A modern, scalable risk system architecture

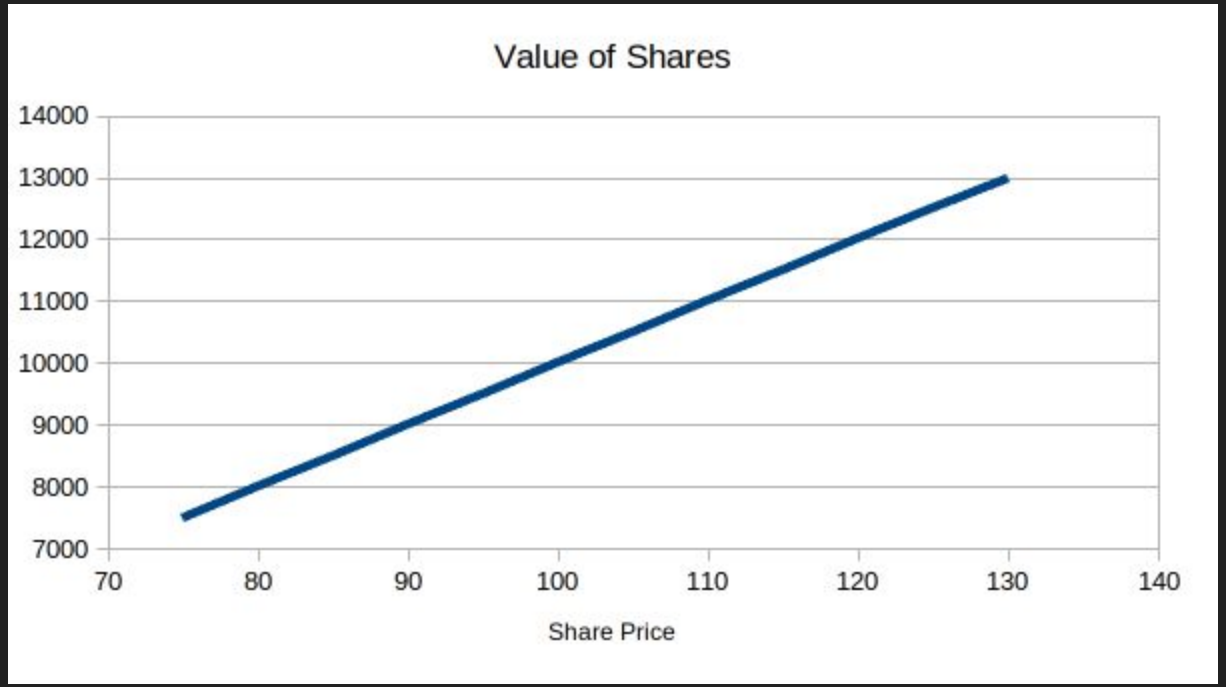
Burkhard Kloss

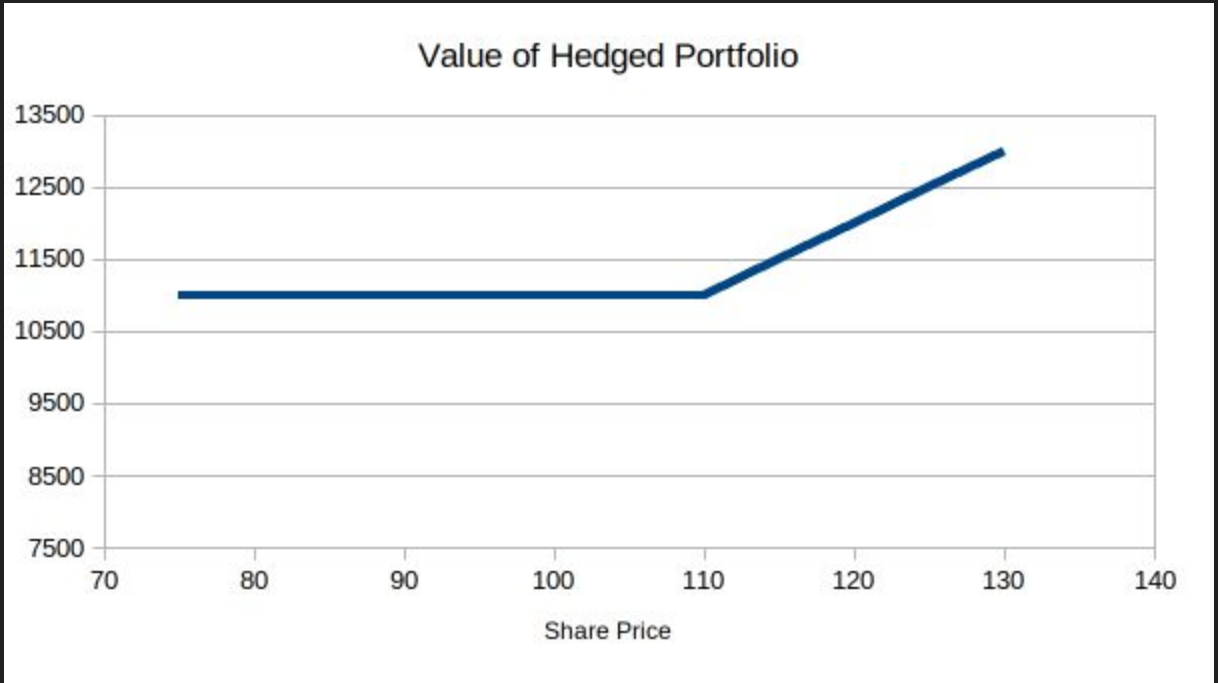
What is a risk system?

Known Knowns

Known Unknowns

Unknown Unknowns


Value of Shares
14000
13000
12000
11000
10000
9000
8000
7000
70
80
90
100
110
120
130
140
Share Price


Value of Hedged Portfolio
13500
12500
11500
10500
9500
8500
7500
70
80
90
100
110
120
130
140
Share Price

$$
\begin{aligned}
C(S_t, t) &= N(d_1)S_t - N(d_2)PV(K) \\
d_1 &= \frac{1}{\sigma\sqrt{T-t}}\left[\ln\left(\frac{S_t}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)\right] \\
d_2 &= d_1 - \sigma\sqrt{T-t} \\
PV(K) &= Ke^{-r(T-t)}
\end{aligned}
$$

A historical perspective

Version 1 - the humble spreadsheet

Ticker	Stock Price	Qty	Maturity	Strike	P/C	Vol	Option Px	Net Value	Delta	Gamma	Vega
AAA.L	149	1100						£163,900.00	£163,900.00	0	0
AAA.L		-2500	Dec 19	74.5	P	0.25	1.4767	-£550,067.80	-£165,020.34	-£33,004.07	-£3,300.41
AAA.L		-3100	Apr 21	186.25	C	0.21	2.6558	-£1,226,691.38	-£368,007.41	-£73,601.48	-£7,360.15
								-£1,612,859.18	**-£369,127.75**	**-£106,605.55**	**-£10,660.56**
AAB.L	121	800						£96,800.00	£96,800.00	0	0
AAB.L		700	Dec 19	60.5	P	0.25	3.1025	£262,779.79	£78,833.94	£15,766.79	£1,576.68
AAB.L		1400	Apr 21	151.25	C	0.21	3.1165	£527,933.52	£158,380.06	£31,676.01	£3,167.60
AAB.L		-300	Apr 21	0	C	0.21	0.5354	-£19,435.72	-£5,830.72	-£1,166.14	-£116.61
AAB.L		4900	Apr 21	0	C	0.21	0.6391	£378,915.69	£113,674.71	£22,734.94	£2,273.49
AAB.L		1200	Apr 21	0	C	0.21	0.4388	£63,715.55	£19,114.67	£3,822.93	£382.29
AAB.L		400	Apr 21	0	C	0.21	4.4368	£214,743.03	£64,422.91	£12,884.58	£1,288.46
								£1,525,451.87	**£525,395.56**	**£85,719.11**	**£8,571.91**
AAC.L	75	-3900						-£292,500.00	-£292,500.00	0	0
AAC.L		4300	Dec 19	37.5	P	0.25	1.2445	£401,341.70	£120,402.51	£24,080.50	£2,408.05
AAC.L		1800	Apr 21	93.75	C	0.21	0.9675	£130,610.98	£39,183.29	£7,836.66	£783.67
AAC.L		-1800	Apr 21	0	C	0.21	4.1102	-£554,881.96	-£166,464.59	-£33,292.92	-£3,329.29
AAC.L		3200	Apr 21	0	C	0.21	3.9164	£939,935.94	£281,980.78	£56,396.16	£5,639.62
AAC.L		-1000	Apr 21	0	C	0.21	4.0373	-£302,799.26	-£90,839.78	-£18,167.96	-£1,816.80
AAC.L		-1700	Apr 21	0	C	0.21	3.0577	-£389,861.95	-£116,958.59	-£23,391.72	-£2,339.17
								£0.00	**-£225,196.36**	**£13,460.73**	**£1,346.07**

Humble Spreadsheets

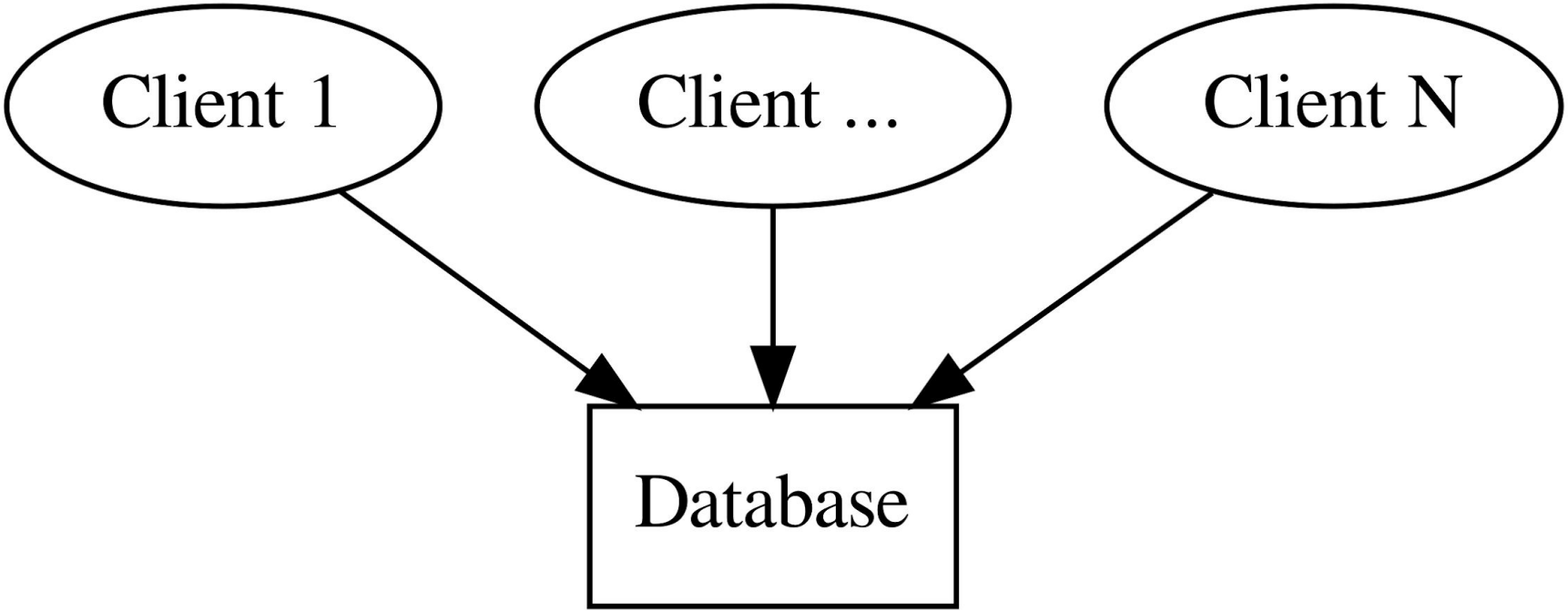
Pro:

- User control
- Simple to get started

Con:

- User control
- Easy to get wrong
- No sharing
- Local Calculations

Version 2 - Use a Database


Client 1
Client ...
Client N
Database

Shared Database

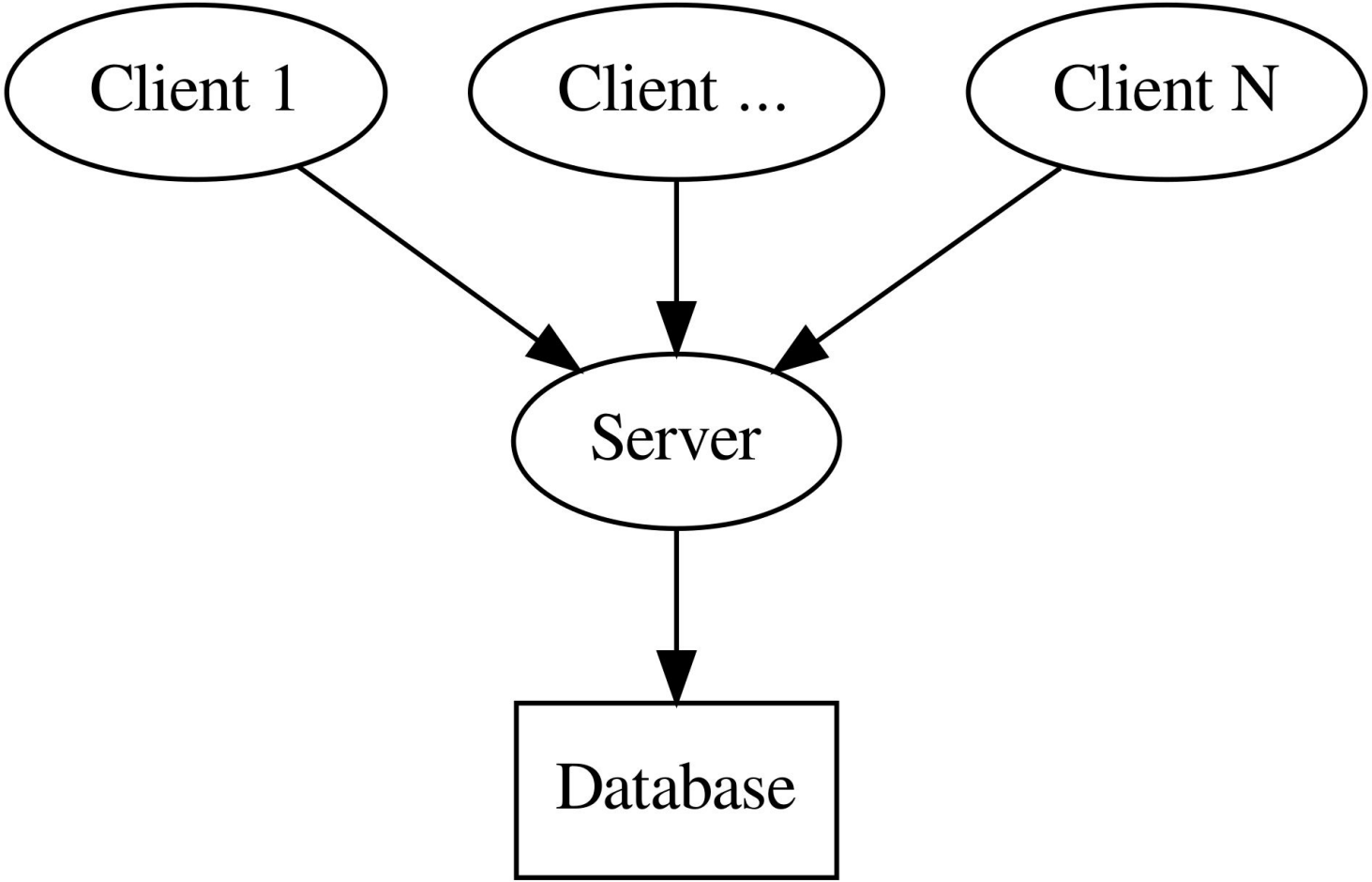
Pro:

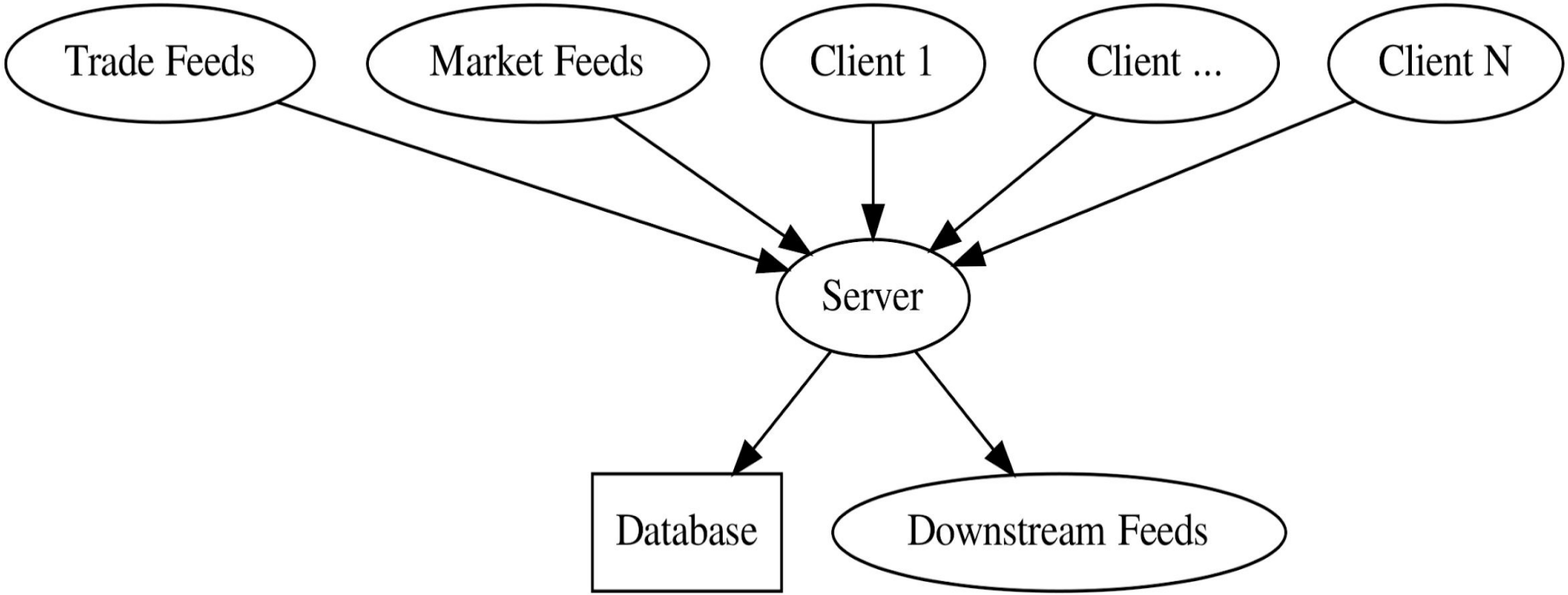
- Data is shared. D’uh!

Con:

- Still local calculations
- Still all the spreadsheet problems if the client is a spreadsheet

Version 2.1 - Client / Server


Client 1
Client ...
Client N
Server
Database


Trade Feeds
Market Feeds
Client 1
Client ...
Client N
Server
Database
Downstream Feeds

Client / Server

Pros:

- Centralised Compute - not overloading clients
- Control

Client / Server

Pros:

- Centralised Compute - not overloading clients
- Control

Cons:

- Limited by Server Power
- Complex
  - Multi-threading
  - C
  - oncurrency
- Not Scalable

Version 2.3 - Heath-Robinson Spreadsheets

Ticker	Stock Price	Qty	Maturity	Strike	P/C	Vol	Option Px	Net Value	Delta	Gamma	Vega
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AAA.L		-2500	Dec 19	74.5	P	0.25	1.4767	-£550,067.80	-£165,020.34	-£33,004.07	-£3,300.41
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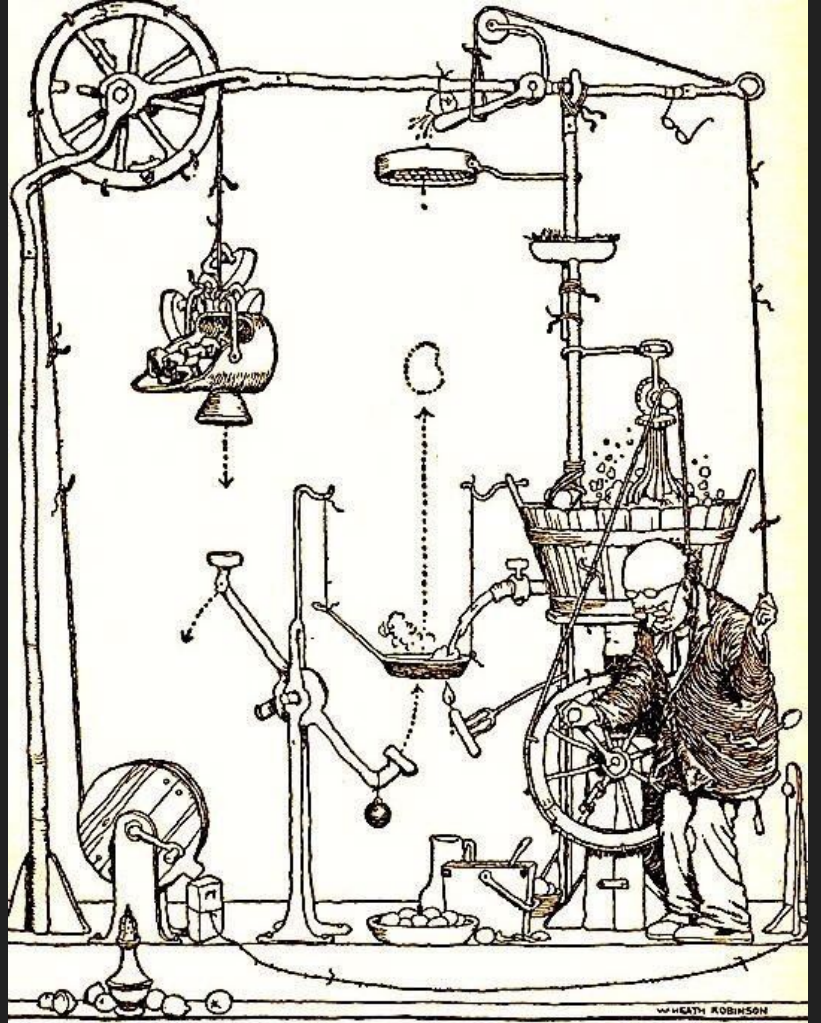
AAC.L		-1700	Apr 21	0	C	0.21	3.0577	-£389,861.95	-£116,958.59	-£23,391.72	-£2,339.17
								£0.00	**-£225,196.36**	**£13,460.73**	**£1,346.07**

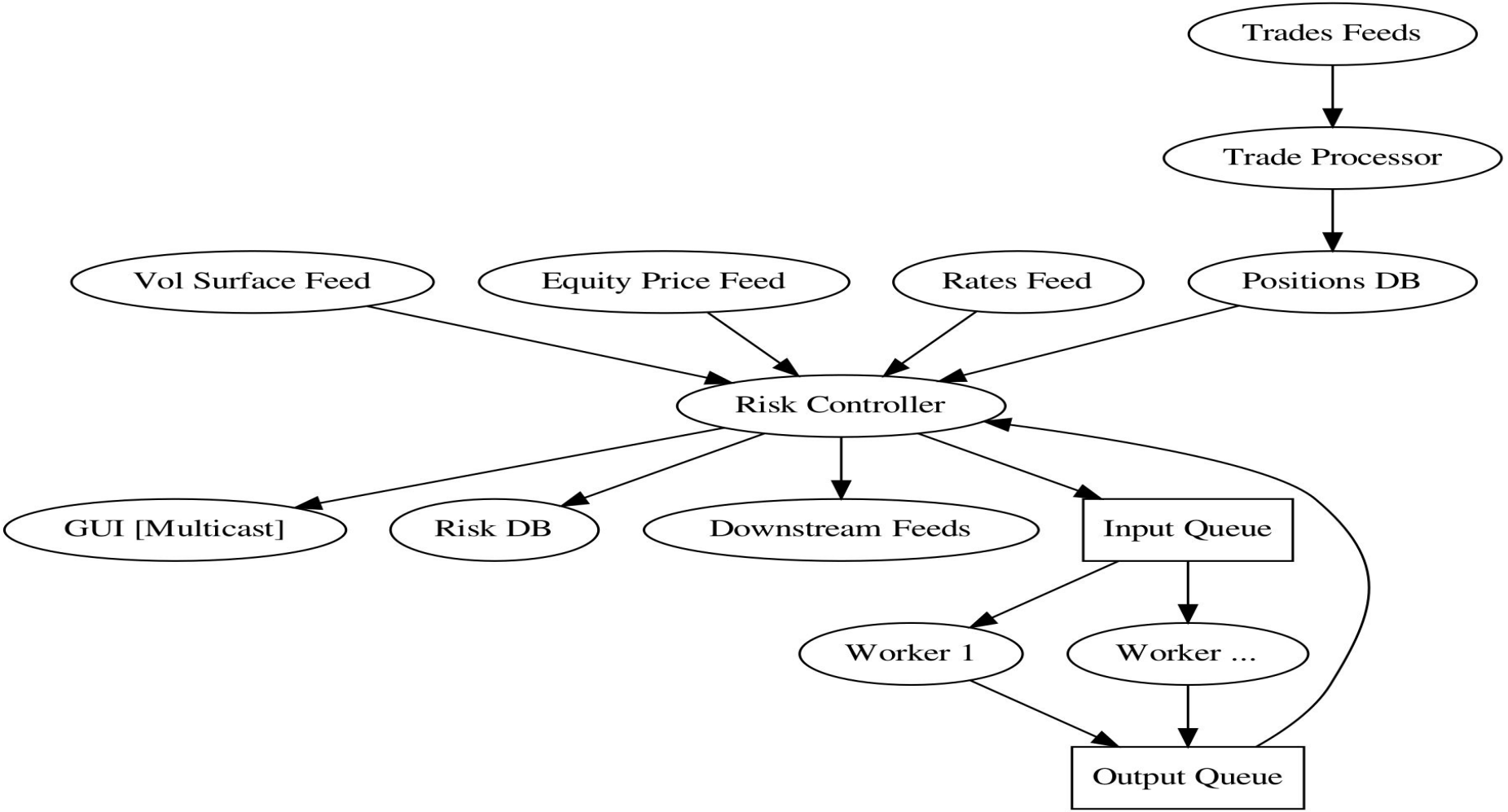


The pancake-making machine

Heath-Robinson in Practice

- Excel sheets connected to custom grids
- Custom infrastructure to
  - Version
  - Start
  - Feed
  - Restart Excel instances
- Server farms running Excel
  - Yes, Excel as a batch engine

Version 4 - Distributed Systems


Trades Feeds
Trade Processor
Vol Surface Feed
Equity Price Feed
Rates Feed
Positions DB
Risk Controller
GUI [Multicast]
Risk DB
Downstream Feeds
Input Queue
Worker 1
Worker ...
Output Queue

Calculation Loop

```
while True:
    market_data = snapshot_market_data()
    positions = snapshot_positions()
    jobs = split_jobs(market_data, positions)
    job_queue.push(jobs)
    results = results_queue.wait_all()
    aggregate_and_publish_results()
```

Distributed Systems

Pros:

- More scalable

Cons:

- Still limited by physical hardware
- Complex

The Future

Goals

- Scalability
- Simplicity
  - Easy to build
  - Easy to understand
  - Easy to test & debug

Core functions of a Risk System

Core functions of a Risk System

- Trade Processing
- Position Aggregation
- Position-level risk calculation

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CONSISTENCY

Everything Changes

Everything Changes

Value = BlackScholes(S, K, t, r, q, sigma)

Everything Changes

Value = BlackScholes(S, K, t, r, q, sigma)

- S - sub second
- r - subsecond
- q - intraday
- sigma - possibly several times an hour

Everything Changes

Value = BlackScholes(S, K, t, r, q, sigma)

- T - well, once a day
- K comes from the instrument

Everything Changes

- Instruments change, too

11/Apr/2019 07:59:00	@	**Value**		
100	17.40 EUR	1,740.00 EUR	Big French Company Shares EUR1	
Total Value		**1,740.00 EUR**		

11/Apr/2019 07:59:00	**@**	**Value**	
100	17.40 EUR	1,740.00 EUR	Big French Company Shares EUR1
Total Value		**1,740.00 EUR**	
11/Apr/2019 08:00:00	**@**	**Value**	
400	4.00 EUR	1,600.00 EUR	Big French Company Shares EUR0.25
10	4.00 EUR	40.00 EUR	Spinoff Company Shares EUR1
10	10.00 EUR	100.00 EUR	EUR Cash
Total Value		**1,740.00 EUR**	

Versioned Datasource

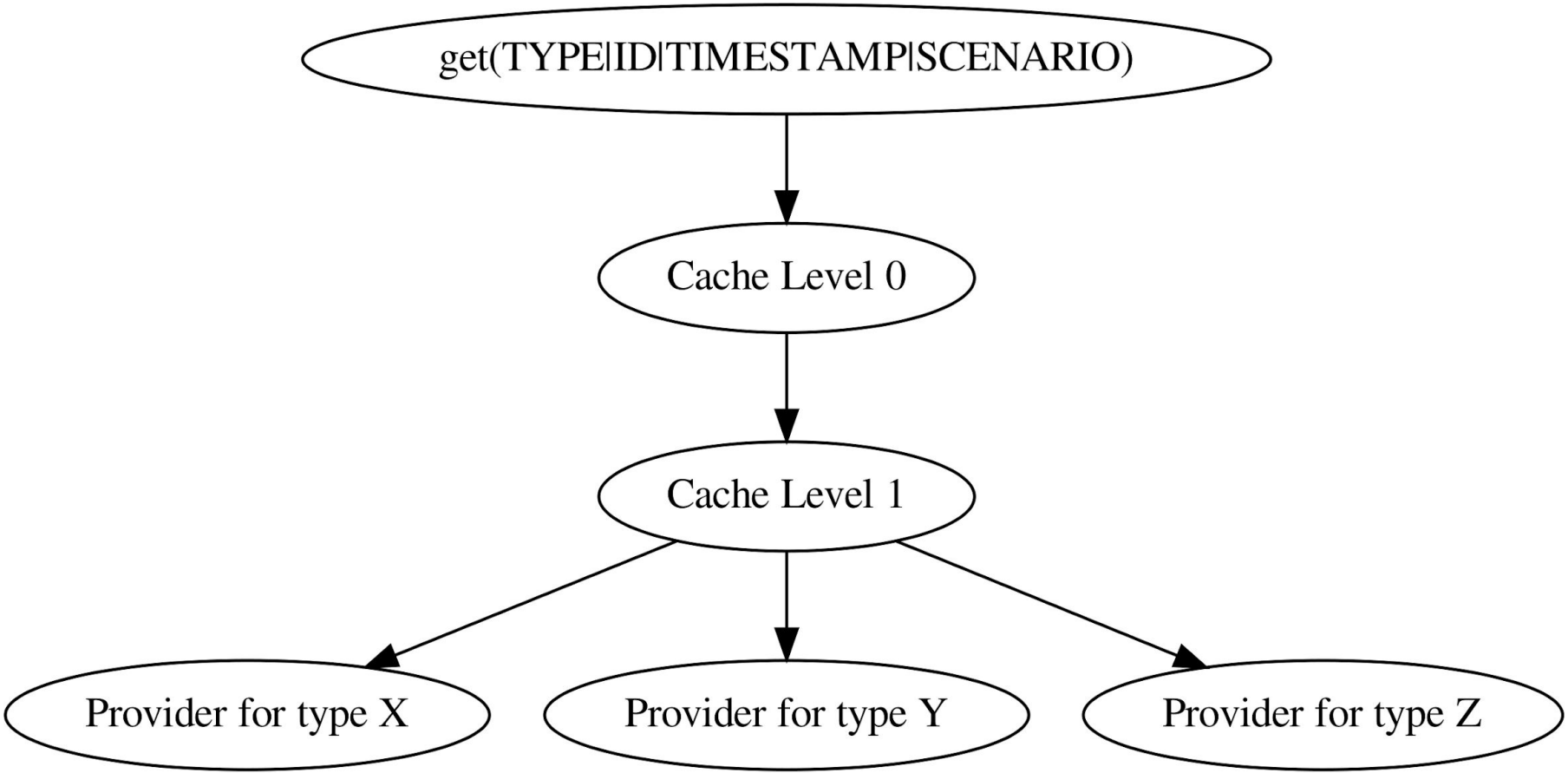
```
key = "ObjectType|ObjectId|Timestamp|Scenario"
```

- Each version is uniquely identified
- Immutable
- Interpolated

T	A	B
08:27:00	1	
08:30:00		
08:33:00	2	1.03
08:36:00		1.02
08:39:00		0.98
08:42:00	3	1.07
08:45:00		

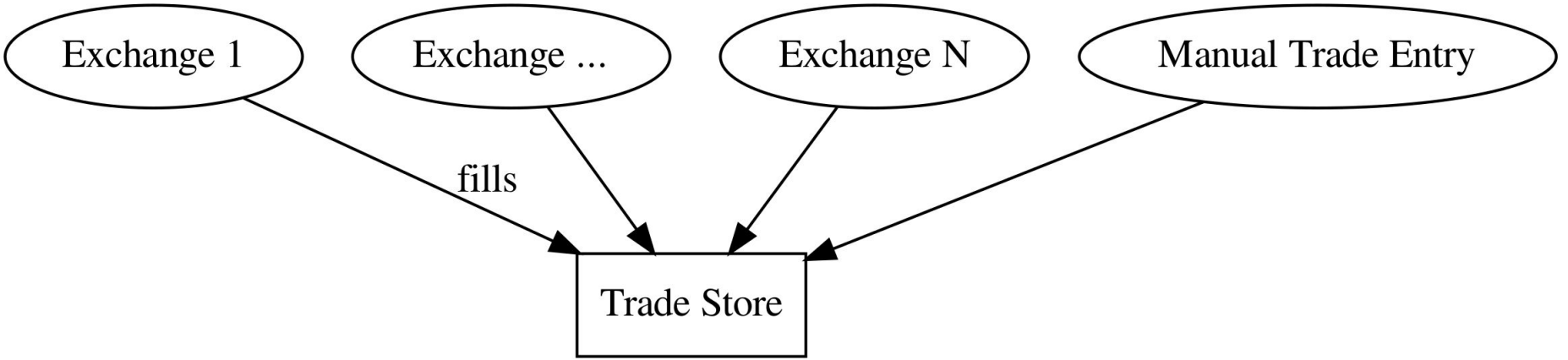
```
key = "ObjectType|ObjectId|Timestamp|Scenario"
```

- Each version is uniquely identified
- Immutable
- Interpolated
- => Caching is trivial
- => Pass around keys, not data


get(TYPE|ID|TIMESTAMP|SCENARIO)
Cache Level 0
Cache Level 1
Provider for type X
Provider for type Y
Provider for type Z

Trade Processing

Trade Processing



Position Aggregation

Trader	Share	Counterparty	Quantity	@	Total
Fred	A	Mega	100	50.00 €	5,000.00 €
Fred	B	Giga	100	120.00 €	12,000.00 €
Joe	A	Giga	-100	48.00 €	-4,800.00 €
Joe	B	Giga	100	122.00 €	12,200.00 €

Trader	Share	Counterparty	Quantity	@	Total
Fred	A	Mega	100	50.00 €	5,000.00 €
Fred	B	Giga	100	120.00 €	12,000.00 €
Joe	A	Giga	-100	48.00 €	-4,800.00 €
Joe	B	Giga	100	122.00 €	12,200.00 €

Fred's View

Trader	Share	Counterparty	Quantity
Fred	A	Mega	100
Fred	B	Giga	100

Joe's View

Trader	Share	Counterparty	Quantity
Joe	A	Giga	-100
Joe	B	Giga	100

Trader	Share	Counterparty	Quantity	@	Total
Fred	A	Mega	100	50.00 €	5,000.00 €
Fred	B	Giga	100	120.00 €	12,000.00 €
Joe	A	Giga	-100	48.00 €	-4,800.00 €
Joe	B	Giga	100	122.00 €	12,200.00 €

Corporate Market Risk View

Share	Quantity
A	**0**
B	**200**

Counterparty Risk View

Counterparty	Total
Mega	5,000.00 €
Giga	19,400.00 €

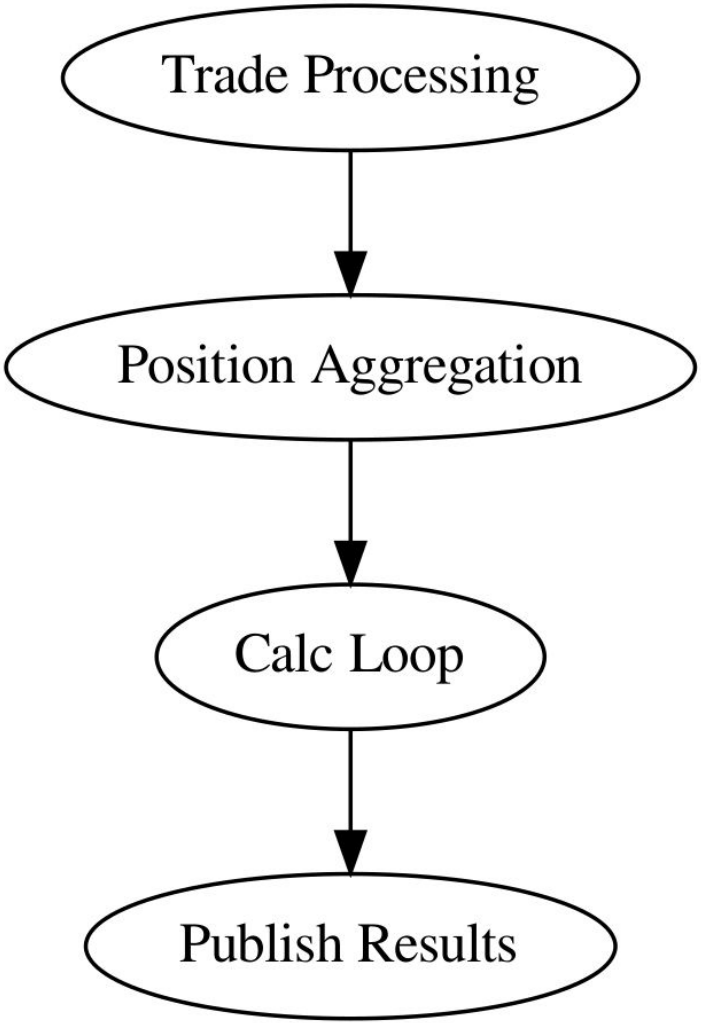
+ Trade reporting, regulatory feeds, etc etc etc etc

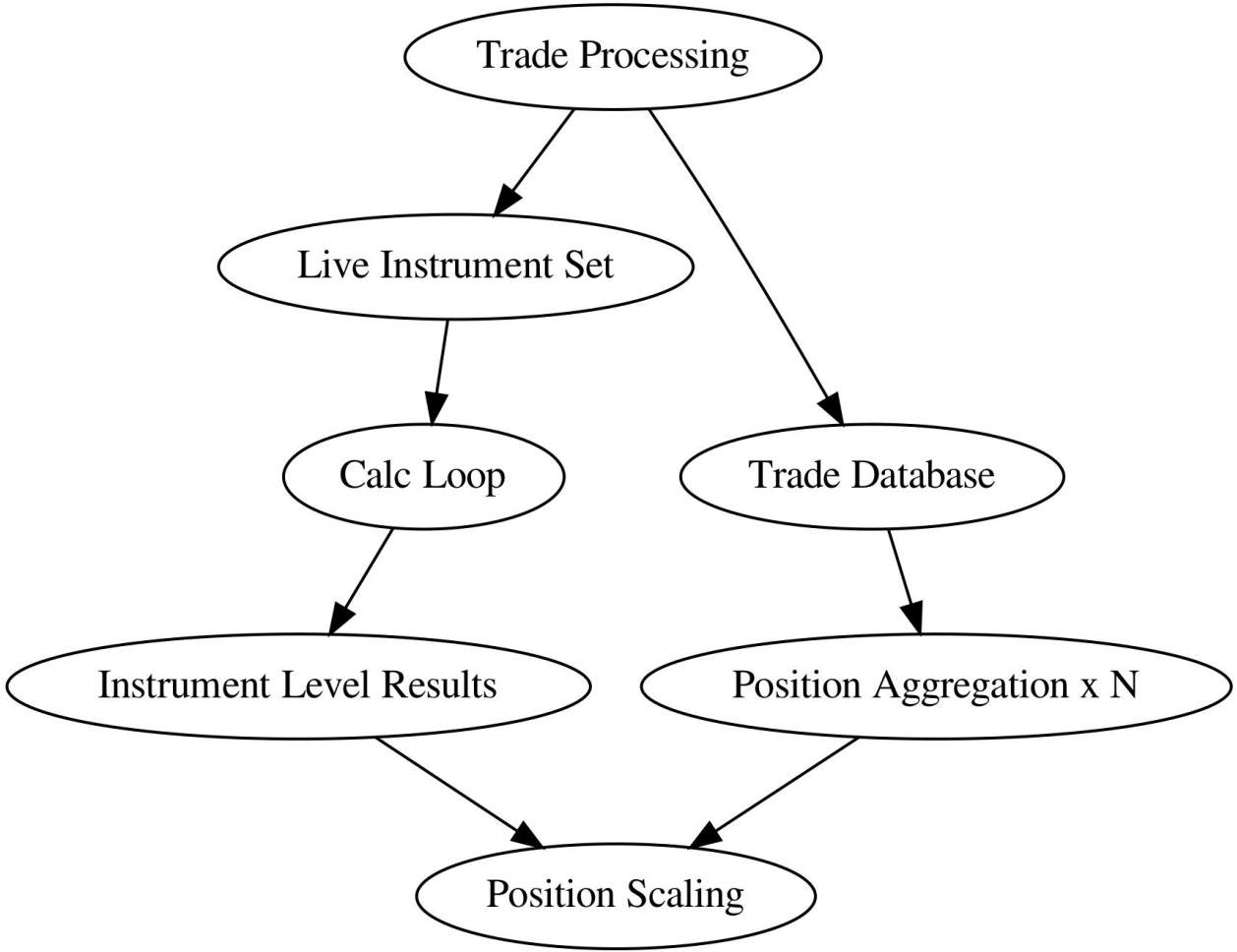
Core functions of a Risk System

- Trade Processing
- Position Aggregation
- Position-level risk calculation

Core functions of a Risk System

- Trade Processing
- Position Aggregation
- Position-level risk calculation
  - Instrument level risk calculation [compute intensive]
  - Scaling by position size [trivial multiplication]


Trade Processing
Position Aggregation
Calc Loop
Publish Results


Trade Processing
Live Instrument Set
Calc Loop
Trade Database
Instrument Level Results
Position Aggregation x N
Position Scaling

Calc Loop

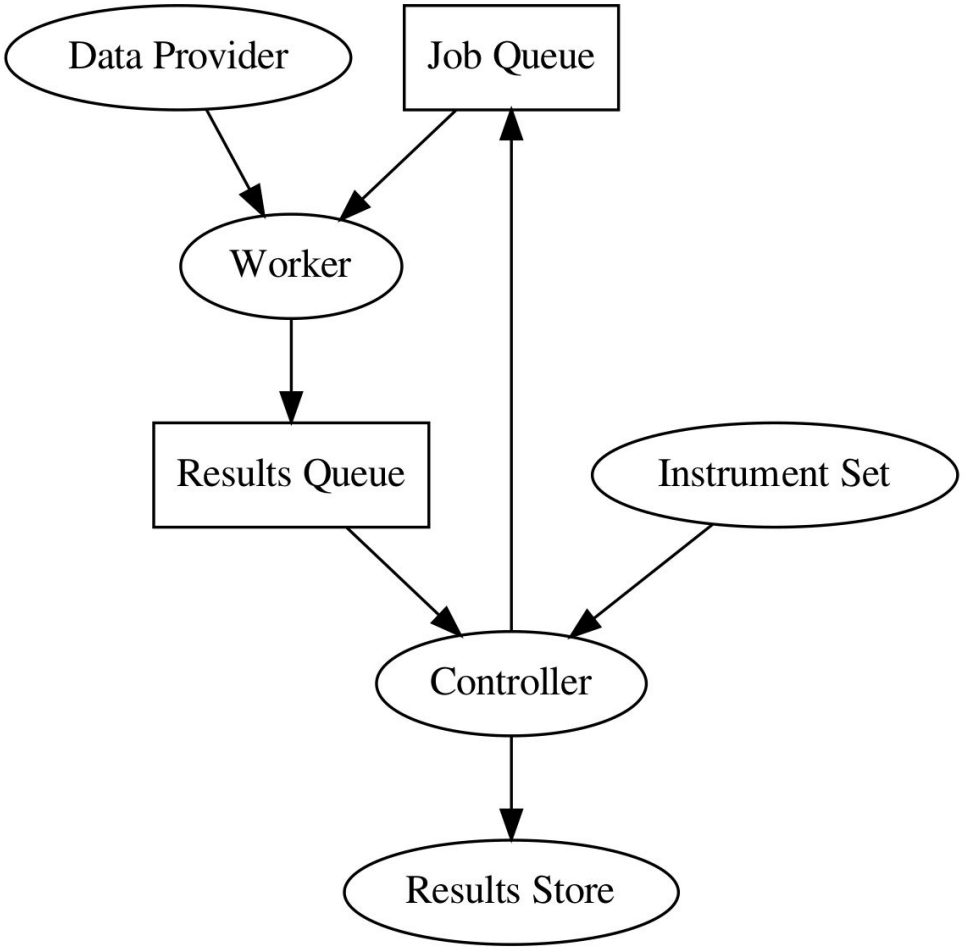
Calculation Loop

```
while True:
    market_data = snapshot_market_data()
    positions = snapshot_positions()
    jobs = split_jobs(market_data, positions)
    job_queue.push(jobs)
    results = results_queue.wait_all()
    aggregate_and_publish_results()
```

```
while True:
    timestamp = create_timestamp()
    instruments = get_live_instrument_set(timestamp)
    jobs = split_jobs(instruments, timestamp)
    job_queue.push(jobs)
    results = results_queue.wait_all()
```

```python
@dataclass
class CalcSpec:
    id : str
    instrument_keys: List[str]
    market_data_timestamp: datetime
    scenario: str
    indicators: Set[str]
```

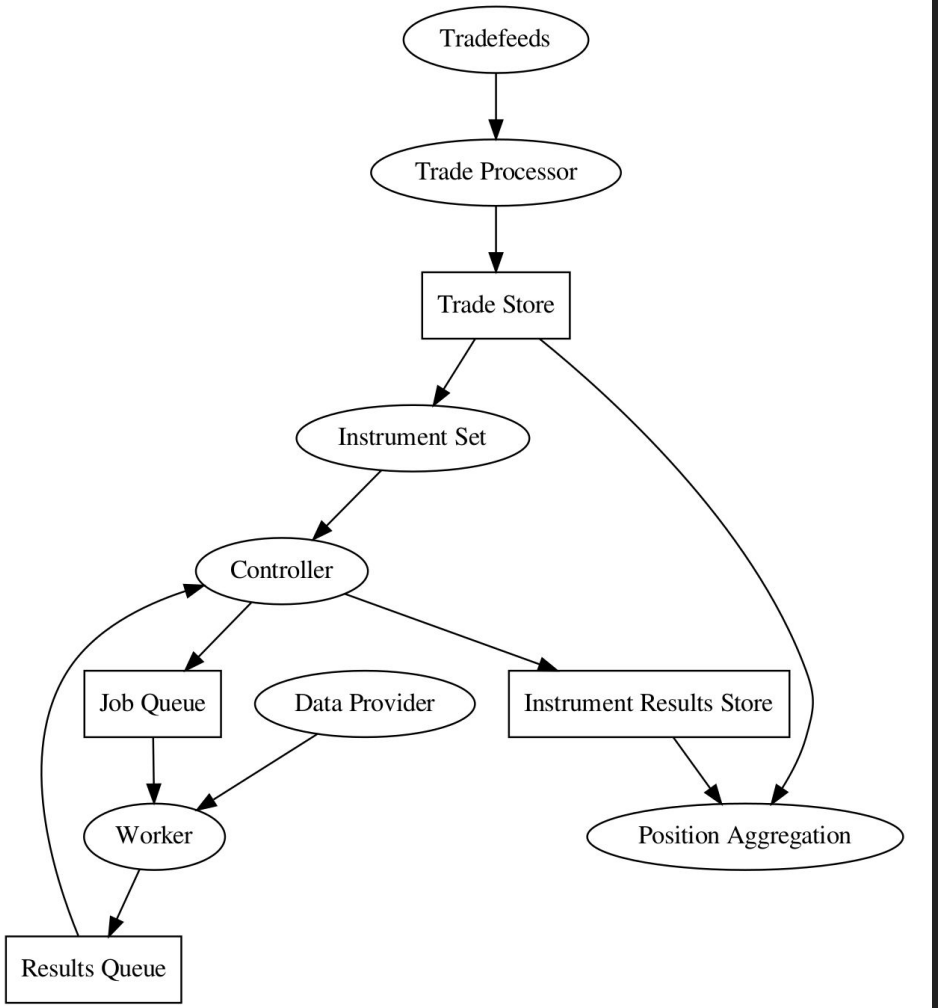
```
key = "ObjectType|ObjectId|Timestamp|Scenario"
```


Data Provider
Job Queue
Worker
Results Queue
Instrument Set
Controller
Results Store

Design Principles

- Single Responsibility
- Versioning and immutability
- Caching
- Loose Coupling

Overview


Tradefeeds
Trade Processor
Trade Store
Instrument Set
Controller
Job Queue
Data Provider
Instrument Results Store
Worker
Position Aggregation
Results Queue

Fin

bk@xk7.com