Intrinsic Events Approach and Agent Based Model

Vladimir Petrov
vladimir.petrov@uzh.ch

How to understand the market’s behaviour?

To agregate knowledge of the **market properties** (stylized facts)

How to understand the market's behaviour?

To agregate knowledge of the **market properties** (stylized facts)

Scaling Laws (or power laws)

How to understand the market's behaviour?

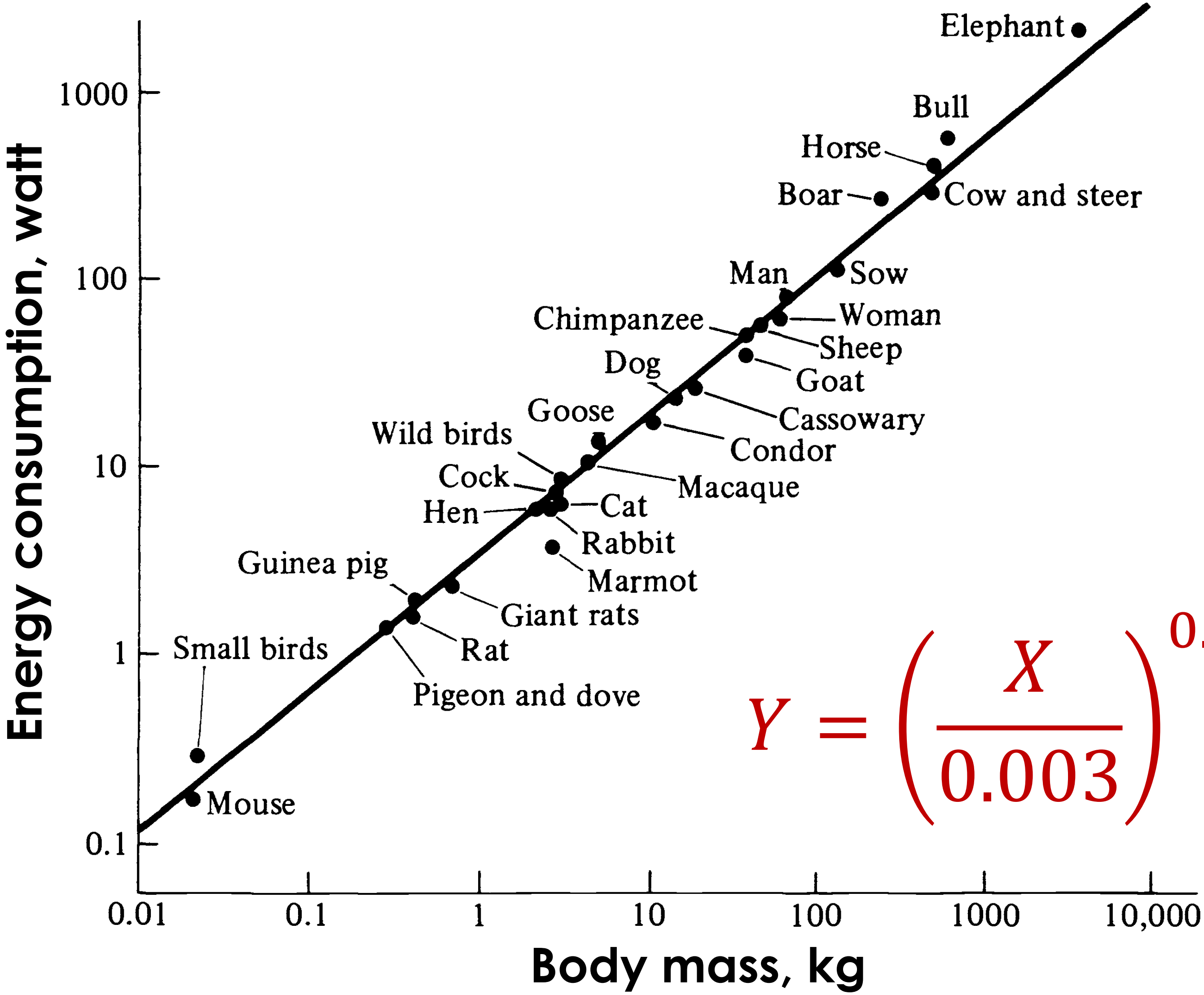
To agregate knowledge of the **market properties** (stylized facts)

Scaling Laws (or power laws)

Newman (2005): "*…[if] a particular value of some quantity varies inversely as a power of that value, the quantity is said to follow a power law…*"

$$Y = \left(\frac{X}{C}\right)^{E}$$

Scaling laws are **everywhere**



$$Y = \left(\frac{X}{0.003}\right)^{0.74}$$

Scaling laws are **everywhere**

1. The Angstrom exponent in aerosol optics
2. The frequency-dependency of acoustic attenuation in complex media
3. The Stevens' power law of psychophysics
4. The Stefan–Boltzmann law
5. The input-voltage–output-current curves of field-effect transistors and vacuum tubes approximate a square-law relationship, a factor in "tube sound".
6. Square-cube law (ratio of surface area to volume)
7. Kleiber's law relating animal metabolism to size, and allometric laws in general
8. A 3/2-power law can be found in the plate characteristic curves of triodes.
9. The inverse-square laws of Newtonian gravity and electrostatics, as evidenced by the gravitational potential and Electrostatic potential, respectively.
10. Self-organized criticality with a critical point as an attractor
11. Exponential growth and random observation (or killing)
12. Progress through exponential growth and exponential diffusion of innovations
13. Highly optimized tolerance
14. Model of van der Waals force
15. Force and potential in simple harmonic motion
16. Kepler's third law
17. The initial mass function of stars
18. The M-sigma relation
19. Gamma correction relating light intensity with voltage
20. The two-thirds power law, relating speed to curvature in the human motor system.
21. The Taylor's law relating mean population size and variance of populations sizes in ecology
22. Behaviour near second-order phase transitions involving critical exponents
23. Proposed form of experience curve effects
24. The differential energy spectrum of cosmic-ray nuclei
25. Fractals
26. Pareto distribution and the Pareto principle also called the "80–20 rule"
27. Zipf's law in corpus analysis and population distributions amongst others, where frequency of an item or event is inversely proportional to its frequency rank (i.e. the second most frequent item/event occurs half as often the most frequent item, the third most frequent item/event occurs one third as often as the most frequent item, and so on).
28. The safe operating area relating to maximum simultaneous current and voltage in power semiconductors.
29. Supercritical state of matter and supercritical fluids, such as supercritical exponents of heat capacity and viscosity.
30. Zeta distribution (discrete)
31. Yule–Simon distribution (discrete)
32. Student's t-distribution (continuous), of which the Cauchy distribution is a special case
33. Lotka's law
34. The scale-free network model
35. Pink noise
36. Neuronal avalanches
37. The law of stream numbers, and the law of stream lengths (Horton's laws describing river systems)[citation needed]
38. Populations of cities (Gibrat's law)[citation needed]
39. Bibliograms, and frequencies of words in a text (Zipf's law)
40. 90–9–1 principle on wikis (also referred to as the 1% Rule)
41. Richardson's Law for the severity of violent conflicts (wars and terrorism)
42. The relationship between a CPU's cache size and the number of cache misses follows the Power law of cache misses.

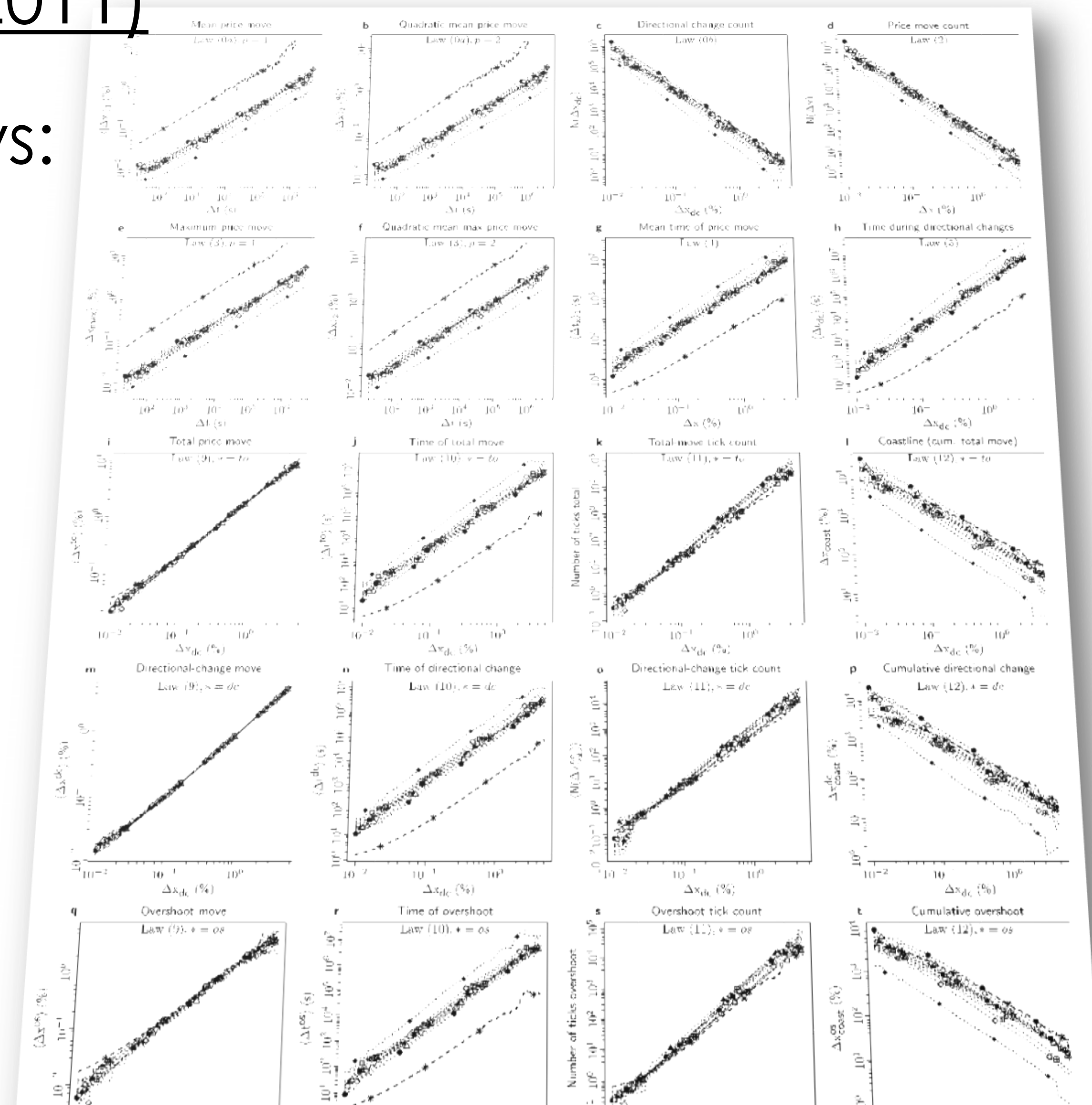
• • •

Scaling laws of the **Forex market**

Glattfelder et al. (2011)

12 new scaling laws:

- Tick count
- Price move count
- Maximum price move
- Time of price move
- Time of directional change
- Total price move
- Overshoot move
- Time of total move
- Time of directional change
- Time of overshoot
- Total-move tick count
- Directional-change tick count



Intrinsic **T**ime:

an event-based definition of time

Intrinsic events, Directional Change (DC)

$$\Delta P = P_t - Extreme$$

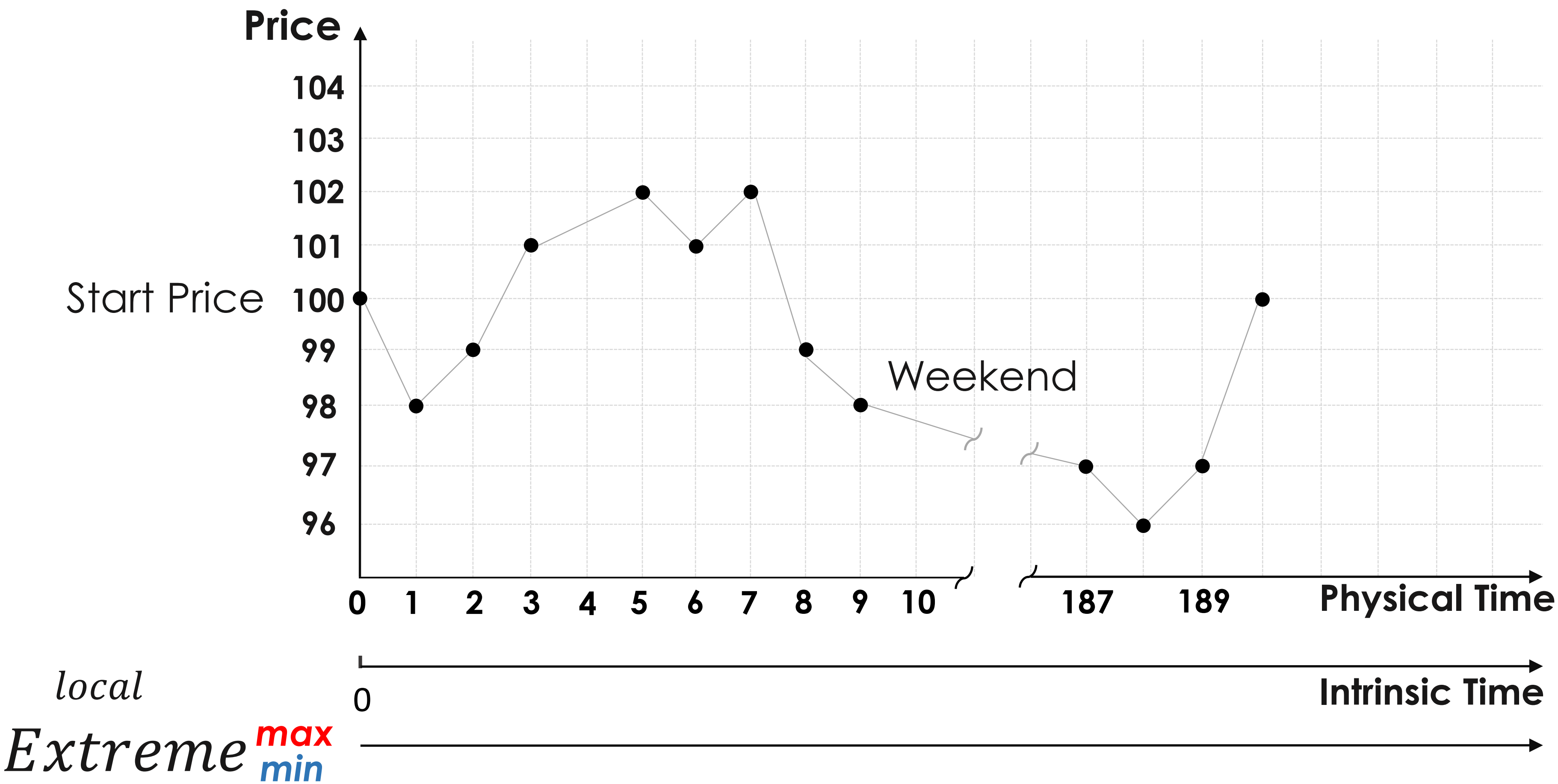
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

$(arbitrary)$

mode: ↑ **or** ↓

$$\Delta P \geq \delta * Ext.\ ?$$

Ext. ○	DC □



Intrinsic events, Directional Change (DC)

$$\Delta P = P_t - Extreme$$

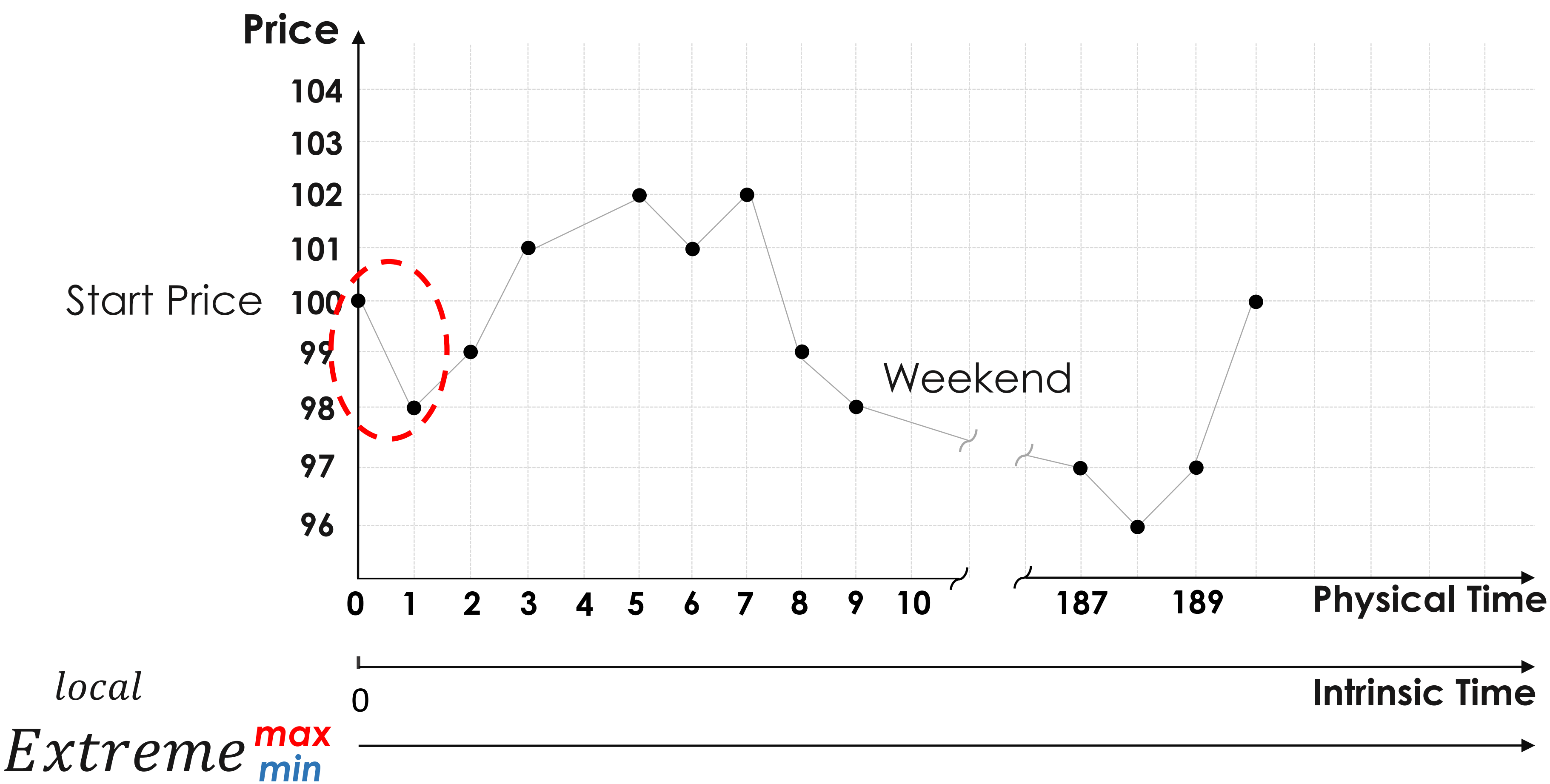
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

$(arbitrary)$

mode: ↑ or ↓

$$\Delta P \geq \delta * Ext.\ ?$$

Ext. ○	DC □



Intrinsic events, Directional Change (DC)

$$\Delta P = P_t - Extreme$$

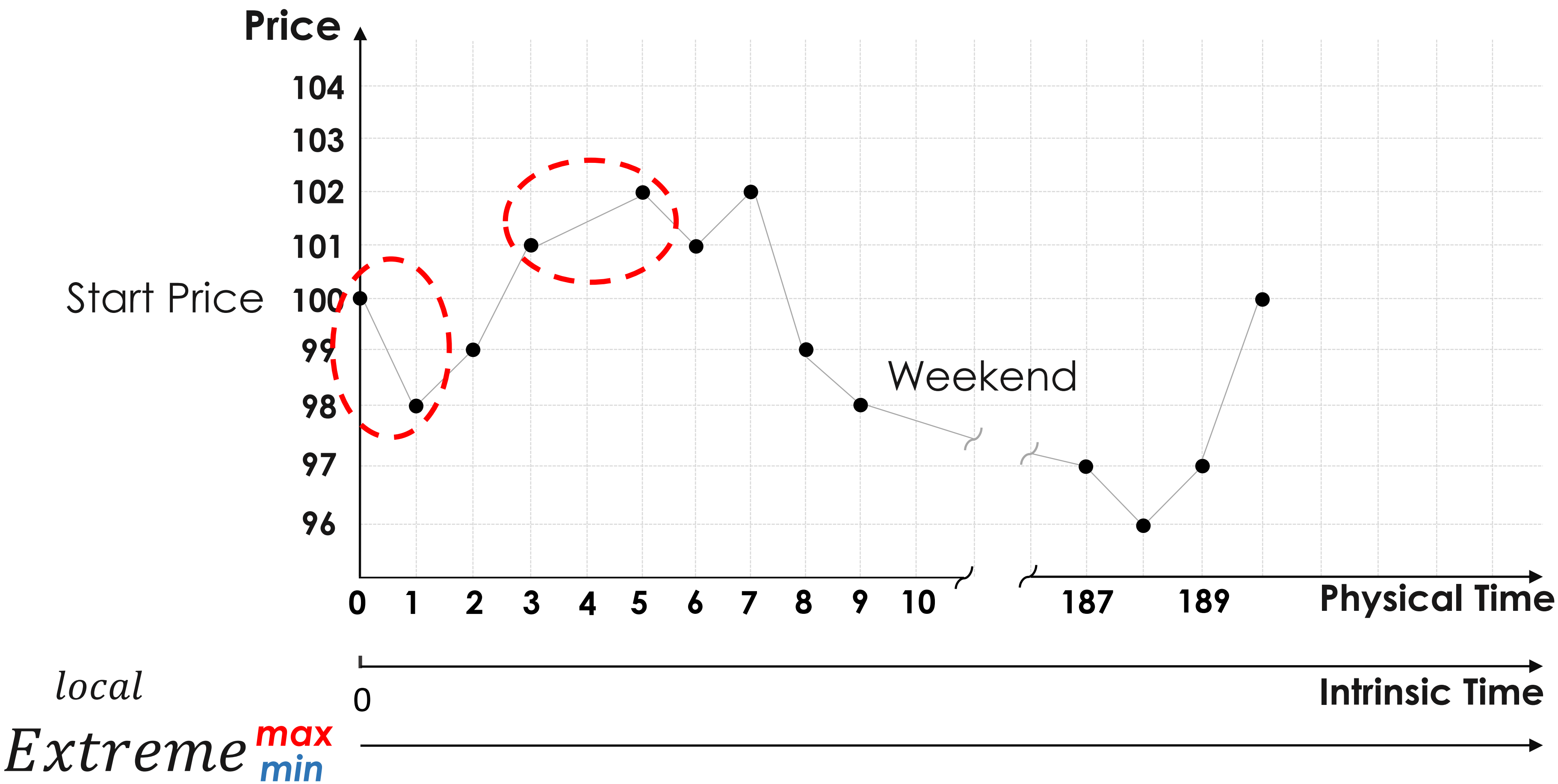
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

$(arbitrary)$

mode: ↑ or ↓

$$\Delta P \geq \delta * Ext.\ ?$$

Ext. ○	DC □



Intrinsic events, Directional Change (DC)

$\Delta P = P_t - Extreme$

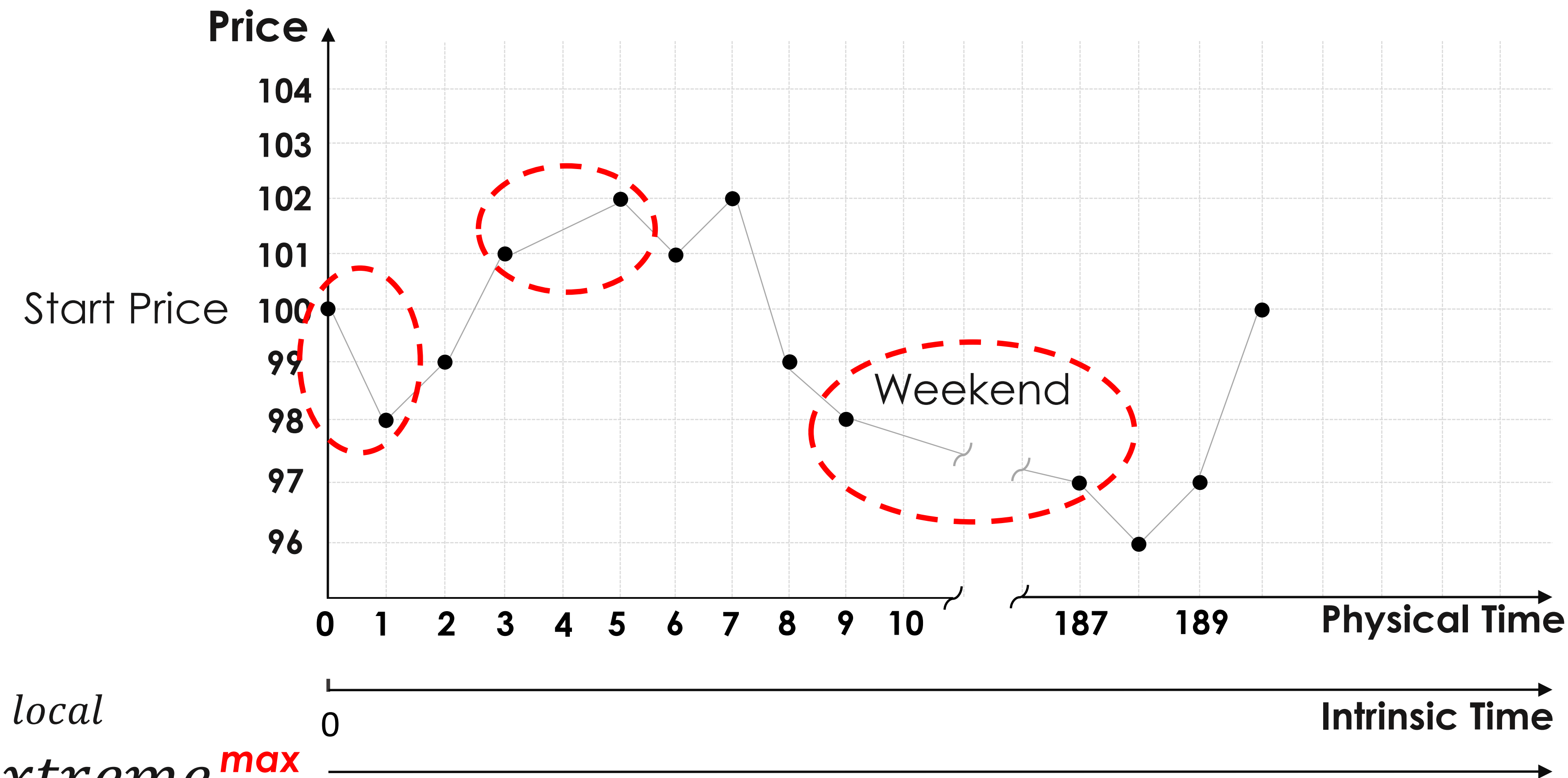
$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$

$(arbitrary)$

mode: ↑ or ↓

$\Delta P \geq \delta * Ext.\ ?$

Ext. ○	DC □



$local$

$Extreme^{max}_{min}$

Intrinsic events, Directional Change (DC)

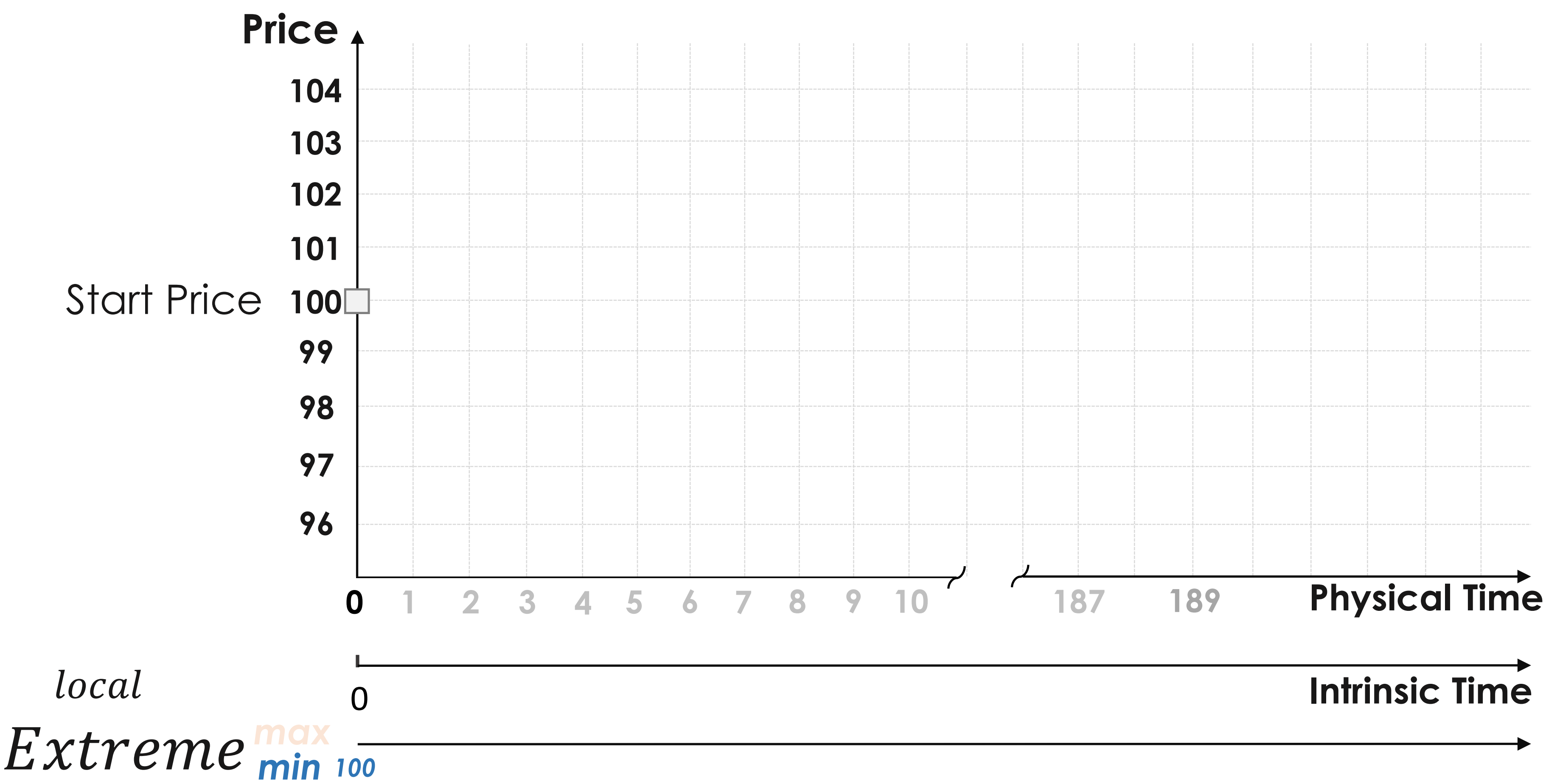
$$\Delta P = P_t - Extreme$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑

$$\Delta P = 0$$
$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100



Intrinsic events, Directional Change (DC)

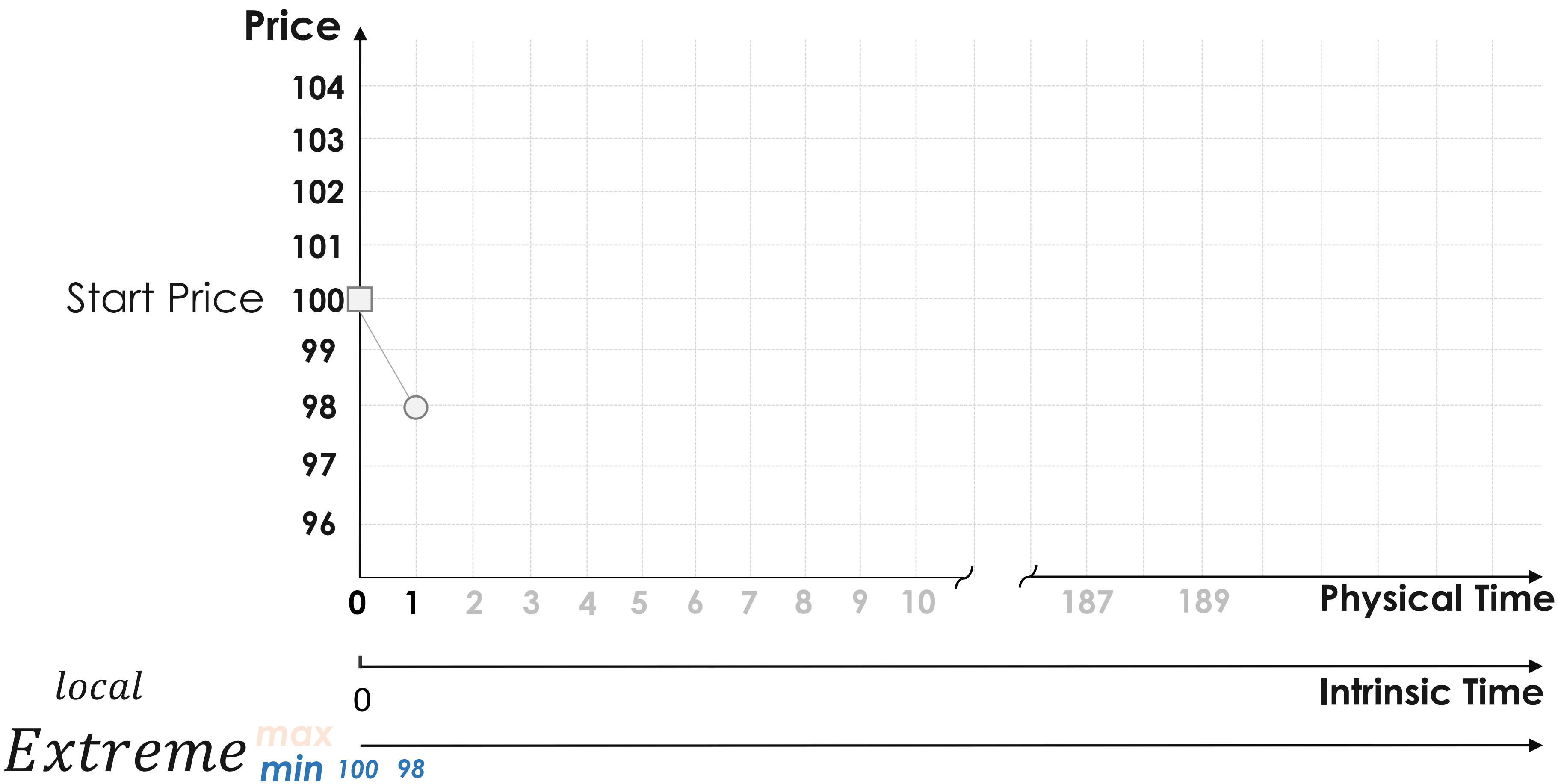
$$\Delta P = P_t - Extreme$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑

$$\Delta P = 0$$
$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100



Intrinsic events, Directional Change (DC)

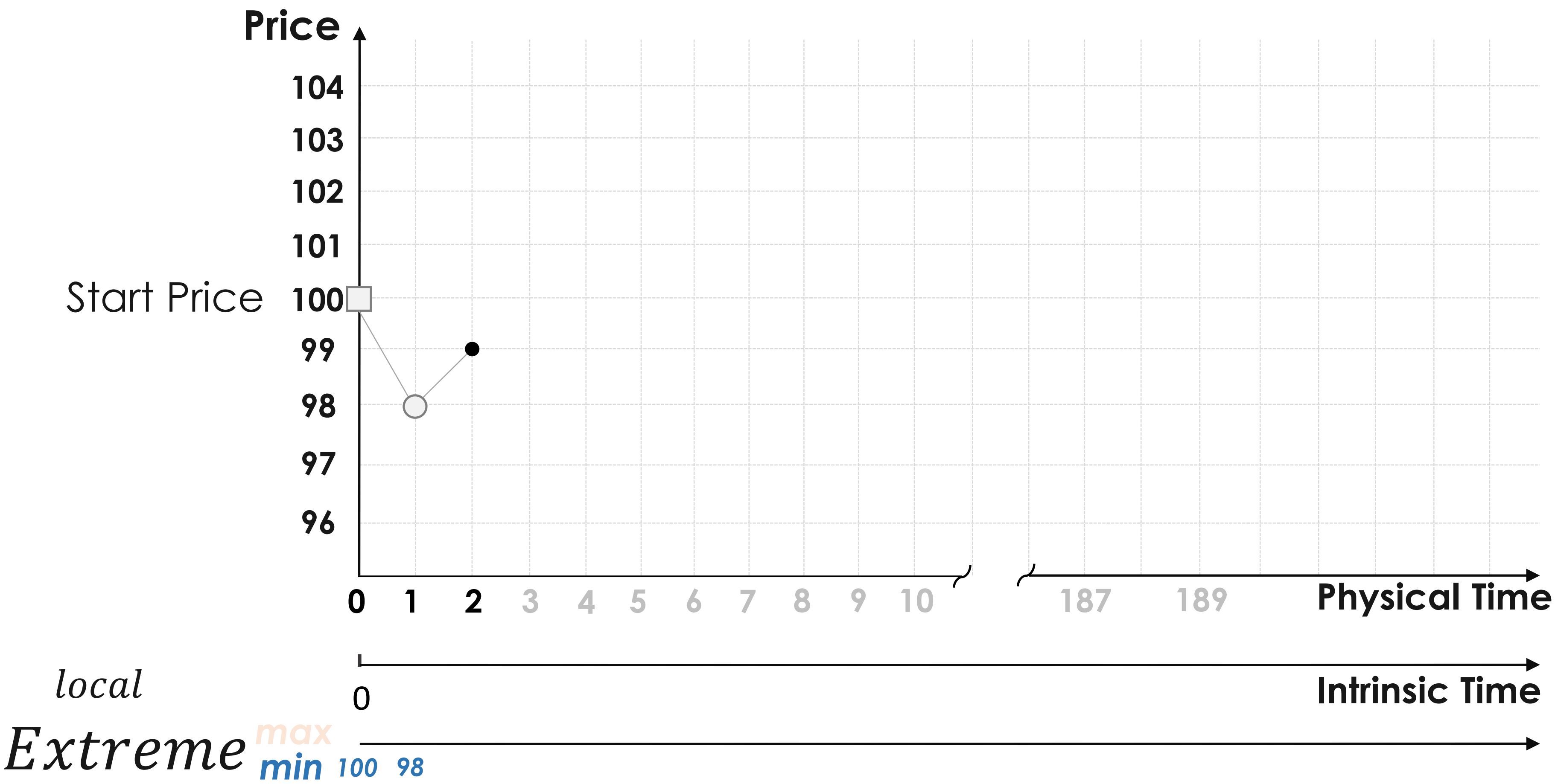
$$\Delta P = P_t - Extreme$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑

$$\Delta P = 1$$
$$\Delta P \geq 2\ ?$$

No

Ext. ○	DC □
-	100



Intrinsic events, Directional Change (DC)

$$\Delta P = P_t - Extreme$$

$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

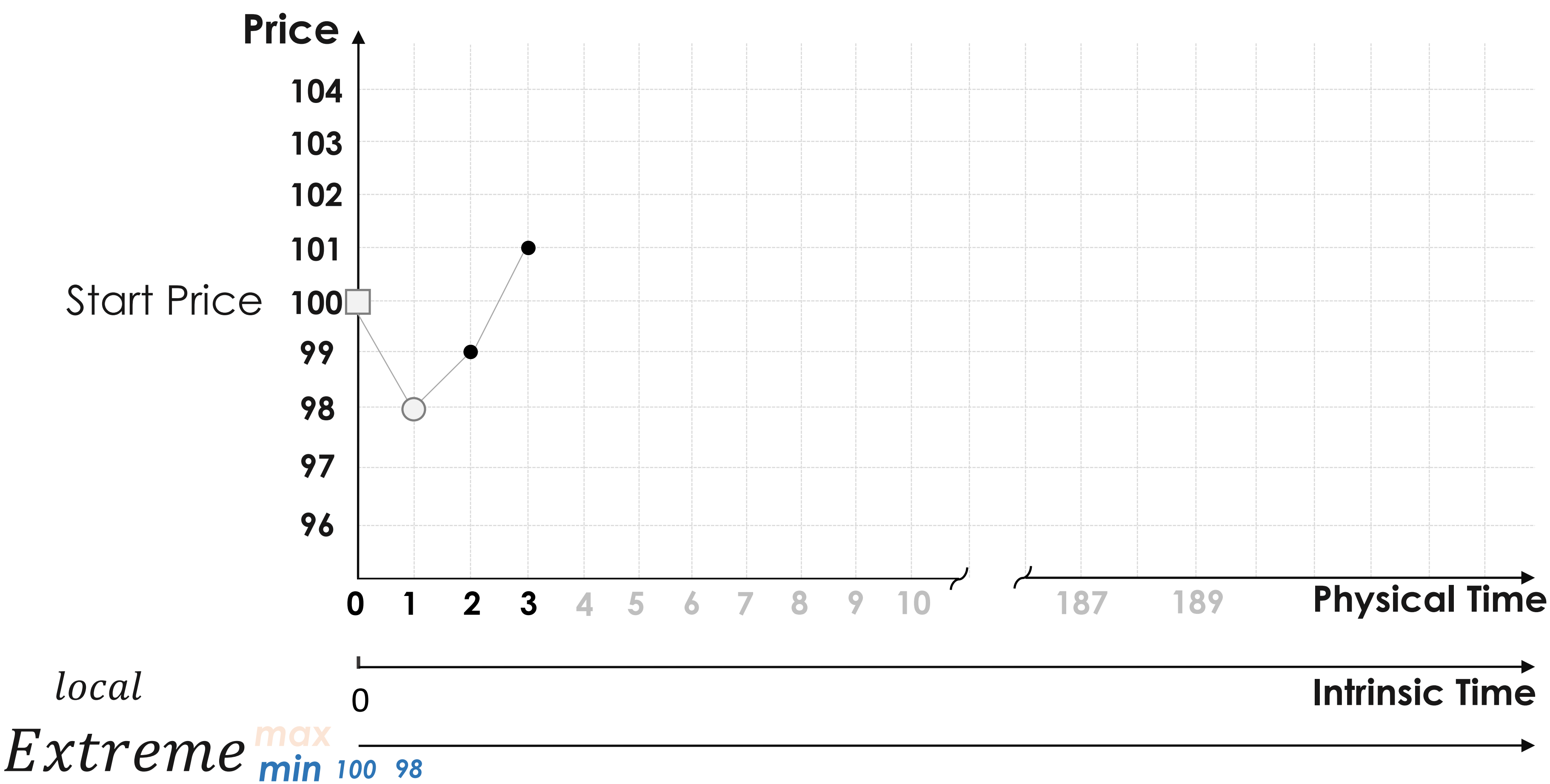
mode: ↑

$$\Delta P = 3$$

$$\Delta P \geq 2 \ ?$$

Yes

Ext. ○	DC □
-	100



Intrinsic events, Directional Change (DC)

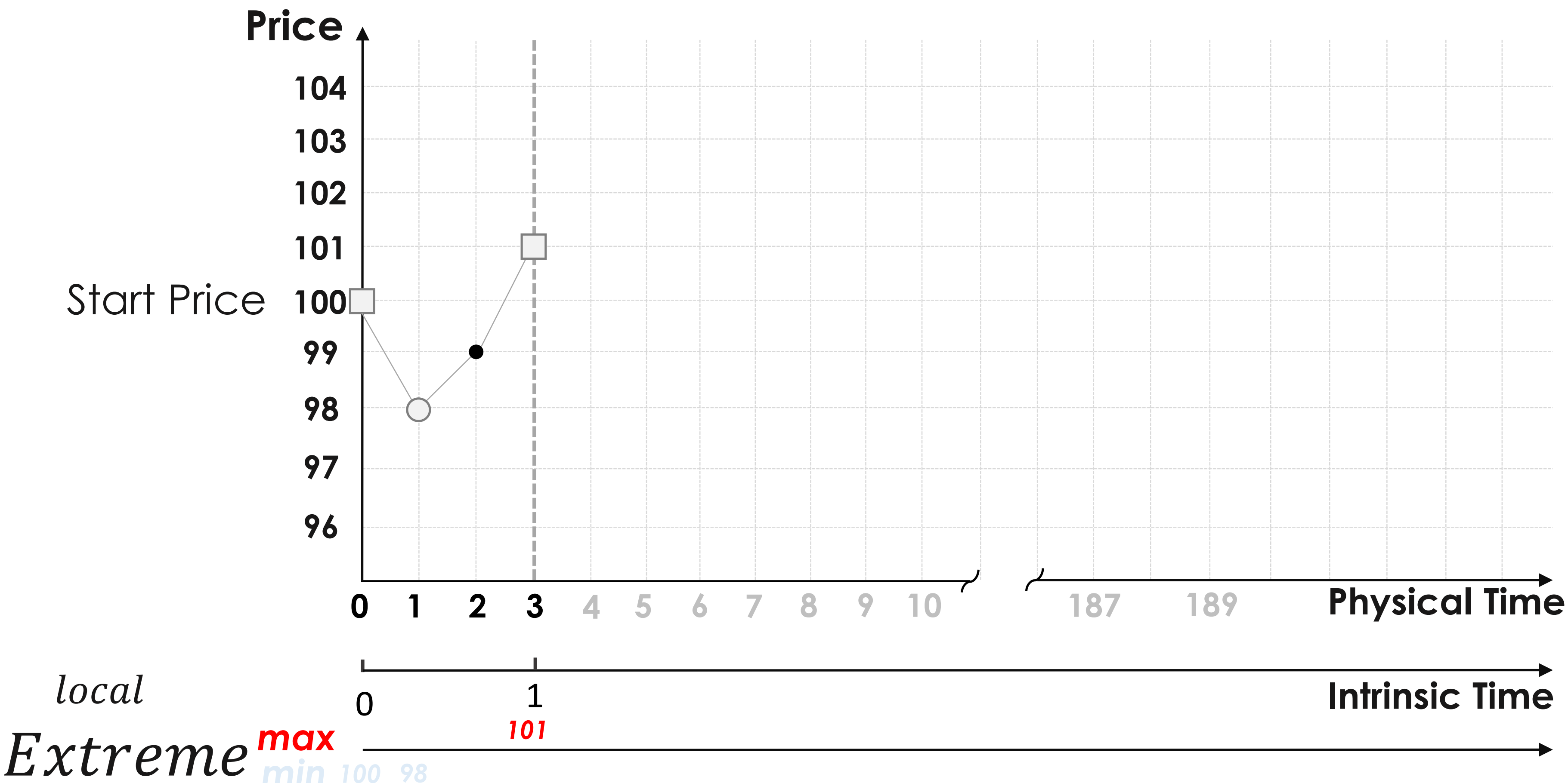
$$\Delta P = Extreme - P_t$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑ ↓

$$\Delta P = 0$$
$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100
98	101



Intrinsic events, Directional Change (DC)

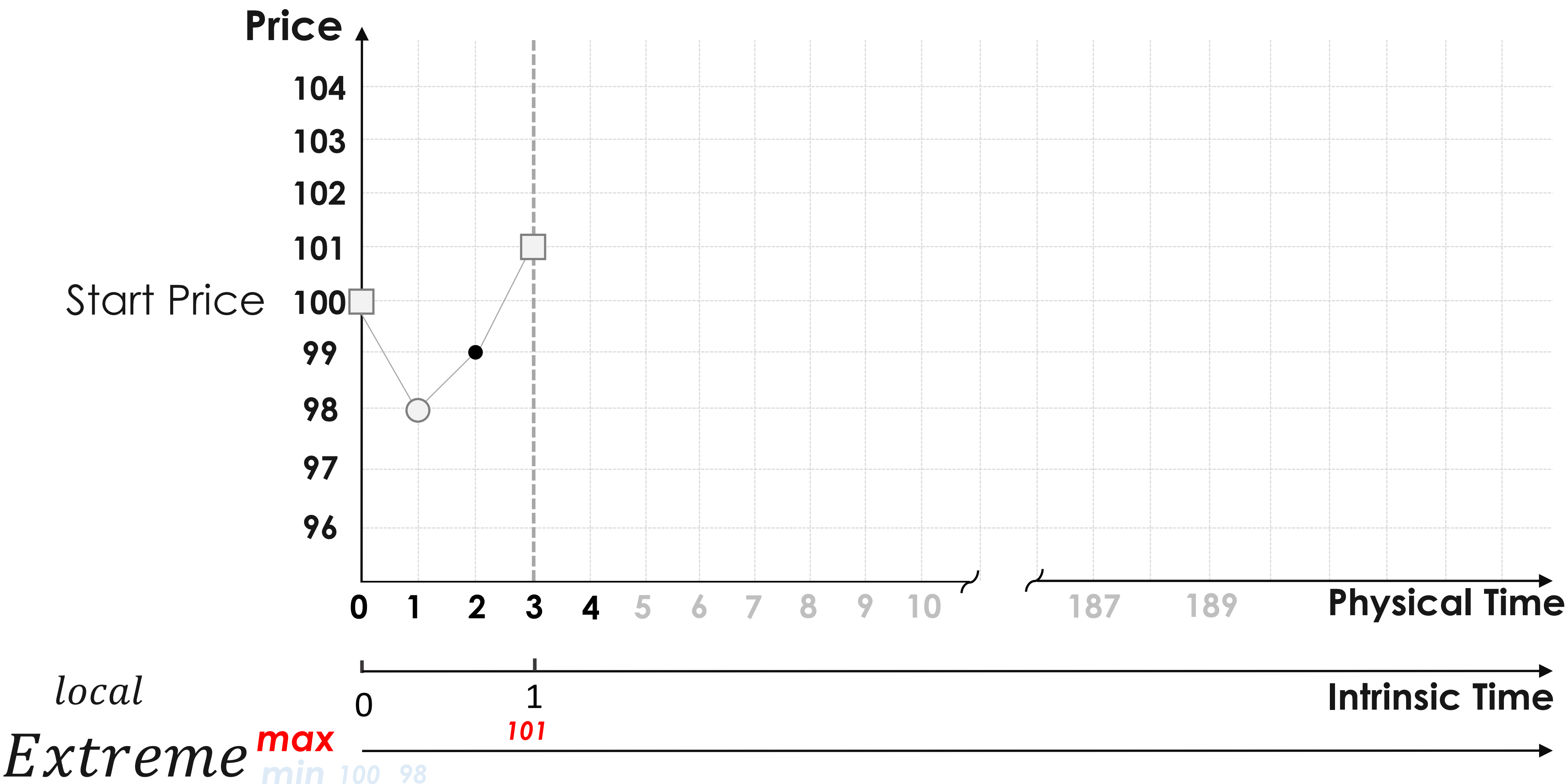
$$\Delta P = Extreme - P_t$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑ ↓

$$\Delta P = 0$$
$$\Delta P \geq 2\ ?$$

No

Ext. ○	DC □
-	100
98	101



Intrinsic events, Directional Change (DC)

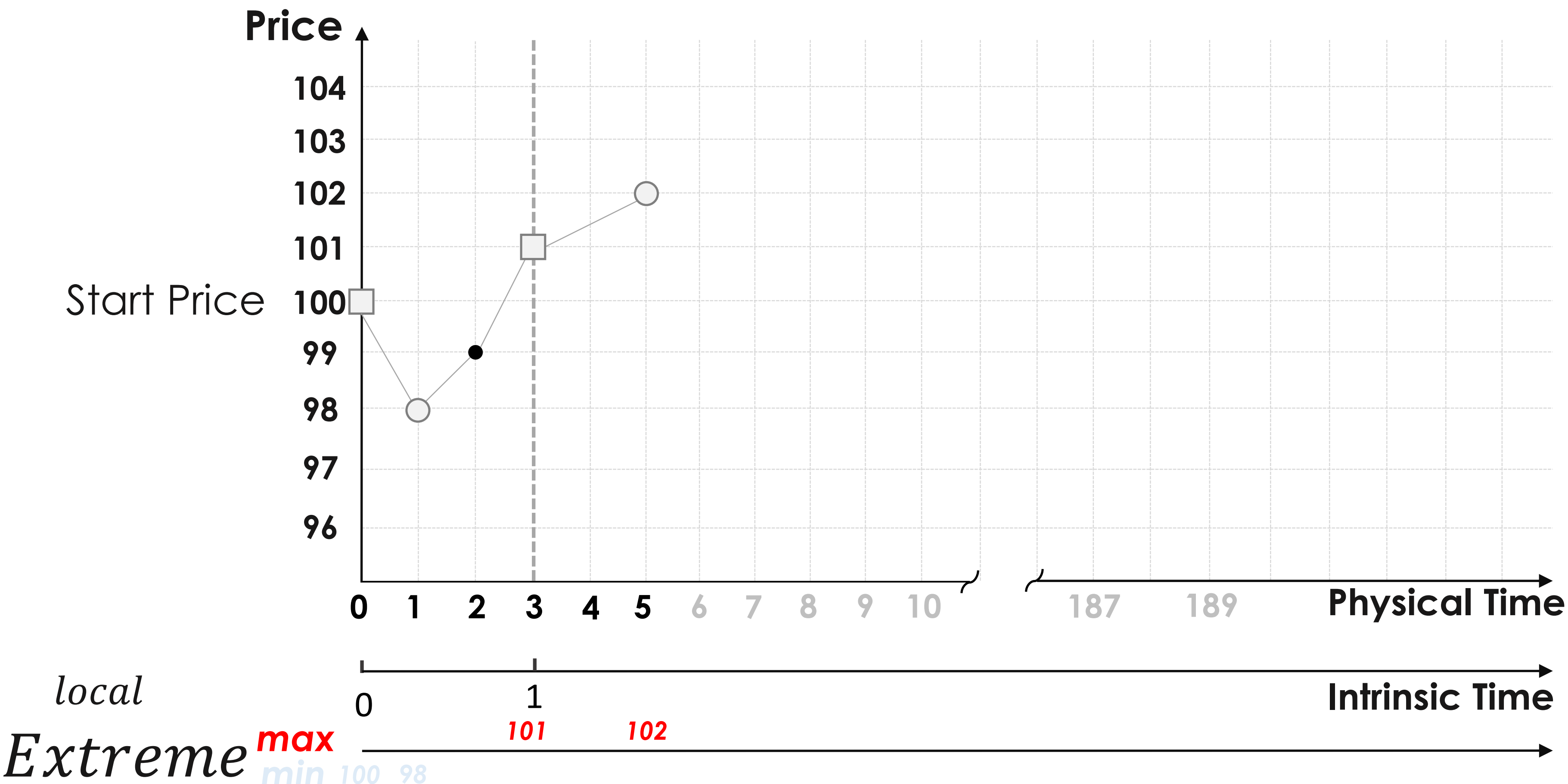
$$\Delta P = Extreme - P_t$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑ ↓

$$\Delta P = 0$$
$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100
98	101



Intrinsic events, Directional Change (DC)

$$\Delta P = Extreme - P_t$$

$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

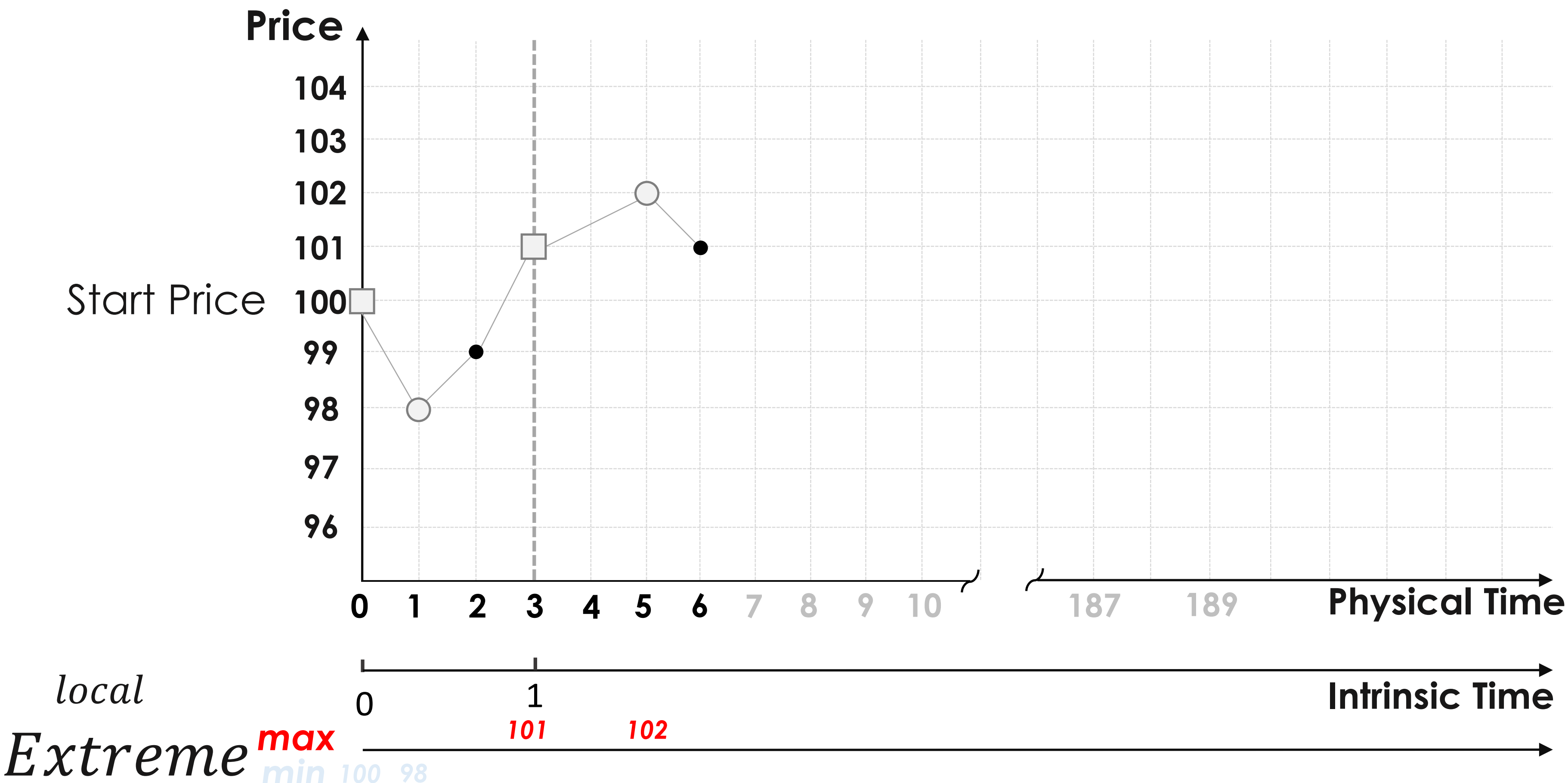
mode: ↑ ↓

$$\Delta P = 1$$

$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100
98	101



Intrinsic events, Directional Change (DC)

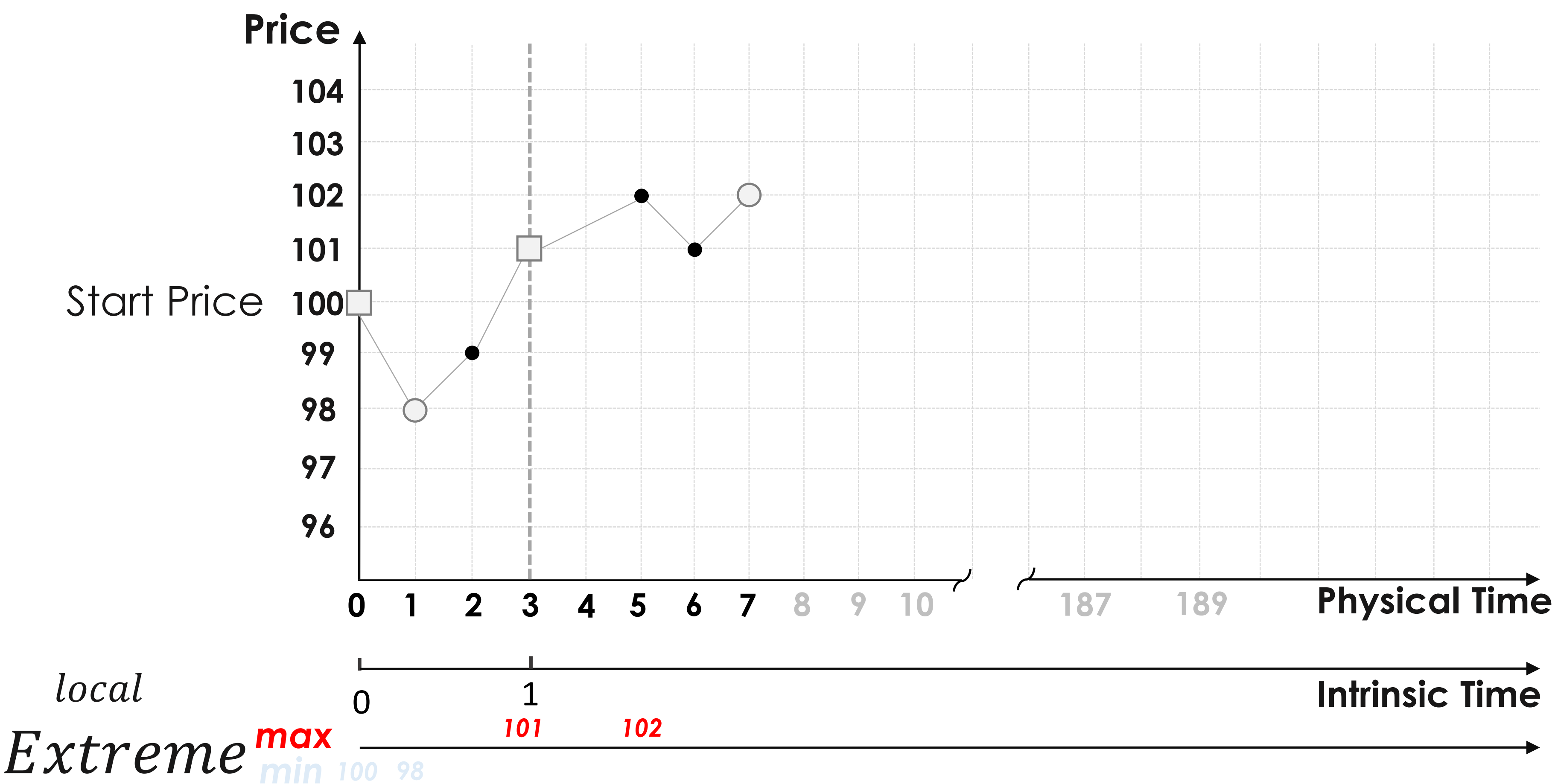
$$\Delta P = Extreme - P_t$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑ ↓

$$\Delta P = 0$$
$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100
98	101



Intrinsic events, Directional Change (DC)

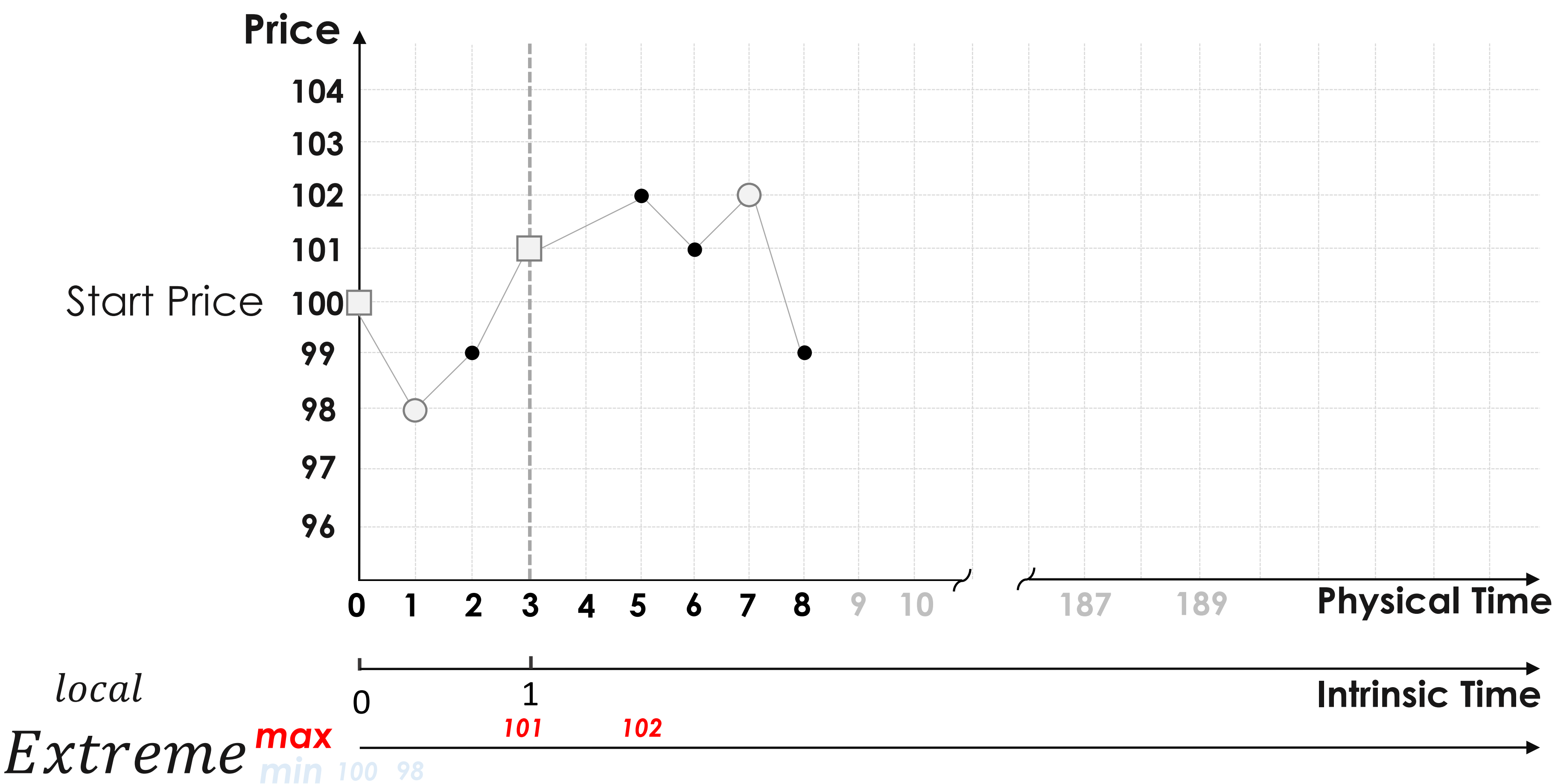
$$\Delta P = Extreme - P_t$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑ ↓

$$\Delta P = 3$$
$$\Delta P \geq 2 \ ?$$

Yes

Ext. ○	DC □
-	100
98	101



Intrinsic events, Directional Change (DC)

$$\Delta P = P_t - Extreme$$

$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

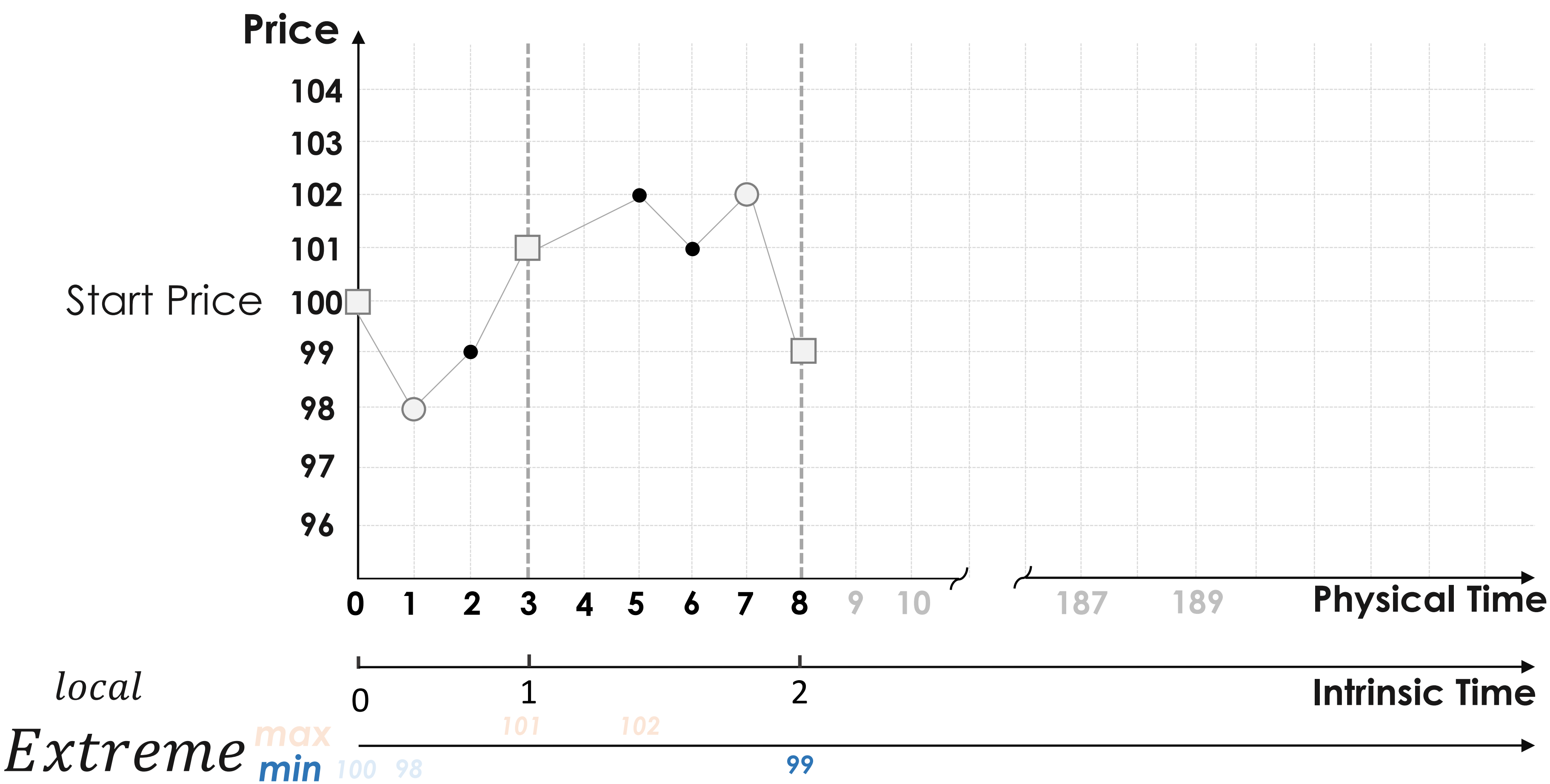
mode: ↑↓↑

$$\Delta P = 0$$

$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100
98	101
102	99



Intrinsic events, Directional Change (DC)

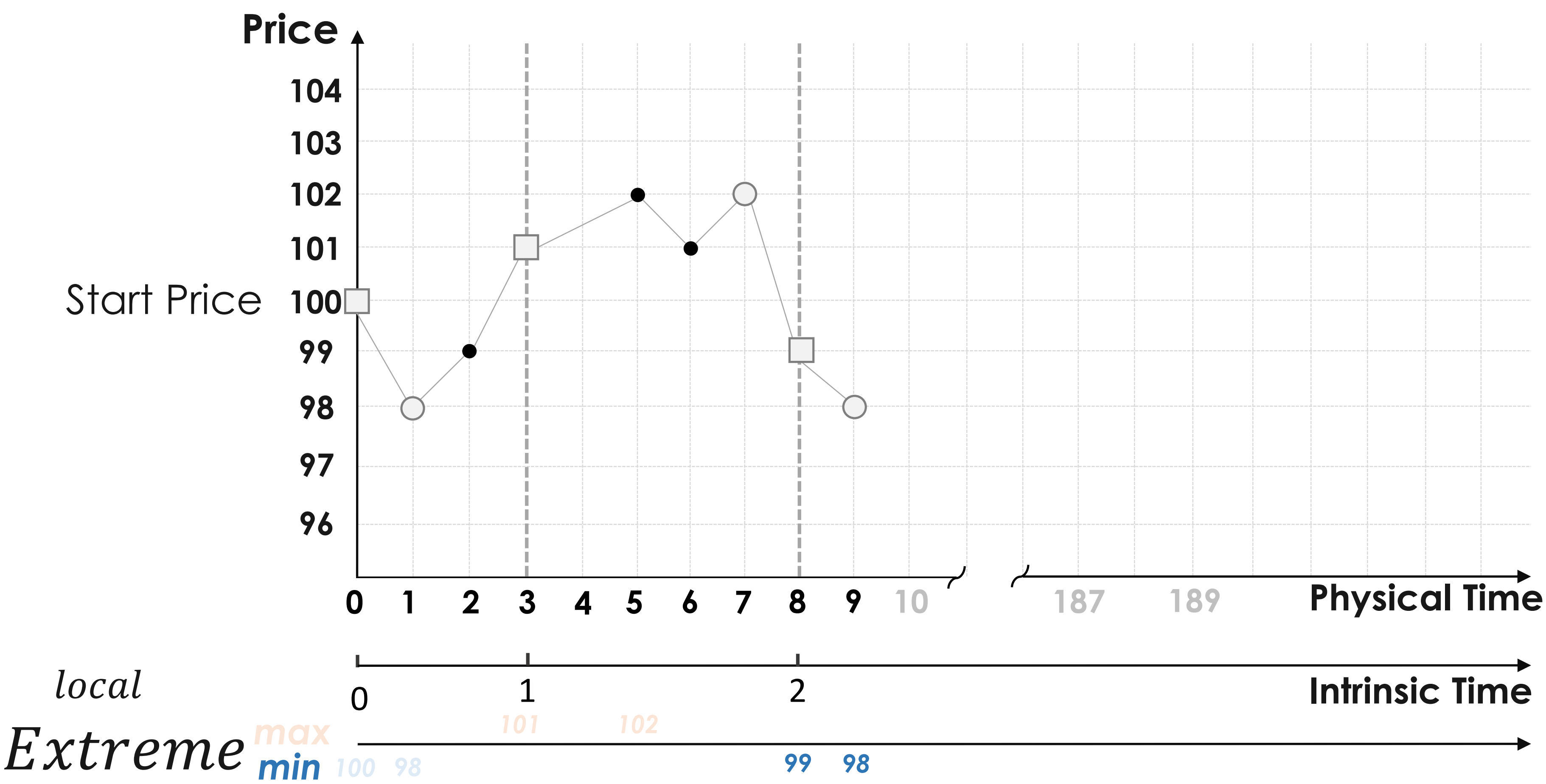
$$\Delta P = P_t - Extreme$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑↓↑

$$\Delta P = 0$$
$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100
98	101
102	99



Intrinsic events, Directional Change (DC)

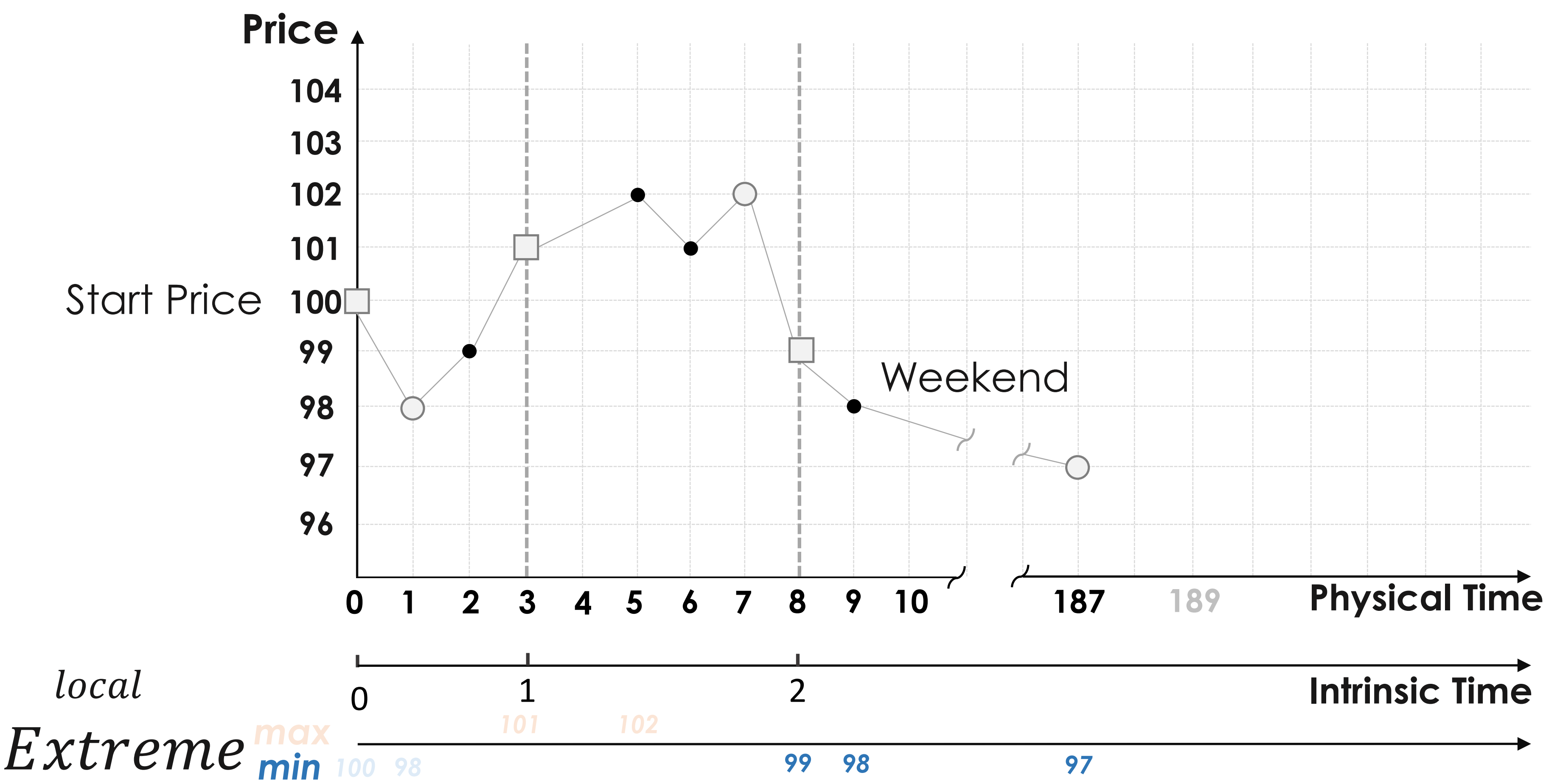
$$\Delta P = P_t - Extreme$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode: ↑↓↑

$$\Delta P = 0$$
$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100
98	101
102	99



Intrinsic events, Directional Change (DC)

$\Delta P = P_t - Extreme$

$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$

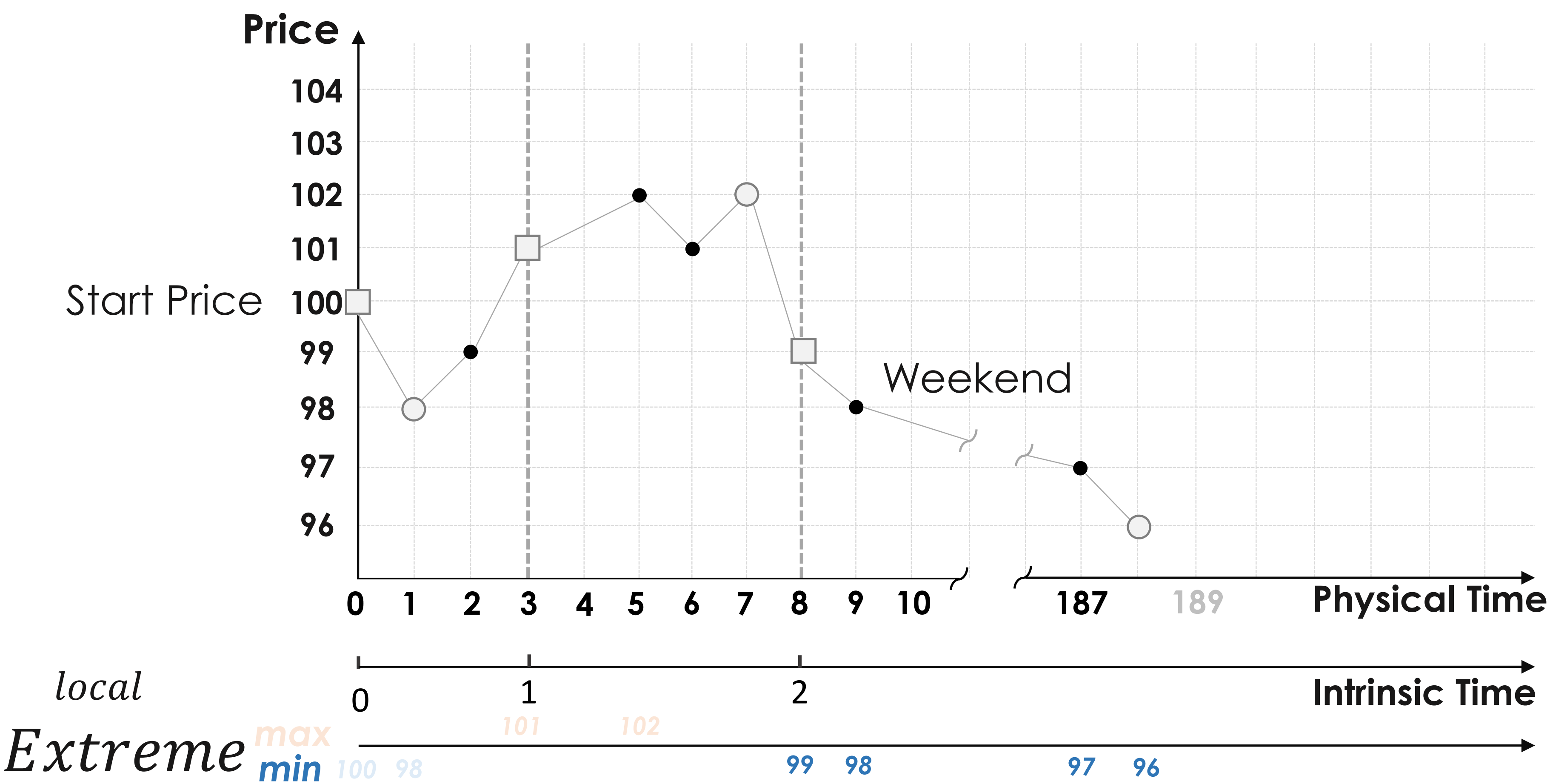
mode: ↑↓↑

$\Delta P = 0$

$\Delta P \geq 2$?

No

Ext. ○	DC □
-	100
98	101
102	99



Intrinsic events, Directional Change (DC)

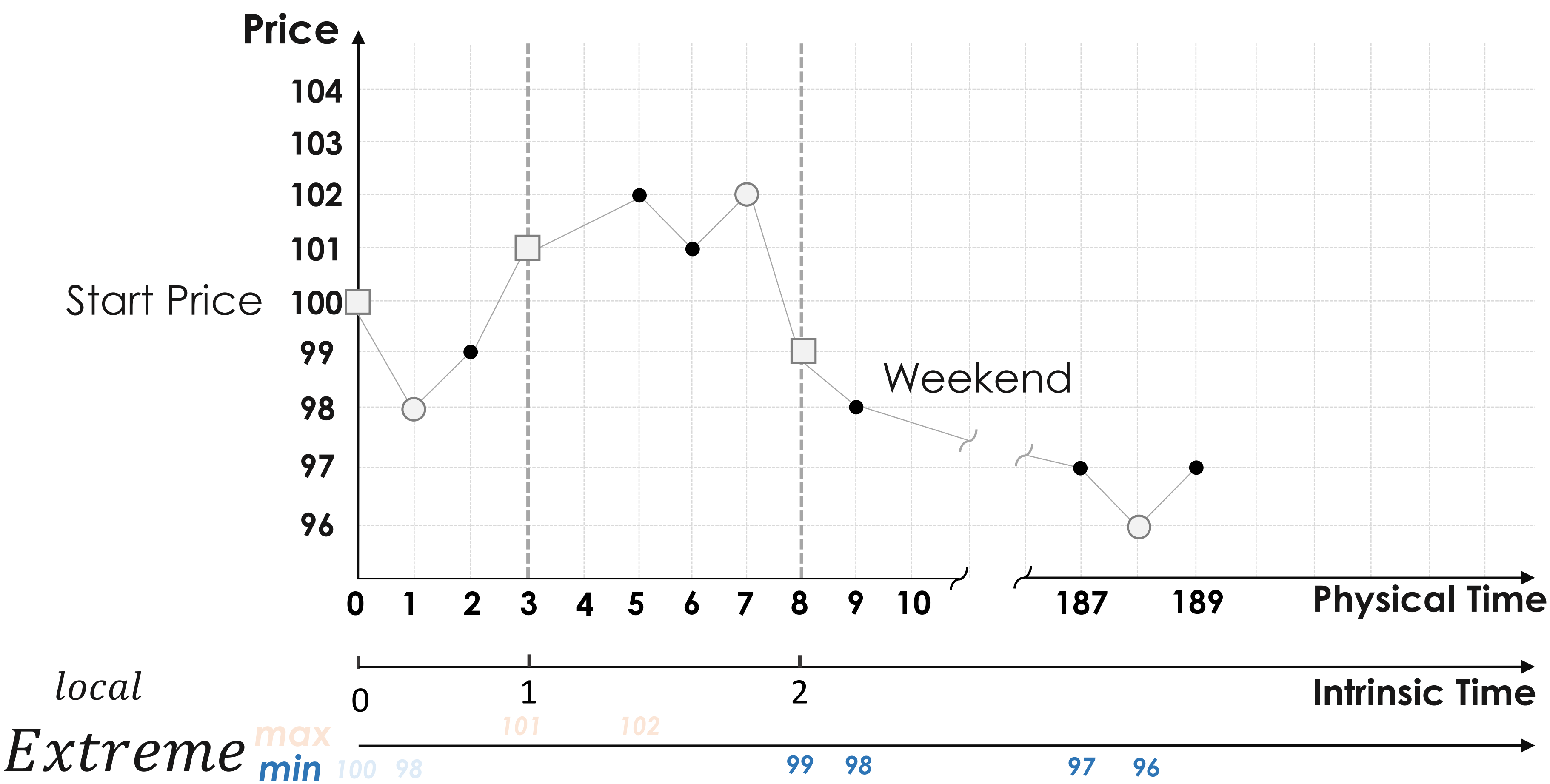
$$\Delta P = P_t - Extreme$$
$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

mode:

$$\Delta P = 1$$
$$\Delta P \geq 2 \ ?$$

No

Ext. ○	DC □
-	100
98	101
102	99



Intrinsic events, Directional Change (DC)

$$\Delta P = P_t - Extreme$$

$$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$$

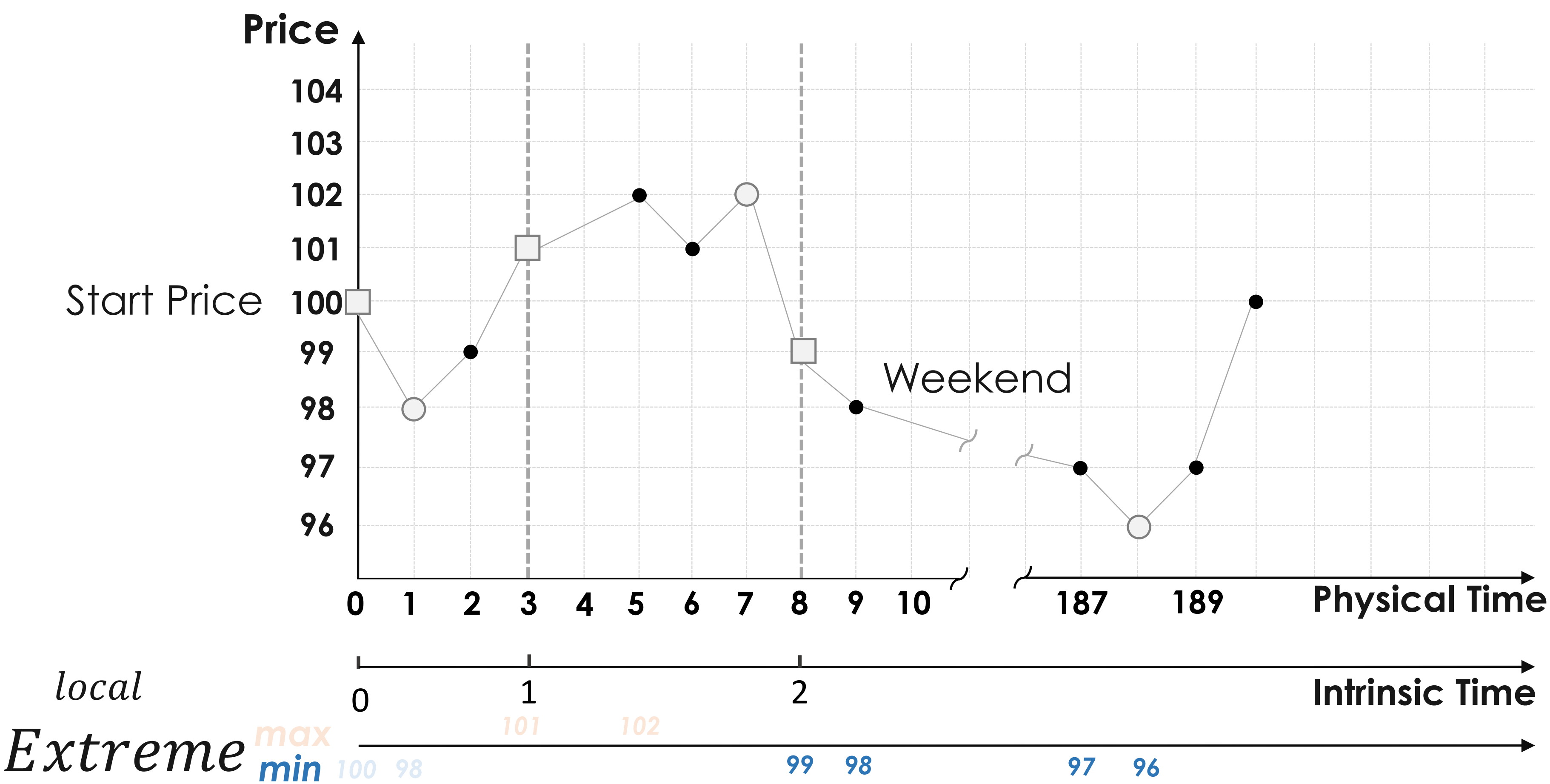
mode: ↑↓↑

$$\Delta P = 4$$

$$\Delta P \geq 2 \ ?$$

Yes

Ext. ○	DC □
-	100
98	101
102	99



Intrinsic events, Directional Change (DC)

$\Delta P = Extreme - P_t$

$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$

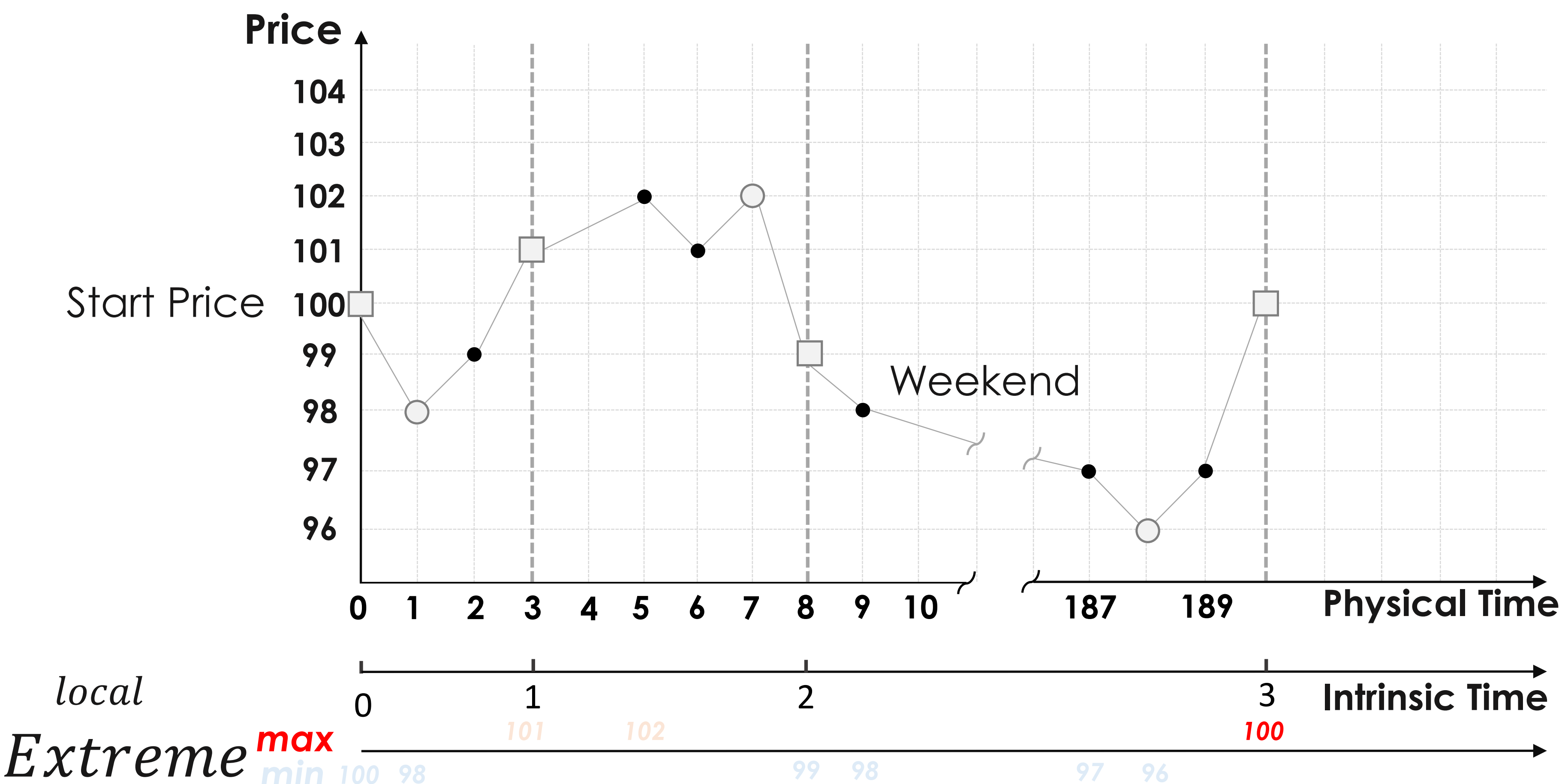
mode: ↑ ↓ ↑ ↓

$\Delta P = 0$

$\Delta P \geq 2$?

No

Ext. ○	DC □
-	100
98	101
102	99
96	100



Intrinsic events, Directional Change (DC)

$\Delta P = Extreme - P_t$

$\delta = 2\% \Rightarrow \delta \cdot P_t \approx 2$

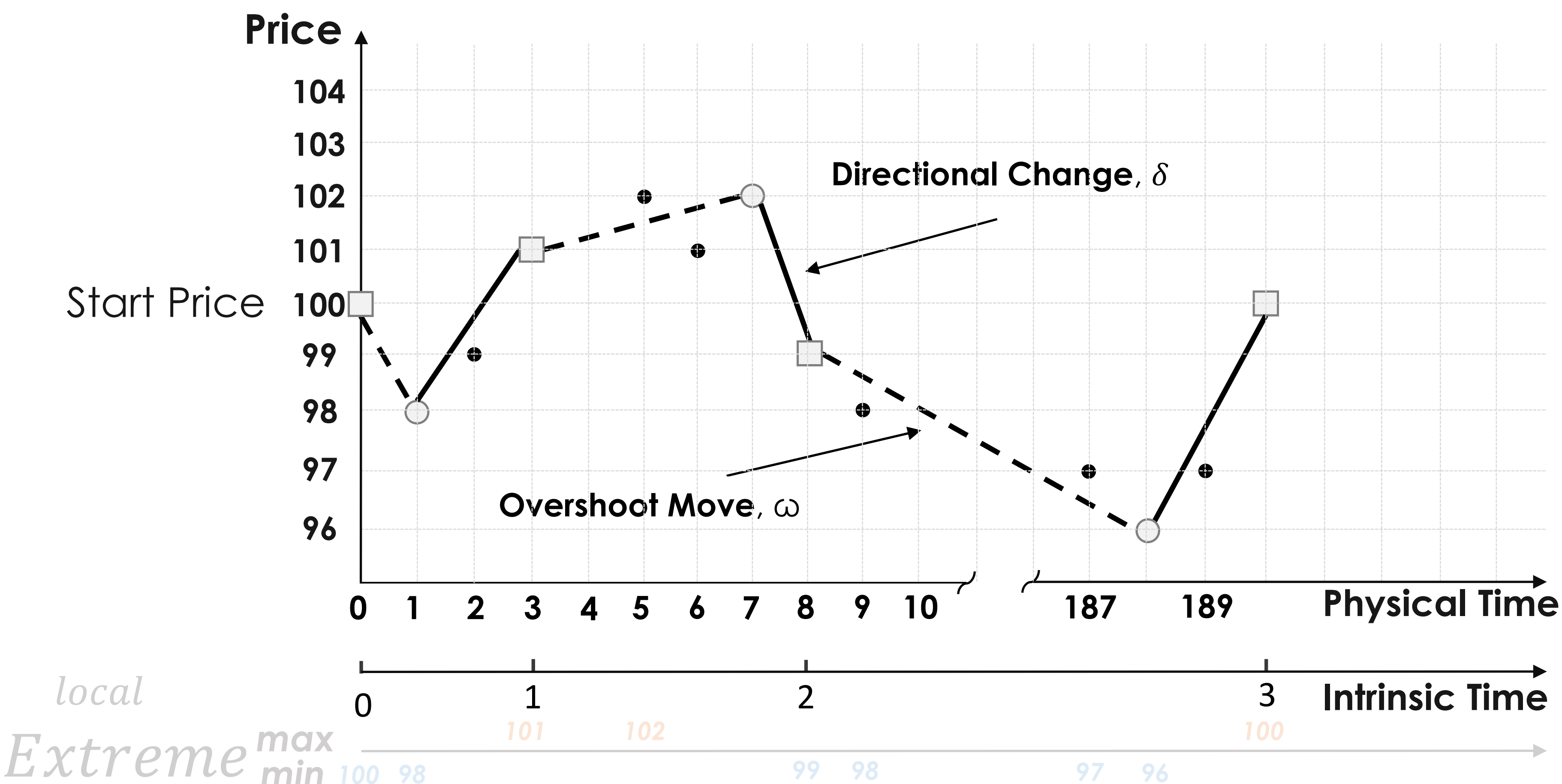
mode: ↑↓↑↓

$\Delta P = 0$

$\Delta P \geq 2$?

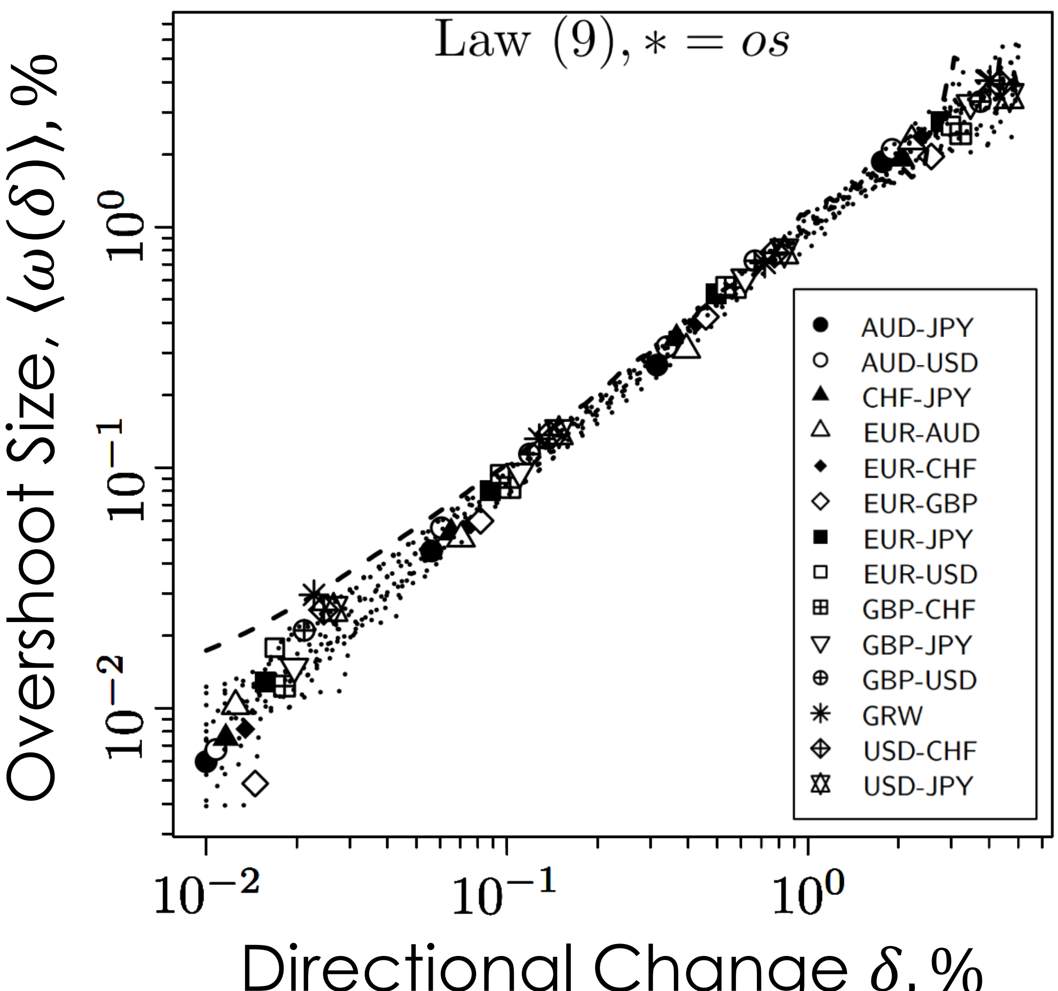
No

Ext. ○	DC □
-	100
98	101
102	99
96	100



Universal scaling law, Intrinsic Events

Average Overshoot Move



Scaling law:

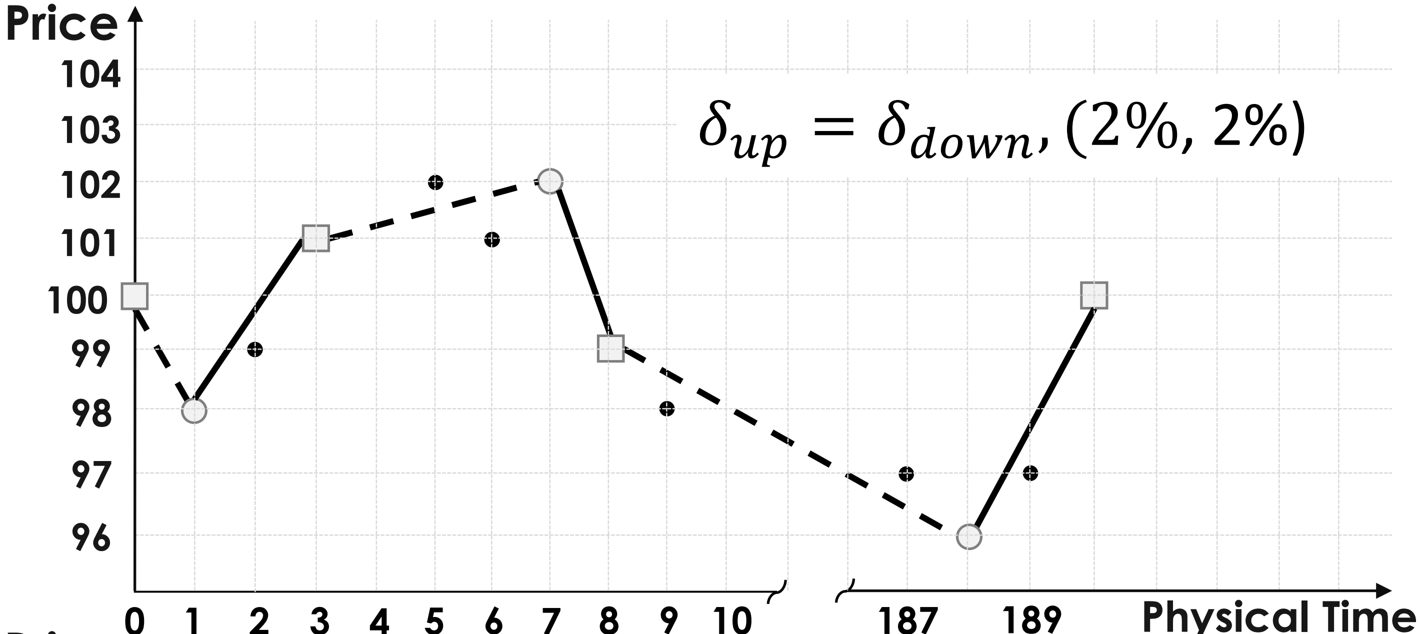
Average size of Overshoots is equal to the size of Directional Changes:

$$\langle|\omega(\delta)|\rangle \approx \delta$$

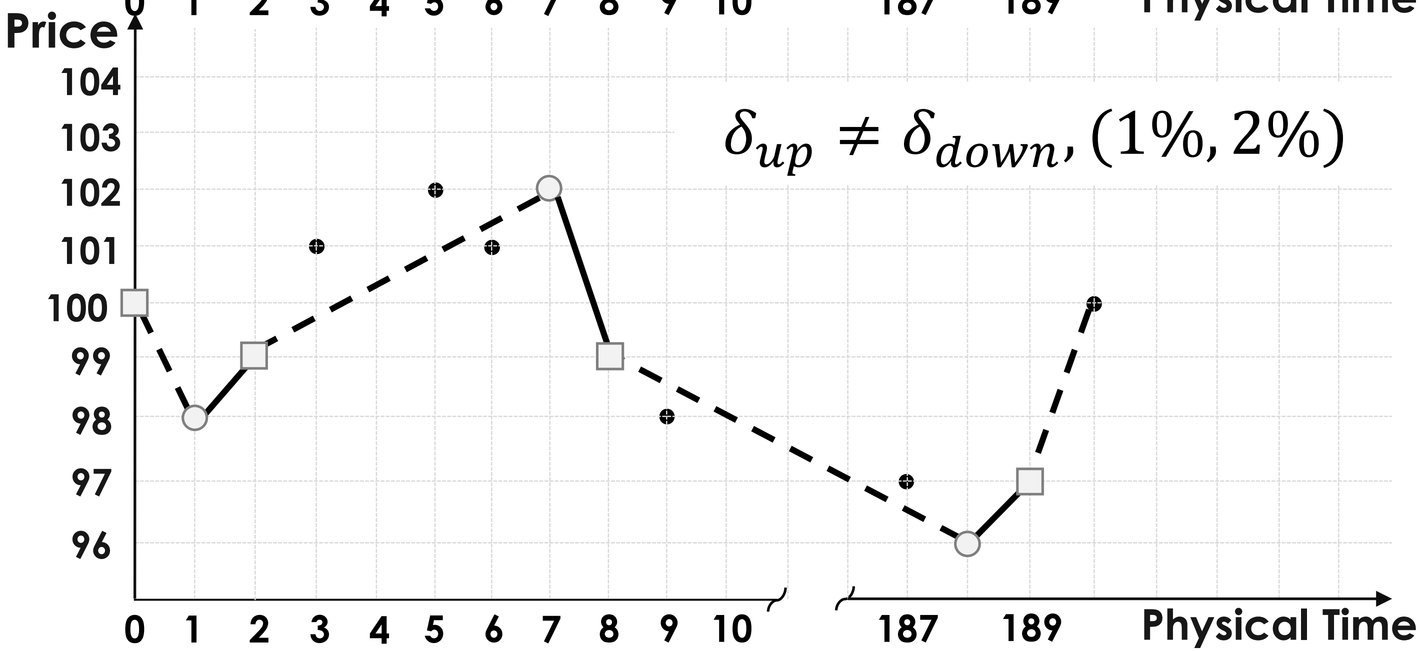
The same result for **13** Forex pairs

Symmetric VS **Assymetric Intrinsic Event Approach**

Symmetric VS **Assymetric Intrinsic Event Approach**



Ext. ○	DC □
-	100
98	101
102	99
96	100



Ext. ○	DC □
-	100
98	99
102	99
96	97

Intrinsic Event Agents

An agent: a piece of computer code, simulation of the real traders behavoiur

Specified by a unique set of parameters:

- size of a the upward threshold $\boldsymbol{\delta_{up}}$
- size of a the downward threshold $\boldsymbol{\delta_{down}}$
- probability to flip position $\boldsymbol{P}$

Agent: $A(\delta_{up}, \delta_{down}, P)$

Intrinsic Event Agents, behaviour

1. Open a short (sell) or long (buy) position at time of the first intrinsic event

2. Holds the opened position until the next intrinsic event

3. When observes a new intrinsic event:

   - can close the current position and open an oposite one with probability P

   - can do nothing with probability $(1 - P)$

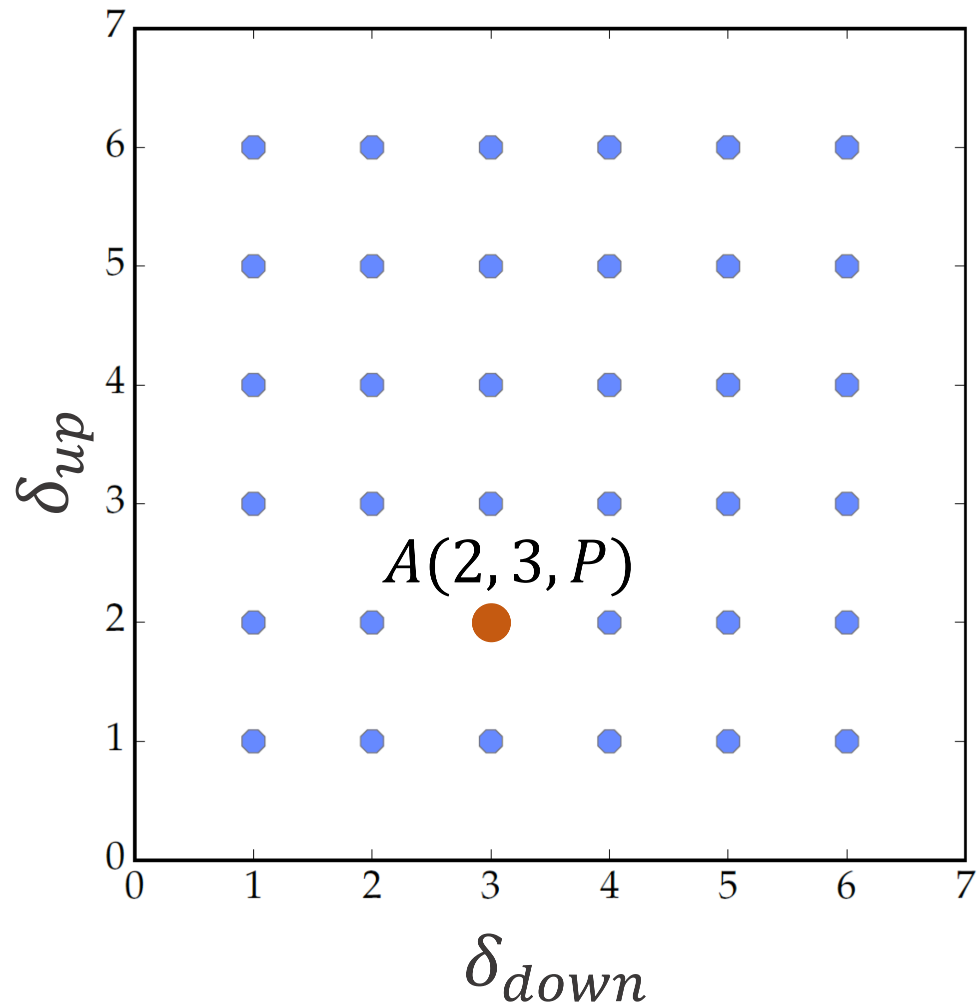
Grid of Intrinsic Event Agents

The main goal: to simulate behaviour of real market participants

Grid of Intrinsic Event Agents

The main goal: to simulate behaviour of real market participants

Simulation: a grid 50x50, **2500** unique agents



Market response, **price changes**

**Bouchaud, Jean-Philippe. "Price impact." Encyclopedia of quantitative finance (2010).*

Market response, **price changes**

One step: all agents receive the same new price and analize it.

**Bouchaud, Jean-Philippe. "Price impact." Encyclopedia of quantitative finance (2010).*

Market response, **price changes**

One step: all agents receive the same new price and analize it.

$\boldsymbol{N_{long}}$ and $\boldsymbol{N_{short}}$: total number of LONG (buy) and SHORT (sell) positions after one step

$$\boldsymbol{\Delta N} = N_{long} - N_{short}$$

**Bouchaud, Jean-Philippe. "Price impact." Encyclopedia of quantitative finance (2010).*

Market response, **price changes**

One step: all agents receive the same new price and analize it.

$\boldsymbol{N_{long}}$ and $\boldsymbol{N_{short}}$: total number of LONG (buy) and SHORT (sell) positions after one step

$$\boldsymbol{\Delta N} = N_{long} - N_{short}$$

$\boldsymbol{\Delta N} > 0$ - lack of sellers, -> price increase

$\boldsymbol{\Delta N} < 0$ - lack of buyers, -> price decrease

Market response, **price changes**

One step: all agents receive the same new price and analize it.

$\boldsymbol{N_{long}}$ and $\boldsymbol{N_{short}}$: total number of LONG (buy) and SHORT (sell) positions after one step

$$\boldsymbol{\Delta N} = N_{long} - N_{short}$$

$\boldsymbol{\Delta N} > 0$ - lack of sellers, -> price increase

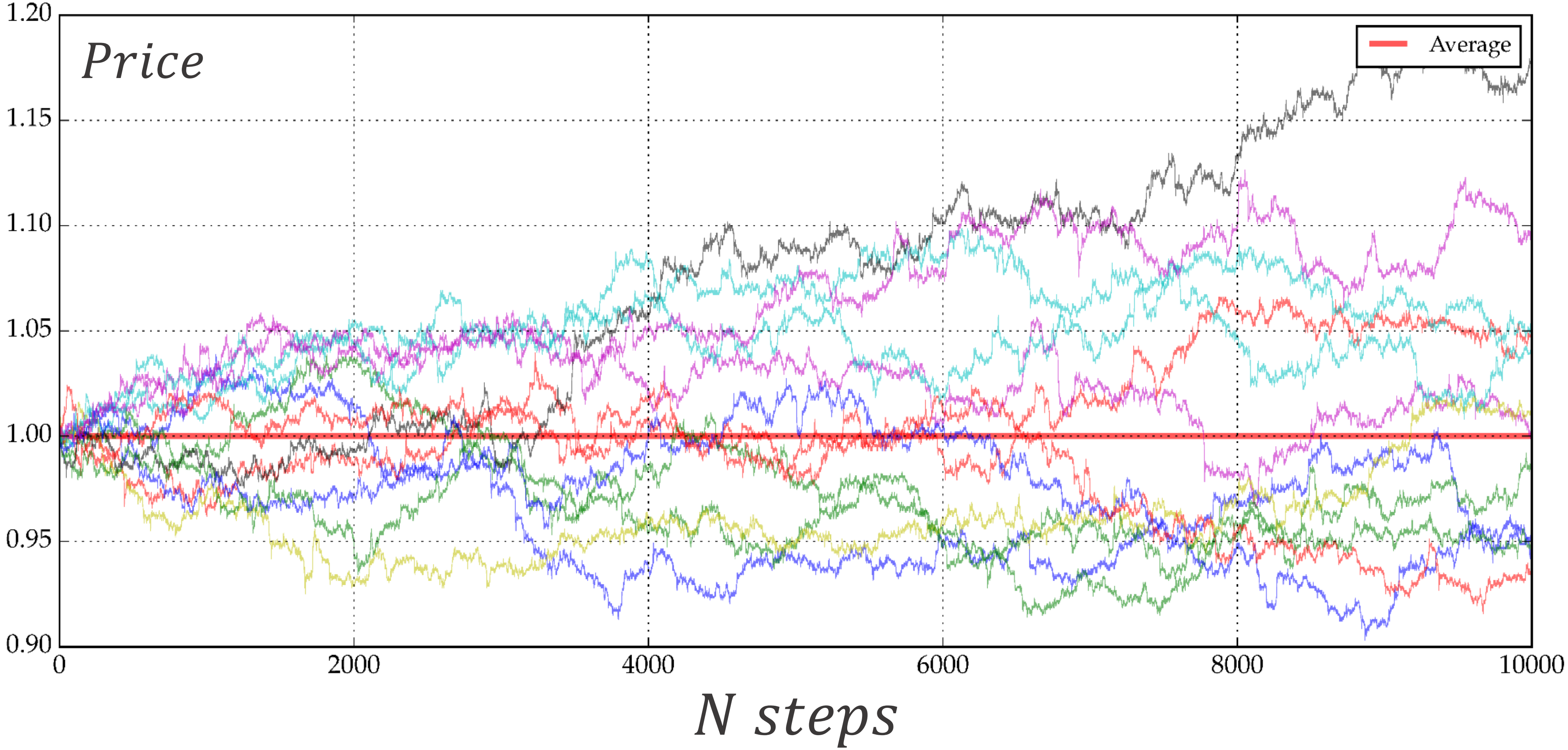
$\boldsymbol{\Delta N} < 0$ - lack of buyers, -> price decrease

$$\Delta P = sgn(\Delta N) \cdot \frac{\sqrt{2}}{2} \cdot \lfloor \sqrt{|\Delta N|} \rfloor$$

**Bouchaud, Jean-Philippe. "Price impact." Encyclopedia of quantitative finance (2010).*

Market Simulation, **Price Curve**

Example of generated time series



Benchmark: Stylized Facts of Financial Time Series

1. Fat-tailed distribution of returns

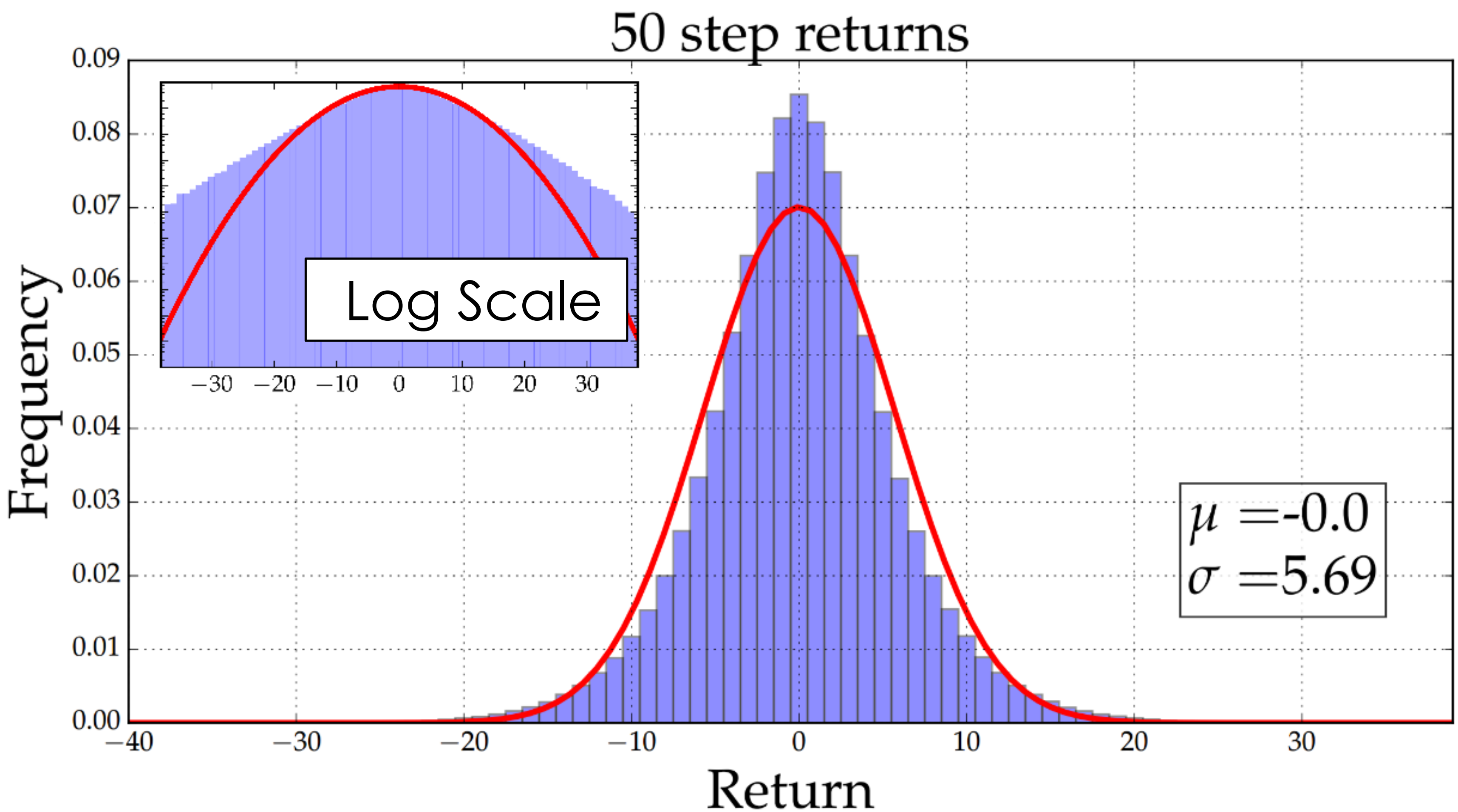
2. Absence of autocorrelations of returns

3. Overshoot Scaling Law

4. Aggregational normality

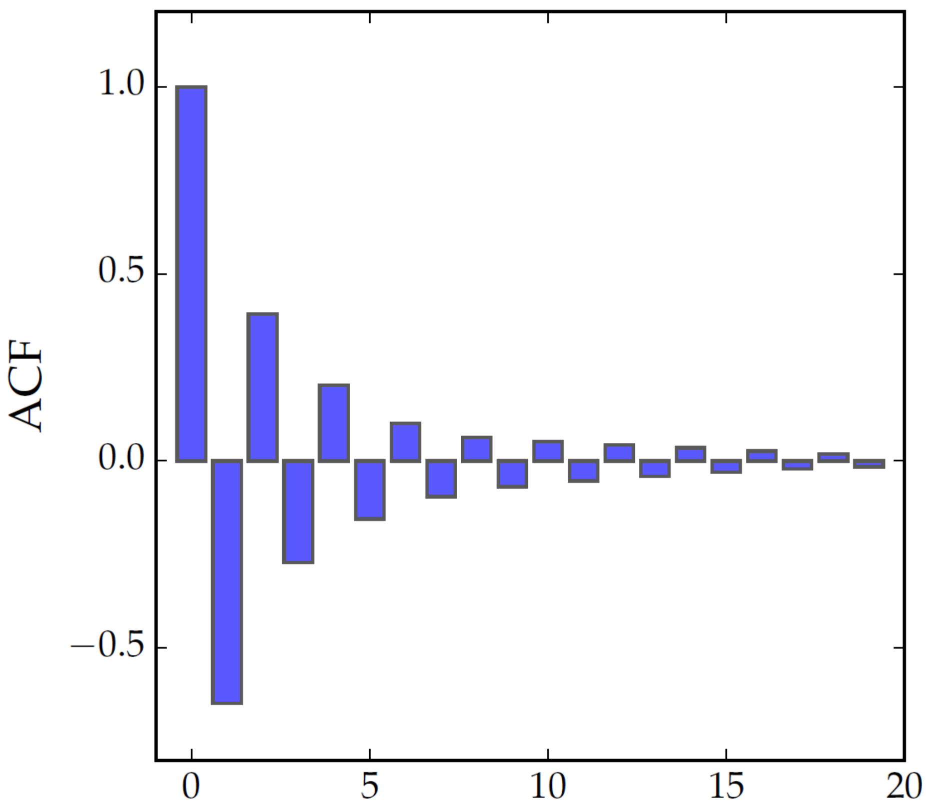
Chakraborti, Anirban, et al. "Econophysics: Empirical facts and agent-based models." arXiv preprint arXiv:0909.1974 (2009).

1. Fat-tailed distribution of returns

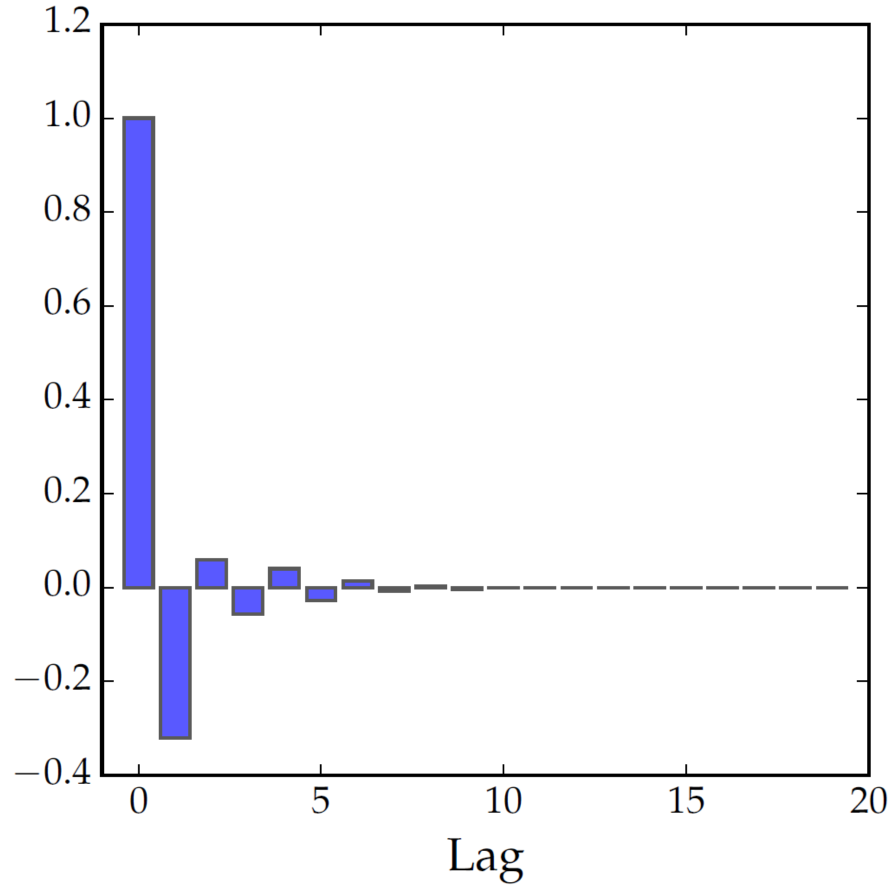


2. Absence of autocorrelations of returns

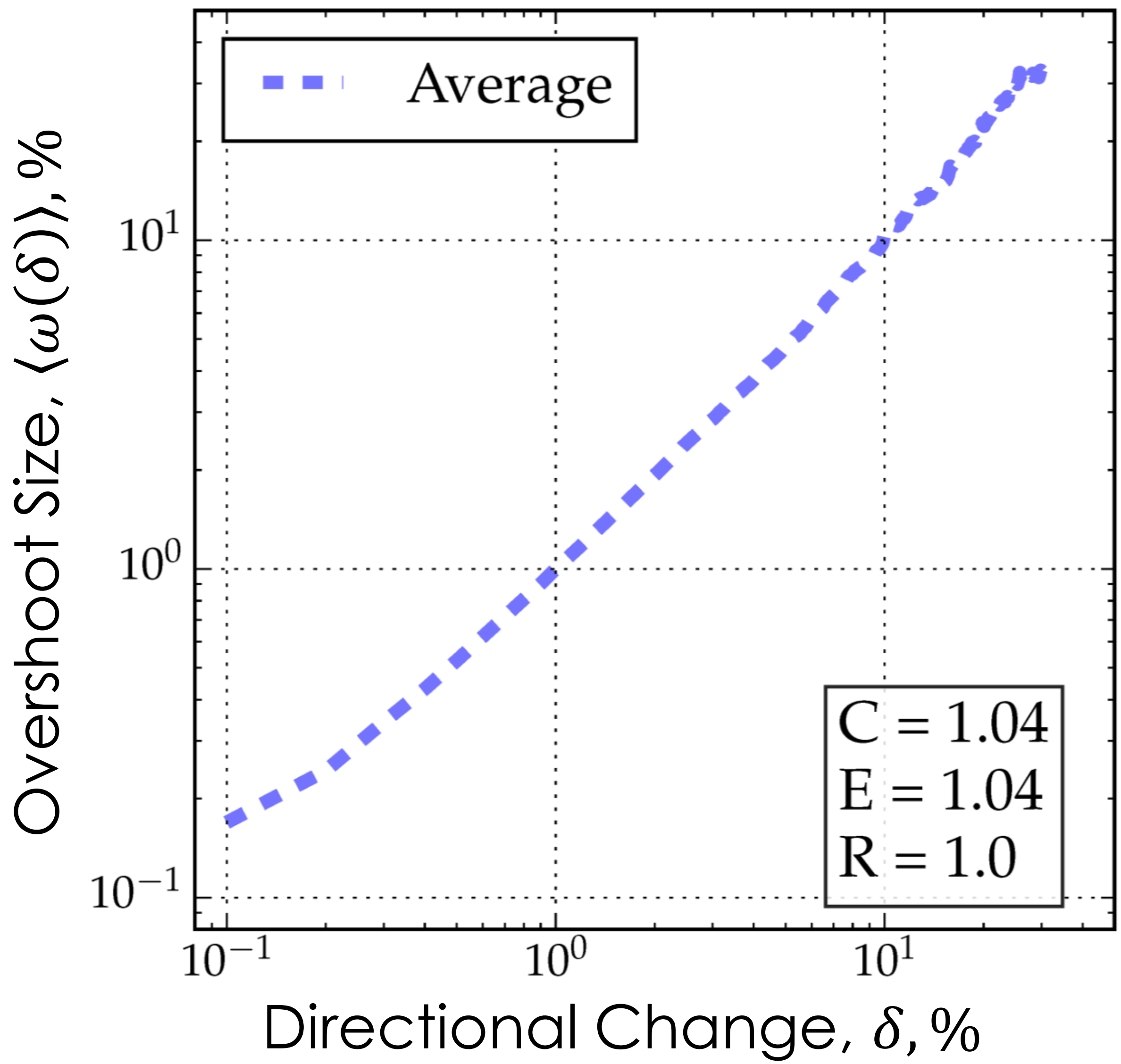
EUR/USD



Generated Time Series



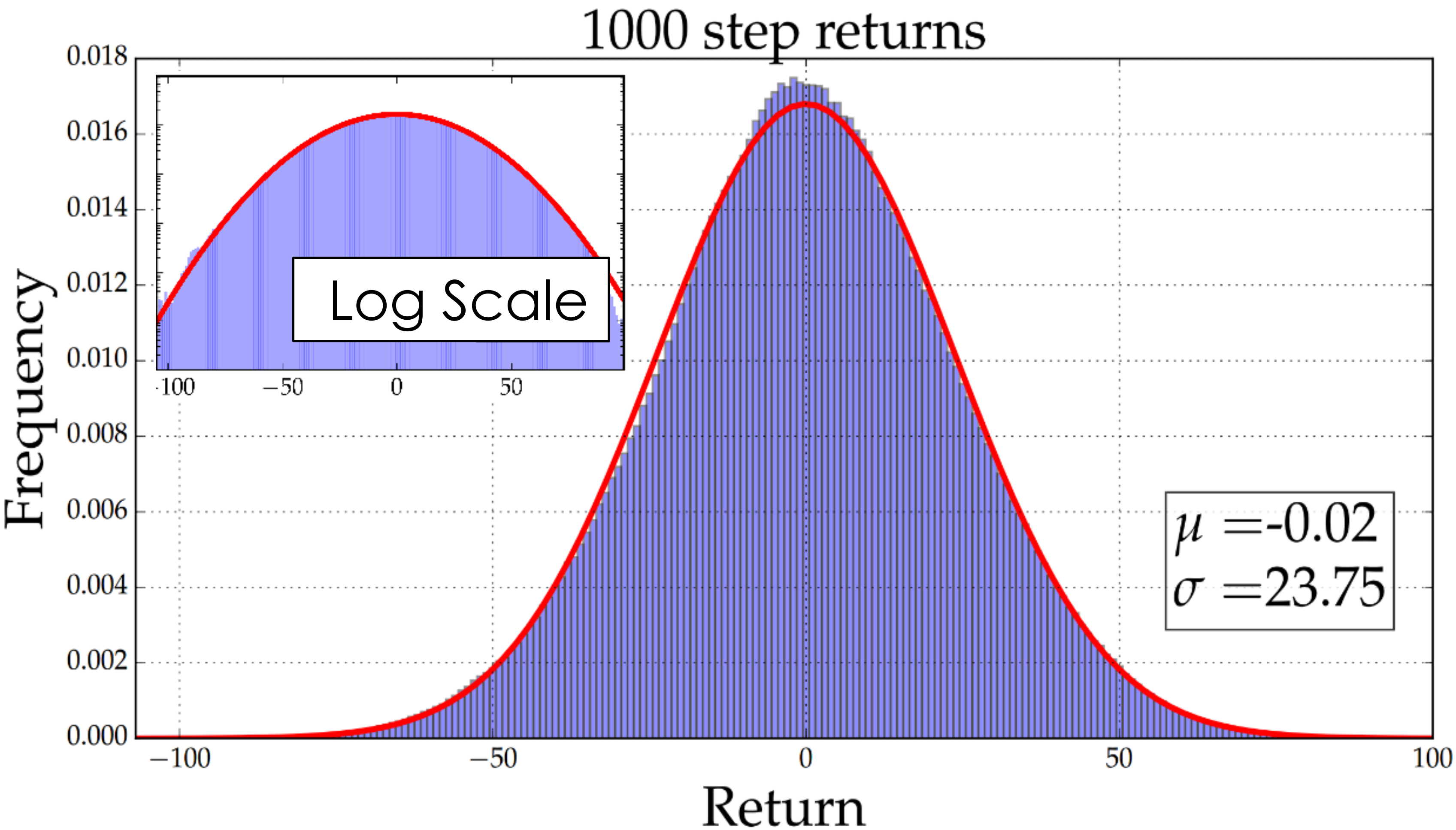
3. Overshoot Scaling Law



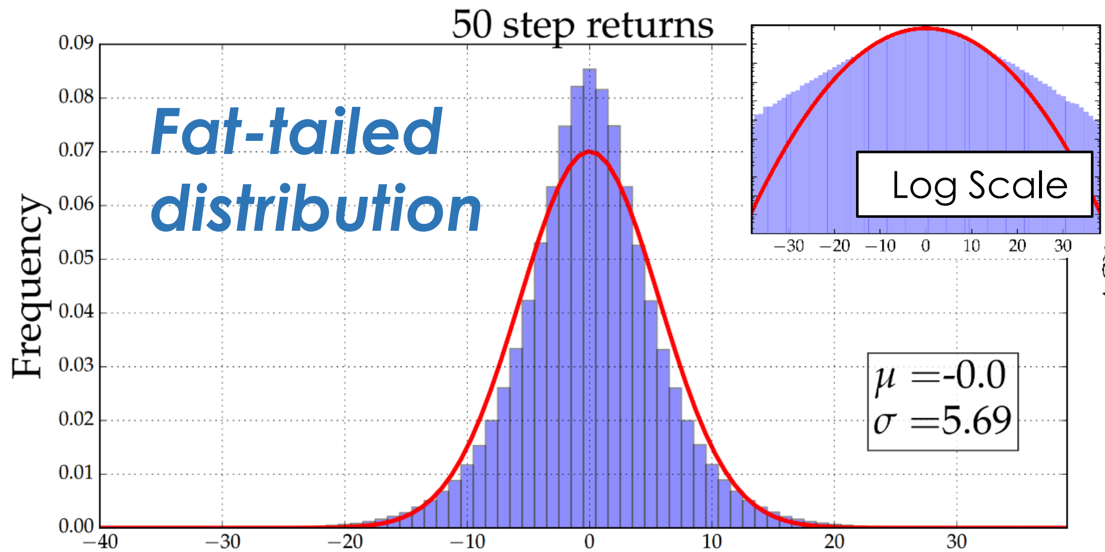
Forex

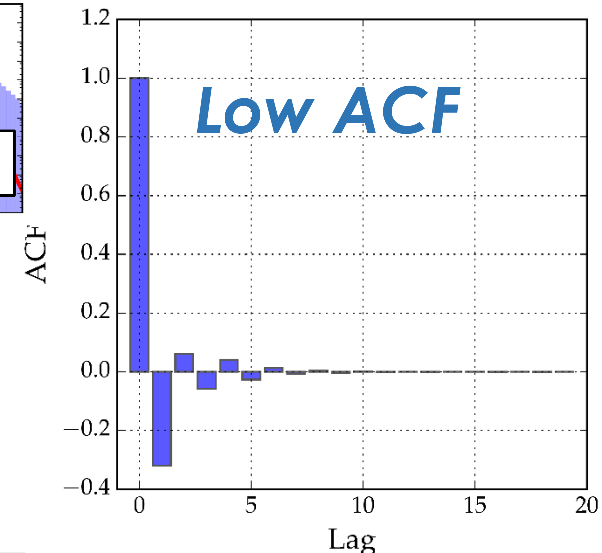
C = 1.06
E = 1.04
R = 1.0

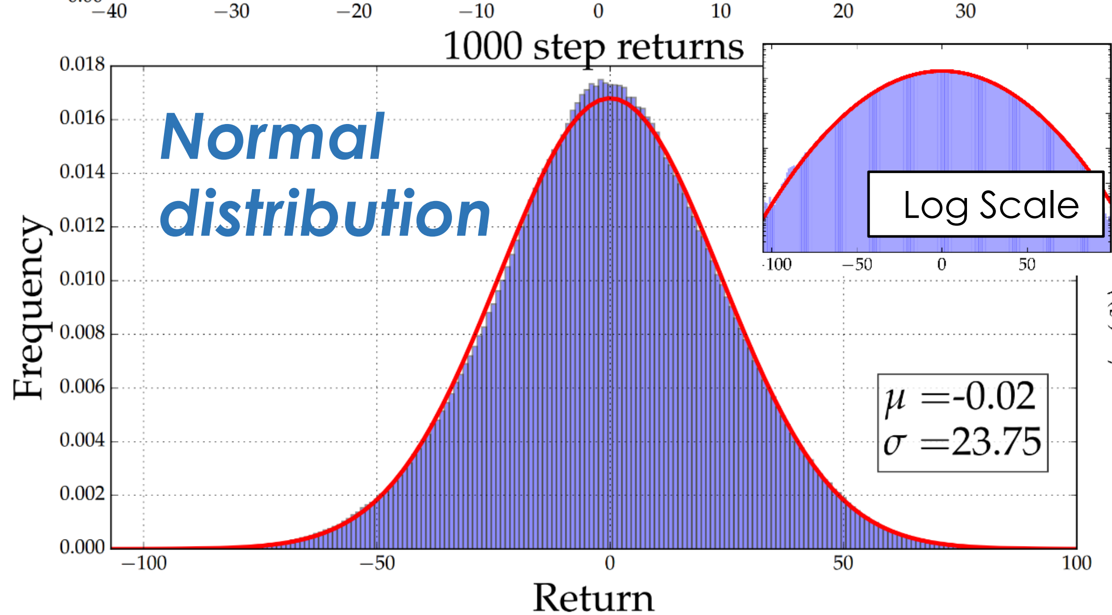
4. Aggregational normality

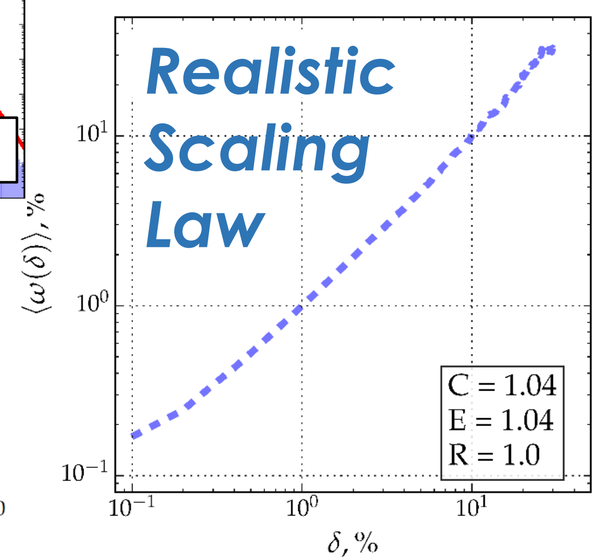


Market Simulation, **all Properties**

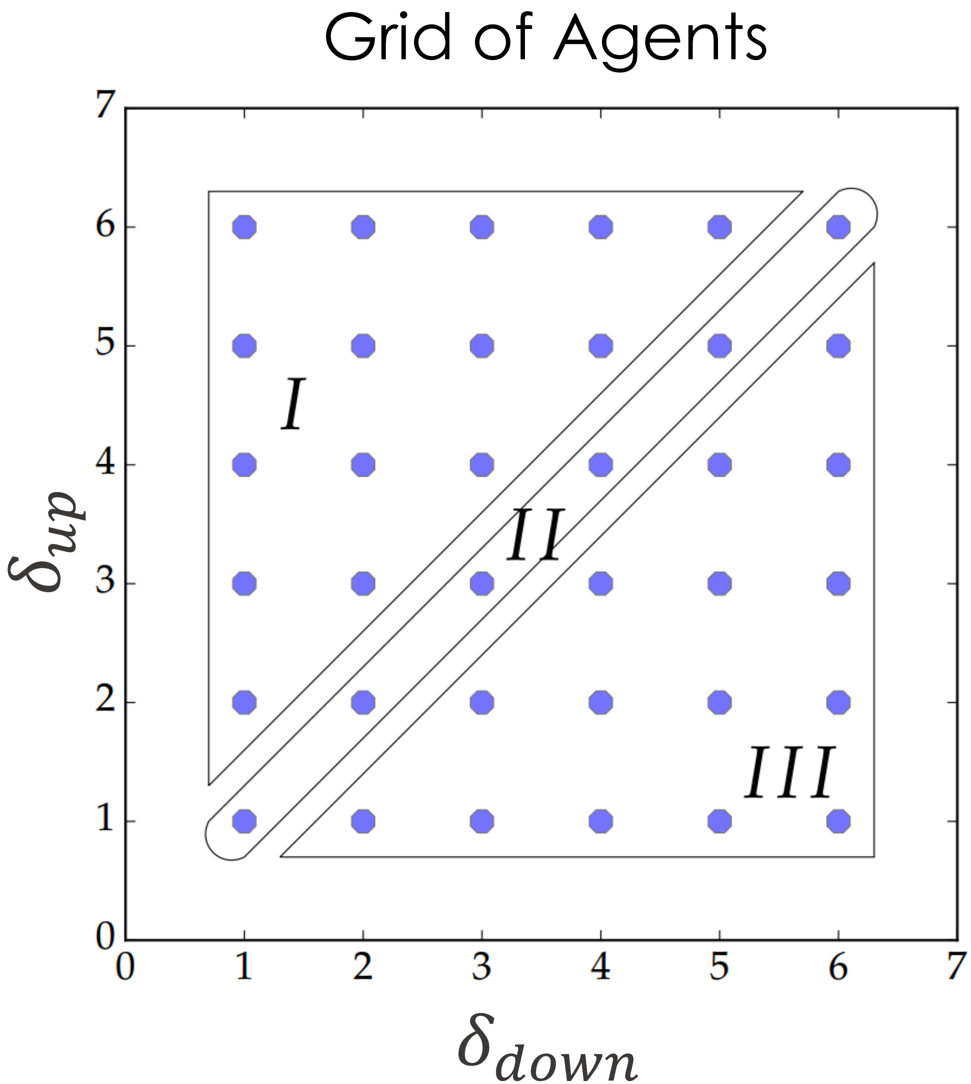








Intrinsic Event Agents, regions



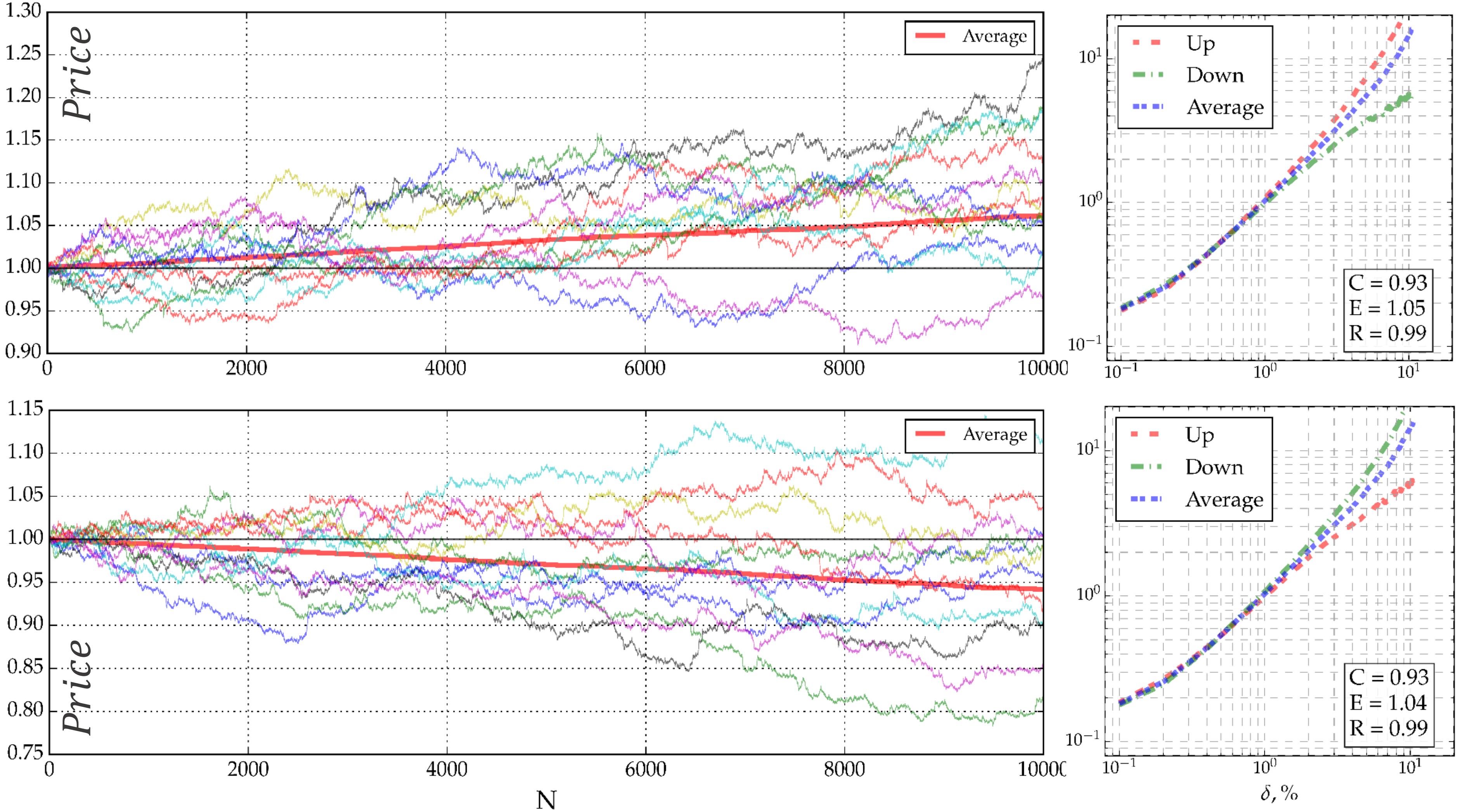
Region I: $\delta_{up} > \delta_{down}$

Region II: $\delta_{up} = \delta_{down}$

Region III: $\delta_{up} < \delta_{down}$

(Grid size = 50)

Effect of **Assymetric Regions**



Conclusion:

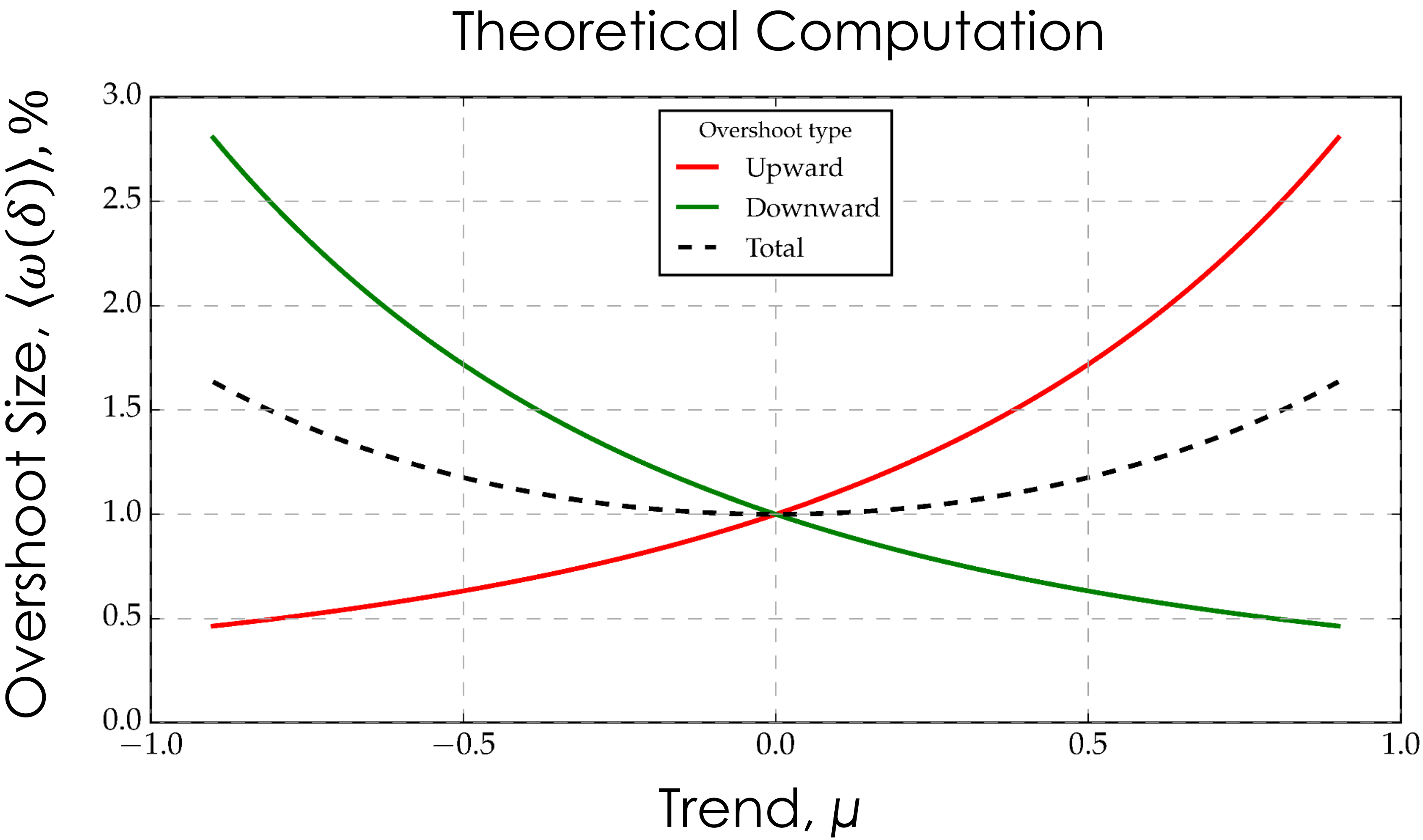
- Traditional methods of time measurements in the world of finanance are not fully correct. Intrinsic Event approach.
- Average Overshoot Move: the main and the universal scaling law
- Statistical properties of time series generated by our artificial agents coincide with those of the real market

Further work:

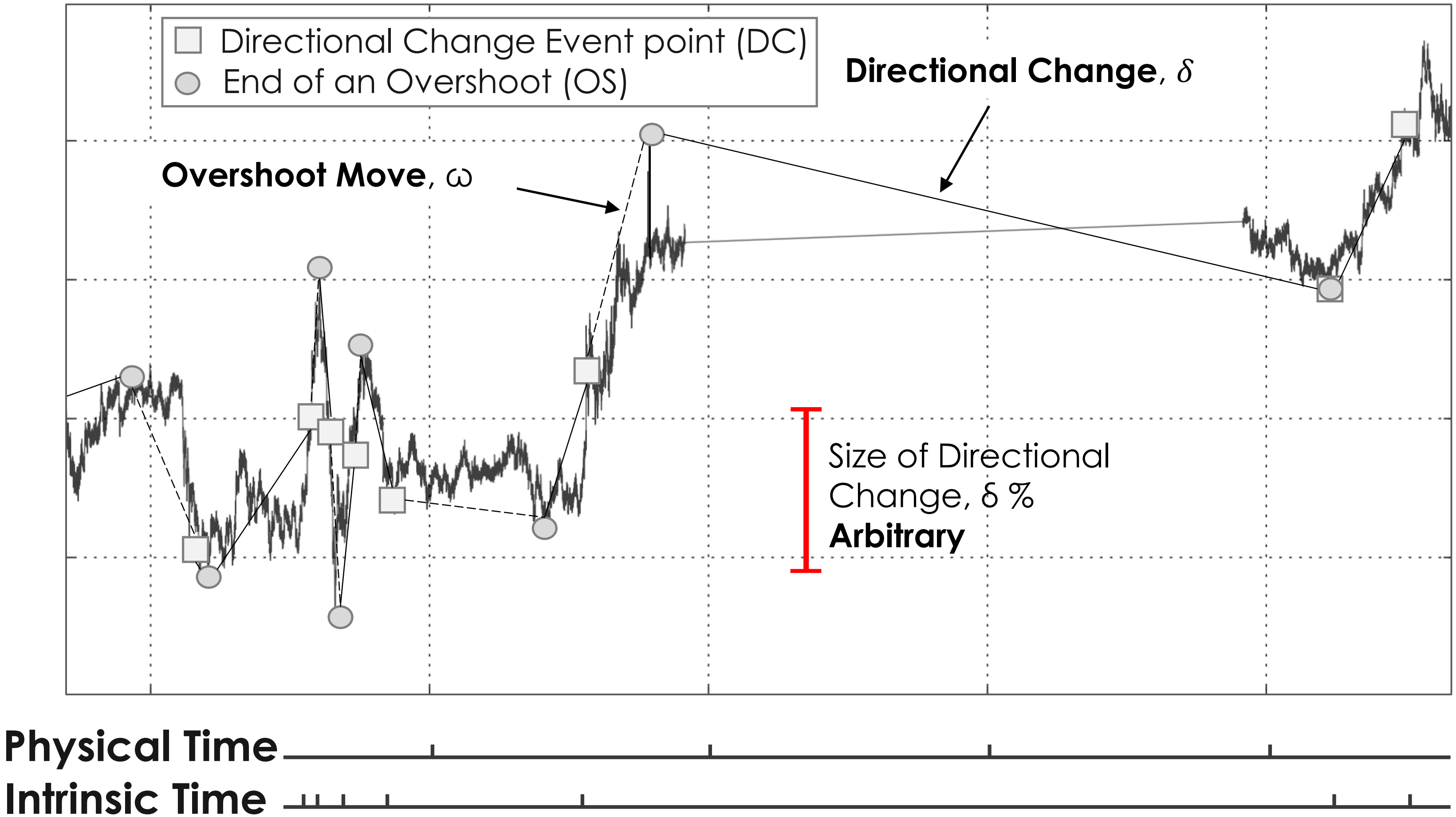
- Directional Change ratio as a measure of trend and momentum
- Intrinsic Event agents as market makers
- Multidimensional Intrinsic Event approach
- Improved option pricing formulas

Vladimir Petrov
vladimir.petrov@uzh.ch

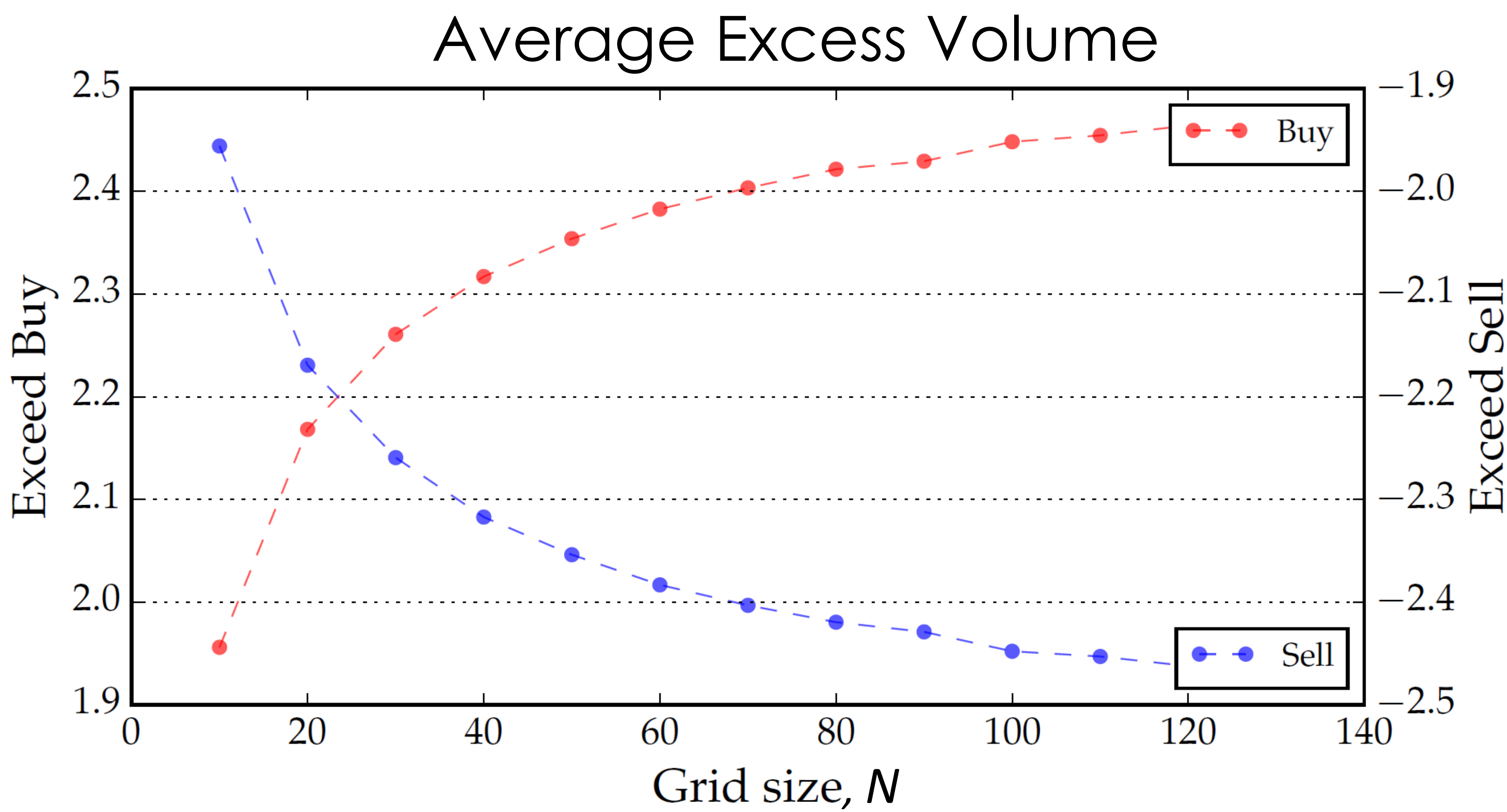
Effect of **Assymetric Regions**



Intrinsic events



Impact of the **grid size**



Impact of the excess volume on the maximum price move:

$$\Delta P_{max} = \alpha N\sqrt{2}$$

Market responce, **price changes**

One step: all agents receive the same new price and analize it.

$\boldsymbol{N_{long}}$ and $\boldsymbol{N_{short}}$: total number of LONG (buy) and SHORT (sell) positions after one step

$$\boldsymbol{\Delta N} = N_{long} - N_{short}$$

$$sgn(\Delta N) = \begin{cases} +1, & \boldsymbol{\Delta N} > 0 \\ 0, & \boldsymbol{\Delta N} = 0 \\ -1, & \boldsymbol{\Delta N} < 0 \end{cases}$$

- lack of sellers
- equilibrium
- lack of buyers

Price changes:

$\boldsymbol{\alpha}$ – constant, sensativity of price

Our model:

$$\Delta P_{min} = 1 \qquad \Delta N_{min} = 2$$

$$\alpha = \frac{\sqrt{2}}{2}$$

*Bouchaud, Jean-Philippe. "Price impact." Encyclopedia of quantitative finance (2010).