Orderbook Visualization & Analysis

by Pavel Schön & Sebastian Neusüß

eurex

Agenda

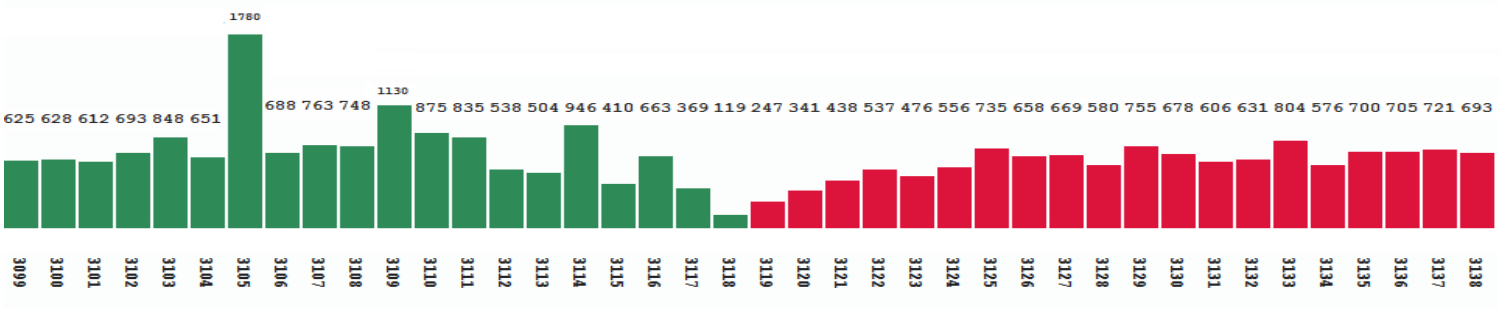
- **Introduction & Motivation**
- **Orderbook Player**
- **2D/3D Orderbook Viewer**
- **Implementation Details**

Motivation

- Initially driven by discussions about HFT participation at EUREX
- Public data is enriched with private data
- Get (fast) insights into market structure and member participation
- Integrated into the existing monitoring tools (browser based)
- Eurex order by order feed (EOBI) as primary data source
- Three modes
  - Orderbook player
  - 2D (everything at a glance)
  - 3D (showcase)

Introduction

- **'(Limit) order book': A list of unexecuted buy and sell orders for a specific financial instrument.**
- **Usually organized by price level, pioritized by time**
- **Key figures: best bid / best offer (volume,price), spread, total bid/offer volume, liquidity measures etc**
- **Two Market Data feeds available on Eurex**
  - **Price Level Aggregate (EMDI)**
  - **Order by Order (EOBI, available for benchmark futures only)**

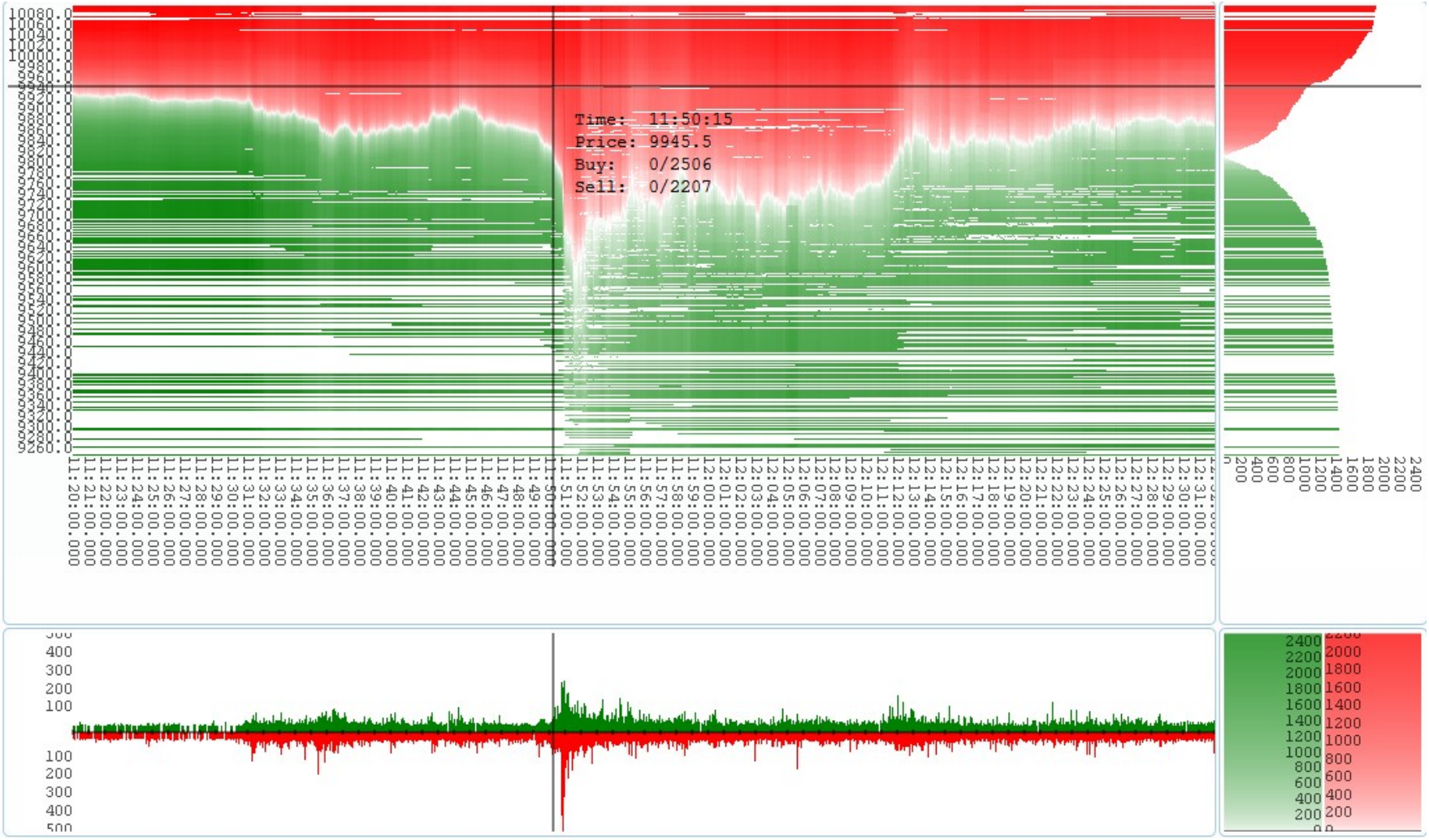


Orderbook Player

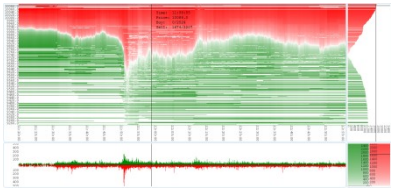
Orderbook Player

- Display orderbook ‘order by order’ and aggregated at a certain time
- ‘Play’ orderbook in configurable steps
- Animations show changes to the orderbook
- Trades of last two time steps are shown in ‘tradebox’
- Highlighting of orders based on ownership (or groups of owners), e.g. ‘HFT’ ▯ ‘non HFT’ participation
- Detailed information for each order in context menu, tracking of individual orders

Orderbook Viewer – 2D



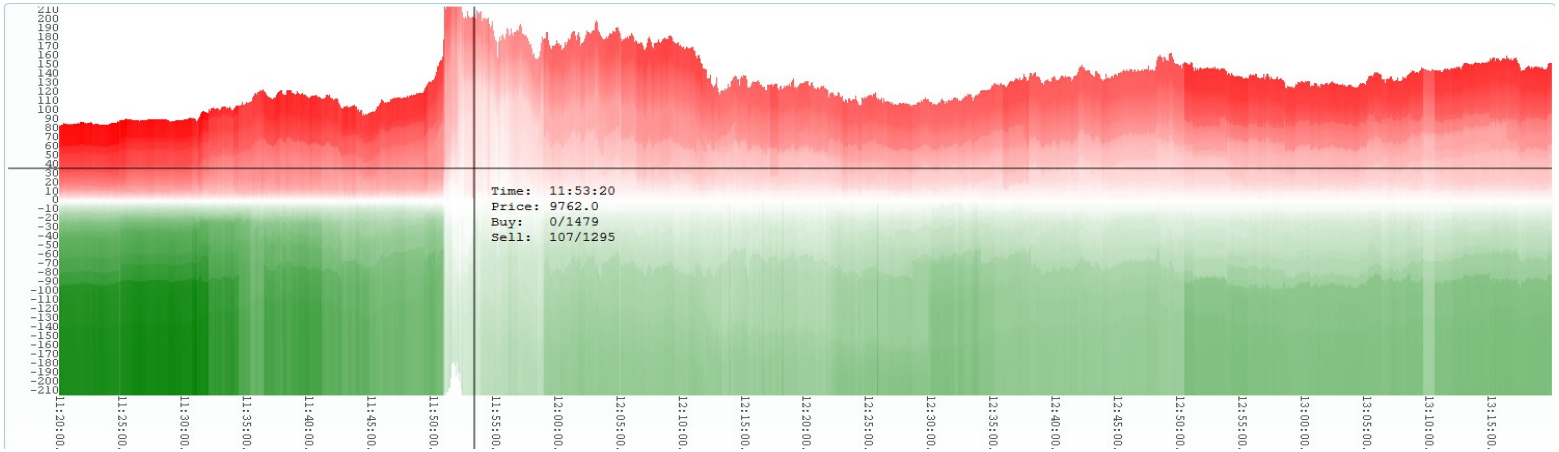
Orderbook Viewer – 2D



- Overview of the orderbook development over time
- Price (y-Axis), Time (x-Axis), volume (color depth)
- Cross-hair for details (orderbook snapshot shown in upper right graph)
- Lower left graph shows and correlates traded volumes
- Zoomable to order by order level
- Selection of orders: by owner, owner group (HFT/non HFT), orders traded/not traded, order lifetime etc
- Configuration for accumulation and aggregation mode, color scale, normalization to best bid/best offer

2D

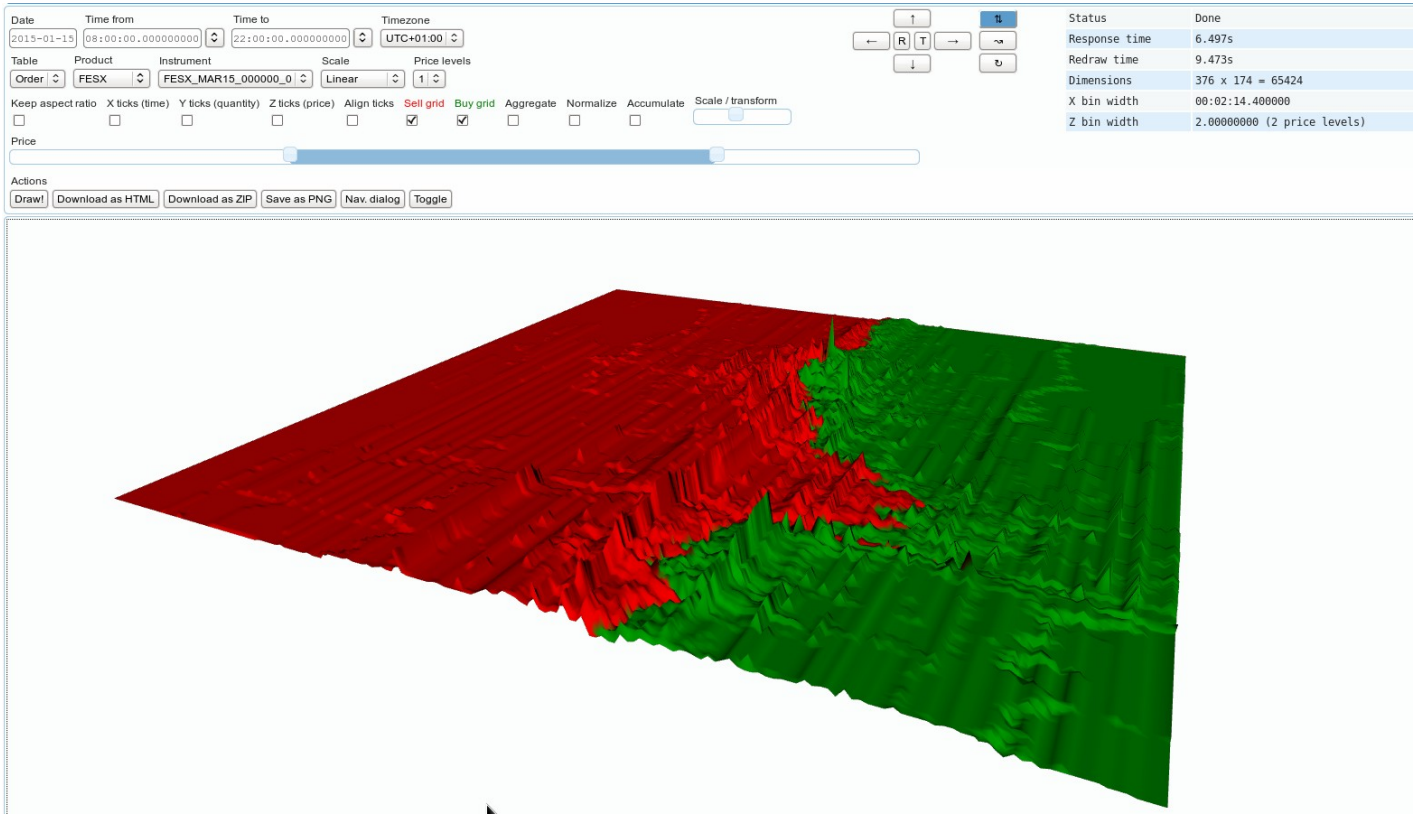
- **Normalized, linear color-scale**



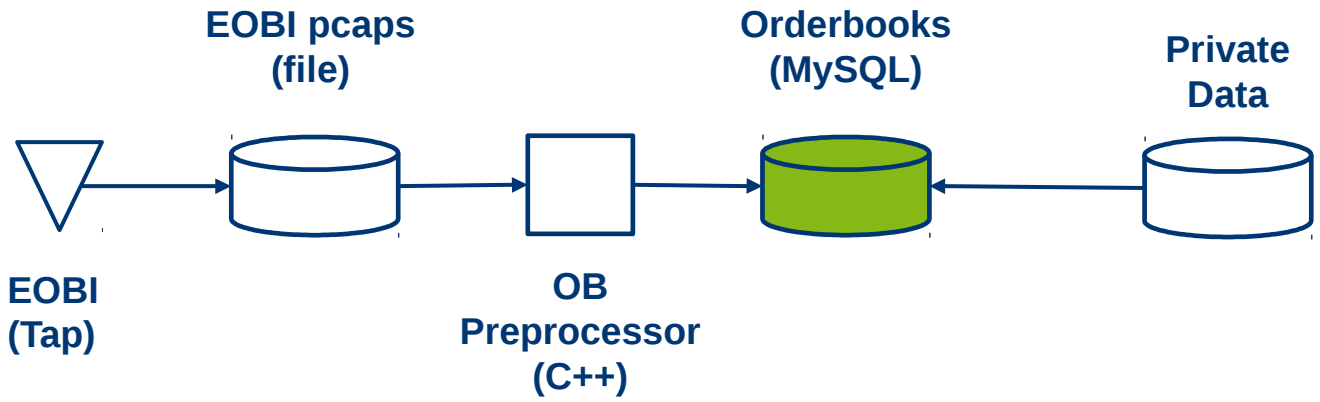
- **Individual contributions**

3D

- **Showcase**
- **Possibility to overlay two orderbooks (soon)**



Data pre-processing



- Main data source is the Eurex order by order feed
- This feed provides order add, modify, delete and execution information for all (visible) orders
- The feed is translated into Order Lifetime records (all times in ns):

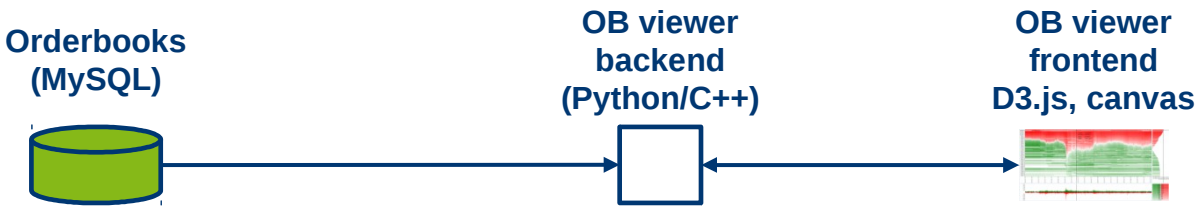
Start	End	Instrument	Side	Priority	Price	Quantity	Executed Quantity	Private Info

- Private Information (Business Unit, Session etc) is added afterwards

Front End – Tech Overview

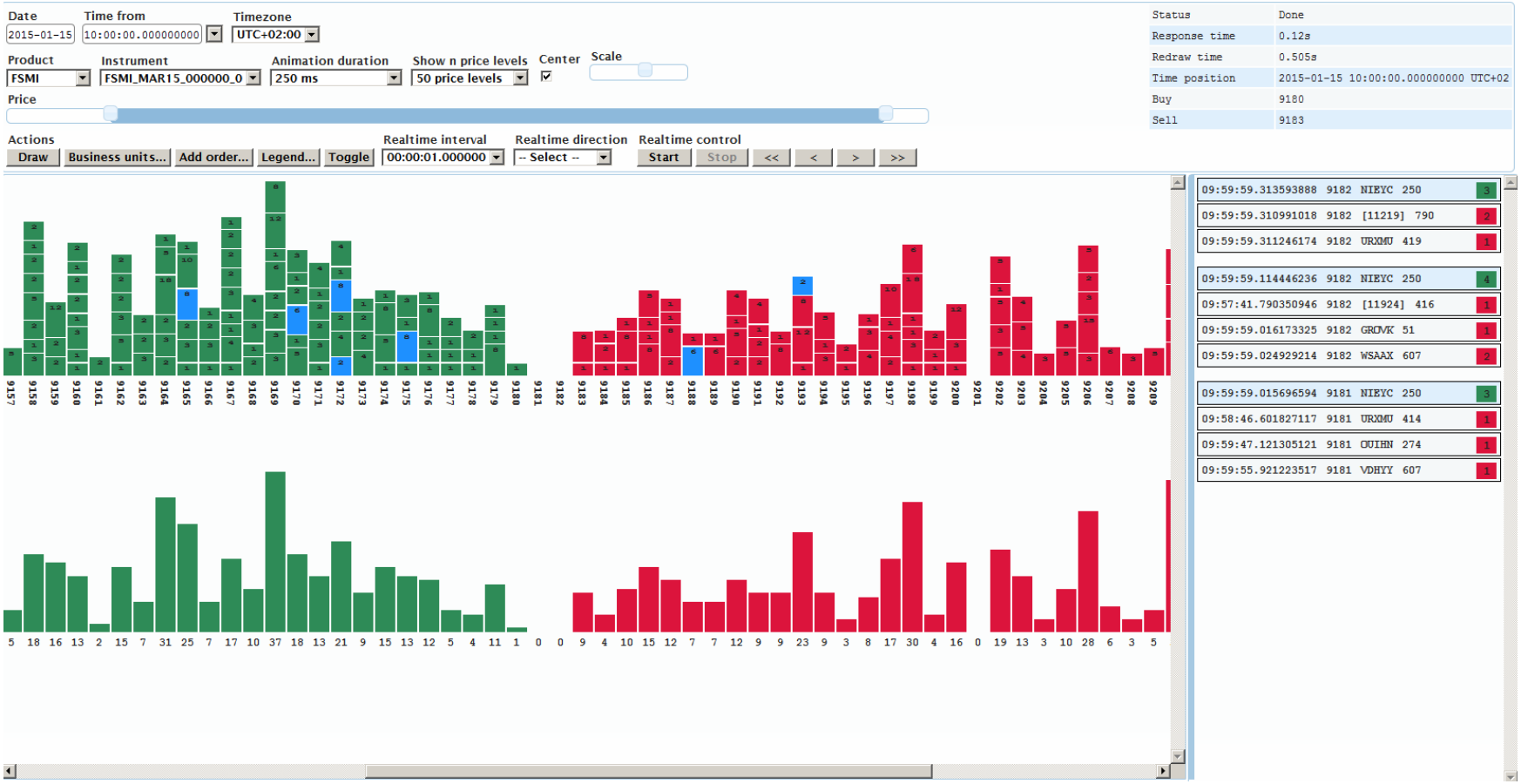
- FE served by webserver using Apache + mod_wsgi
- Python modules partly using C++ modules (boost::python)
- SQLAlchemy as database abstraction layer
  - We combine both SA Core and SA ORM
- Jinja2 as templating engine
- JavaScript libraries: jquery(-UI), D3.js, X3DOM.js, Flot.js, canvas API
- Official support only for firefox (reduces testing efforts)

Front End Data Flow



- Mysql Database SQL Alchemy python/c++ WebGUI (javascript, d3)
- Frontend backend communication via ajax using json

Orderbook Player – Technical Overview



Order book player – 1st stage

- Setup and animations using D3.js enter(), update(), exit()
- For smooth animations data prepared in background (New Orderbook + Delta to Old)
- elements are marked using CSS classes and for animation and removal are re-selected in the 2nd stage.

```
priceLevels = orderBook.selectAll('div.priceLevel').data(data.priceLevels);
priceLevels.enter().append('div').classed({ 'priceLevel': true, 'new': true });
priceLevels.each( unpack( function( price, side, qty, orders ) { // unpacked tuple
    priceLevel.orders = this.selectAll('div.order').data(orders);
    priceLevel.orders.enter().append('div').classed({ 'order': true, 'new': true });
    priceLevel.orders.each( unpack( function( timePrio, side, qty, execQty ) {
        order.classed('changed-qty', qty < order.prevQty ) });
        order.classed('trade', execQty > 0); // check if order is traded
    });
    priceLevels.orders.exit().classed('remove-this', true); });
priceLevels.exit().classed('remove-this', true); // mark them for removal
```

Order book player – 2nd stage

- **Animate divs marked as new/trade/changed-qty**

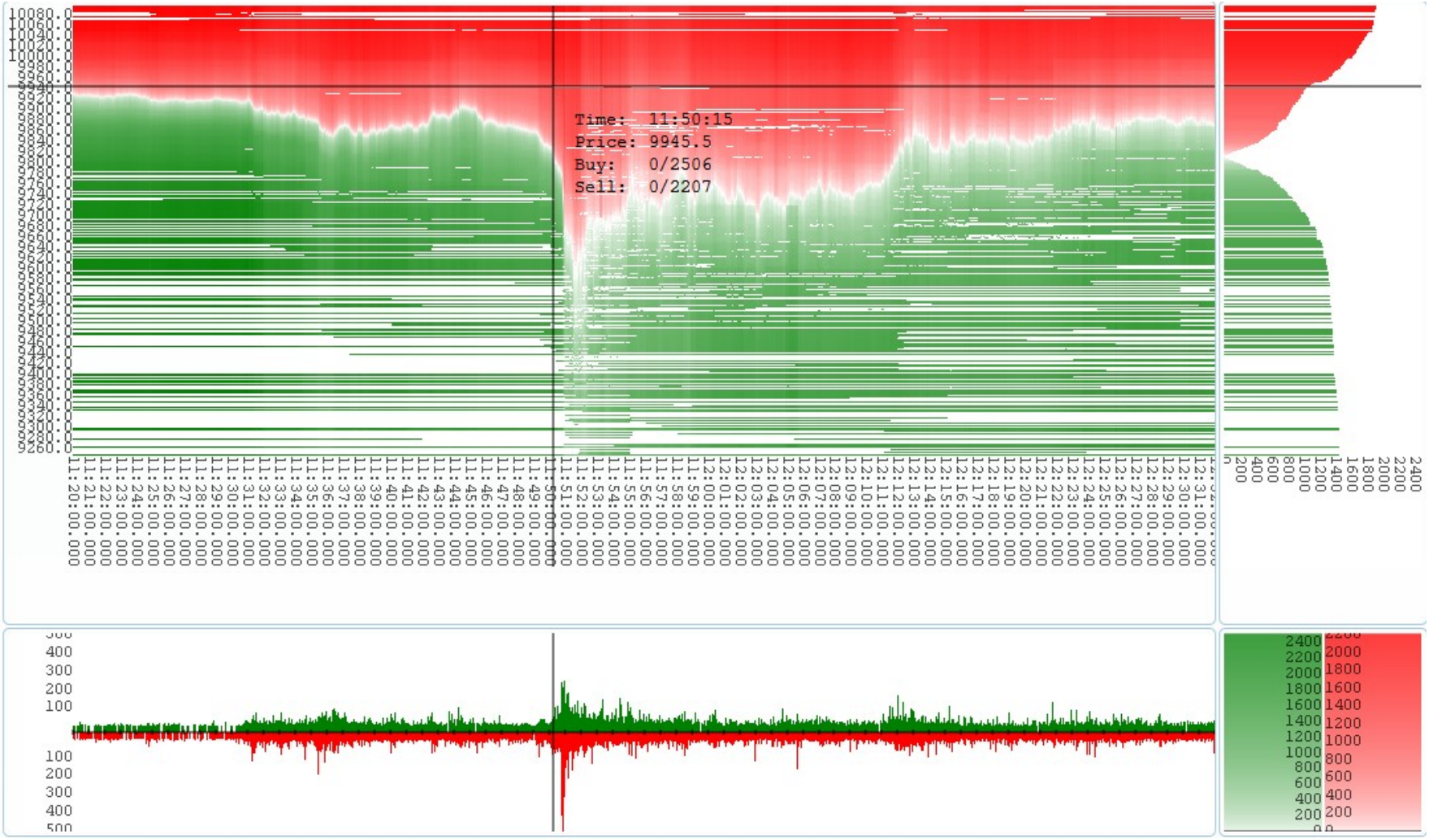
```
orderBook.selectAll('div.priceLevel.new')
orderBook.selectAll('div.order.new')
orderBook.selectAll('div.order.changed-qty')
orderBook.selectAll('div.order.trade') // after animation mark as remove-this
```

- **Remove divs (orders and price levels) marked as remove-this**

```
orderBook.selectAll('div.order.remove-this, div.trade.remove-this').remove()
```

- **No d3.transitions, just simple setTimeout()**
- **No d3.layouts and behaviours**

Orderbook Viewer – Technical Overview

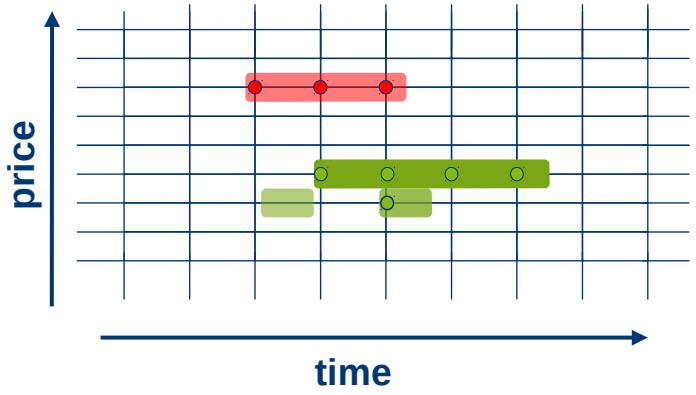


2D / 3D: Input Parameters

- **Product ID, Instrument ID**
- **Time and Price interval**
- **Available display area (X-Y in pixels)**
- **Aggregation, accumulation and normalization mode**
- **User permission (public/private)**

Output for (2D and 3D)

- **Array of contracts on offer in price-time matrix [xDim * yDim]**



- **[minBuy, maxBuy],[minSell,maxSell] used as domain for d3.scale**
- **Color scales: sqrt(), linear(), log()**

```
var buyScale  =  d3.scale.sqrt().domain([ 0, maxBuy  ]).range([ “white”, “green” ]);
var sellScale =  d3.scale.sqrt().domain([ 0, maxSell ]).range([ “white”, “red” ]);
```

- **Best Bid/Ask kept separately in ‘top-of-book’ array [2 * xDim]**
- **Used for ‘normalization’: price_norm(t) = price(t) – midpoint(t)**

X3D, X3DOM.js

- **SVG is 2D**
- **<rect>, <circle>, <line>, <path>, <a>, <g>, ...**
- **Supported in modern browsers, part of HTML5**

- **X3D is 3D**
- **<box>, <sphere>, <cylinder>, <elevationgrid>, <material>...**
- **X3D is unsupported in browsers (yet), so we need to use library X3DOM.js, which renders the scene using WebGL API**
- **If HW acceleration is not available (e.g. when accessing via remote desktop), then X3DOM.js renders using Flash plugin (included)**
- **X3DOM.js is officially in beta stage, but works pretty well**

Time for questions

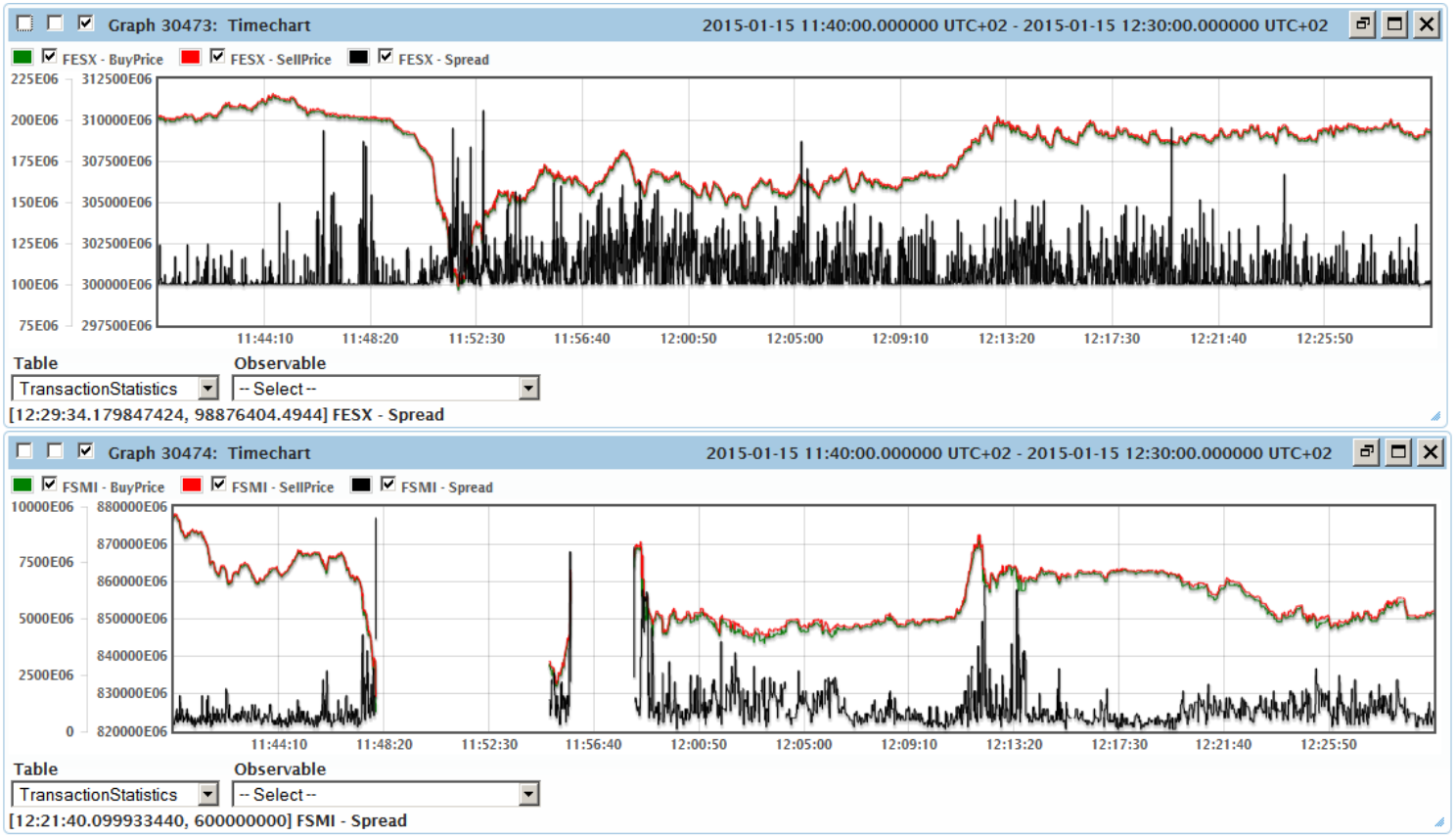
Contact

Pavel Schön
pavel.schon@deutsche-boerse.com

Sebastian Neusüß
sebastian.neusuess@deutsche-boerse.com

Backup- Orderbook Analysis

- **Additional orderbook statics prepared in separate tables:**
- **Spreads, total volume, liquidity indicators (soon)**



Backup: Order book player – JSON data format

Array of objects

```
priceLevels = [
{
   'price': 1000,
   'side': 1,
   'qty': 10,
   'orders': [
   {
      'timePrio': 1421313372687320862,
      'side': 1,
      'qty': 2,
      'execQty': 0,
   }, ... ],
 },{
   'price': 1500,
   'side': 1,
   'qty': 20,
   'orders': [...],
}, ... ]
```

+ Human readable
- Large JSON size
- Slow (de)serialization
- Objects are noticeably slower than arrays when dealing with hundreds of items

Array of tuples

```
priceLevels = [
   [ 1000, 1, 10, [ [1421313372687320862, 1, 2, 0 ],
...],
   [ 1500, 1, 20, [ ... ],
   ...
]
```

+ Compact JSON size
+ Faster (de)serialization
- Not easily readable by human
- Need to remember index of price, side, qty, etc...
- More work when adding new properties

We decided to use array of tuples. Structures are assembled in C++ / boost::python module.

Backup: Zoom in 2D

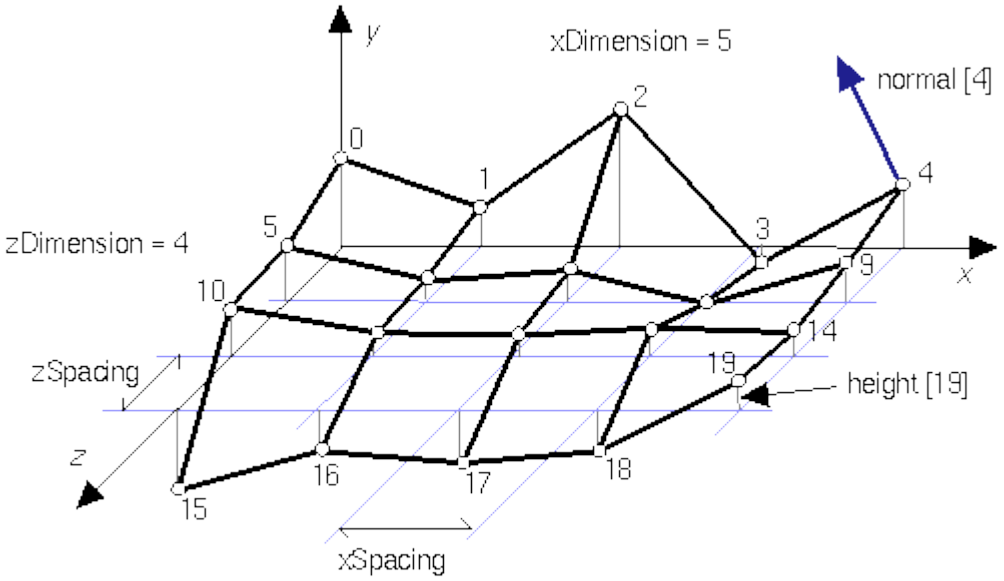
- Available e.g. WSXGA+ resolution (xDim = 1680 px, yDim = 1050 px)
- Take minTime, maxTime, minPrice, maxPrice of rectangular region.
- Compute xBucketWidth as (maxTime – minTime) / xDim + 1
- Result is e.g. 17.334 s. Round it down to 15 s.
- Compute yBucketWidth as (maxPrice – minPrice) / yDim + 1
- Result is e.g. 2.45, but price level width 0.5, so round it up to 2.5.
- Parameters for elevation grid are:
  - minTime, maxTime, minPrice, maxPrice (adjusted)
  - xBucketWidth = 15 s
  - yBucketWidth = 2.5
  - xDim = 1680 px
  - yDim = 1050 px

Backup: X3D: sample scene

```
<x3d id="x3dArea" xmlns="http://www.x3dom.org/x3dom">
    <scene id="x3dScene">
        <navigationinfo transitionType="linear" transitionTime="0"></navigationinfo>

        <shape>
            <appearance>
                <twosidedmaterial diffusecolor="0.2 0.6 0.9"></twosidedmaterial>
            </appearance>

                                                                    <!-- value for each vertex -->
            <elevationgrid solid="true" xdimension="329" zdimension="199" height="4 8 8 8 4 4 4 4 5 4 4 4….">

                <!-- computed color for each vertex ( positive-green, negative-red ) -->
                <color color="0.9 0 0 0.9 0 0……..”></color>
            </elevationgrid>
        </shape>
    </scene>
</x3d>
```

- ElevationGrid has limit maximum of 65536 vertices, else scene may render with deffects
- We need to adjust bin-widths and dimensions to fit this limitation
- When computing best dimensions, we try to be close as possibble to 65536, but not over.
- Max xDim, yDim can be 256x256, 300x218, 335x195, ..., 500x131

Backup: X3D, <ElevationGrid>



http://www.web3d.org/documents/specifications/19775-1/V3.2/Part01/components/geometry3D.html#f-ElevationGridnode