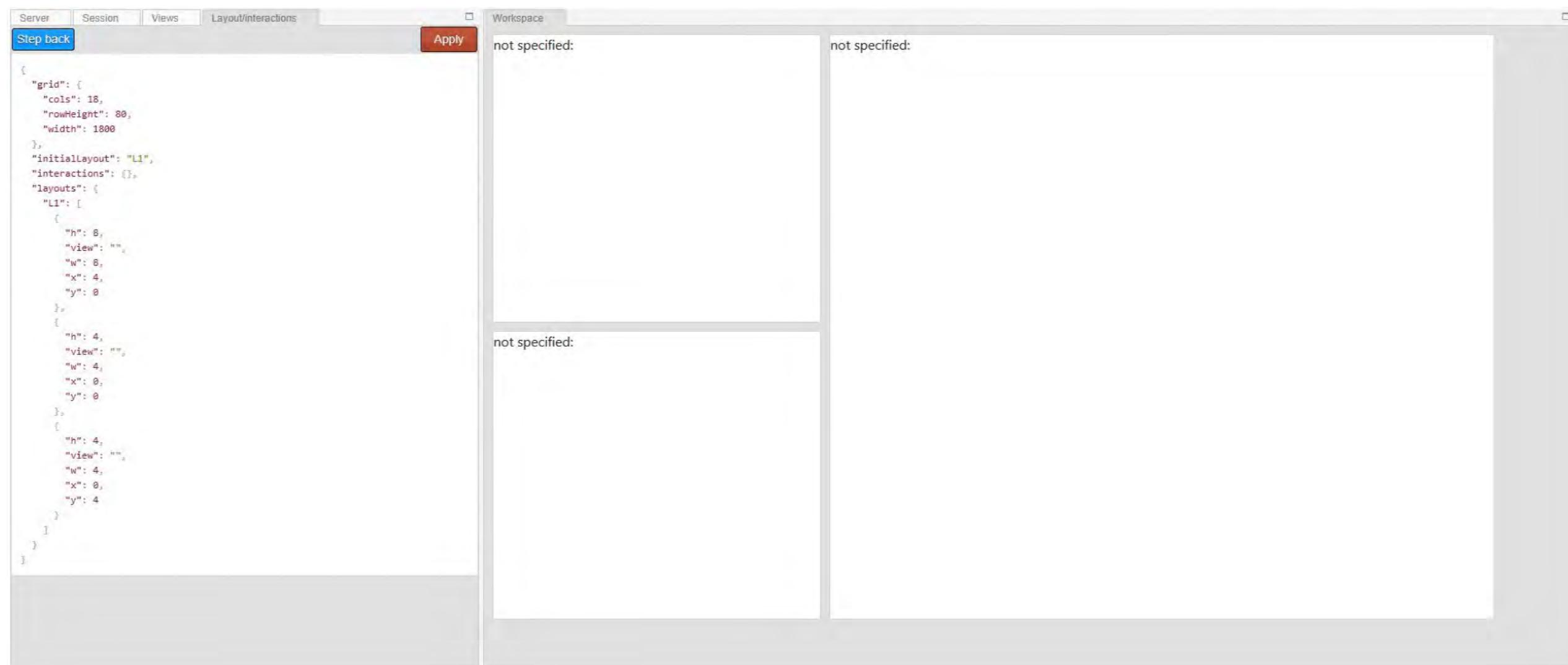
Technical realization



Technical realization

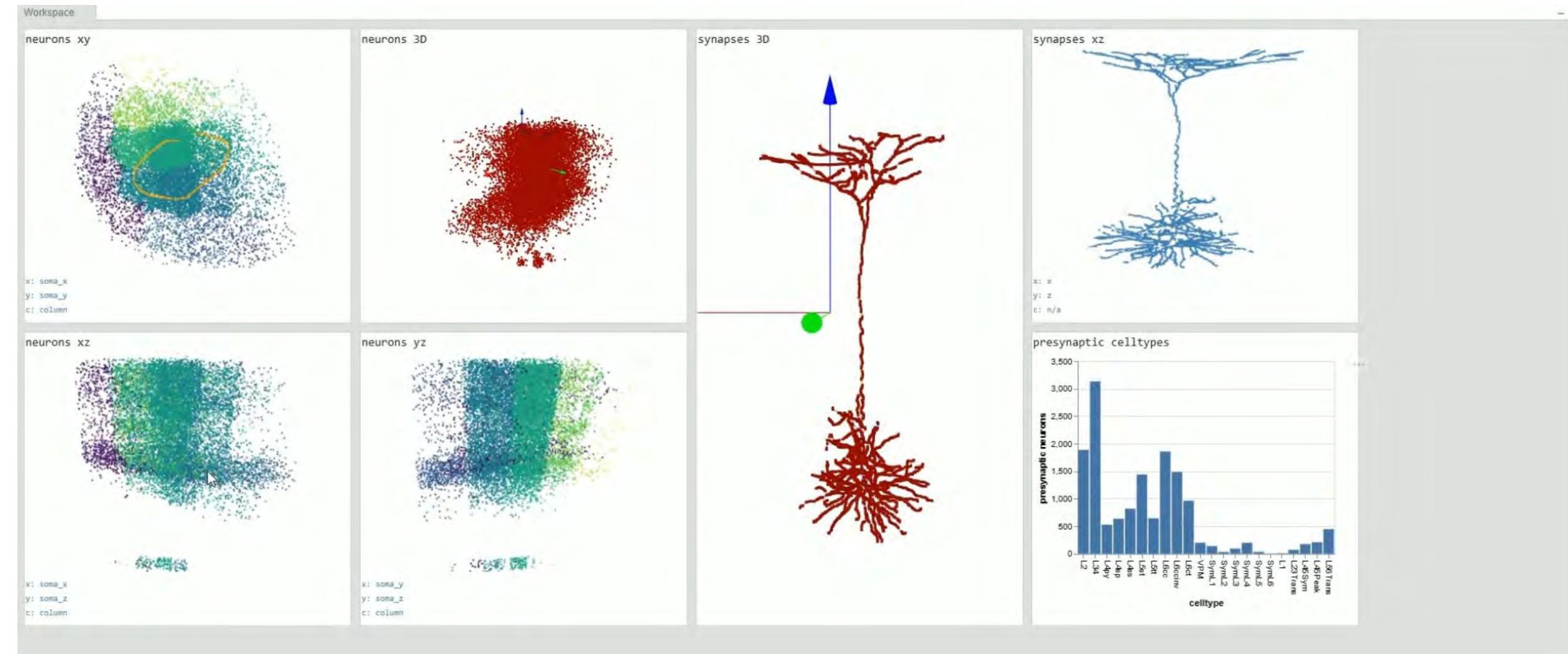


Simple demo – specifying linked views for point cloud data

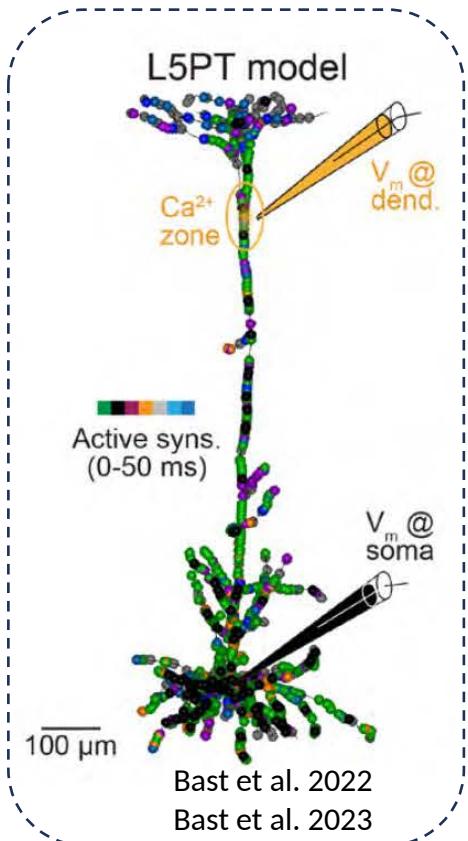


- Visual computing in computational neuroscience
- Design considerations and technical realization
- Application of tool and preliminary results
- Summary and outlook

Tool in usage with neuroscientific model data



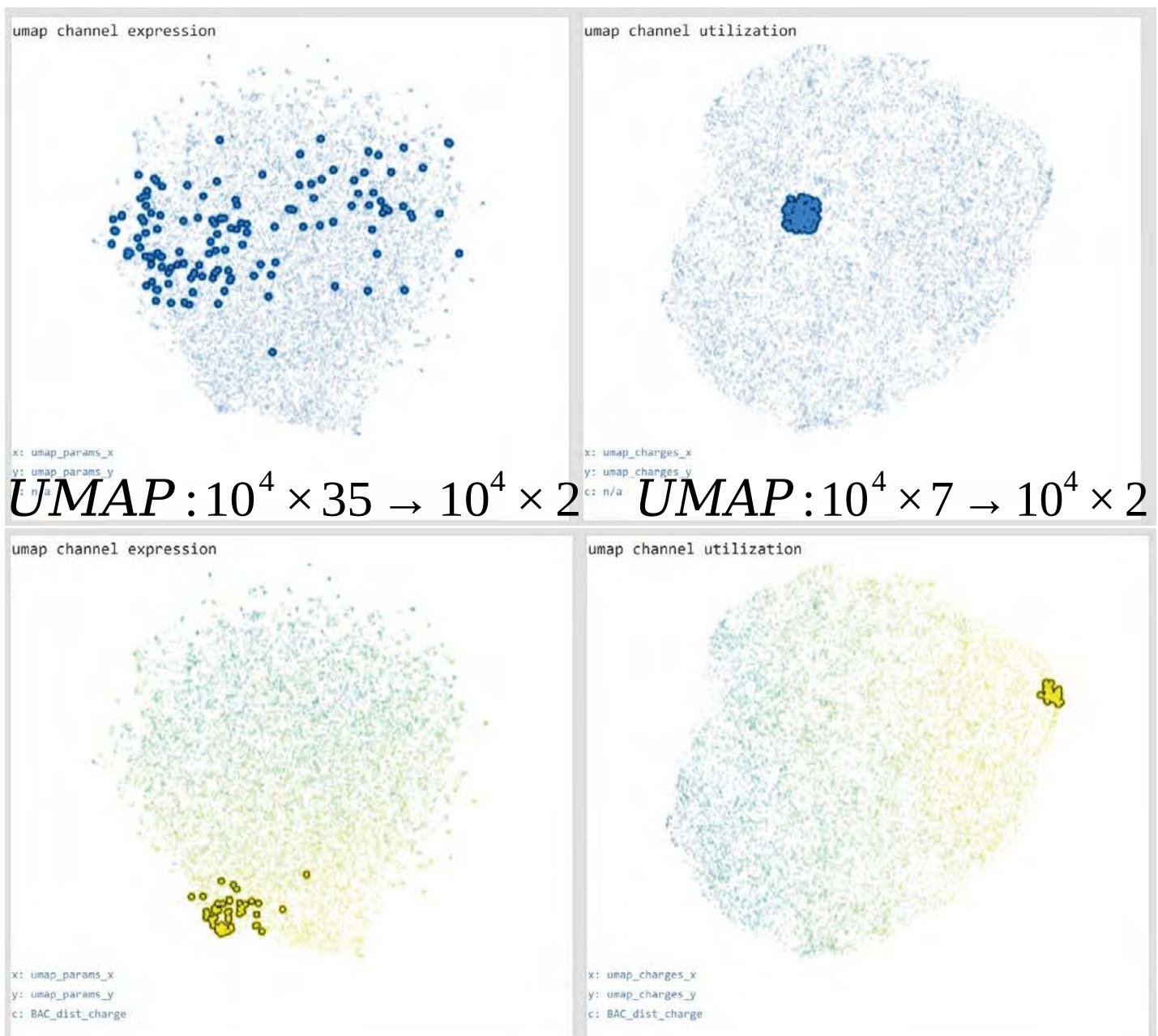
Biophysical model parameter analysis – preliminary results



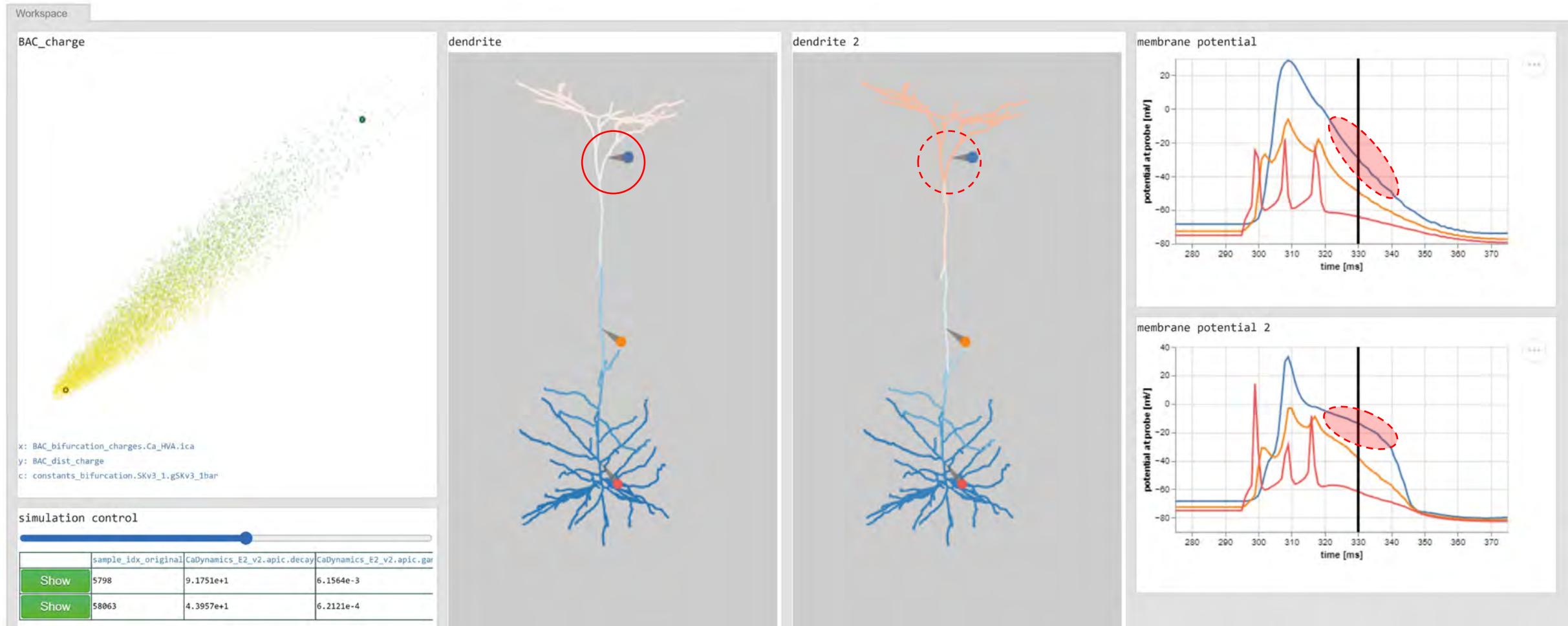
channel utilization
features for zone

channel expression
parameters

uniformly sampled
simulation runs



Biophysical model parameter analysis – preliminary results



comparing membrane potentials on neuron morphology for two selected parameter samples

- Visual computing in computational neuroscience
- Design considerations and technical realization
- Application of tool and preliminary results
- **Summary and outlook**

Key features of tool

- Web-based coordinated views
- Combines InfoVis & SciVis views from different JavaScript libraries
- JSON-based specification of layout and interactions
- Code: <https://github.com/zibneuro/coordinated-views>

Future work

- Integrate vaex (<https://vaex.io/>) to improve performance of Python backend
- Integrate backend server into Jupyter notebook
- Develop expressive syntax for configuration of 3D view
- Demonstrate generalizability with data from other domains

Thank you for your attention!

Acknowledgements:

SPP 2041 Computational Connectomics (DFG)



References

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- Boelts, J., **Harth**, P., Gao, R., Udvary, D., Yáñez, F., Baum, D., Hege, H.-C., Oberlaender, M., & Macke, J. H. (2023). Simulation-based inference for efficient identification of generative models in computational connectomics. *PLOS Computational Biology*; accepted for publication
- **Harth**, P., Vohra, S., Udvary, D., Oberlaender, M., Hege, H.-C., & Baum, D. (2022). A Stratification Matrix Viewer for Analysis of Neural Network Data. In R. G. Raidou, B. Sommer, T. W. Kuhlen, M. Krone, T. Schultz, & H.-Y. Wu (Eds.), *Eurographics Workshop on Visual Computing for Biology and Medicine (VCBM)*. The Eurographics Association. <https://doi.org/10.2312/vcbm.20221194>
- **Harth**, P., Bast, A., Troidl, J., Meulemeester, B., Pfister, H., Beyer, J., Oberlaender, M., Hege, H.-C., & Baum, D. (2023). Rapid Prototyping for Coordinated Views of Multi-Scale Spatial and Abstract Data: A Grammar-based Approach. *Eurographics Workshop on Visual Computing for Biology and Medicine (VCBM)*; accepted for publication
- Shapson-Coe, A., Januszewski, M., Berger, D. R., Pope, A., Wu, Y., Blakely, T., Schalek, R. L., Li, P. H., Wang, S., Maitin-Shepard, J., Karlupia, N., Dorkenwald, S., Sjostedt, E., Leavitt, L., Lee, D., Bailey, L., Fitzmaurice, A., Kar, R., Field, B., ... Lichtman, J. W. (2021). A connectomic study of a petascale fragment of human cerebral cortex. *BioRxiv*. <https://doi.org/10.1101/2021.05.29.446289>
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- Udvary, D., **Harth**, P., Macke, J. H., Hege, H.-C., de Kock, C. P. J., Sakmann, B., & Oberlaender, M. (2022). The impact of neuron morphology on cortical network architecture. *Cell Reports*, 39(2). <https://doi.org/10.1016/j.celrep.2022.110677>

Implementation – code snippets

WebGL-enabled scatter plot
[Lekschas, 2023]

```
class WebGLScatterPlot extends CoordinatedView {
  constructor(props) {
    super(props);

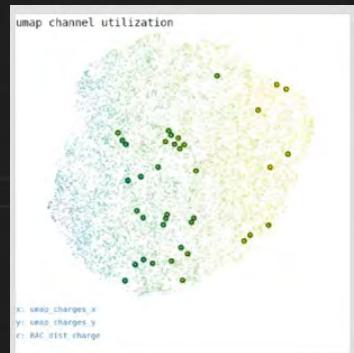
    handleSelect(eventArgs) {
      this.notifyInteraction(new SelectionEvent(this.name, this.dataTables).setIndices(eventArgs.point));
    }

    handleDeselect() {
      this.notifyInteraction(new SelectionEvent(this.name, this.dataTables).setDeselect());
    }

    render() {
      return <div style={styleBackground}><canvas ref={this.myRef} width={this.width} height={this.height}></canvas>
    }
  }

  componentDidMount() {
    const canvas = this.myRef.current;
    canvas.fillStyle = "white";
    if (this.dataTables.length < 2) {
      return;
    }

    const { width, height } = canvas.getBoundingClientRect();
    this.scatterplot = createScatterplot({
      x: umap_charges_x,
      y: umap_charges_y
    });
  }
}
```



```
class CoordinatedView extends React.Component {
  constructor(props) {
    super(props);

    this.name = props.name;
    this.dataTables = props.dataTables;
    this.dataColumn = props.dataColumn;
  }
```



parallel coordinates
Plotly.js

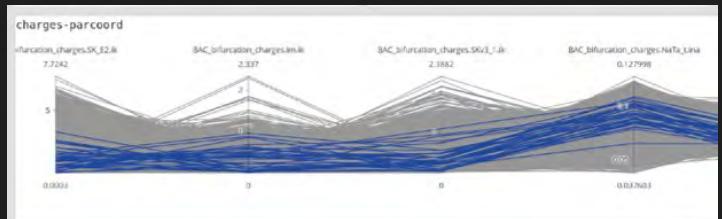
```
class ParallelCoordinates extends CoordinatedView {
  constructor(props) {
    super(props);

    this.state = {
      traces: empty_traces,
    };
    this.constraints = undefined;
  }

  this.notifyInteraction(new SelectionEvent(this.name, this.dataTables).setIndices(filtered_indices));
}

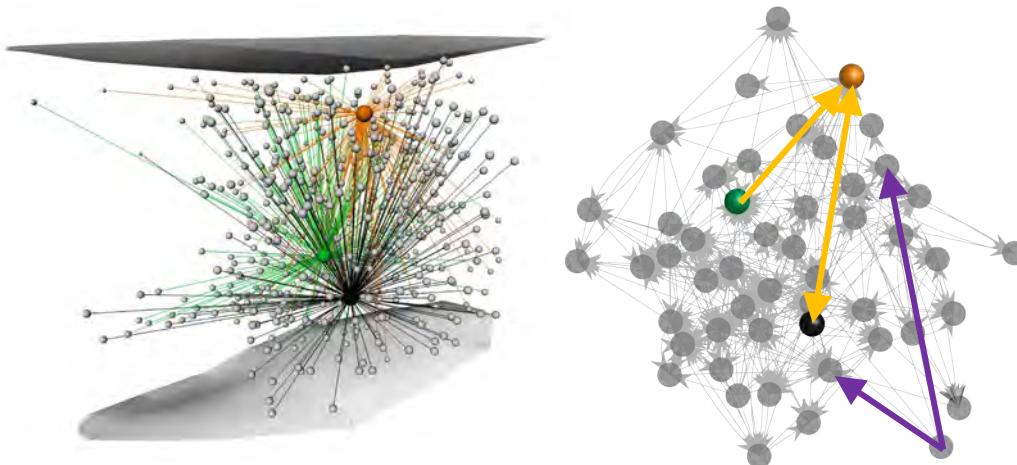
render() {
  const layout = {
    margin: {
      l: this.marginLeft,
      r: this.marginRight,
      t: this.marginTop,
      b: this.marginBottom,
    },
    width: this.width,
    height: this.height
  }

  return <Plot
    data={this.state.traces}
    layout={layout}
    onUpdate={this.handleEvent.bind(this)}
  />
};
```



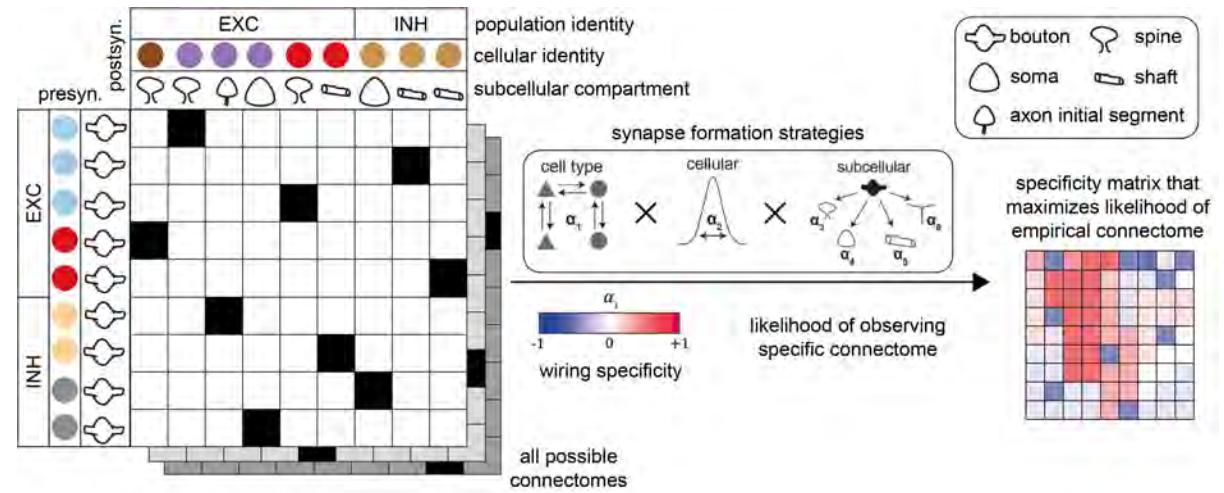
Network analysis

impact of neuron morphology on connectivity



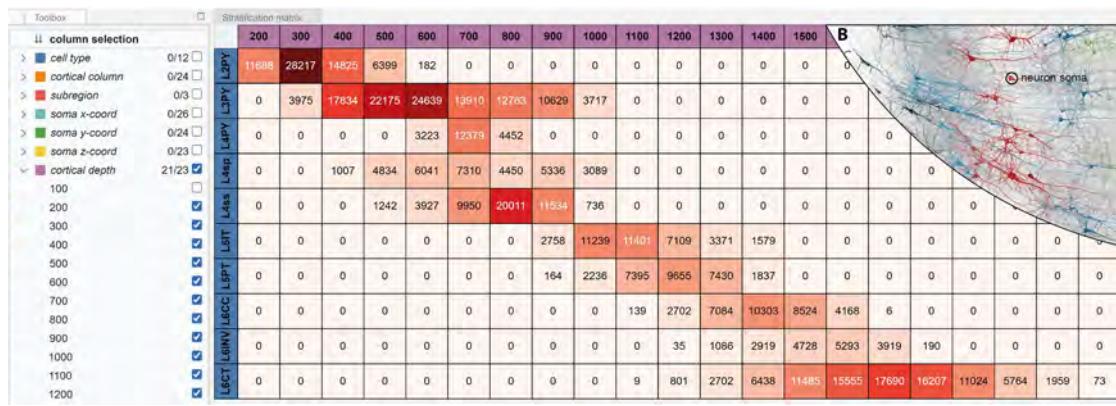
Udvary, Harth et al.; *Cell Reports*, 2022.

feature-rich generative network models



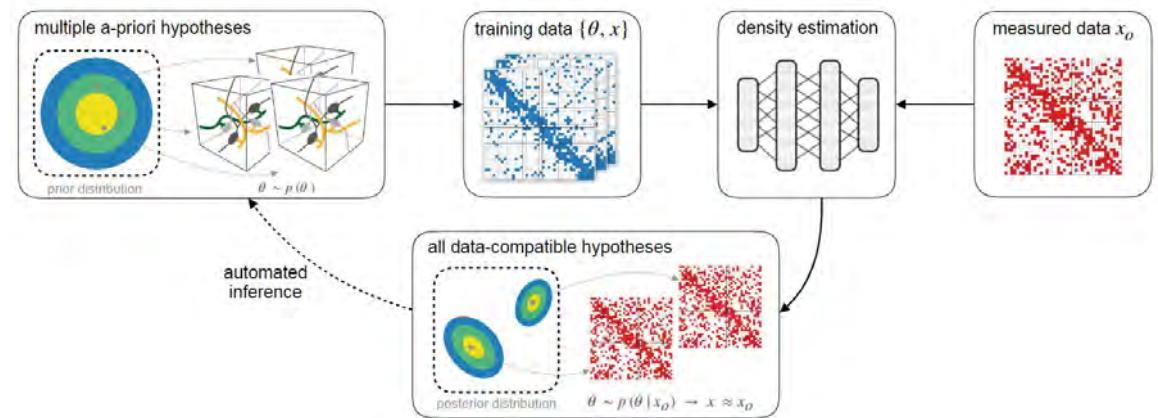
(in preparation)

stratification matrix viewer



Harth, Vohra et al.; VCBM, 2022.

simulation-based inference of parameters



Boelts, Harth et al.; *PLOS Comp. Biol.*, 2023. (accepted for publication)