Agent-Oriented Evolutionary Control Systems

Autonomously Finding Optimal Control Codes for the Rowing Blade “Ro”

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Goal

- Autonomously define the optimal machine-oriented combination of signals to obtain efficient control for a robotic Ro

Motivation

Address systems that involve:

- Dynamical control
- Multi-dimensional spaces
- Multiple coordinate systems
- Inter dependent variables
- Unknown best solution

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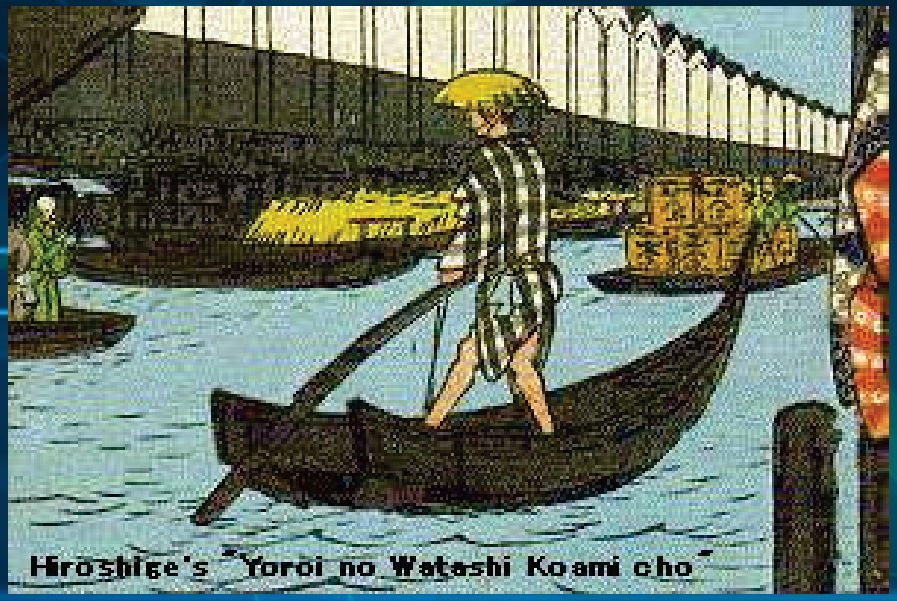
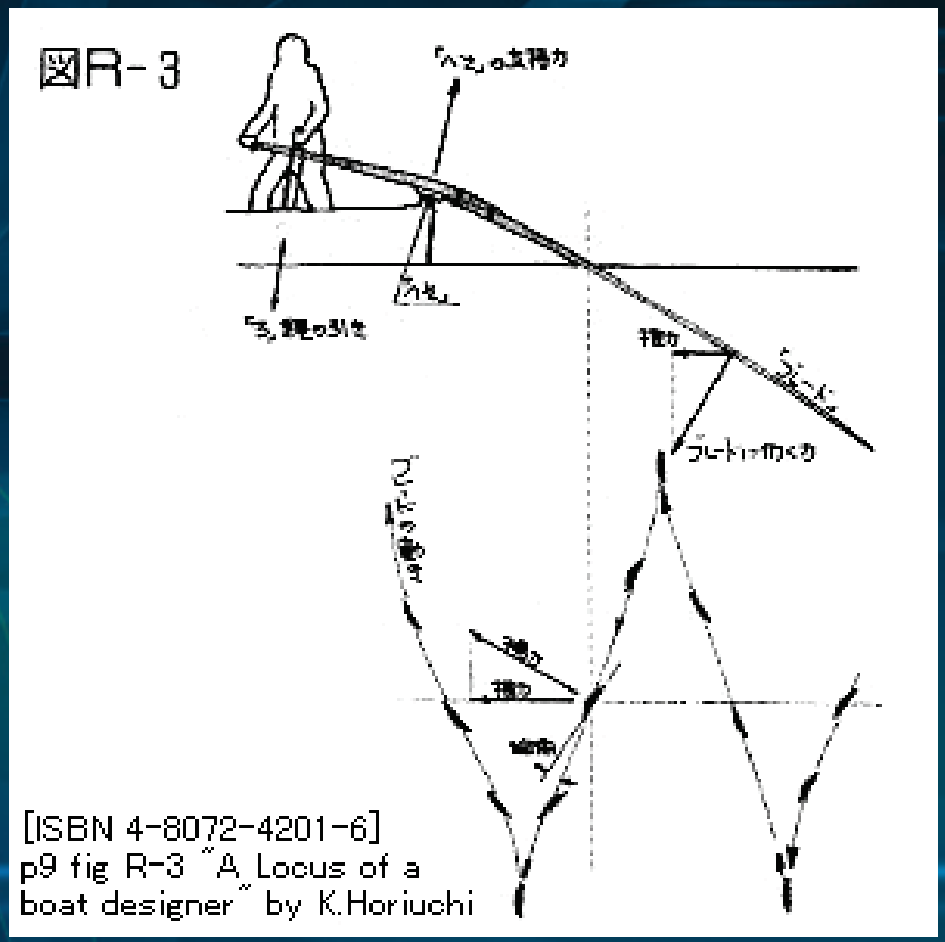
Application

Oriental Oar (Ro)



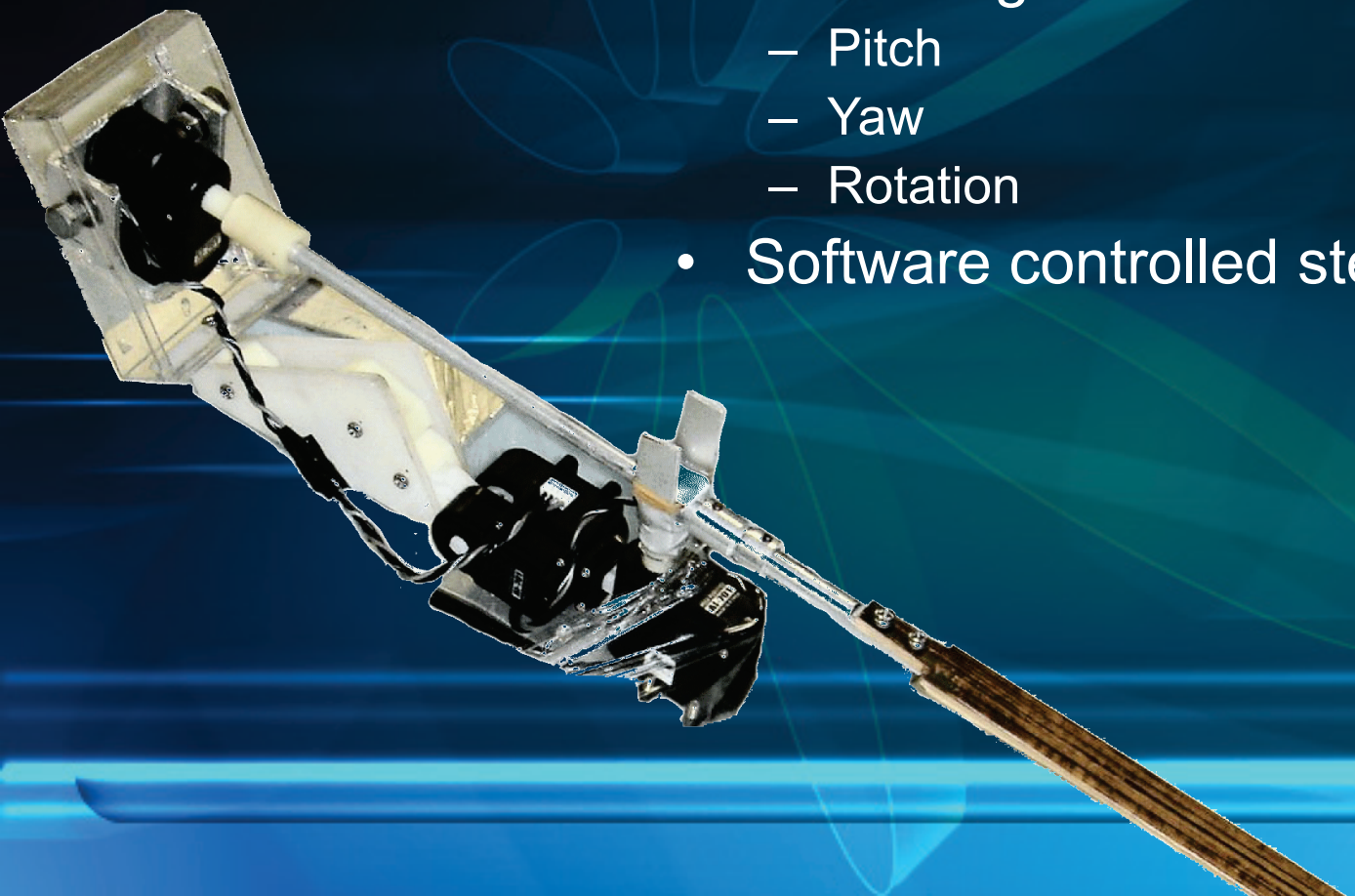
One paddle rowing system (Sculling)



[ISBN 4-8072-4201-6]
p9 fig R-3 "A Locus of a boat designer" by K.Horiuchi

Ro-bot

- Mechanical arm
- Three degrees of freedom (3DF)
  - Pitch
  - Yaw
  - Rotation
- Software controlled step-motors



Conventional solution

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Proposed Solution

Apply Evolutionary computing to find optimal solutions in a new technique based in:

- Multi-Agent Systems (MAS)
- Code optimization by GA
- Efficiency evaluation by simulations
- Distributed computing

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Advantages

- No knowledge needed about the inner workings of the system
- Allows obtaining a sort of different solutions by scanning different regions of multi-variable space simultaneously
- Allows parallelization of operations, use of distributed or multi-processed systems to solve the problem in 1/n or less factor time

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Multi Agent Systems (MAS)

- Agents are independent programs
- Agents carries one or more solutions
- Agents have a determined set of rules (fitness)
- Agents manage to increase its solution's efficiency, and reach its goals
- Agents applies operators to increase solution efficiency, operators use a sort of techniques derived from GA, Neural Nets or Simulated Annealing

Genetic Algorithms

- Based on Natural Selection rule “Survival of the fittest”
- Employ genetic recombination and mutation rules to improve solution

GA

- GA is based on the optimization of a specific code, usually called DNA (like in genetics)
- The DNA is expressed by a STRING.
- Segments of the string that express some feature represented in the string are called CHROMOSOMES and can be a byte or any sub size of the string

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Mutation operator

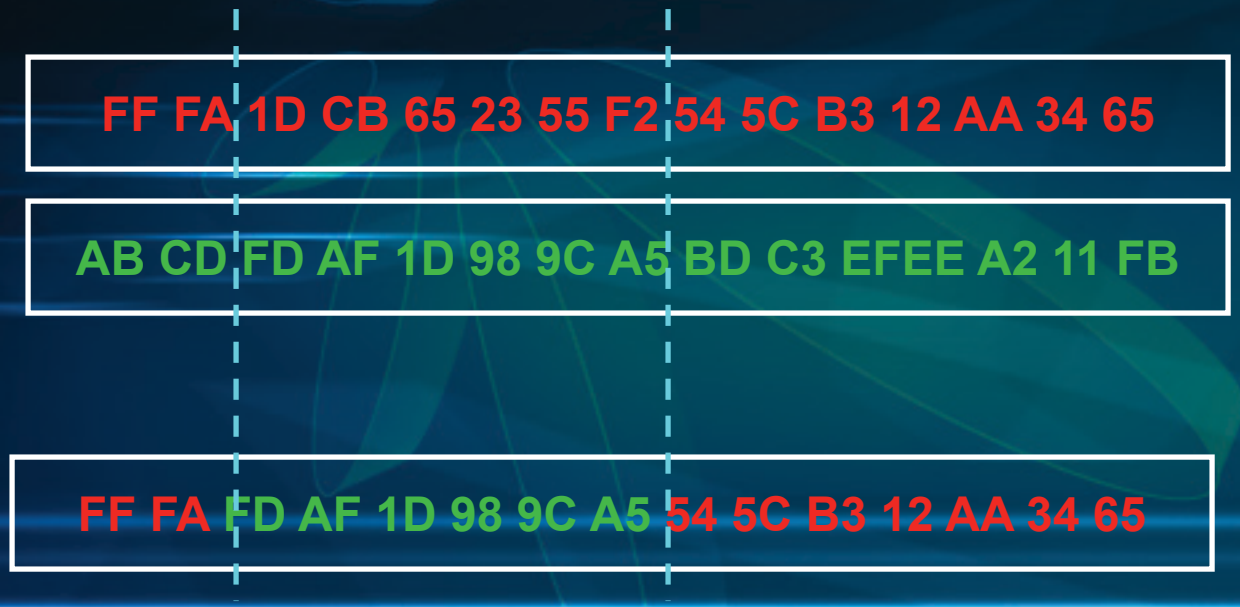
1. Great chance of a small mutation (change lesser bits)
2. Small chance of a big mutation (operate meaningful bits)

Example (1 byte chromosomes):

```
   DNA       = FF FA 1C A8 B6 06 0A
1. P(10%)    = FF FA 1D A8 B6 06 0A
2. P(0.1%)   = 5B FA 1C A8 B6 06 0A
```

Crossover operator

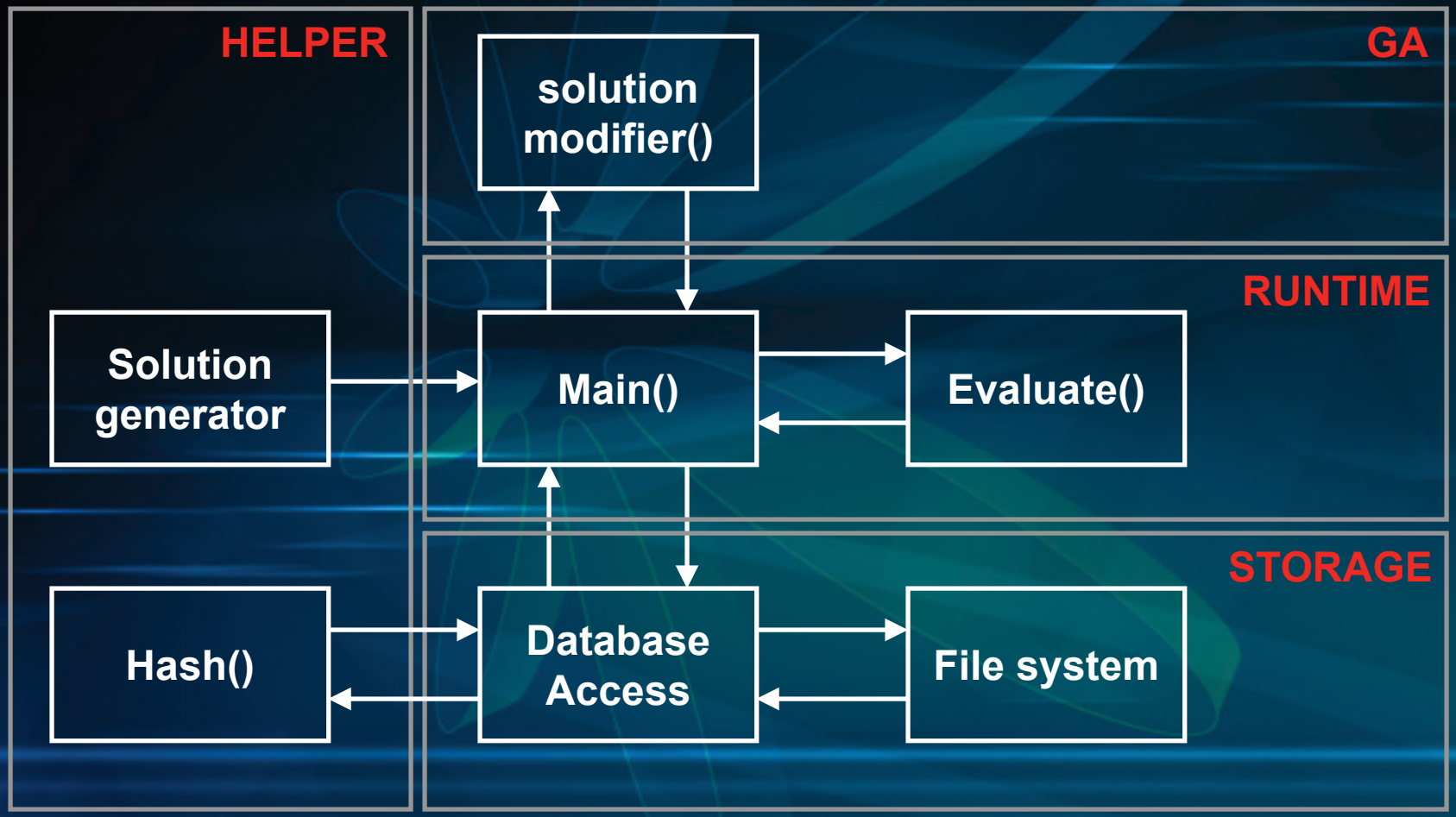
- Based on gene combination
- Parts of DNA 1 and DNA2 are used to build DNA3



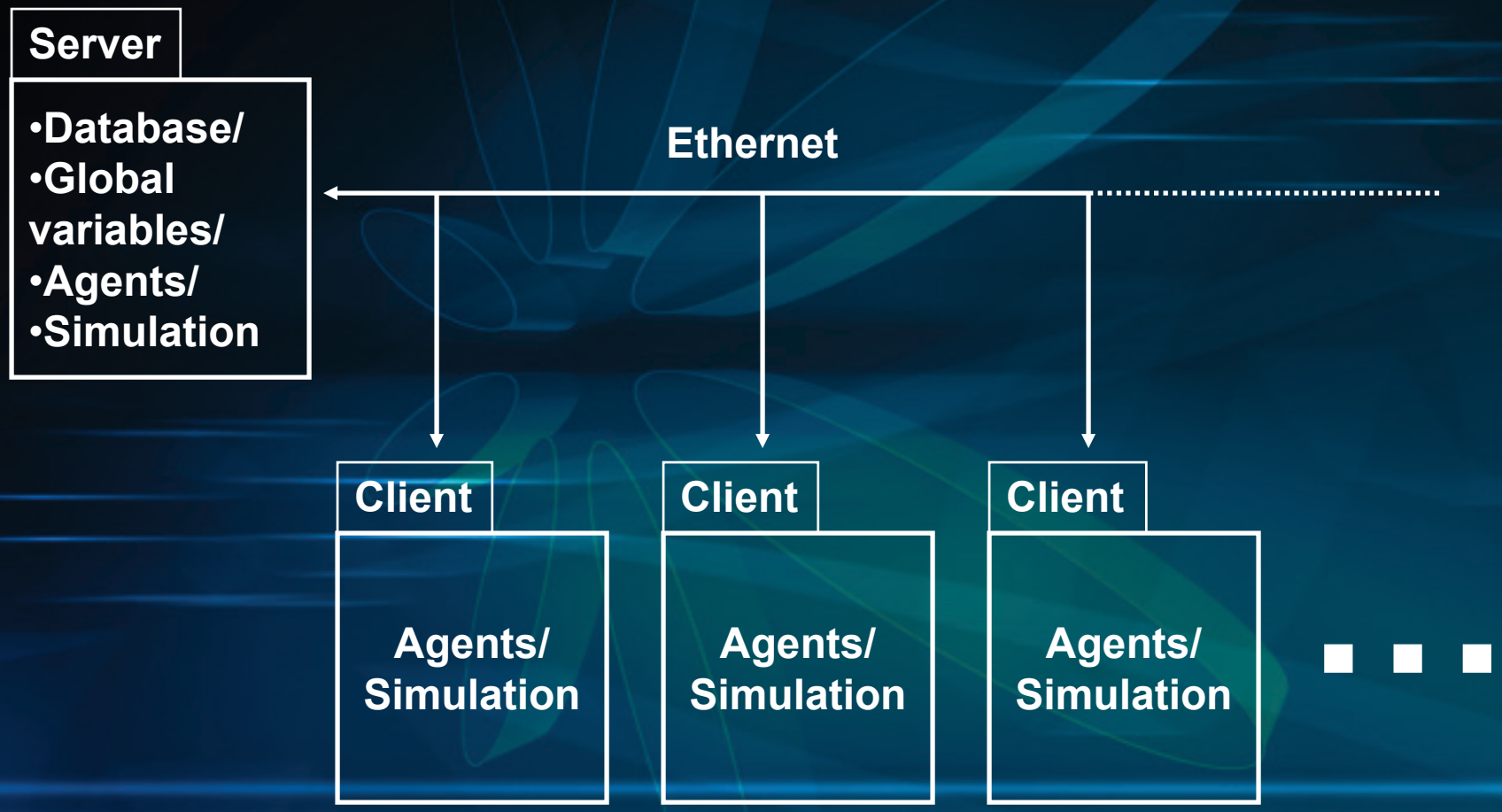
Procedure

- Solutions are tested into a simulated environment and given one quantitative evaluation, called fitness
- Solutions are classified by fitness
- Worst solutions are eliminated
- Mediocre solutions are mutated
- Best solutions are kept and evolved, by cloning/mutating/crossing-over

Agent Modules



Network topology



Parallel Computing

- When using Genetic Algorithms together with higher level fitness functions, the time consumed for each evaluation increases with the simulation complexity
- In order to achieve useful solutions in a reasonable timeframe, parallel search procedures need to take place

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Parallel GA and MAS

- New approaches are needed in order to expand the concept of parallel genetic algorithms to various computer topologies
- The MAS in OOP approach allows an Agent to span across processors or computers while still communicating objects trough the network

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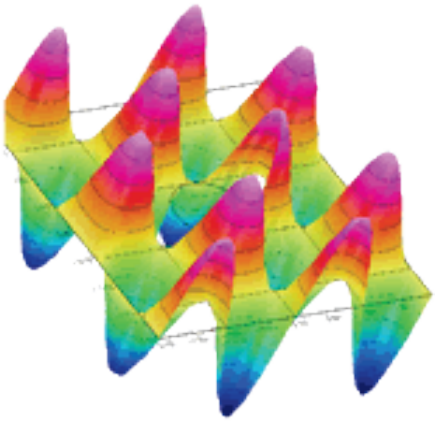
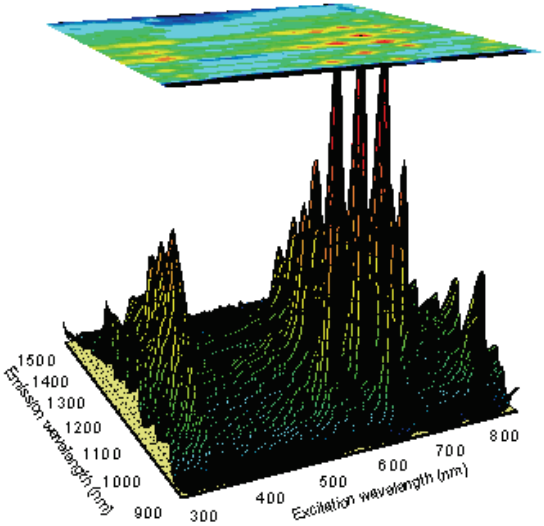
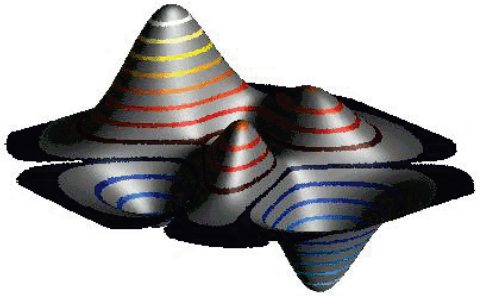
Advantage

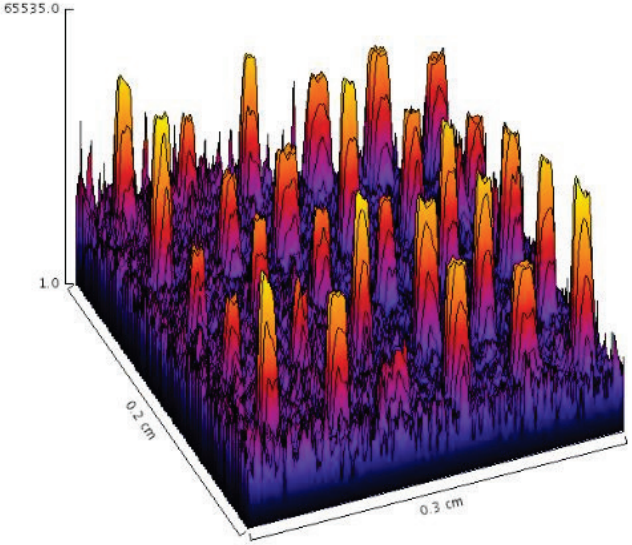
What is the advantage of the proposed method?

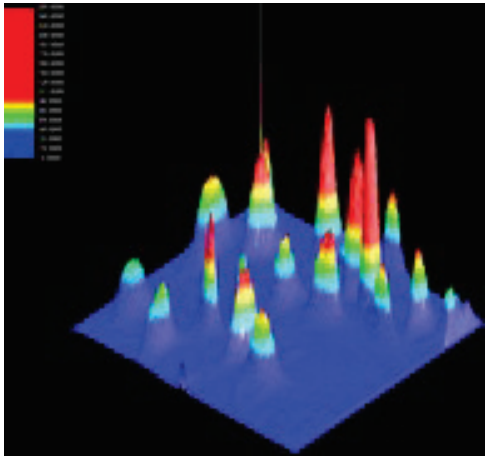
Examples of Multi-variable Space

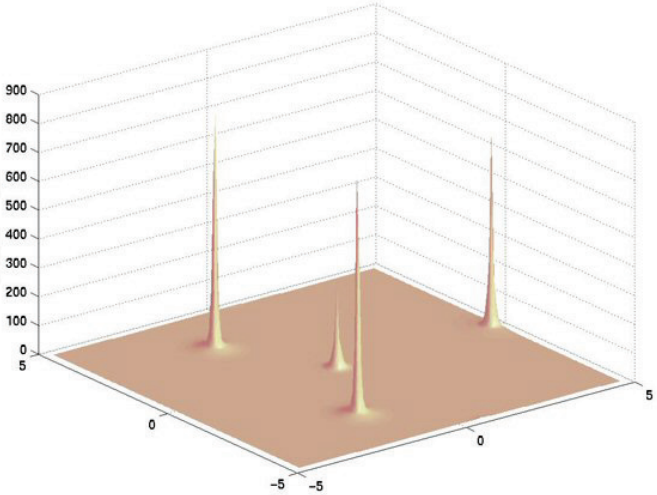












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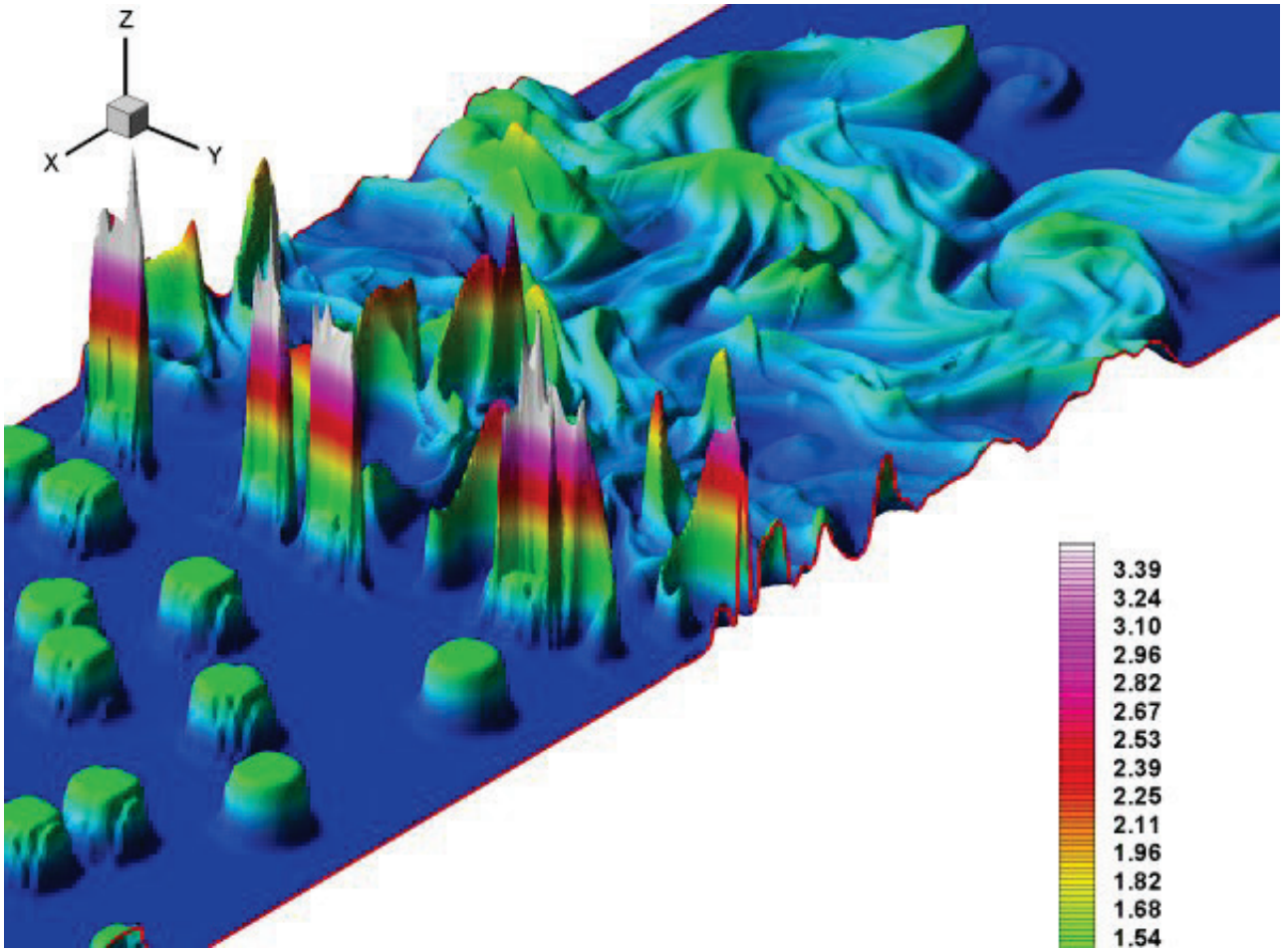
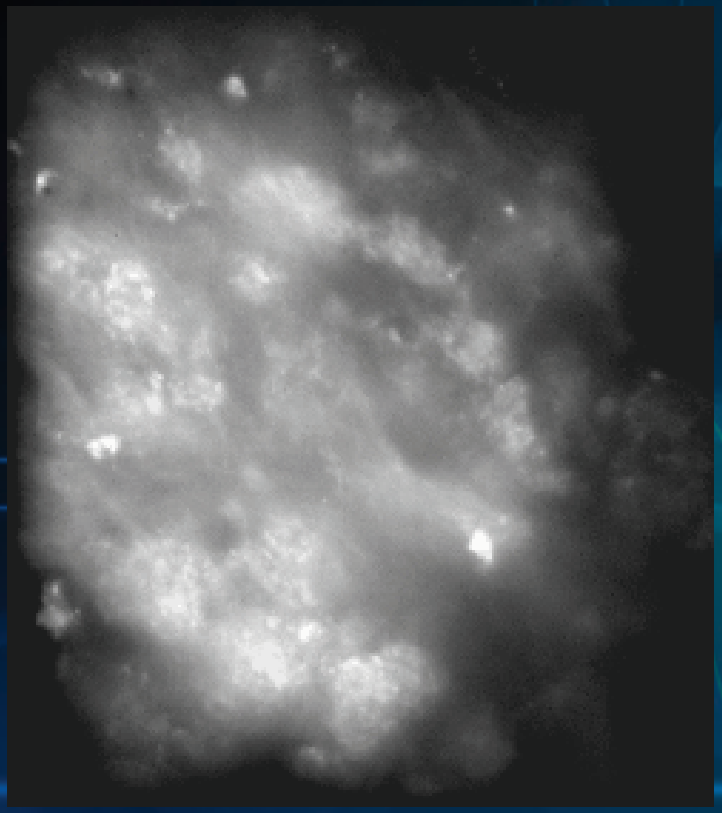
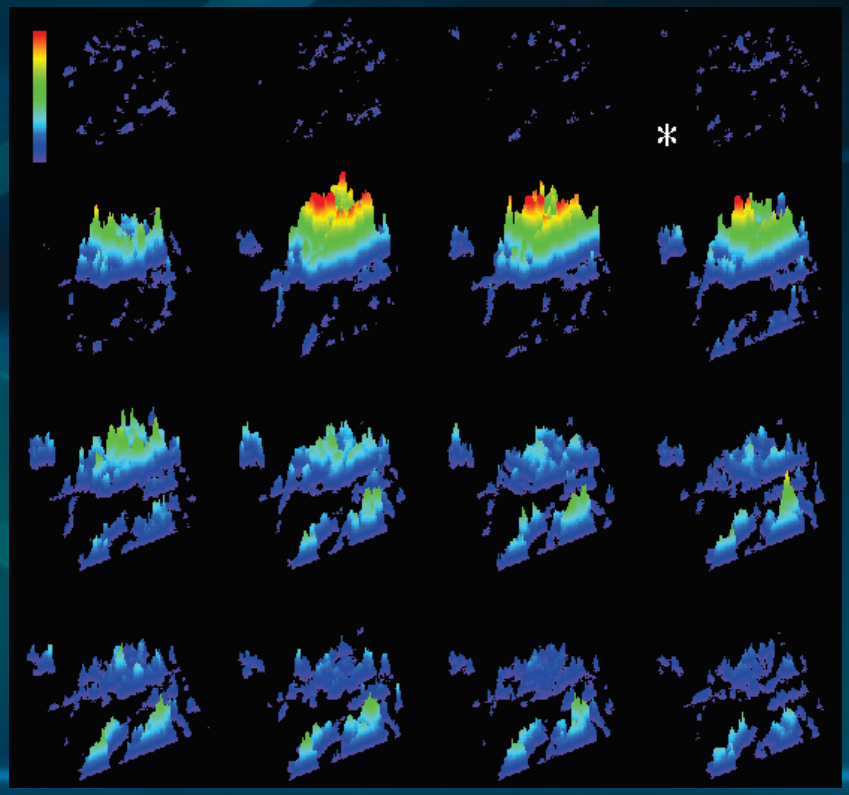
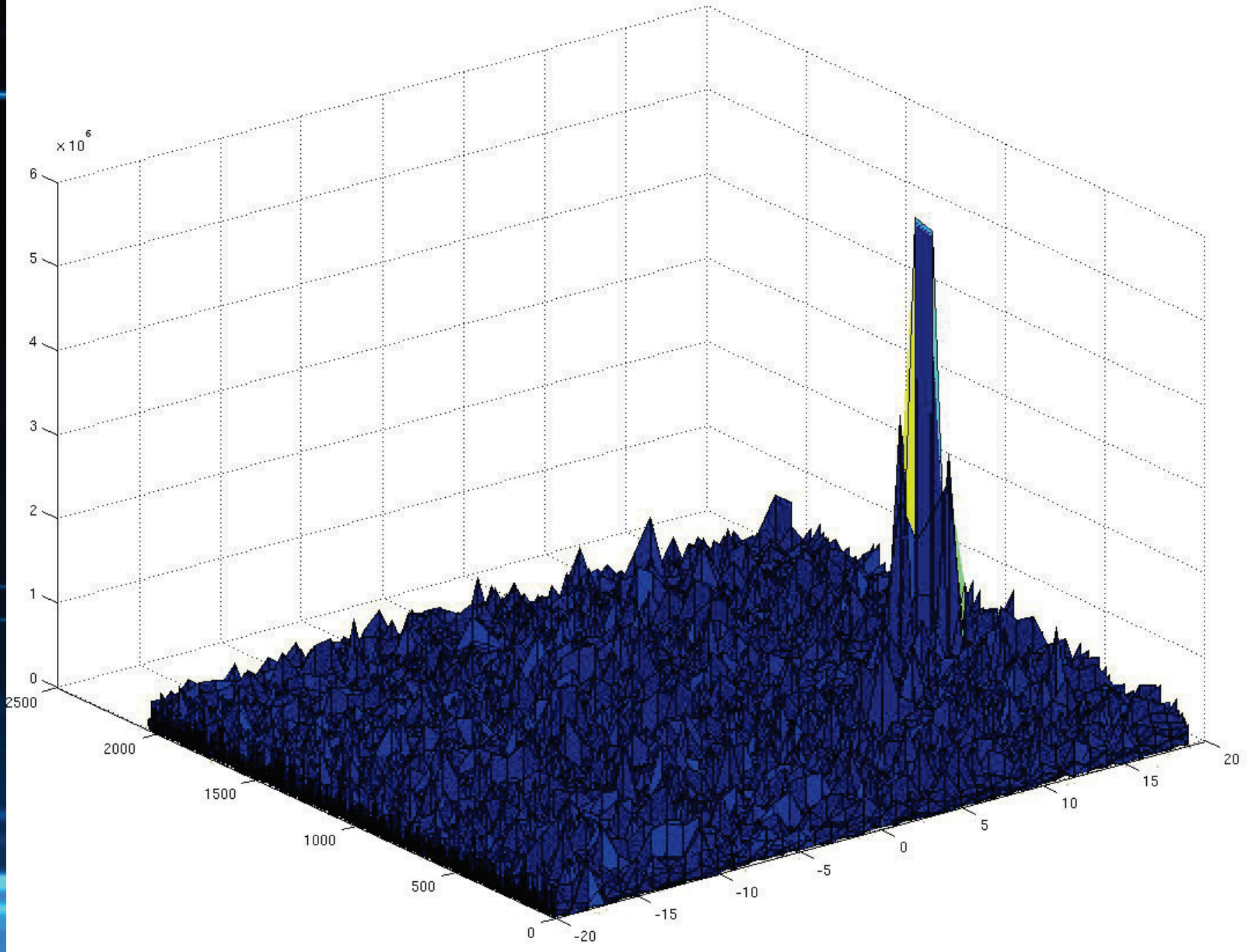


Multi-dimensional volume representation



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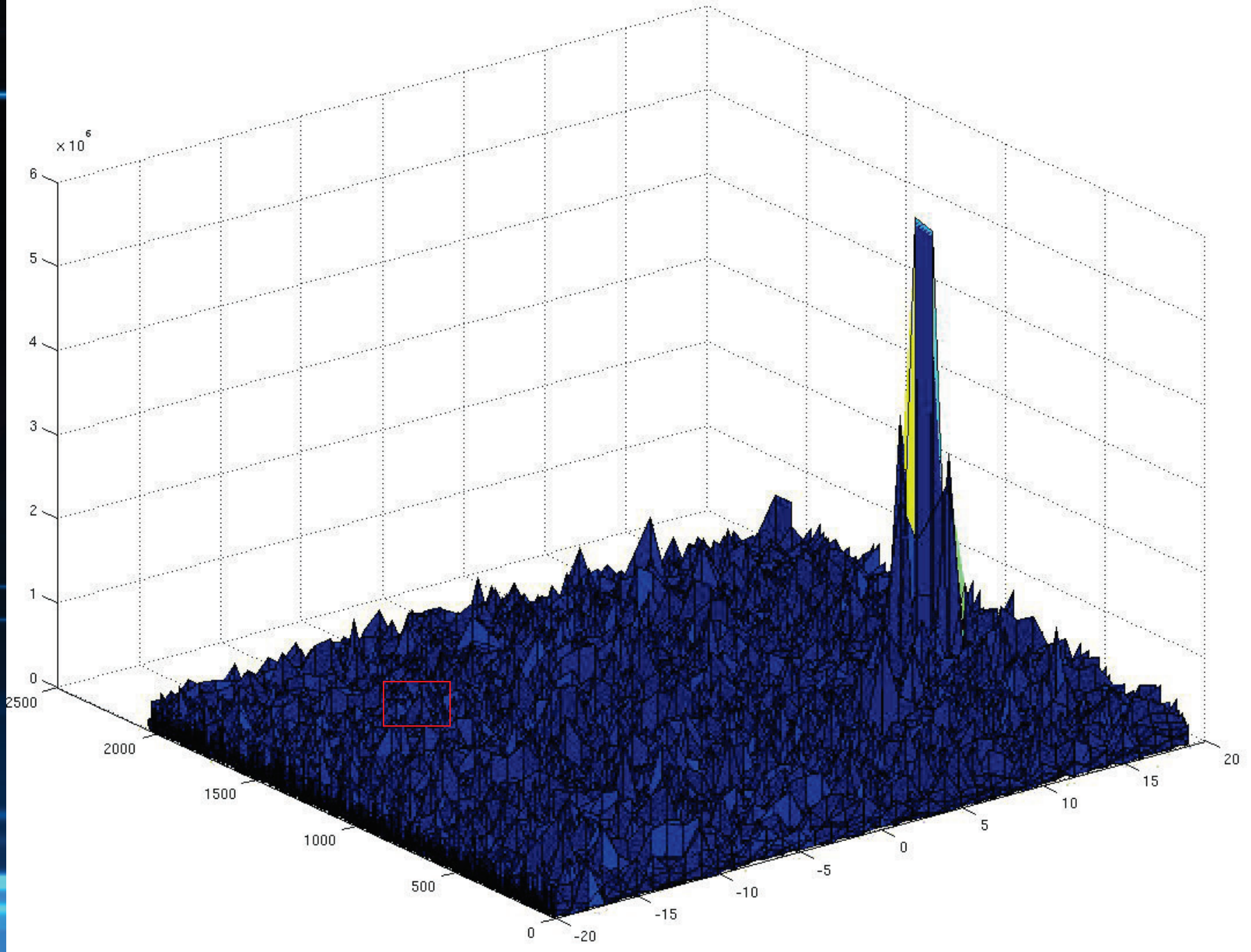
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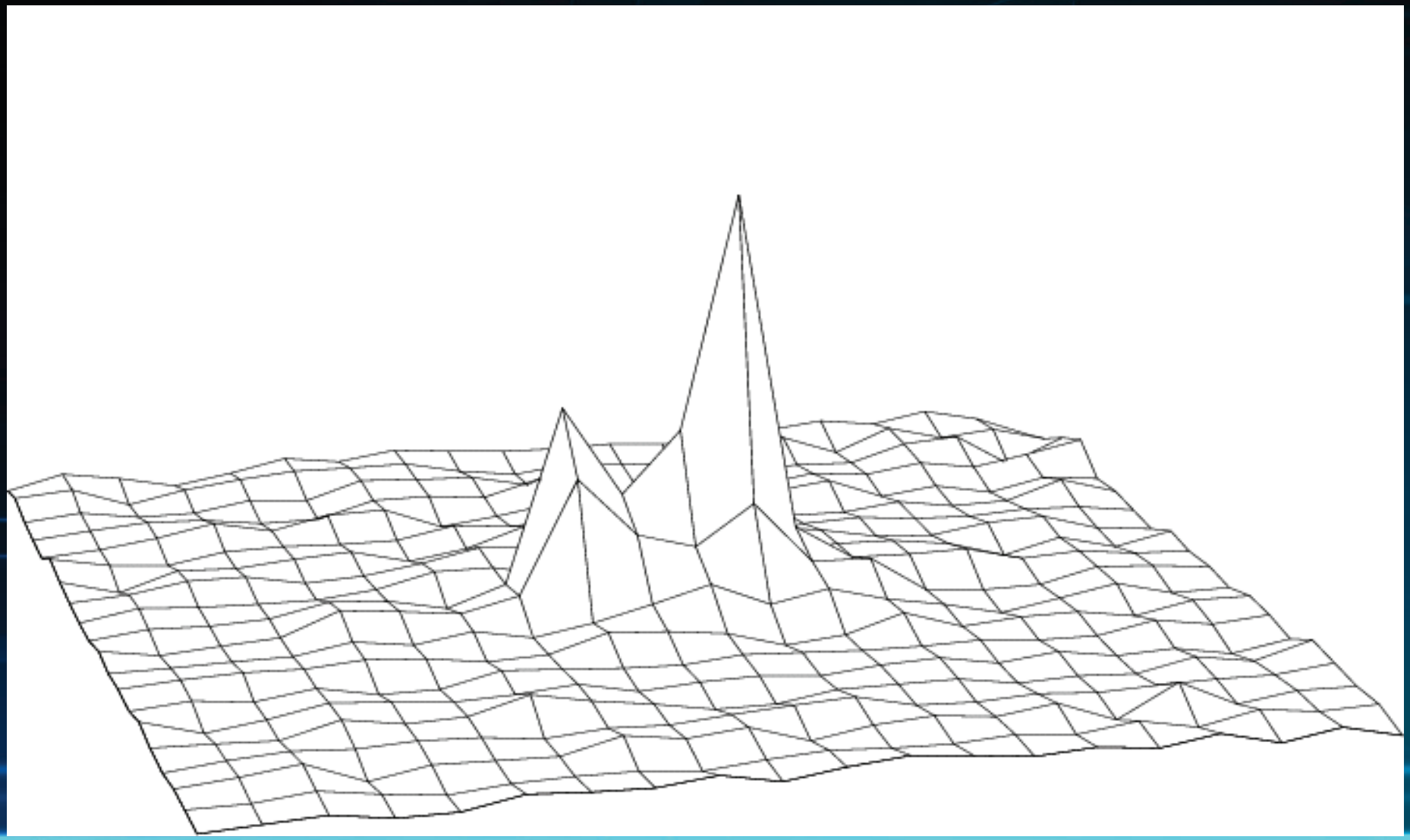

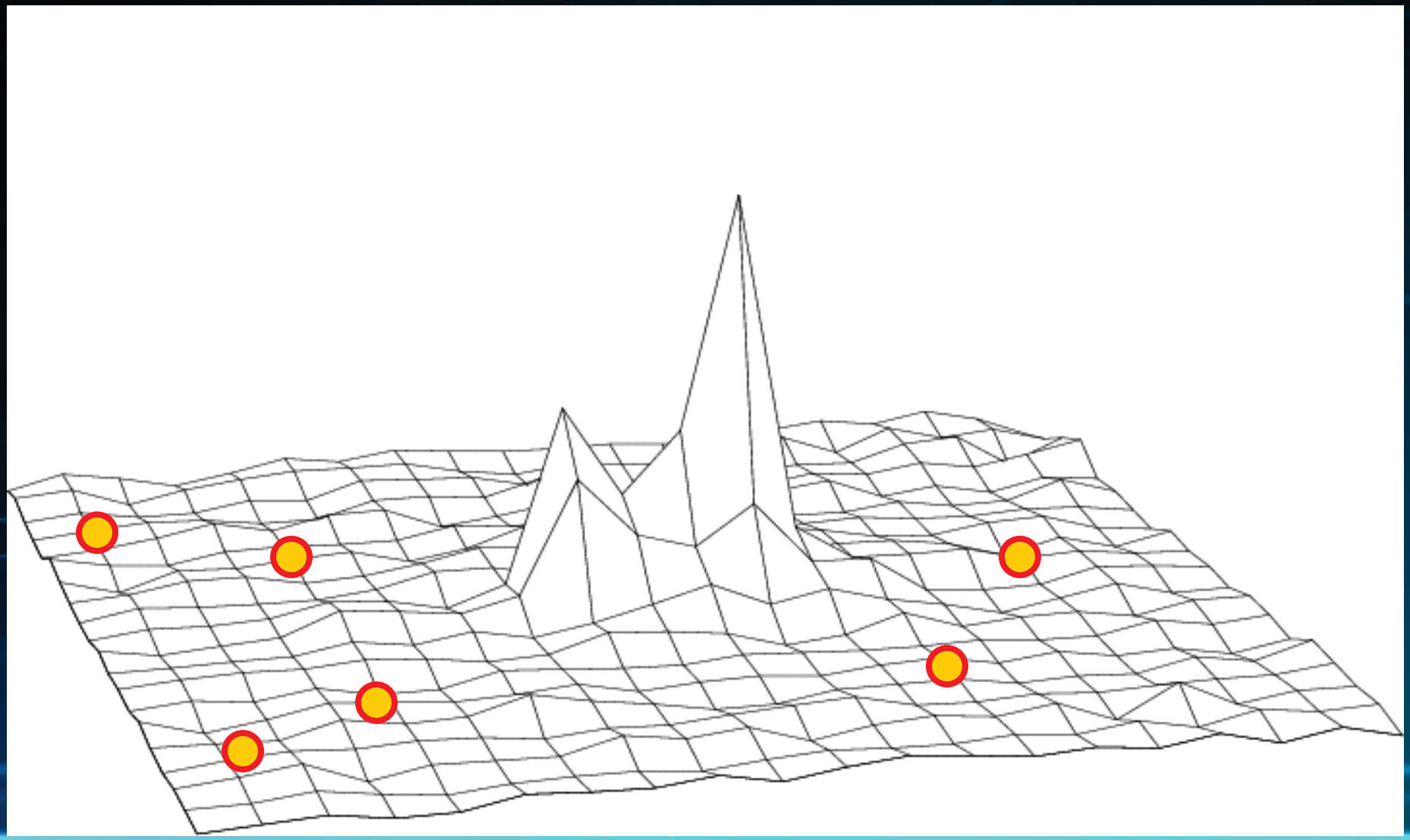

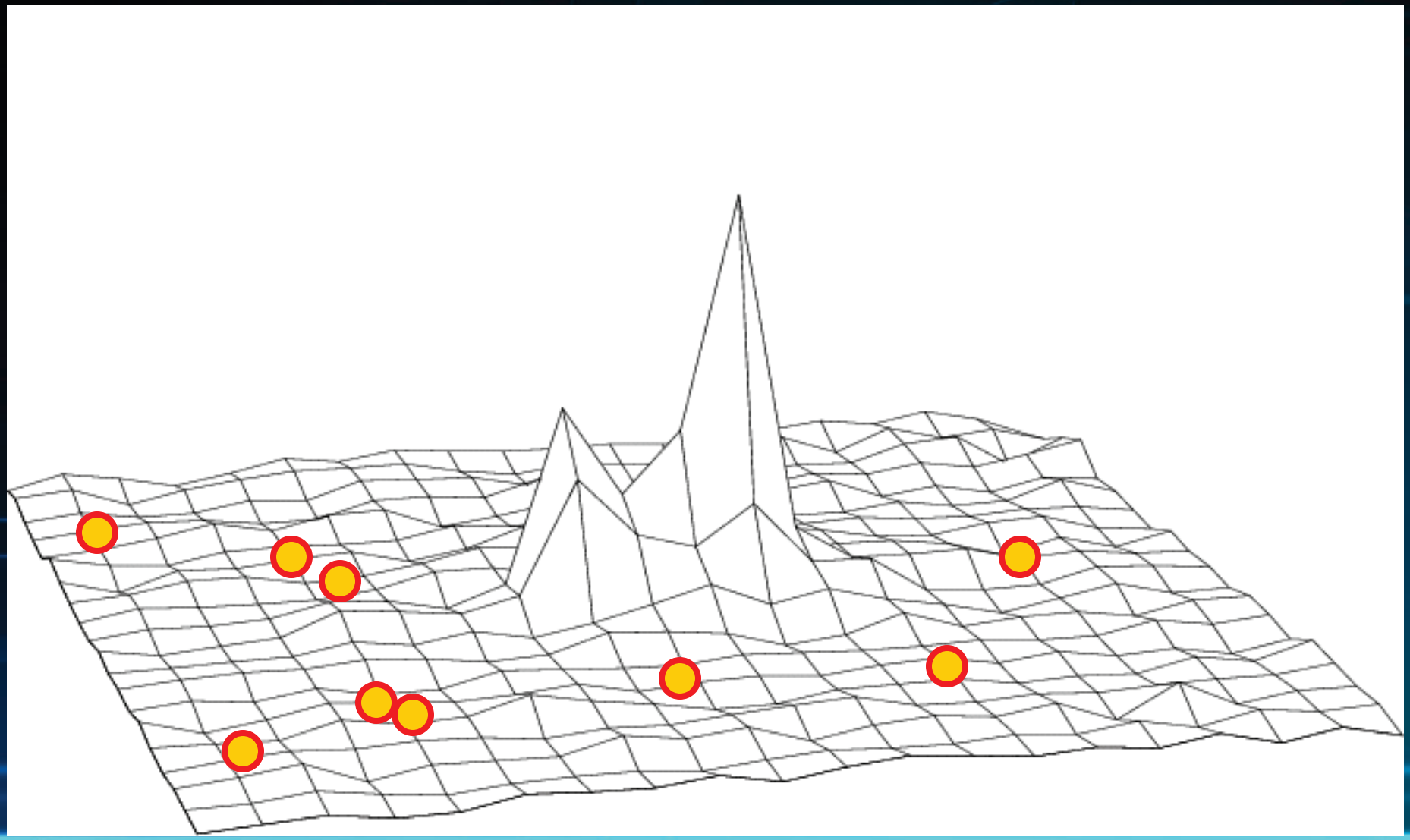

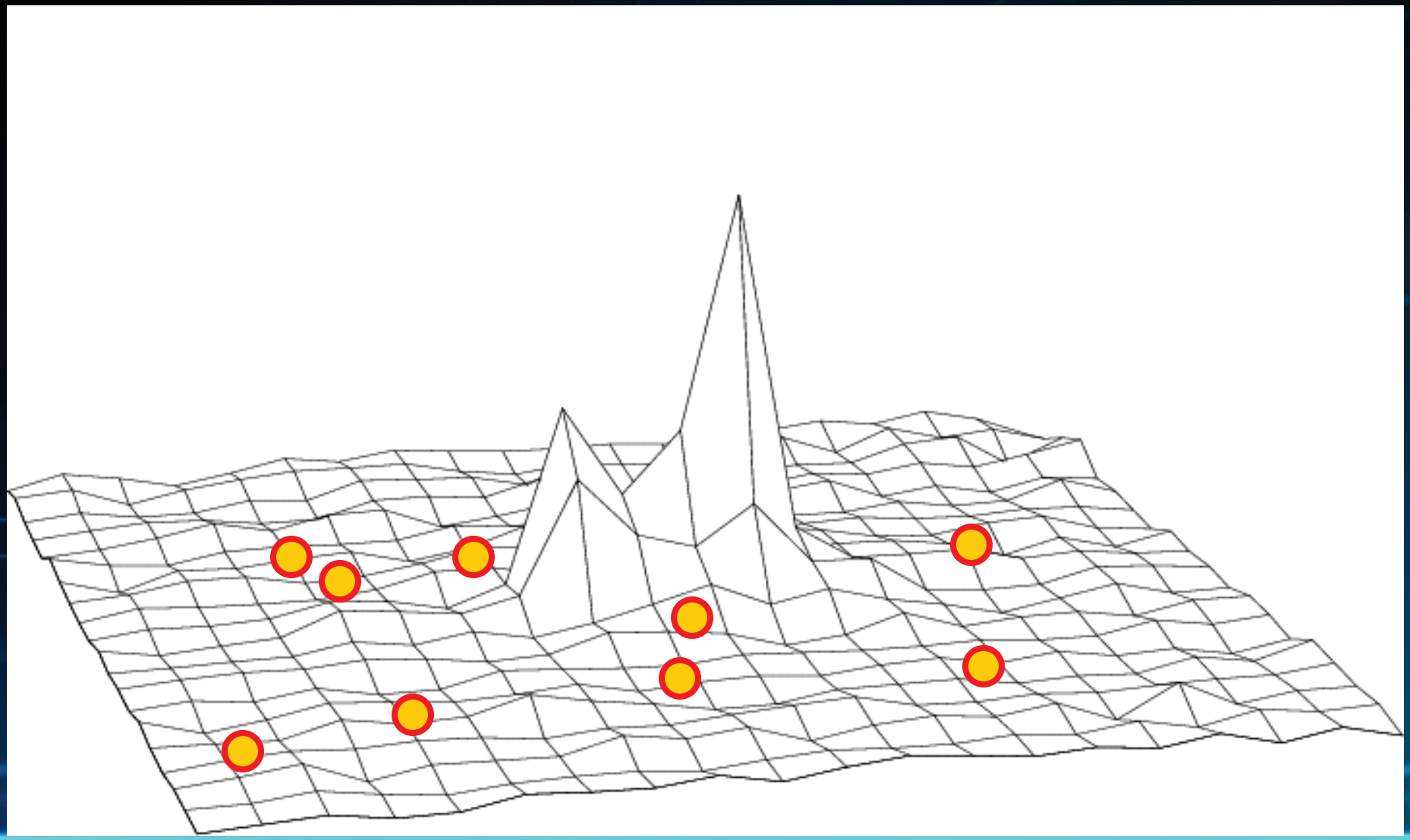

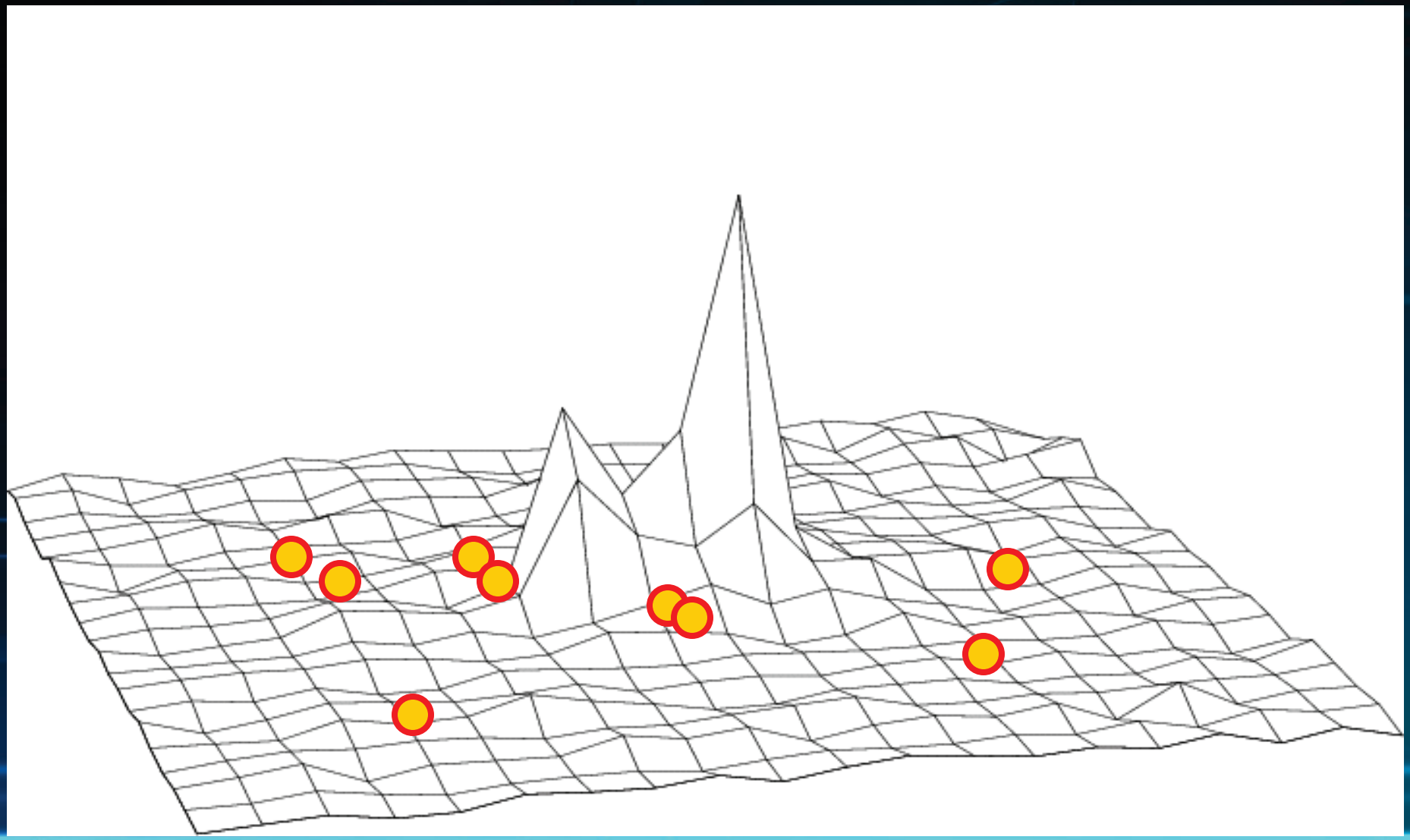

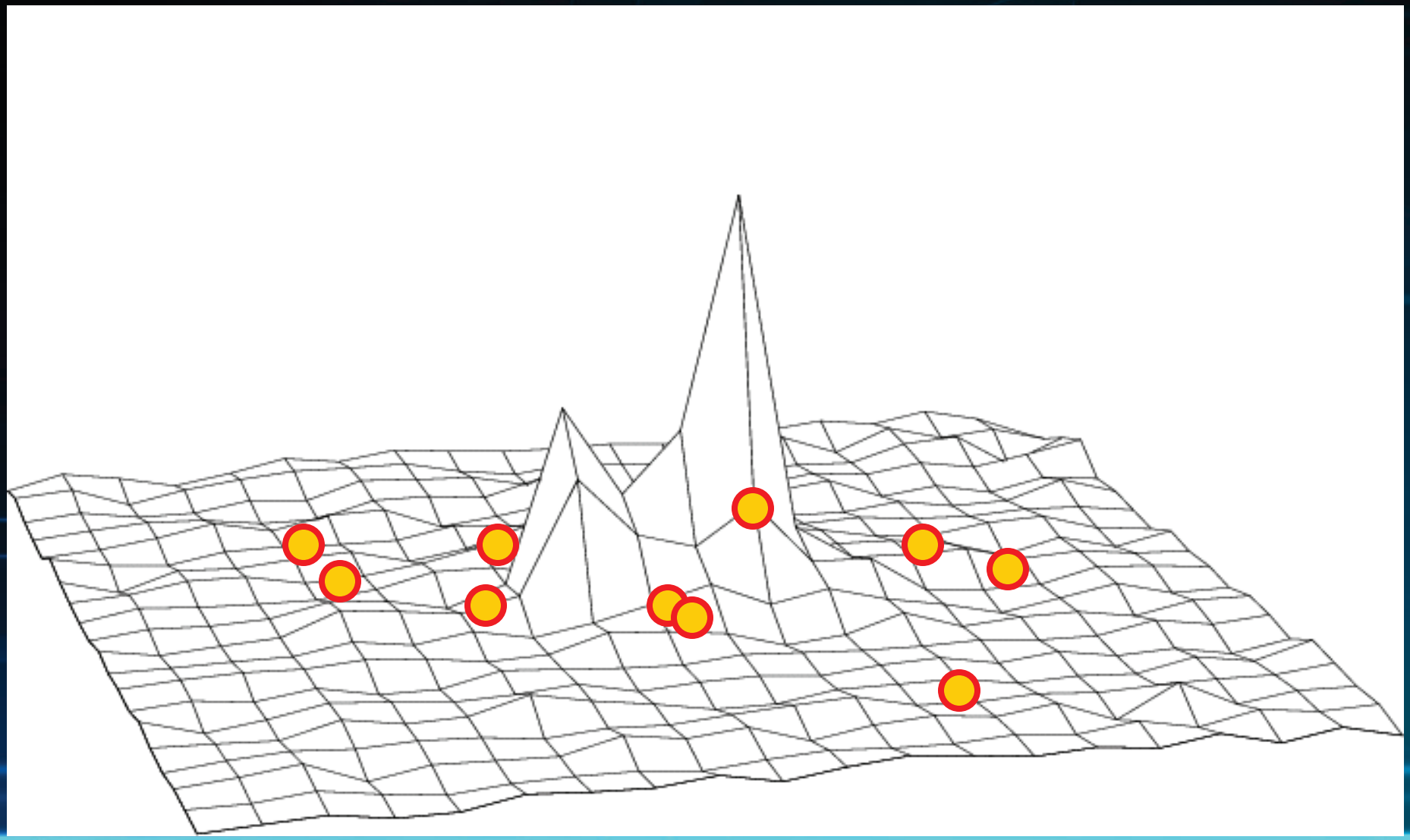

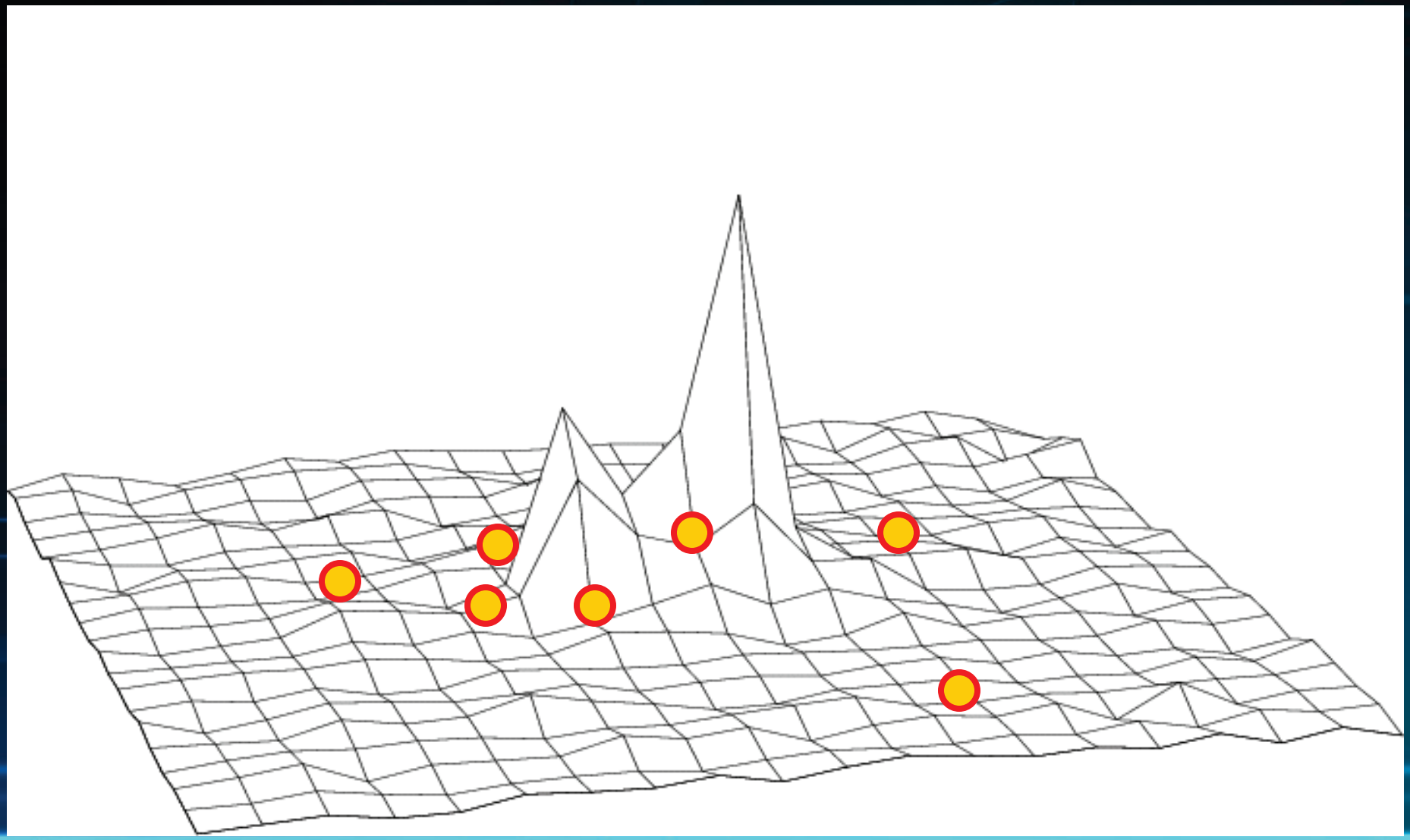

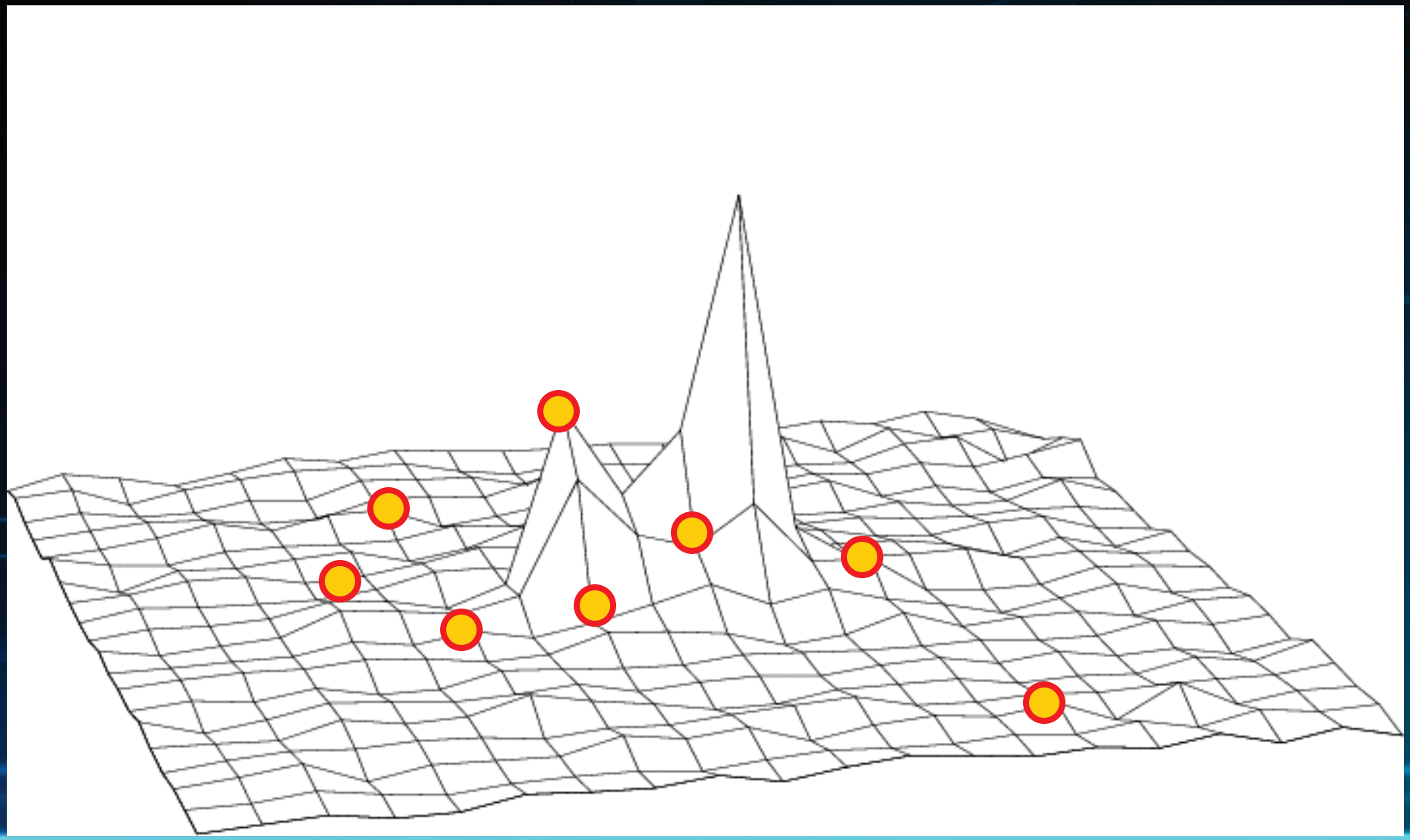

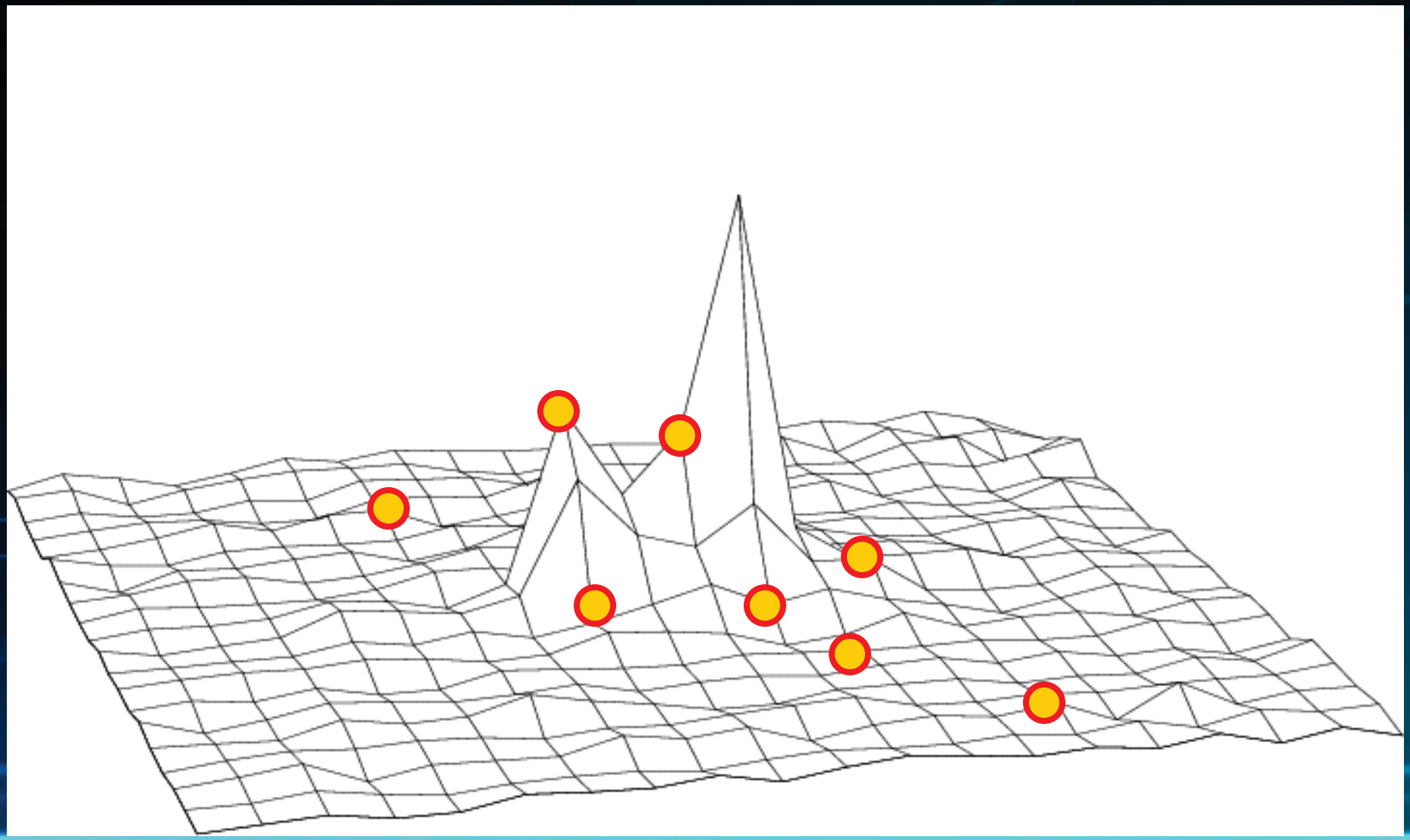

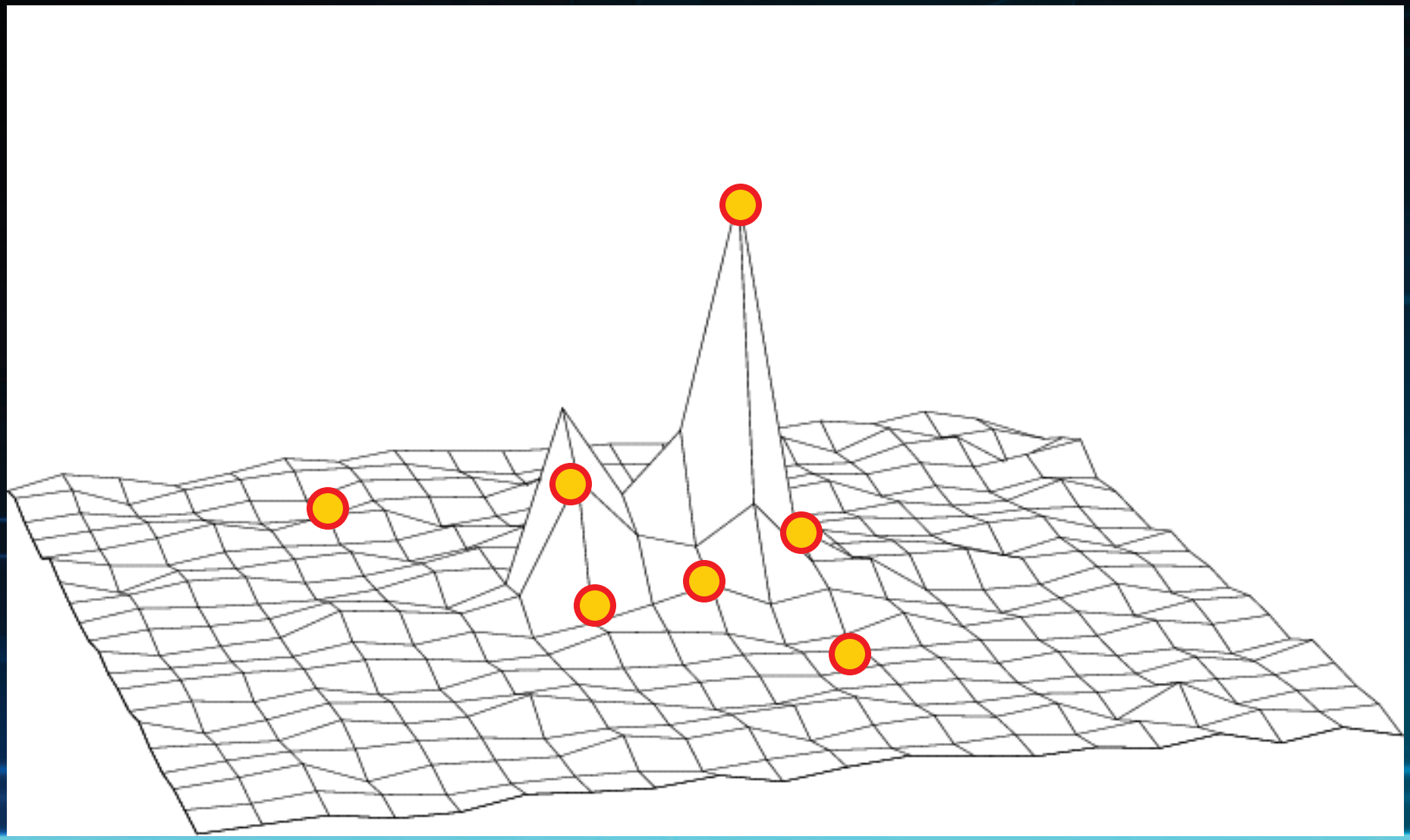

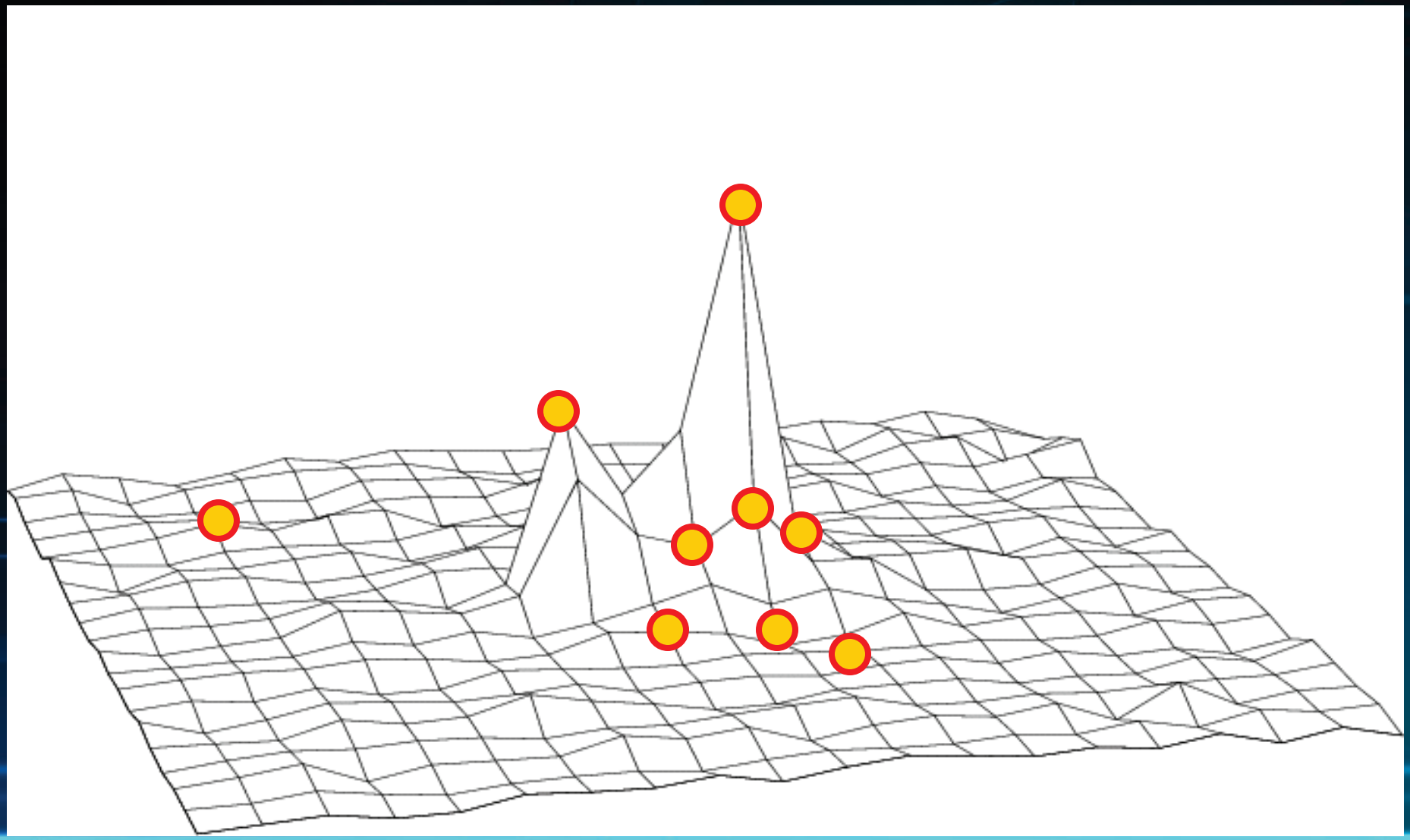

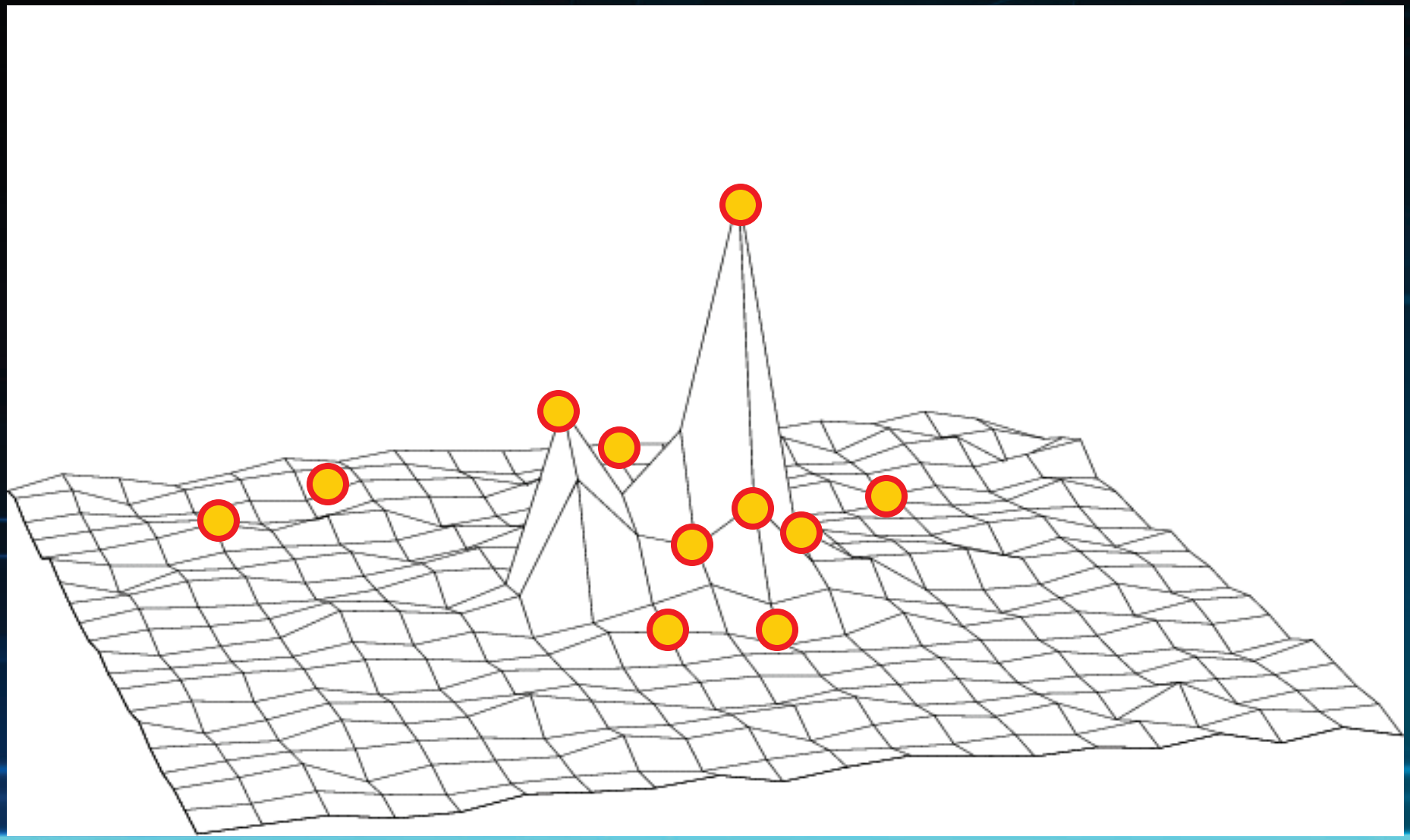

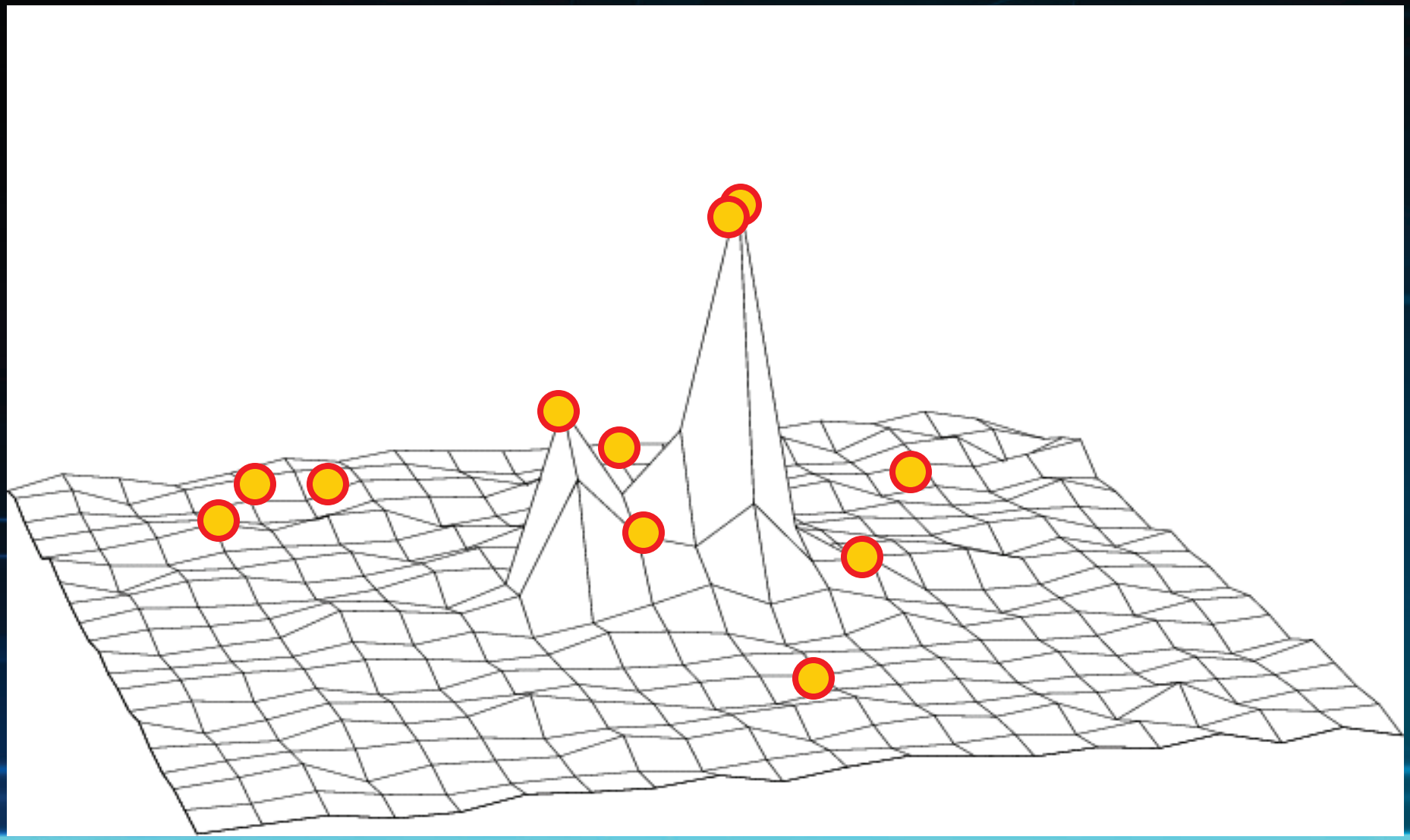

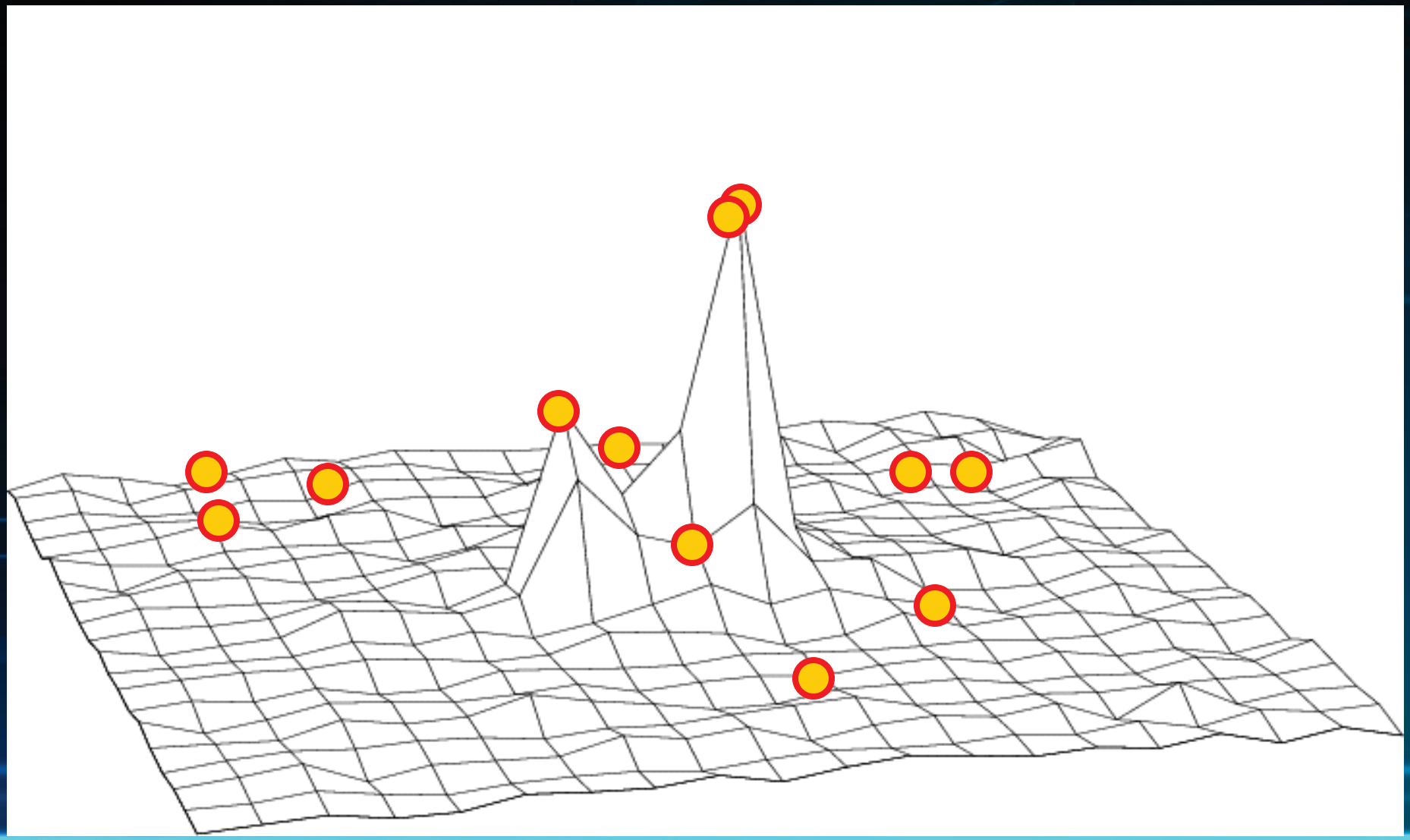

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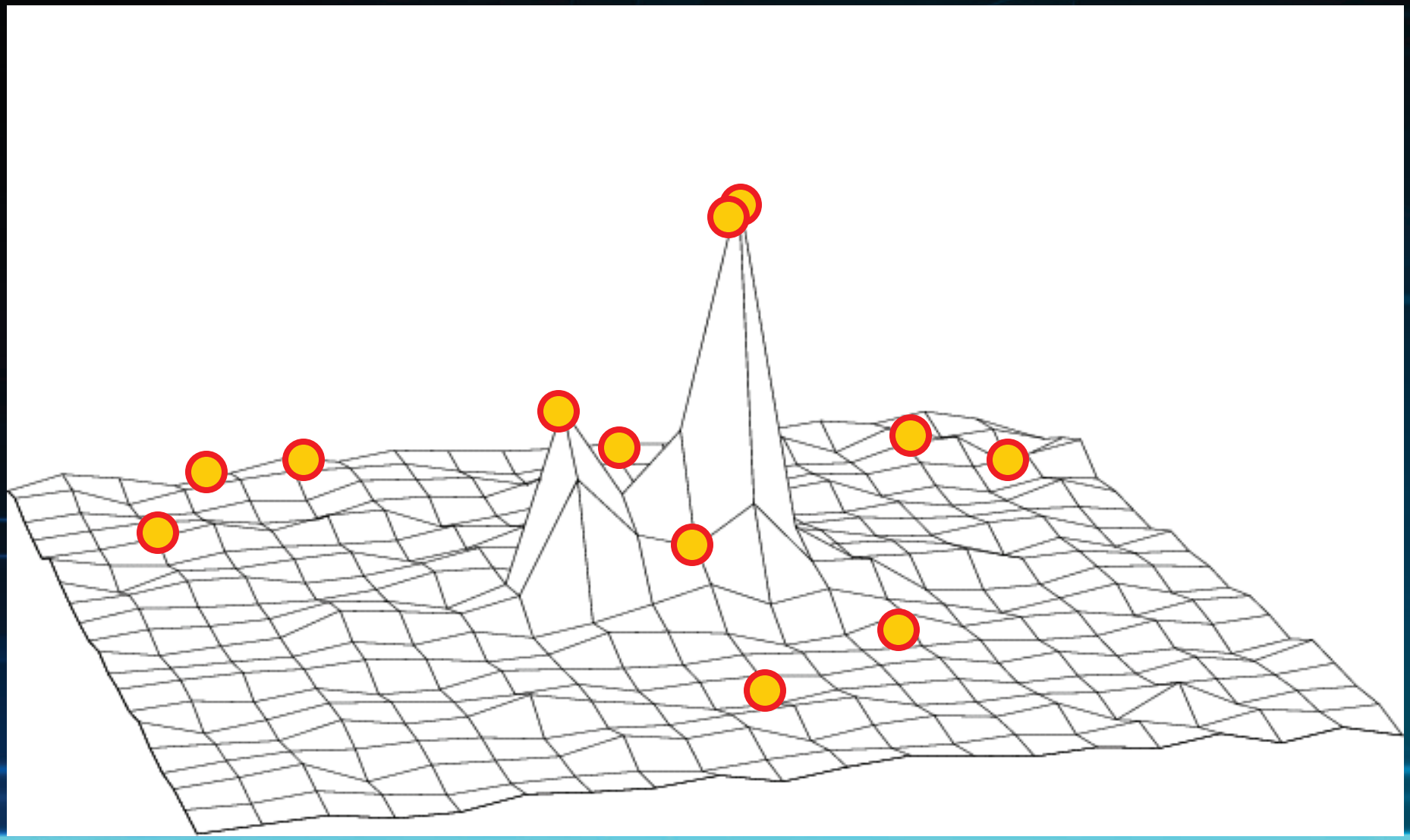

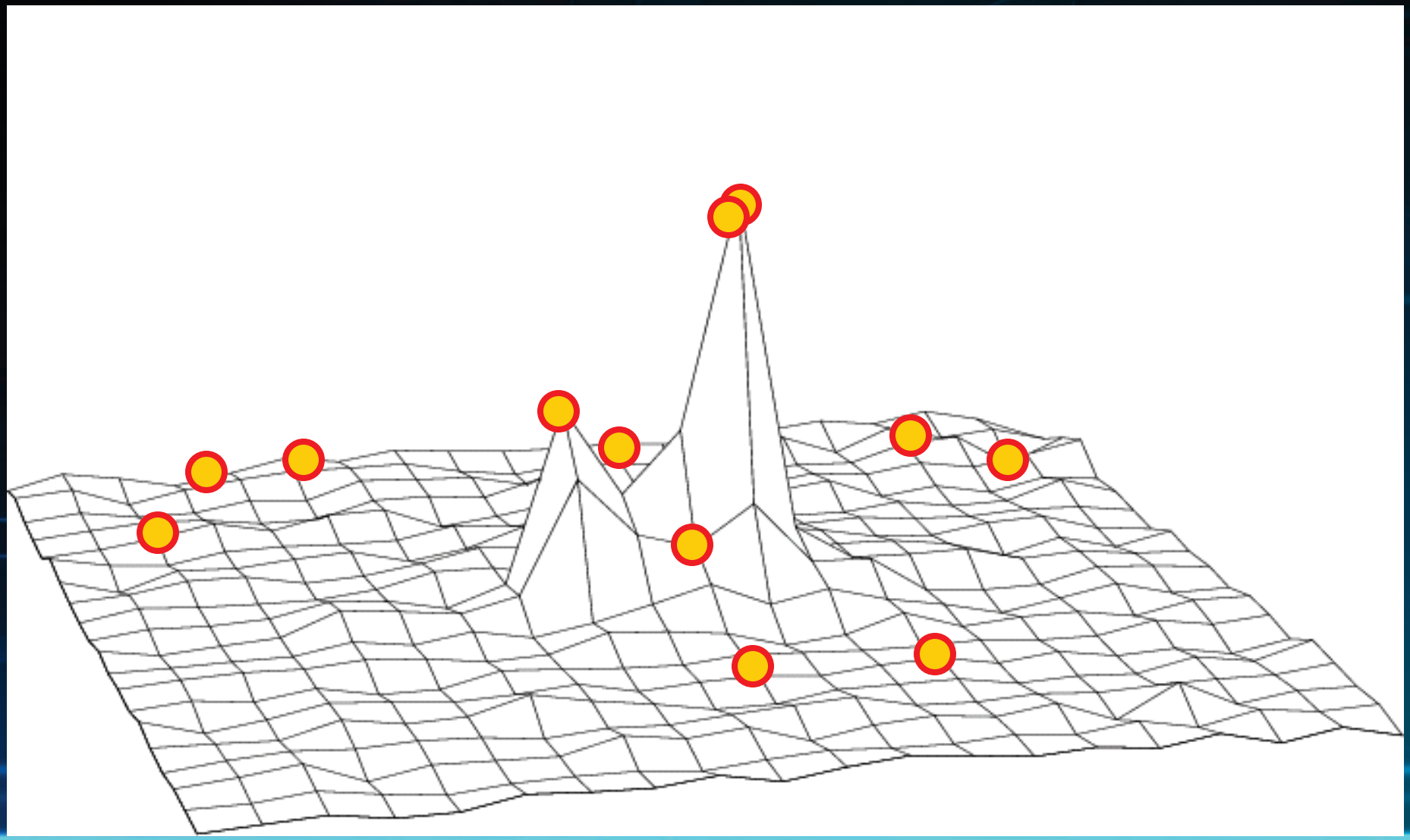

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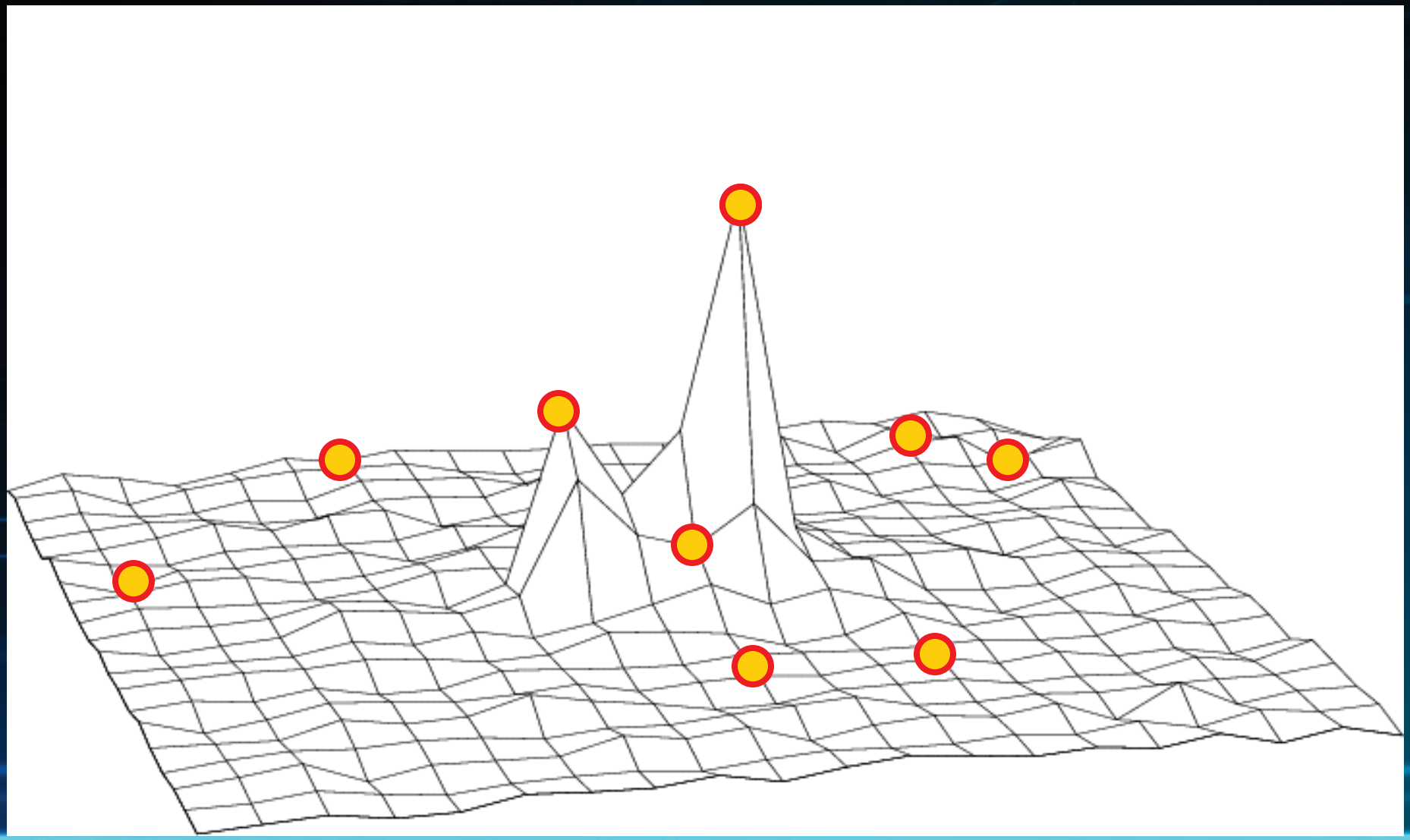

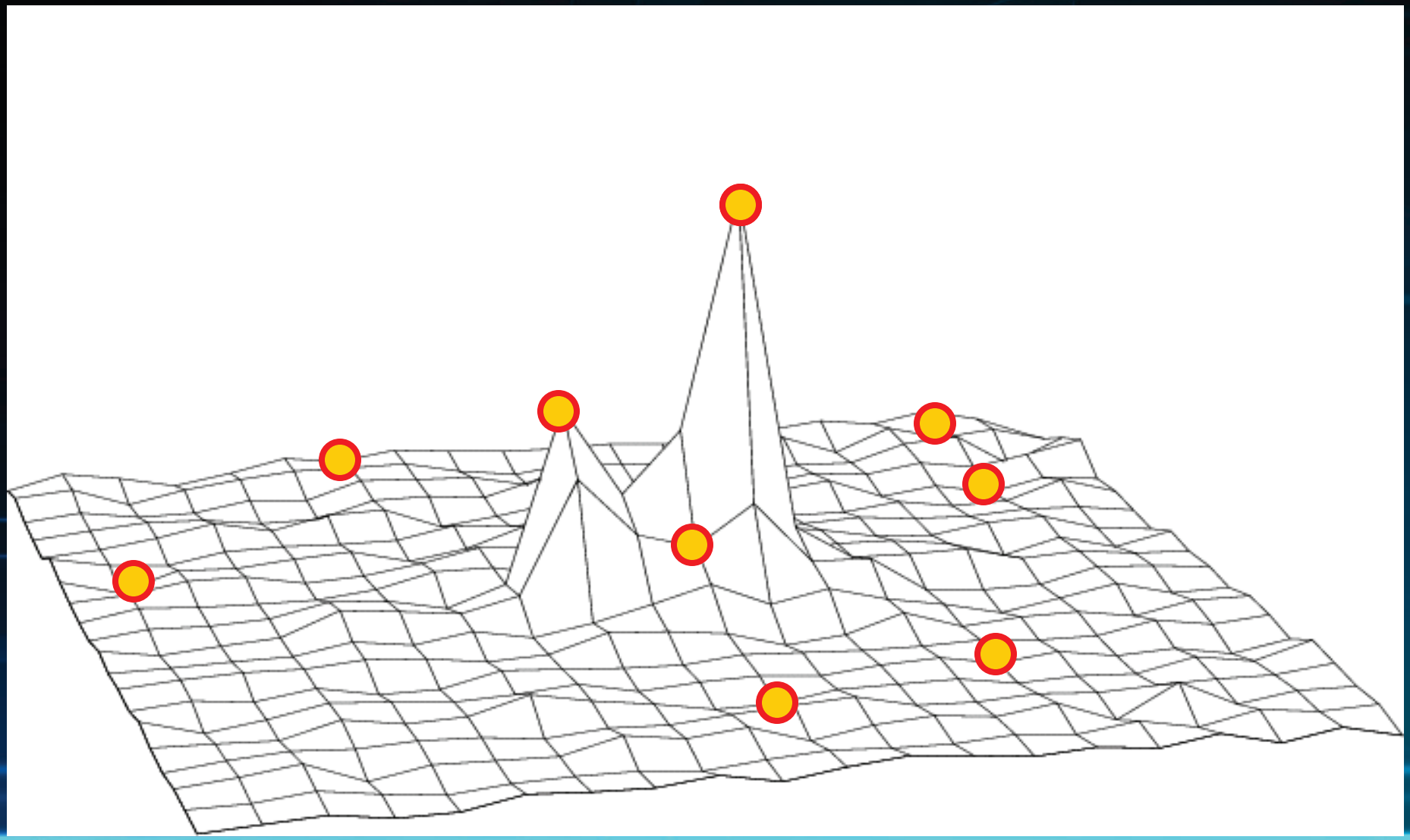

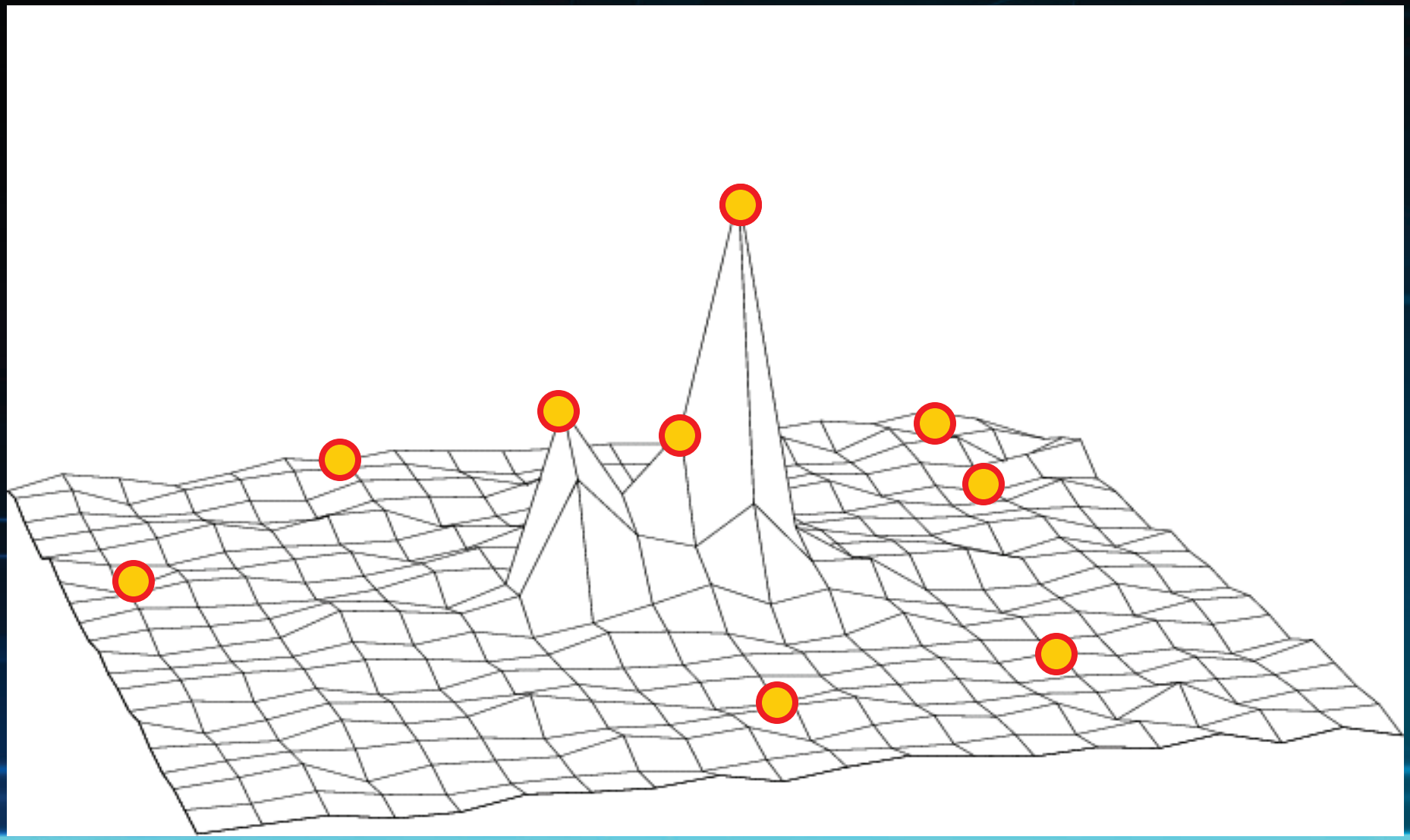

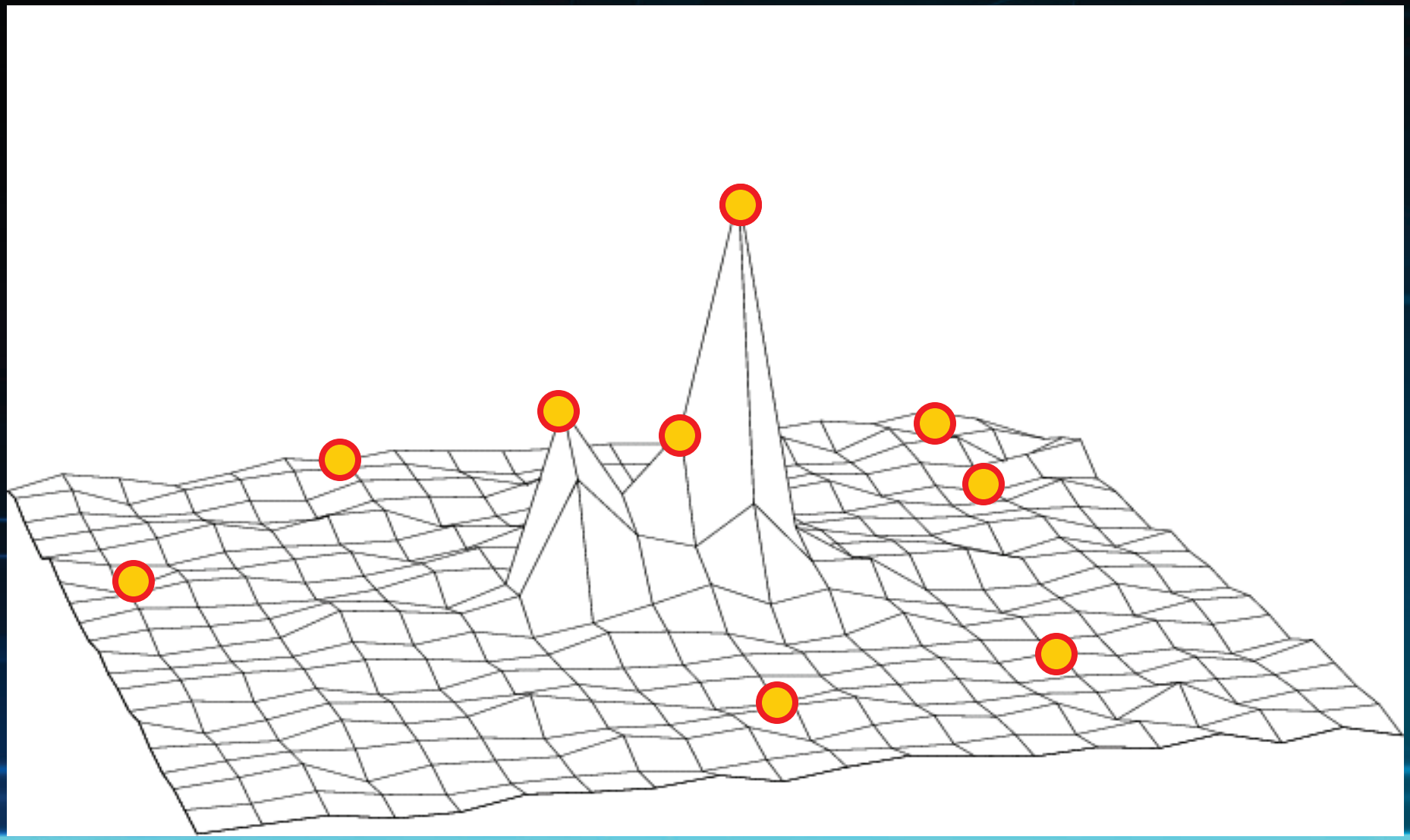

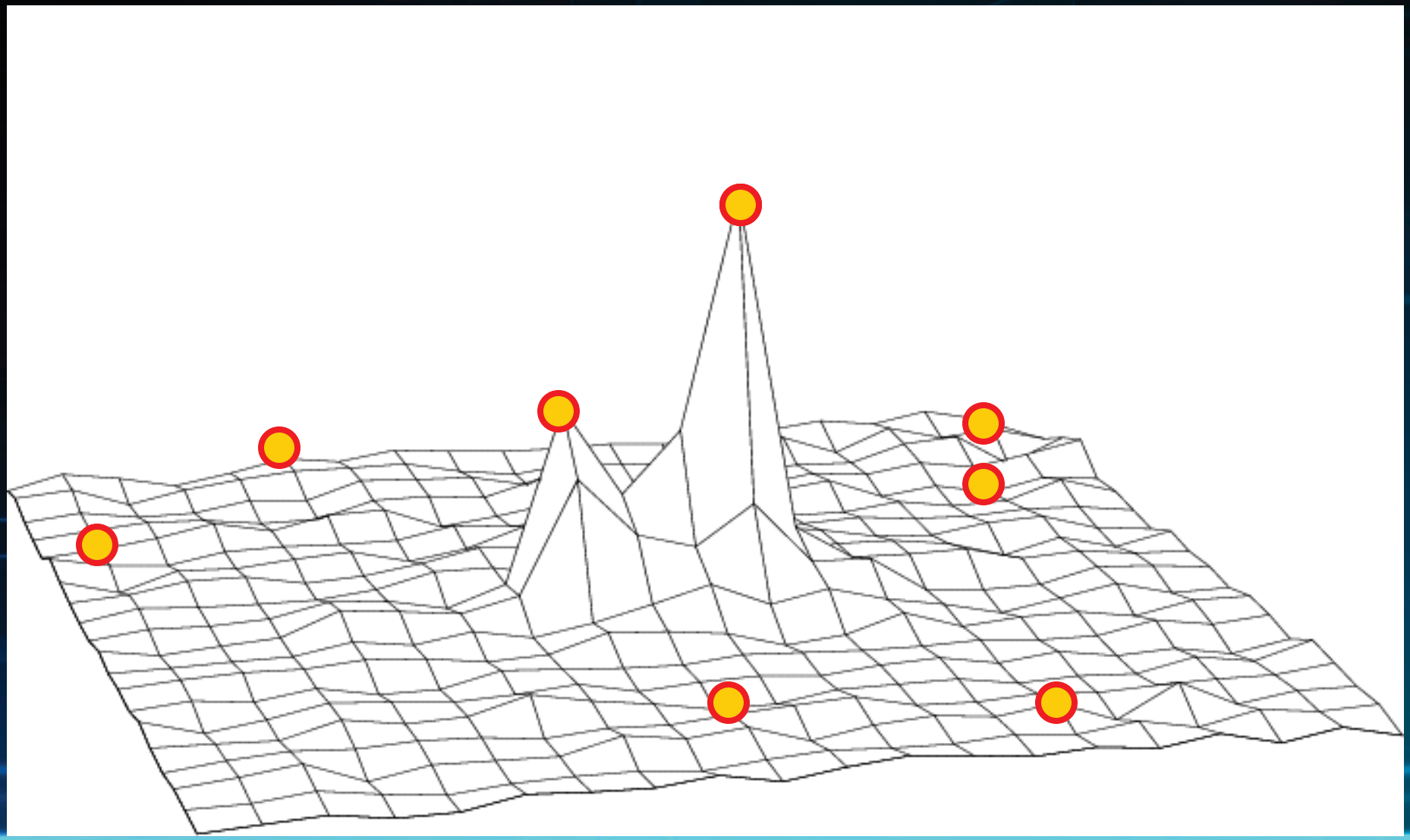

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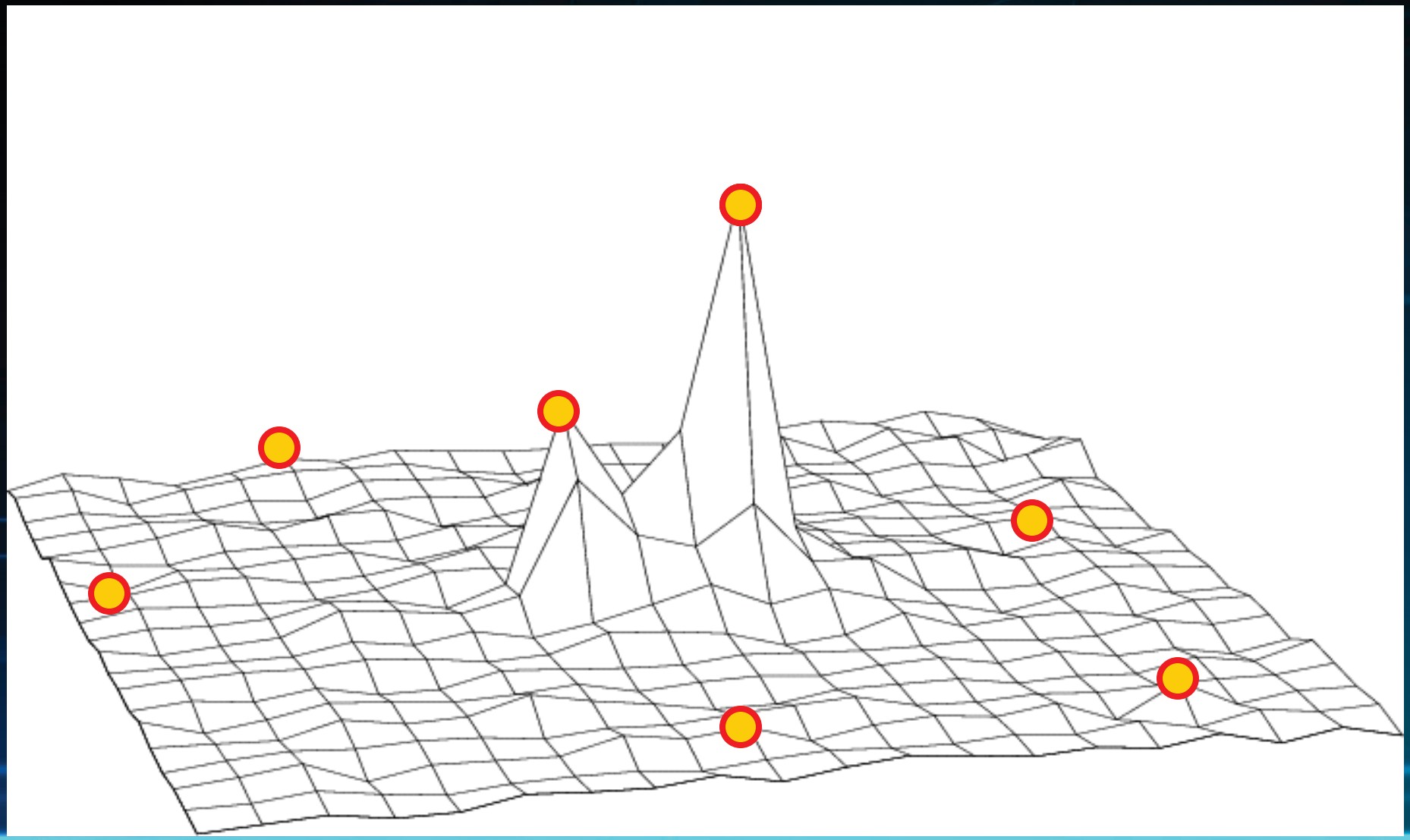

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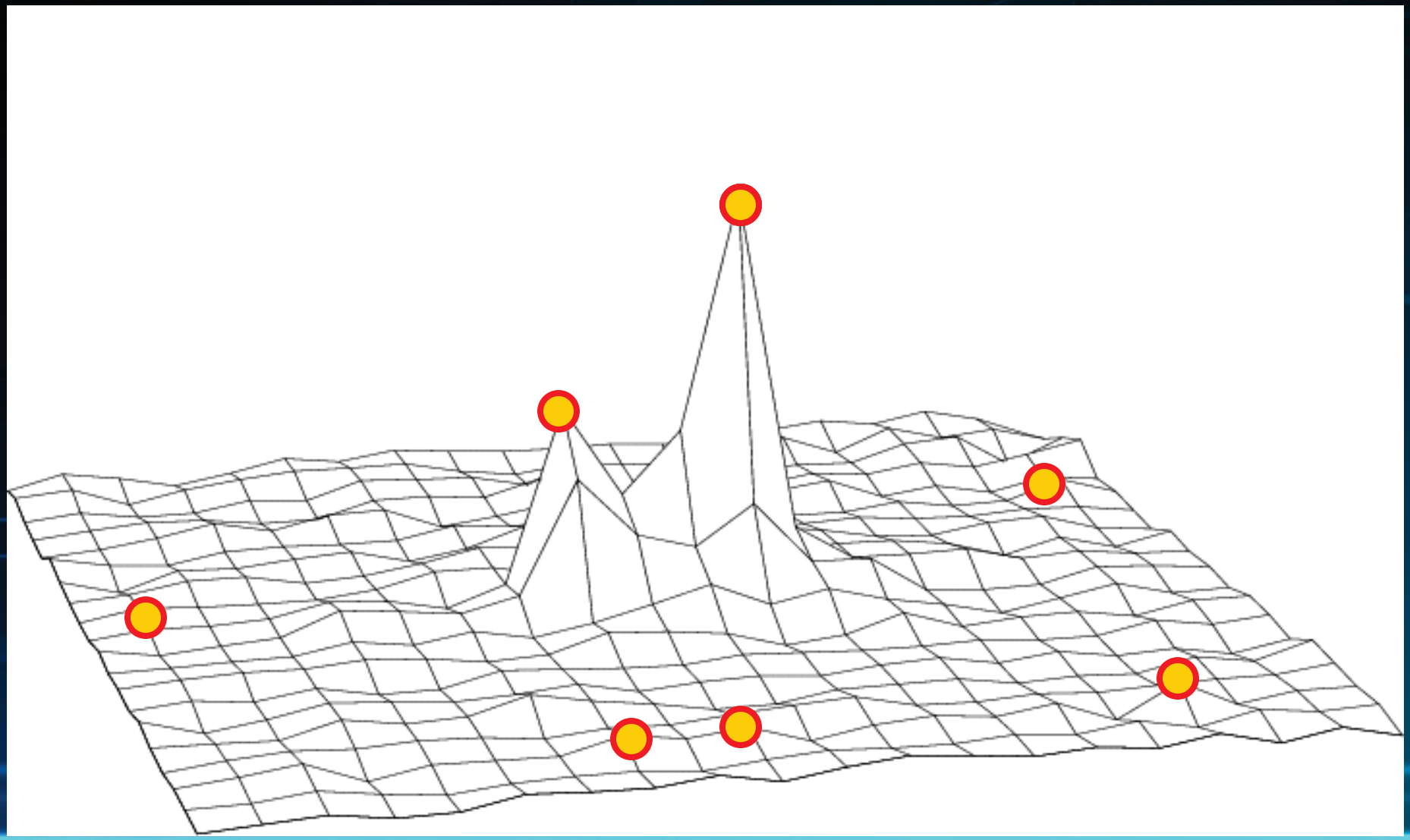

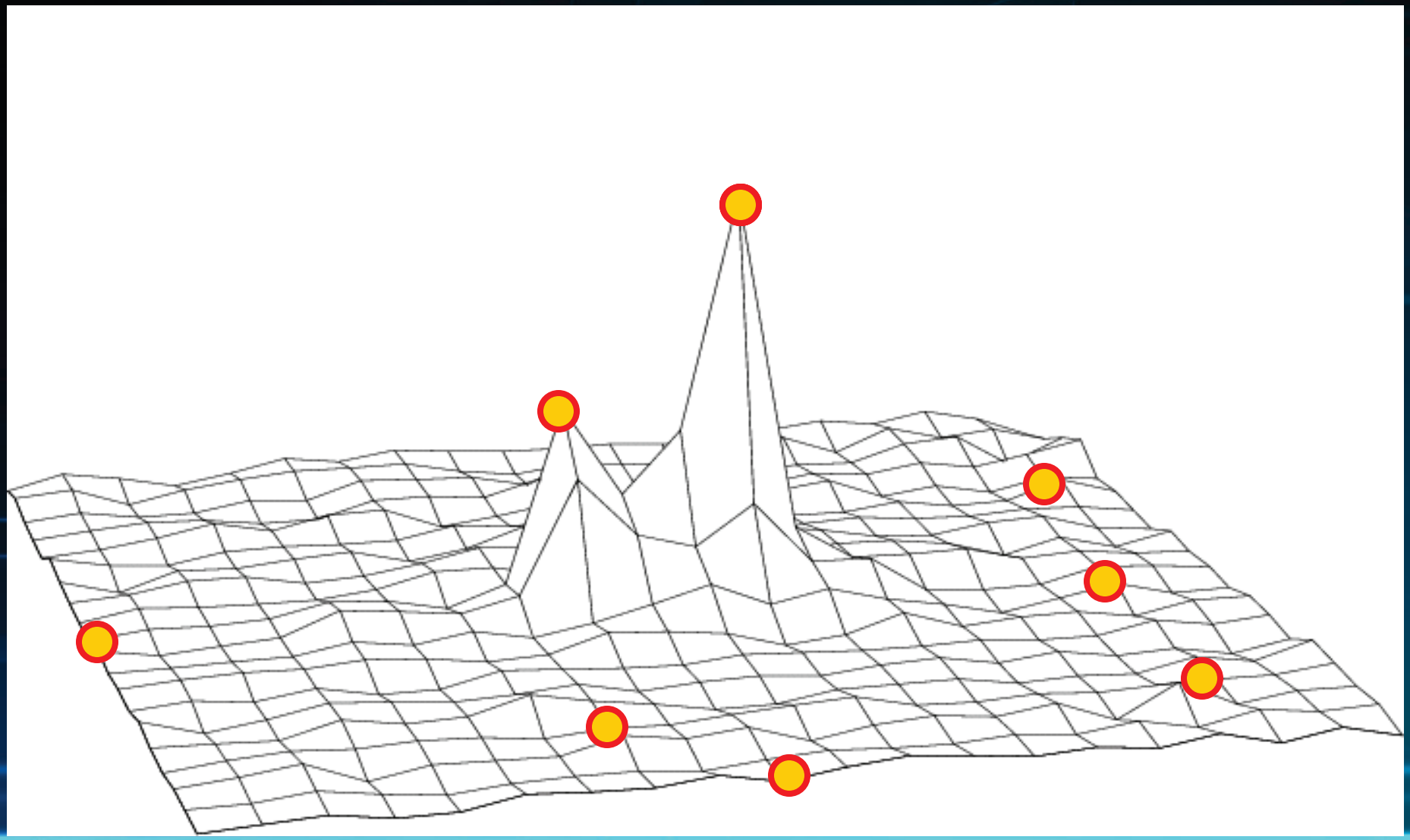

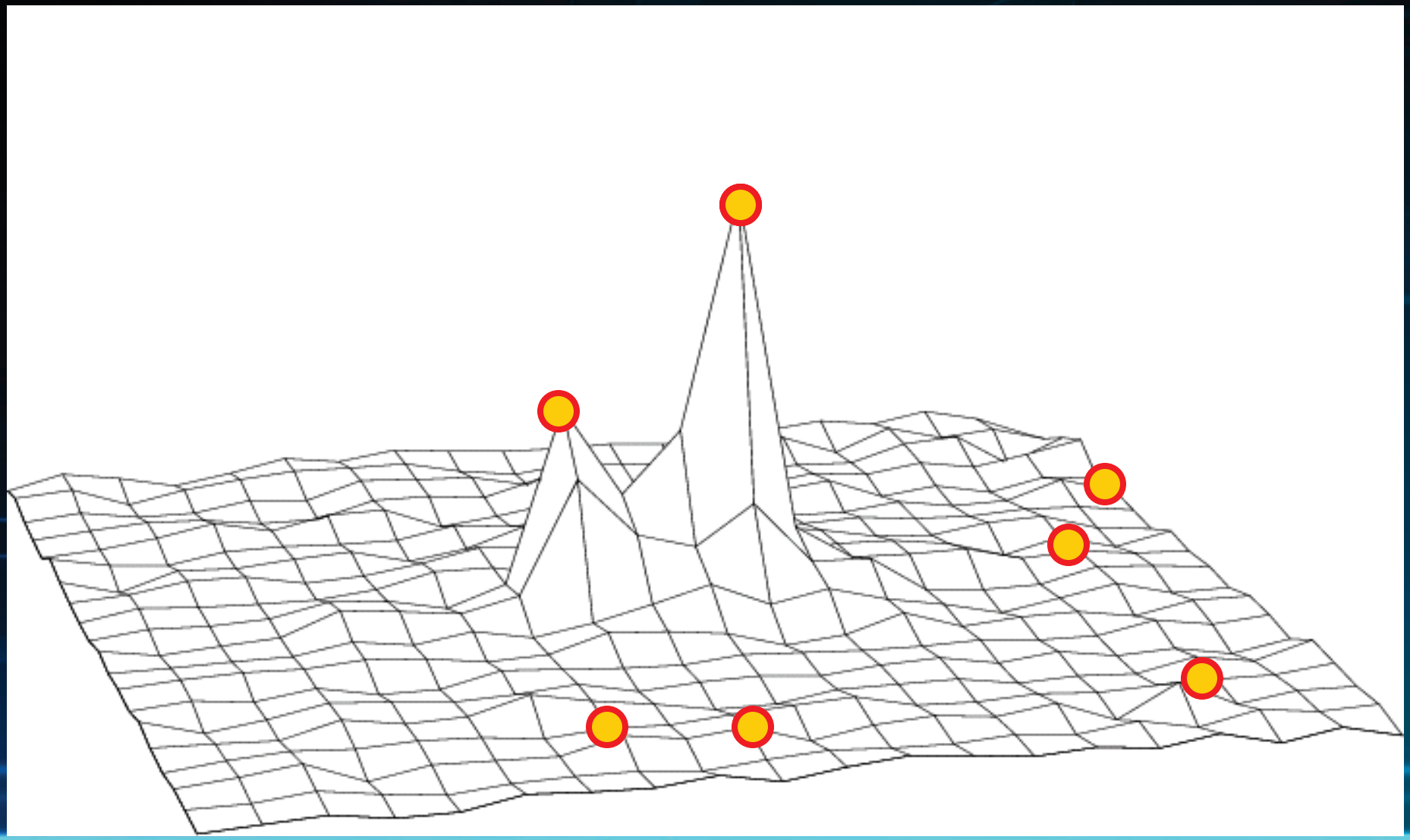

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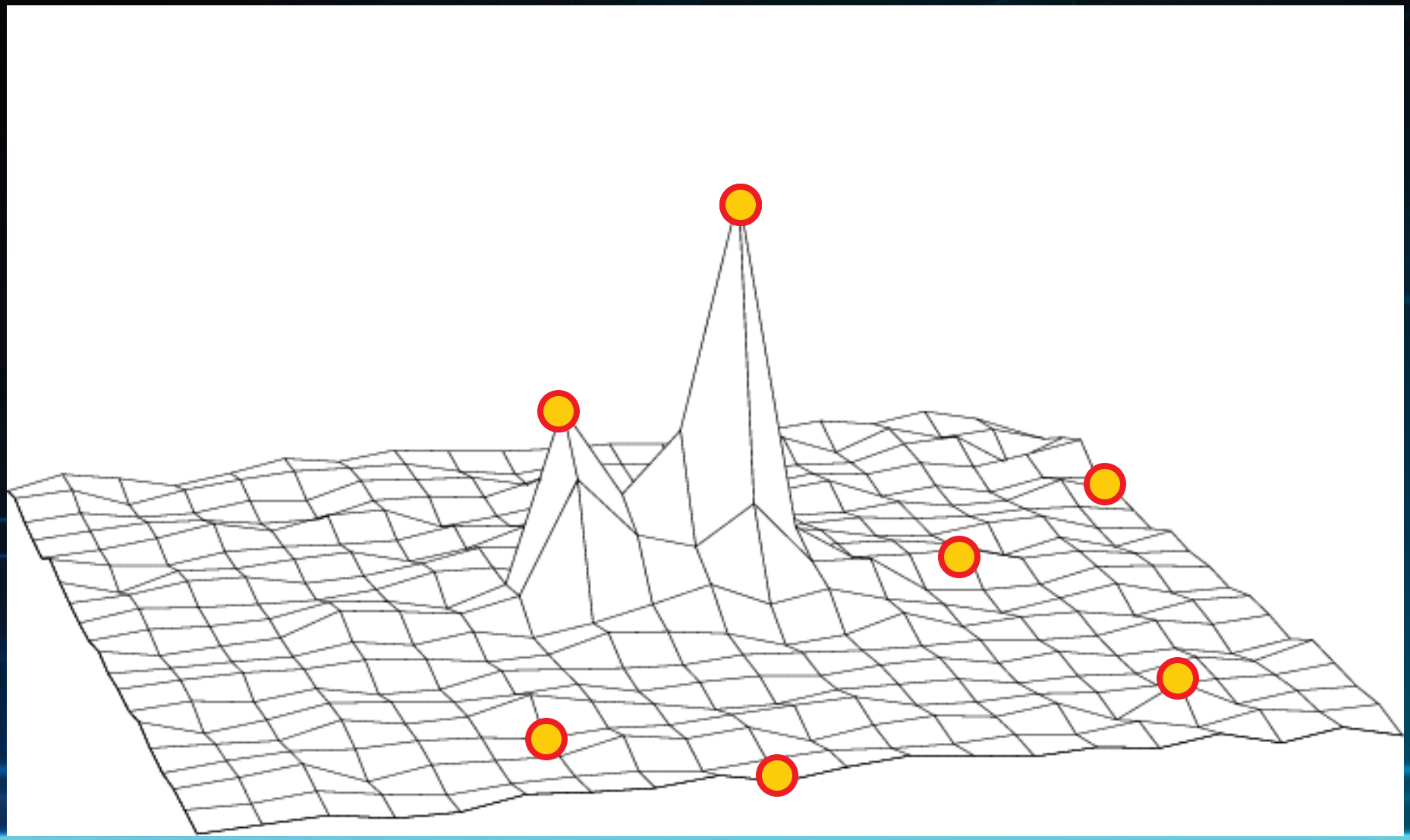

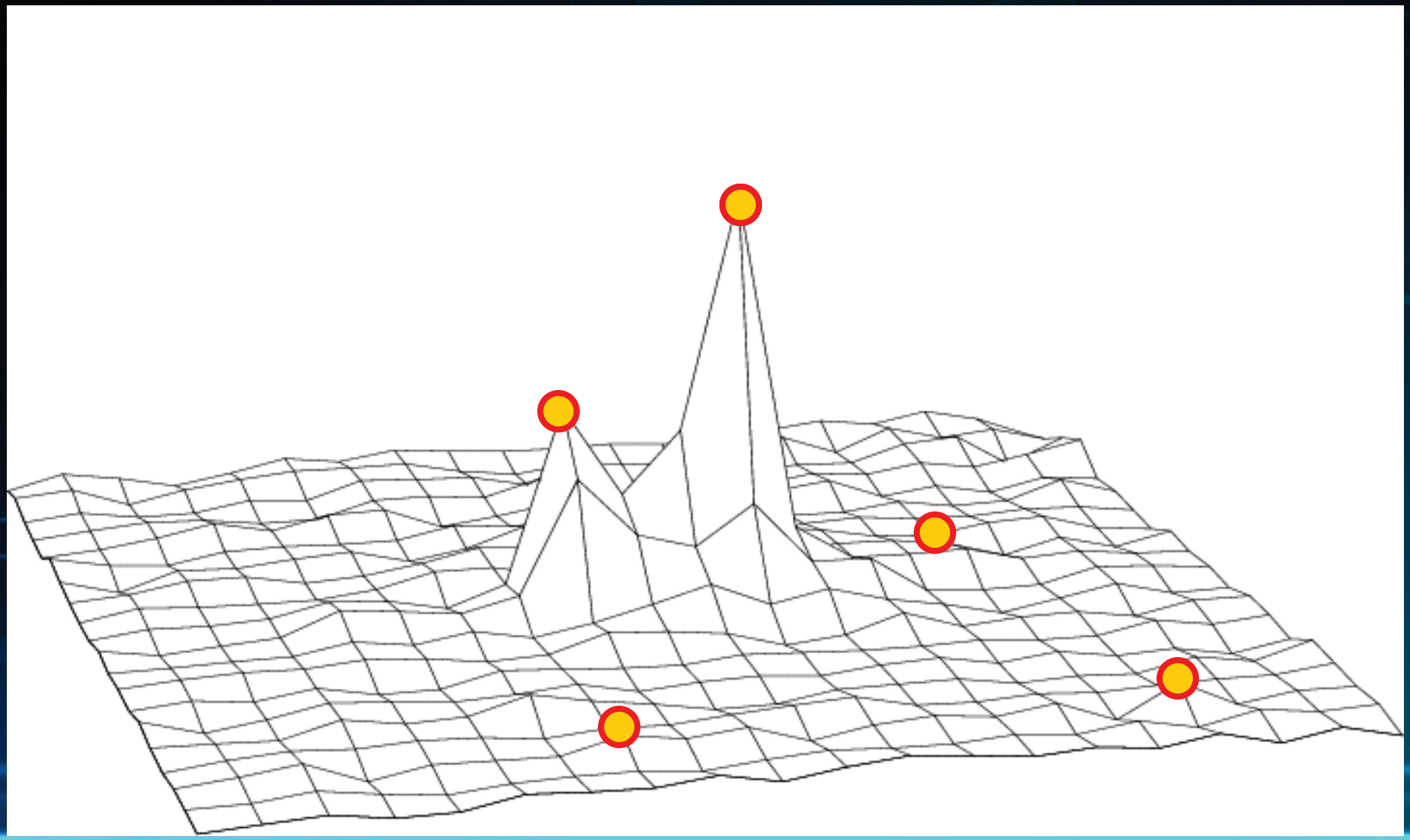

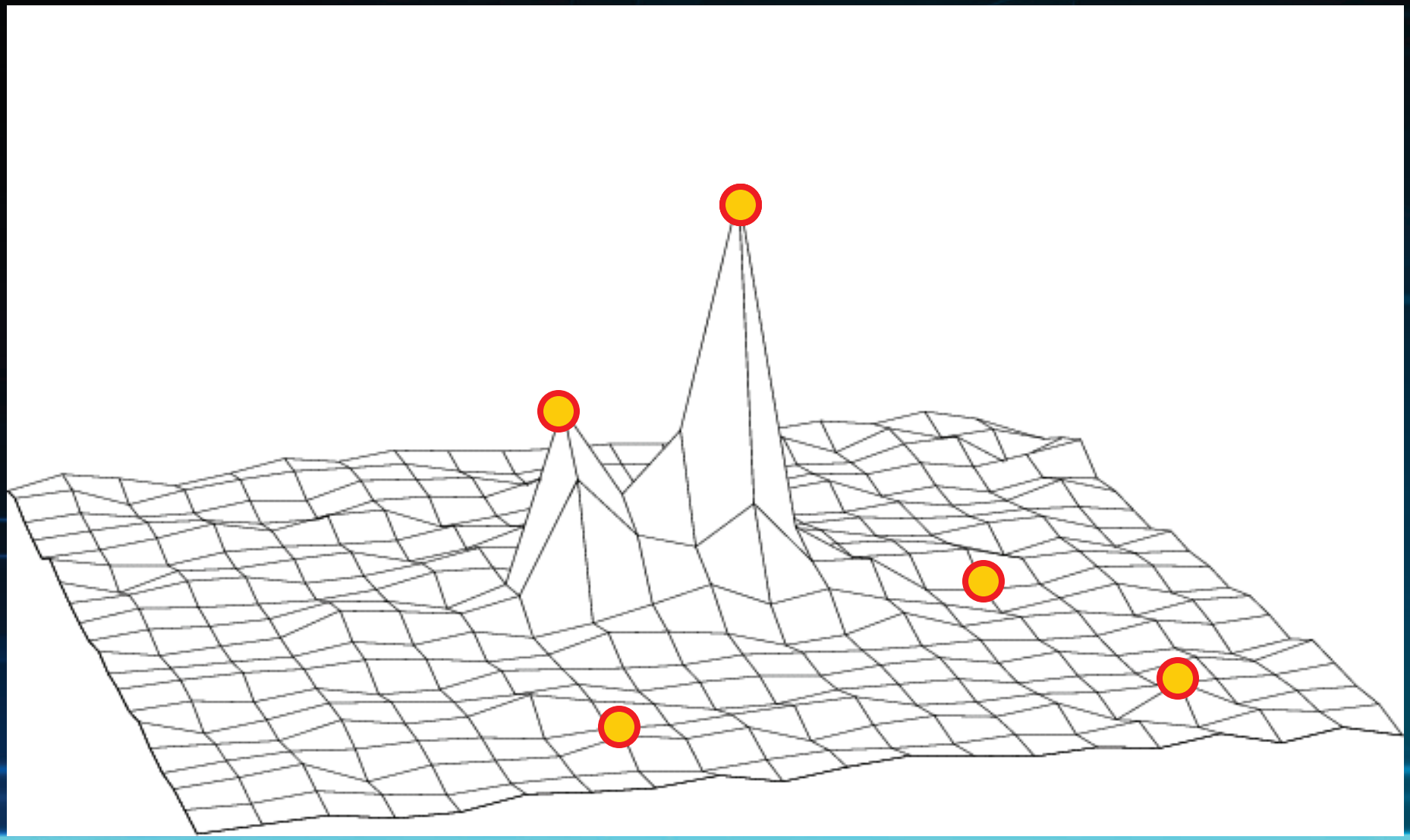

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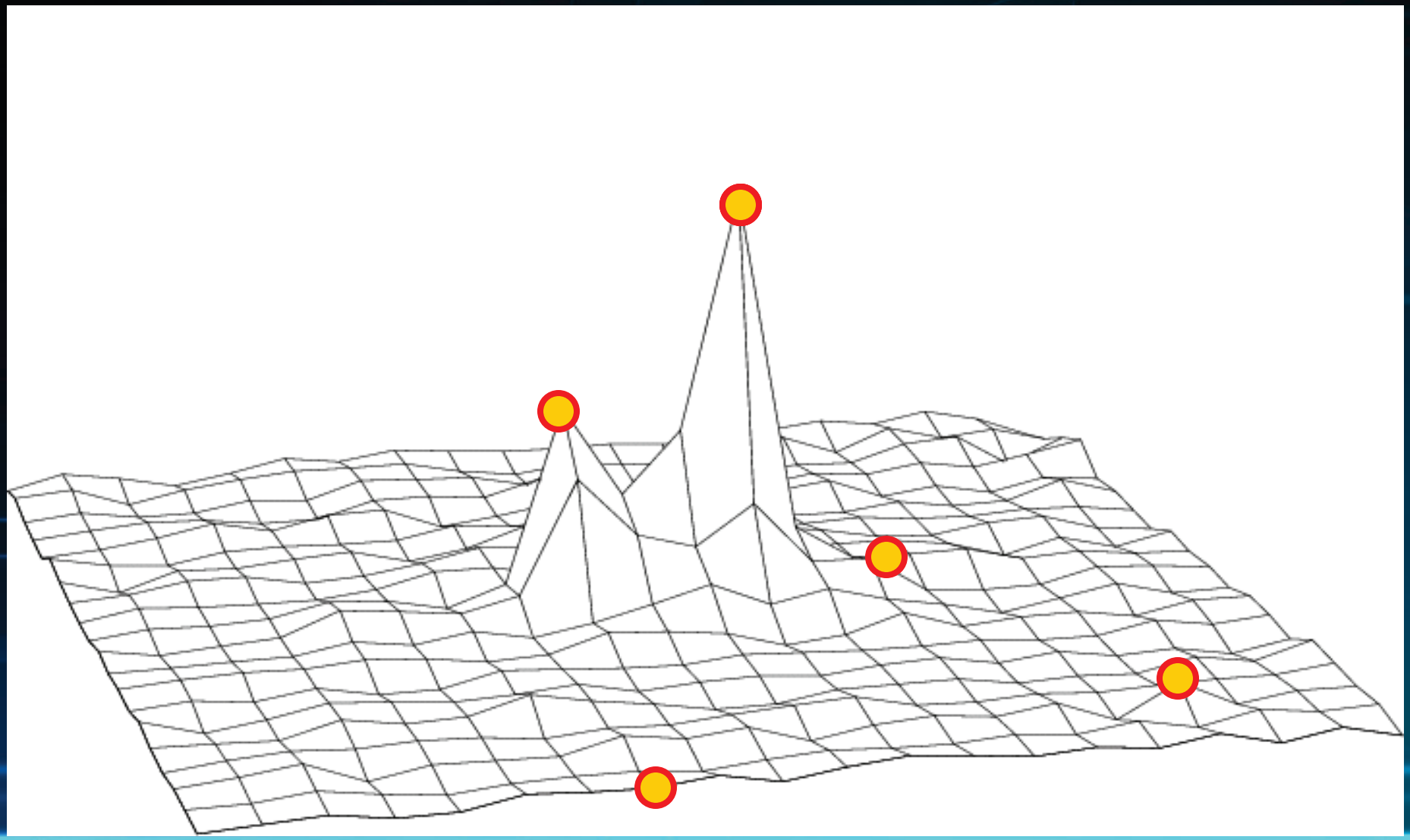

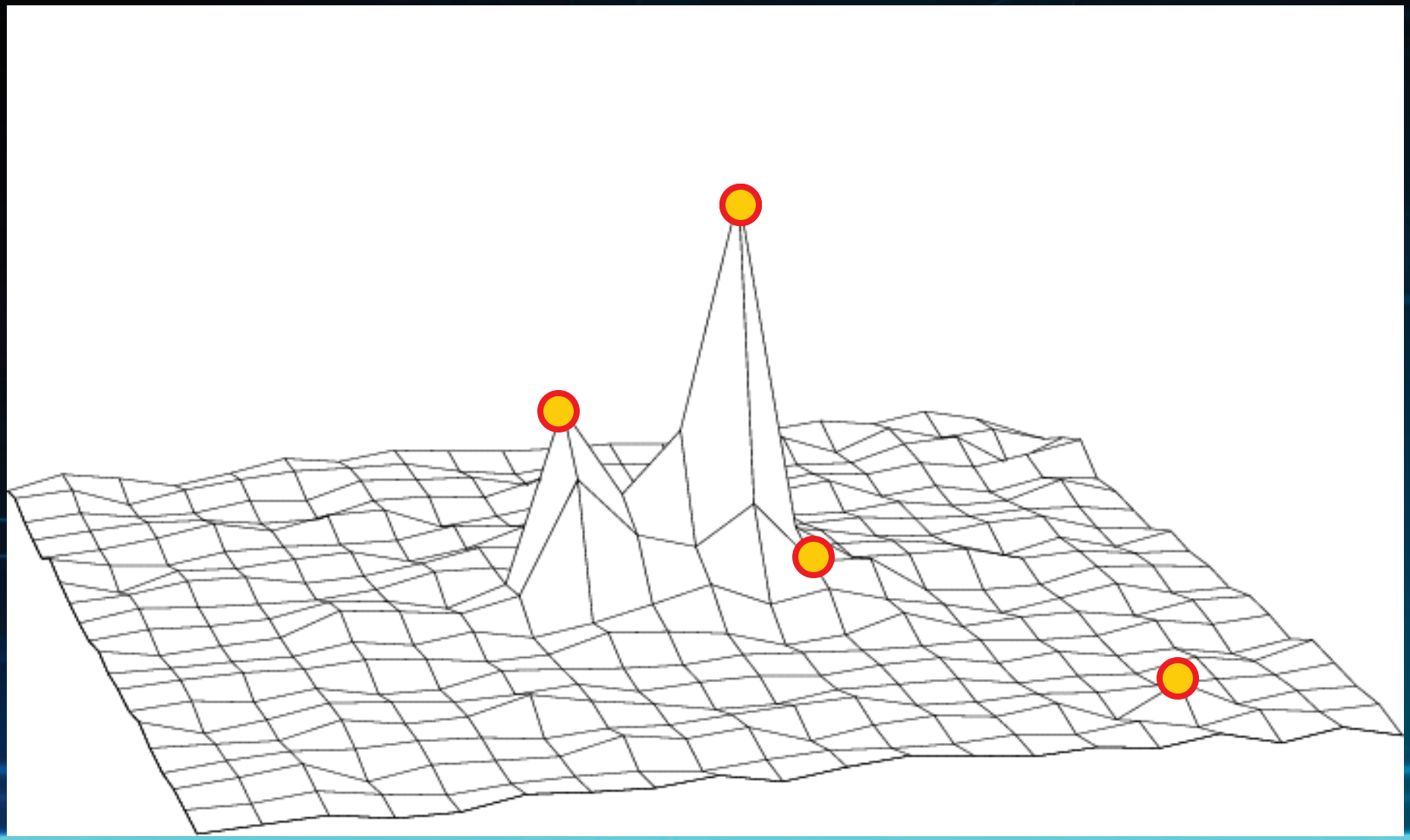

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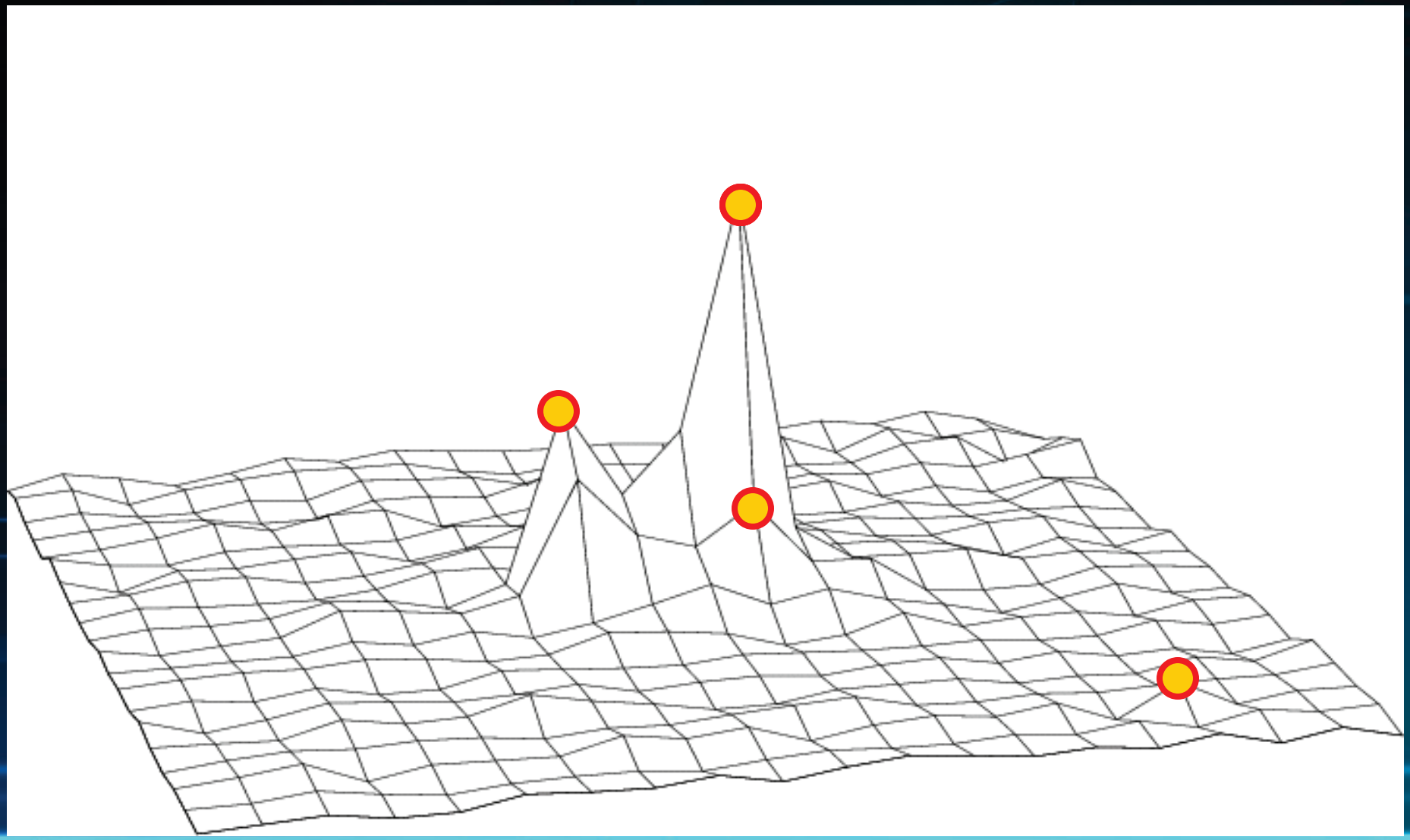

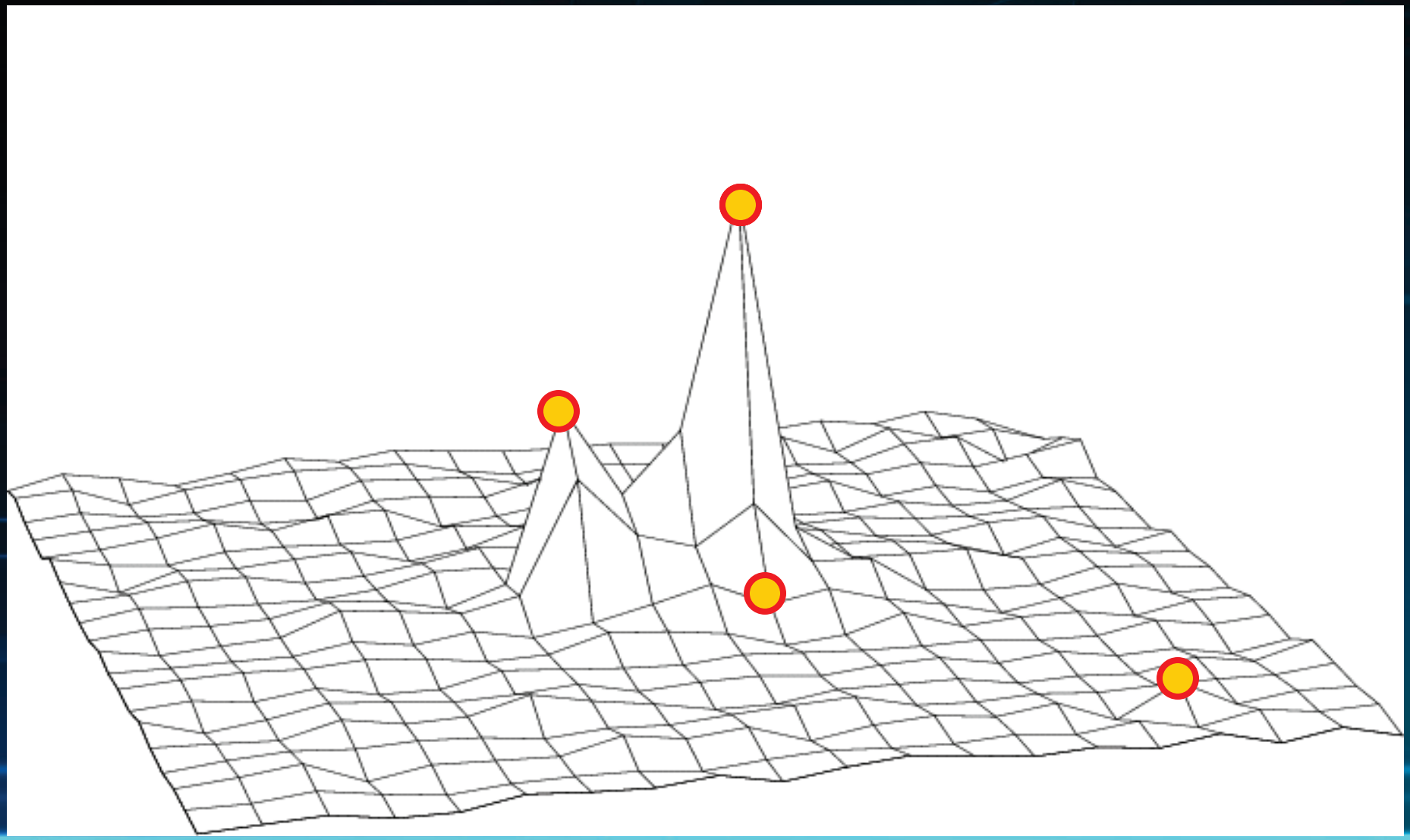

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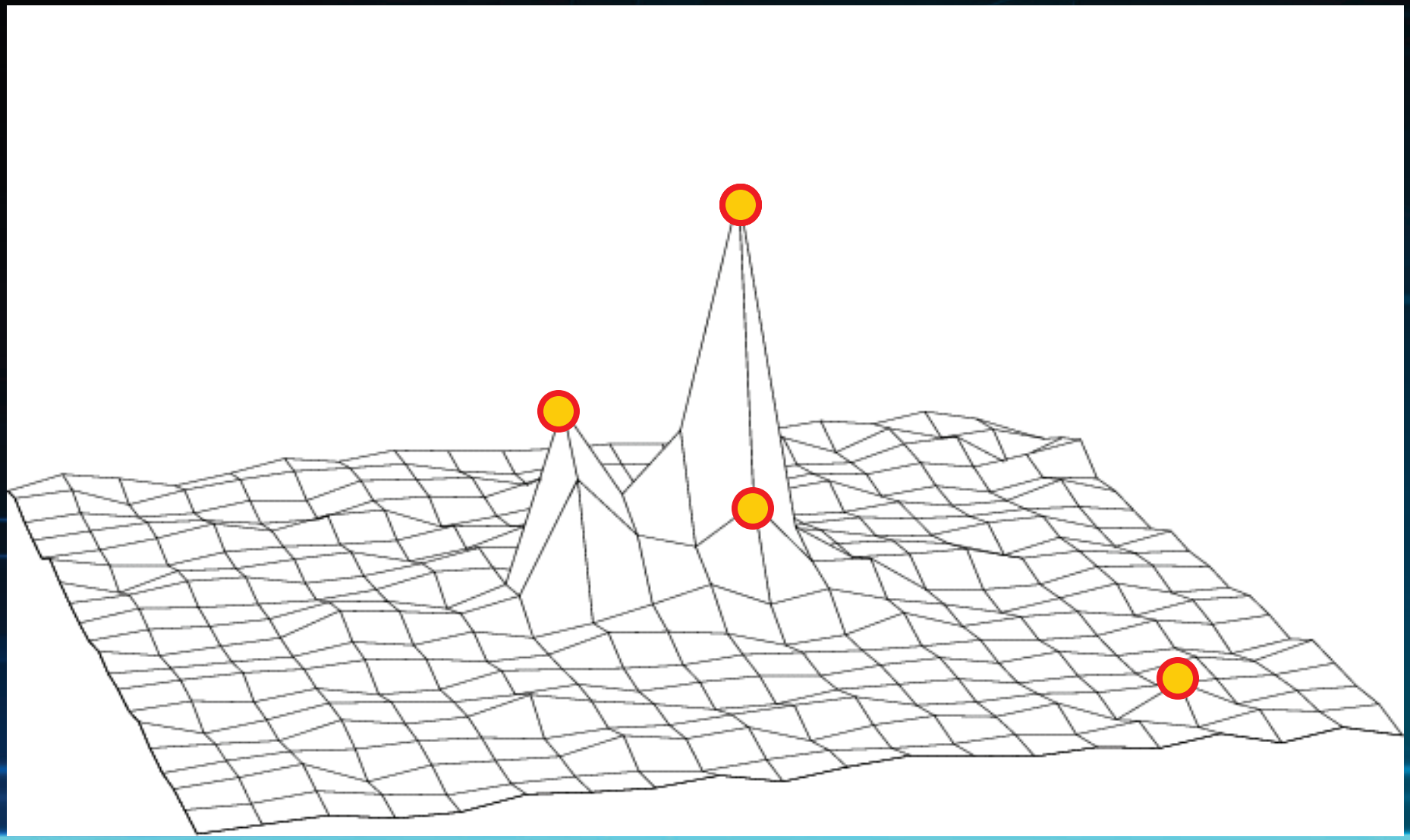

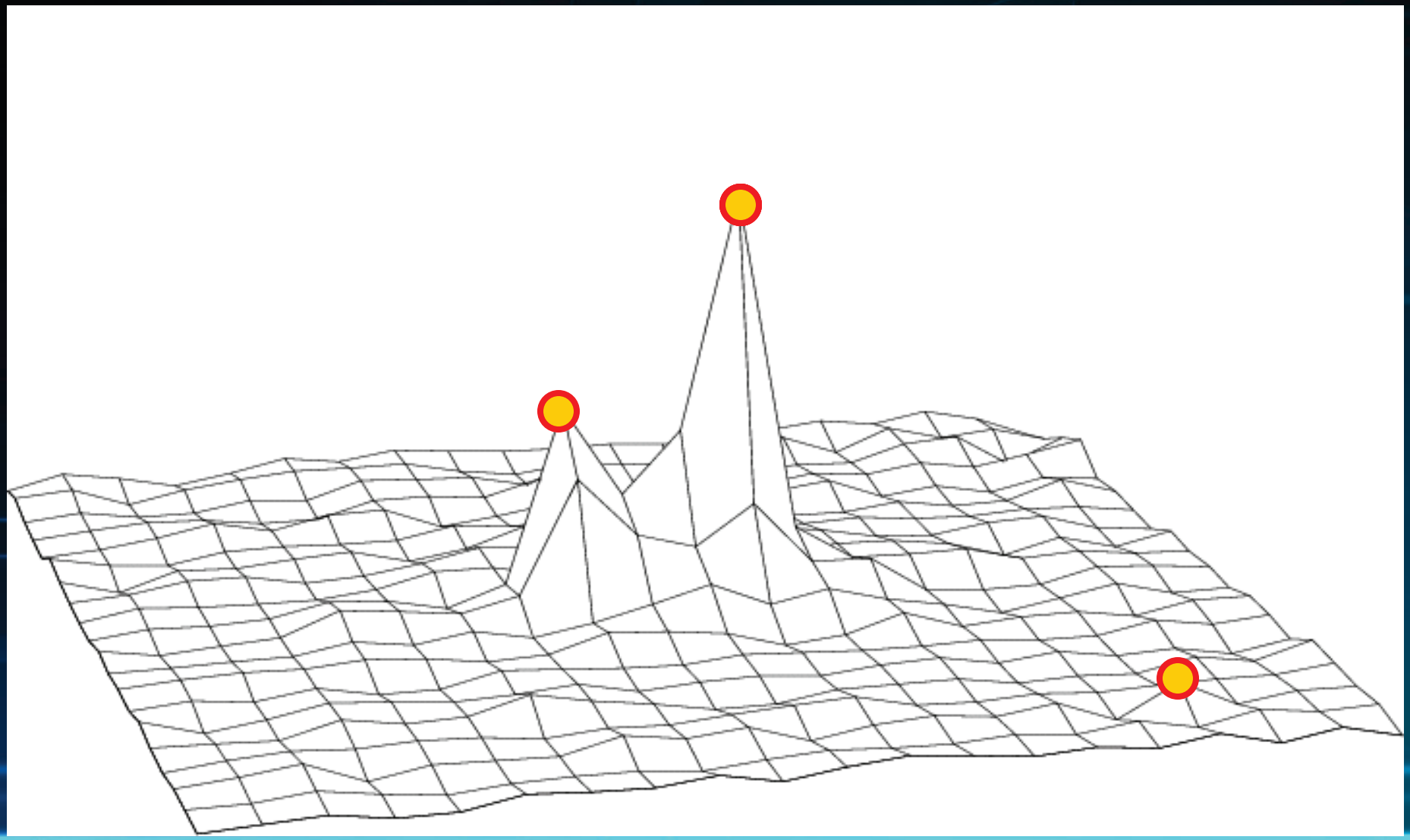

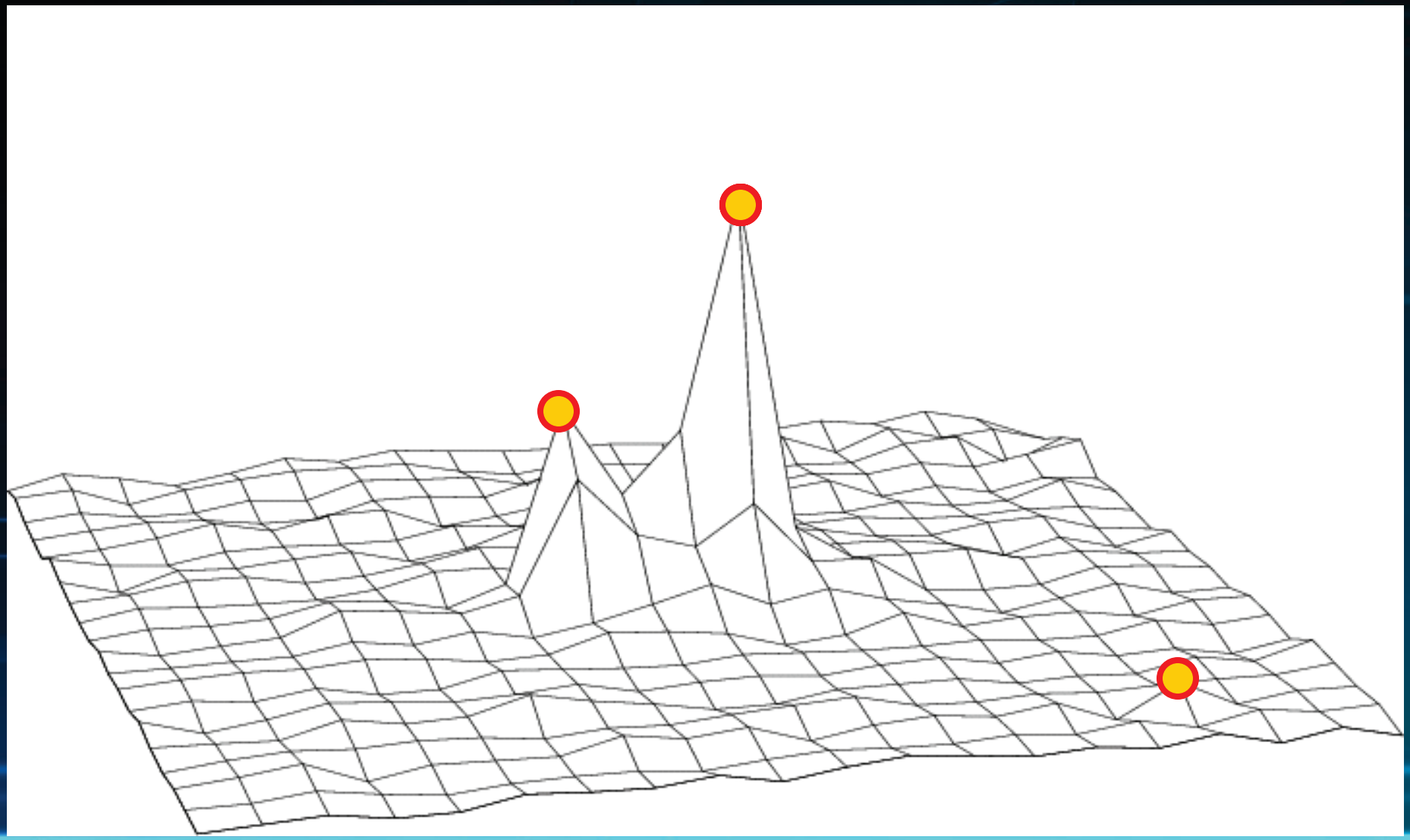

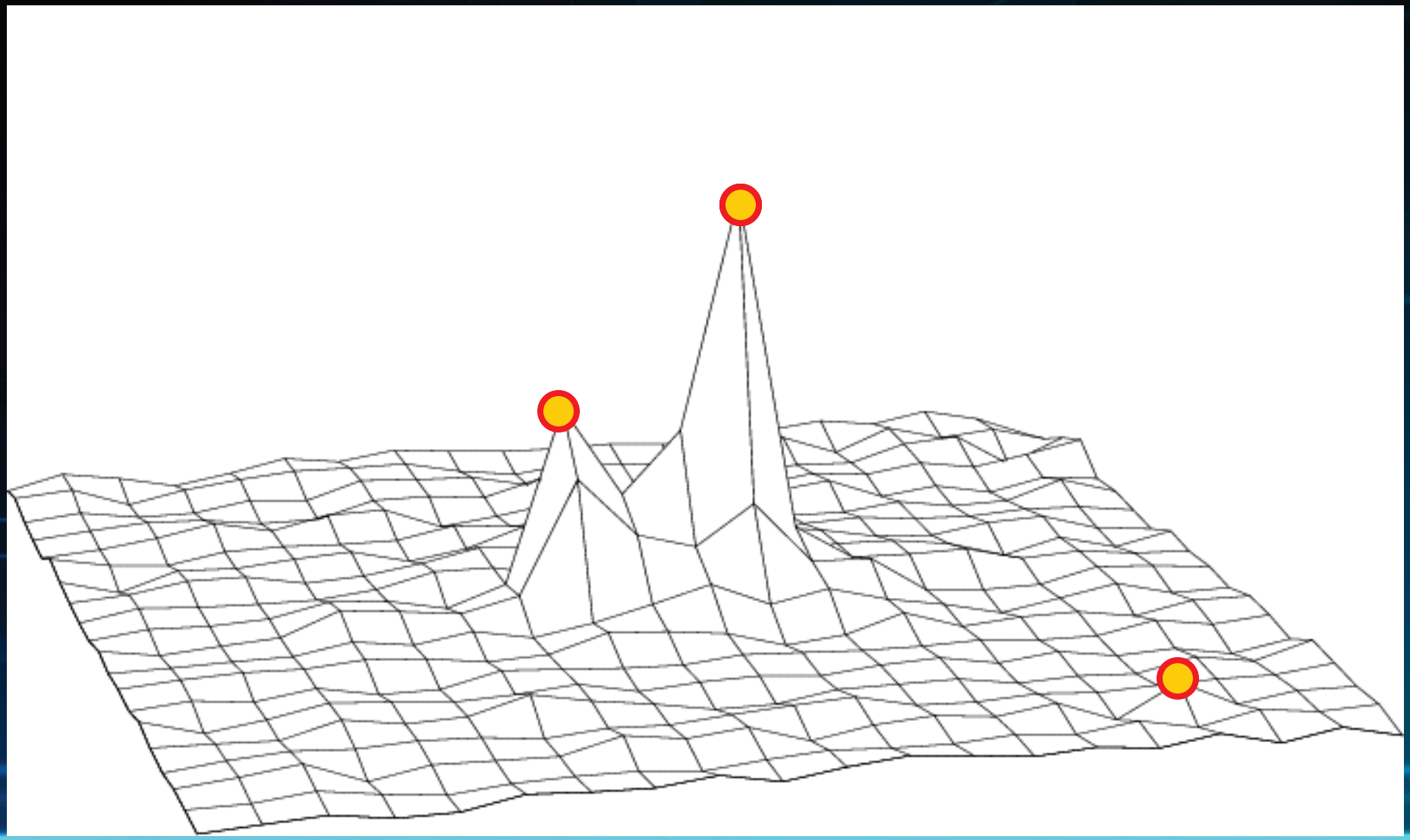

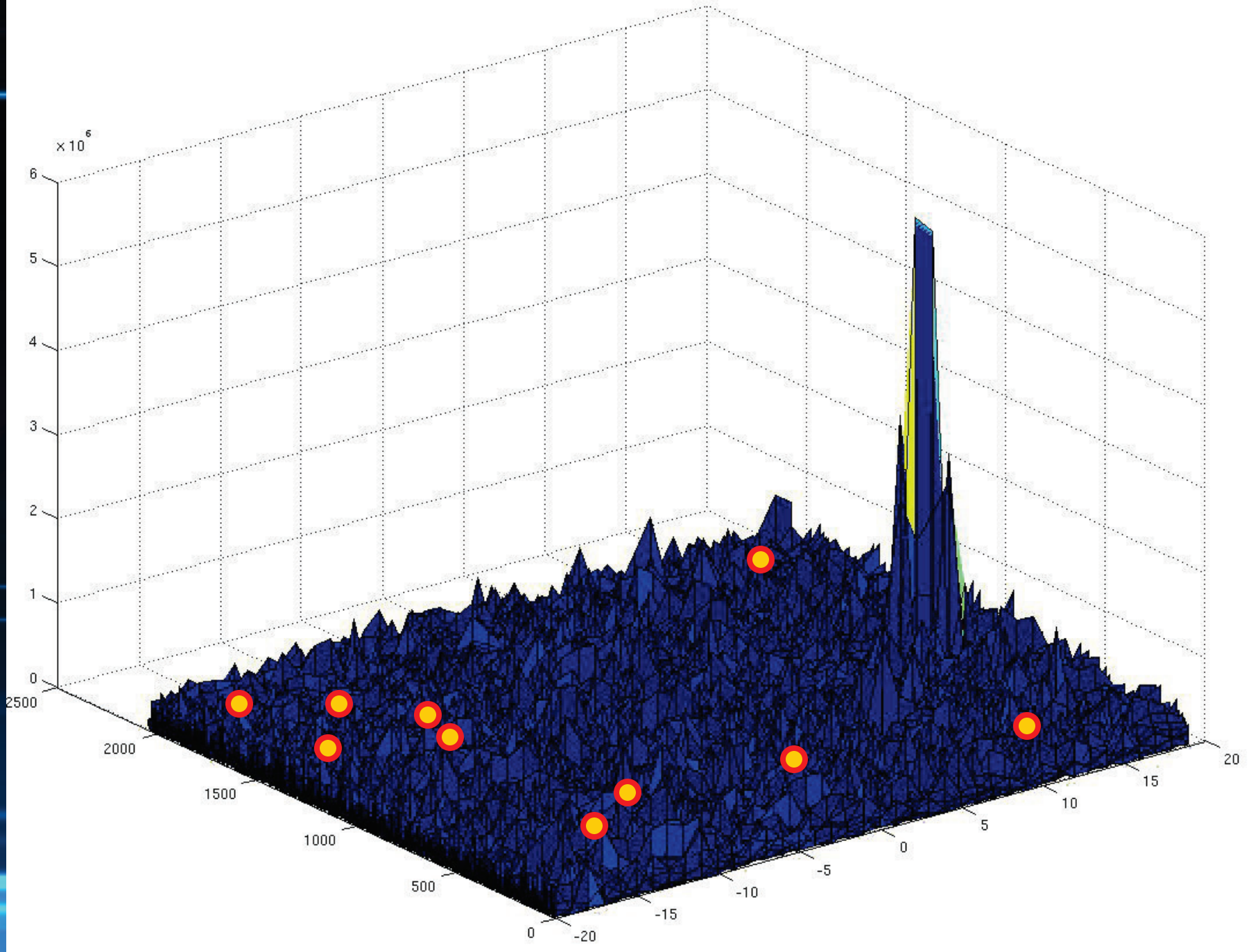
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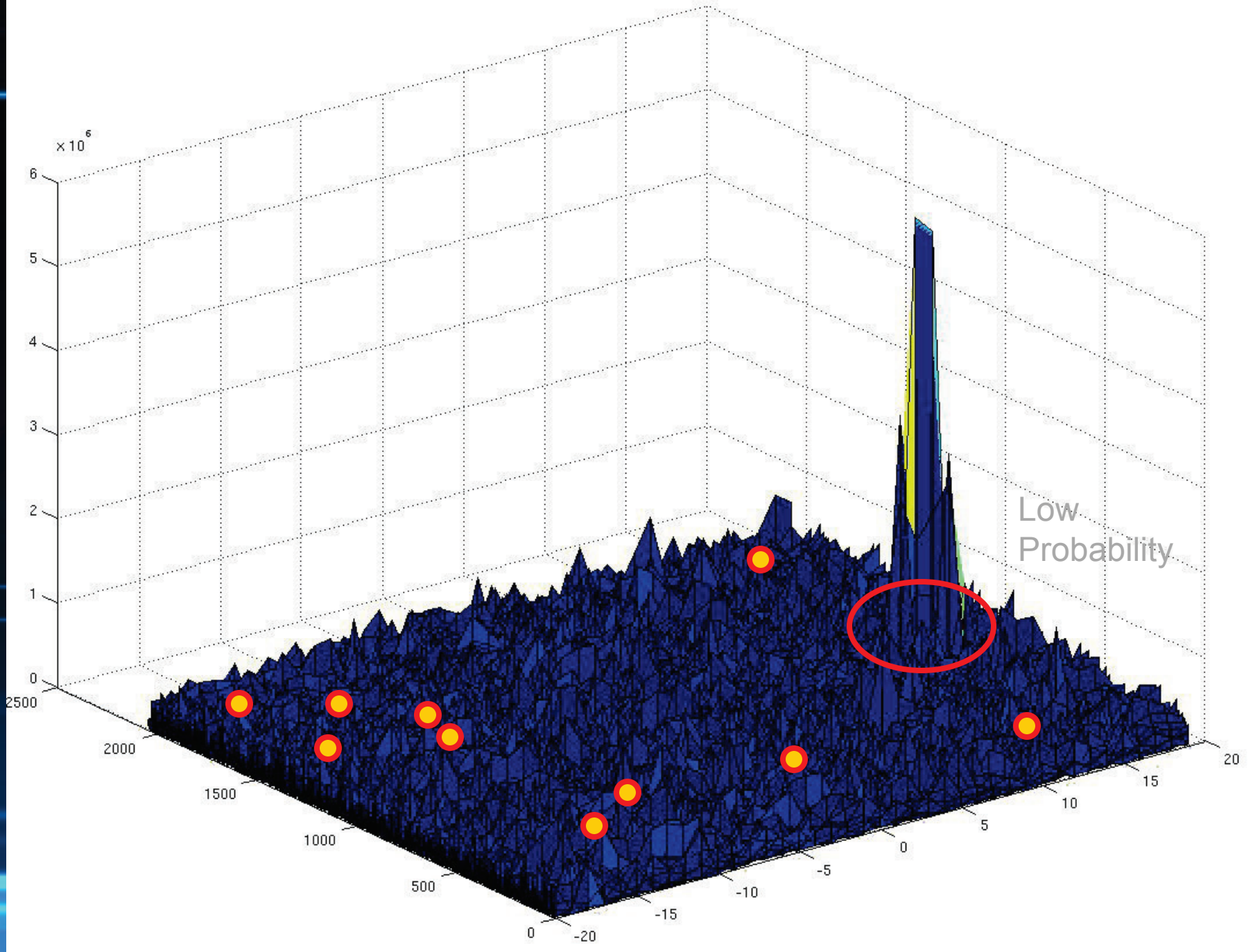
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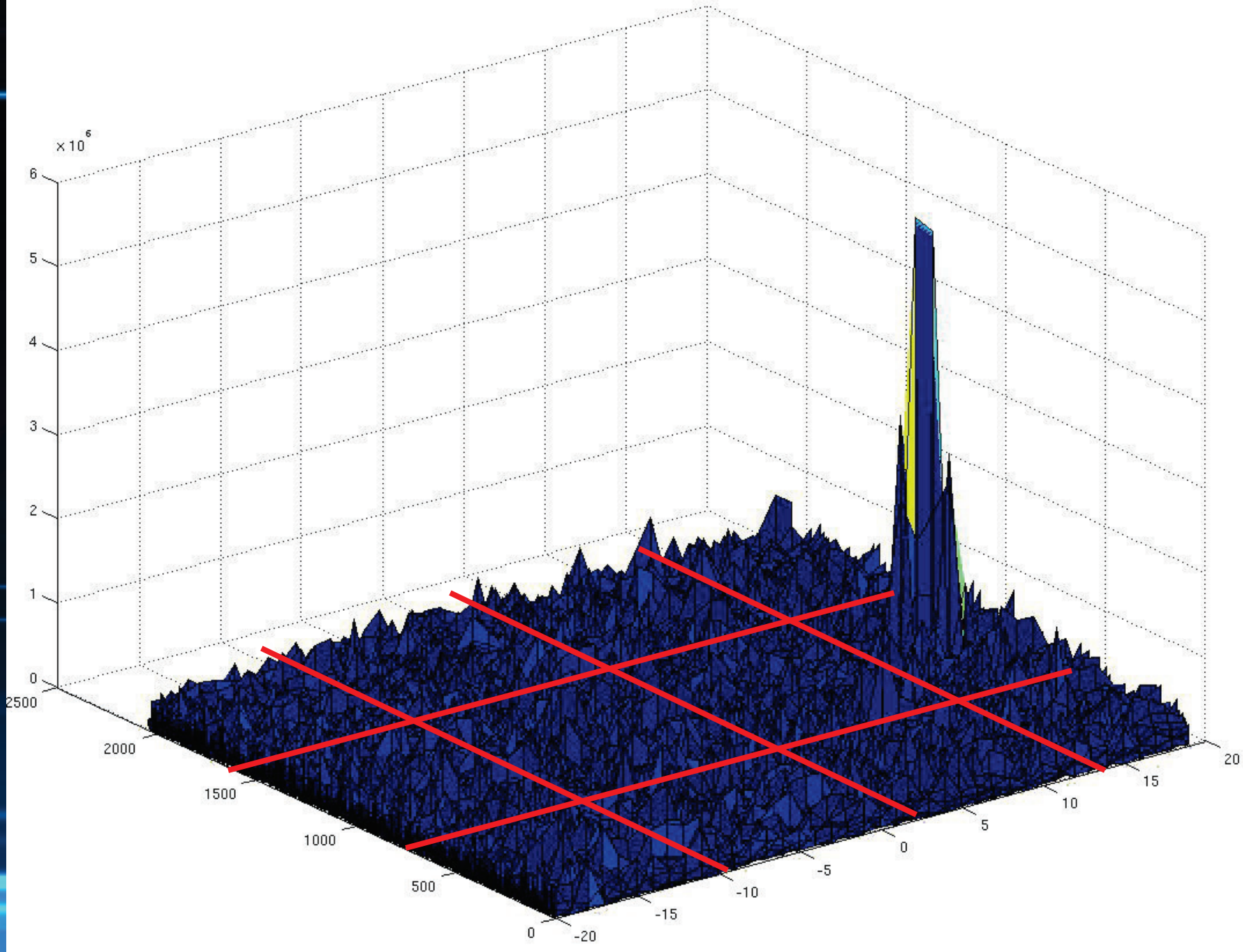
Low
Probability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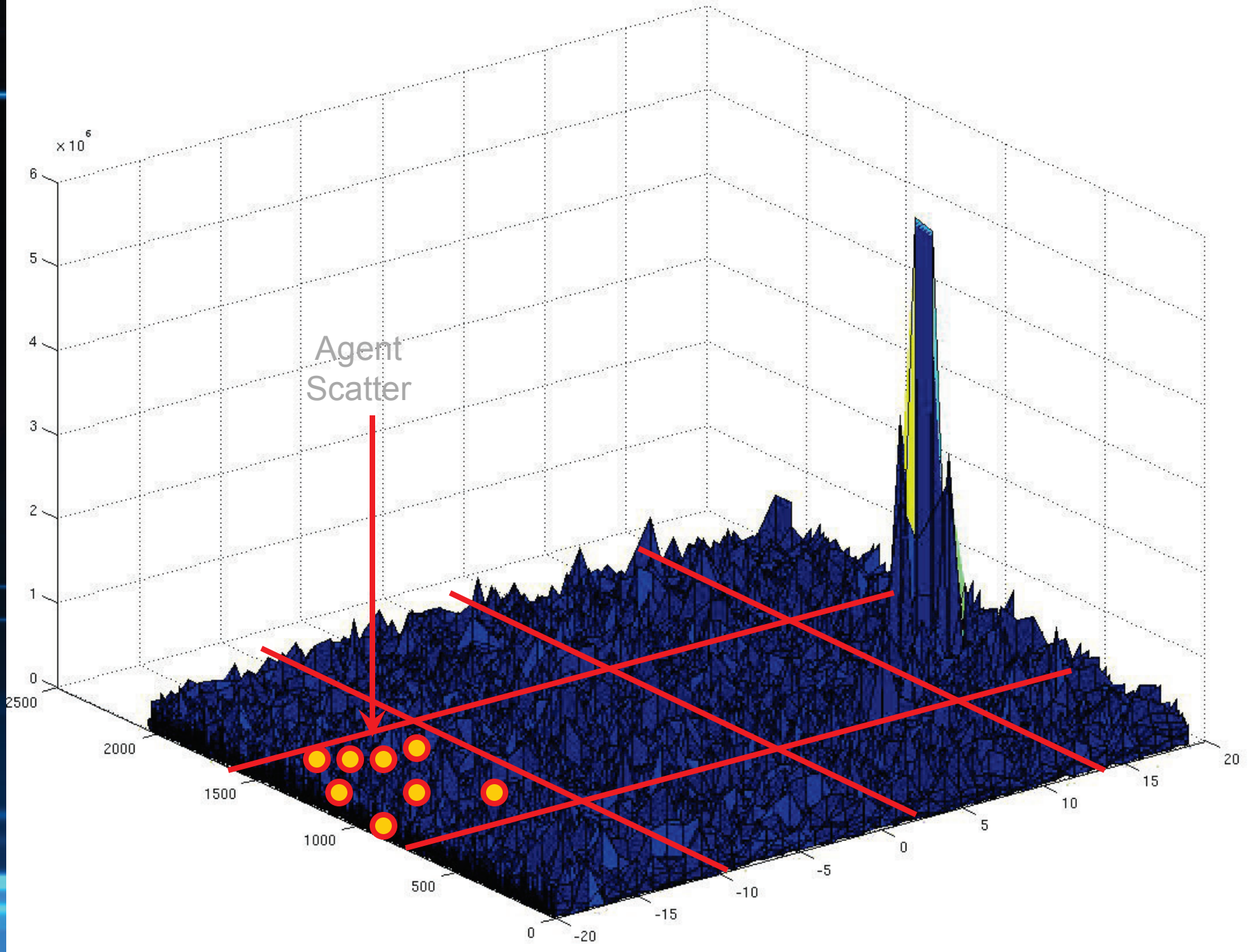
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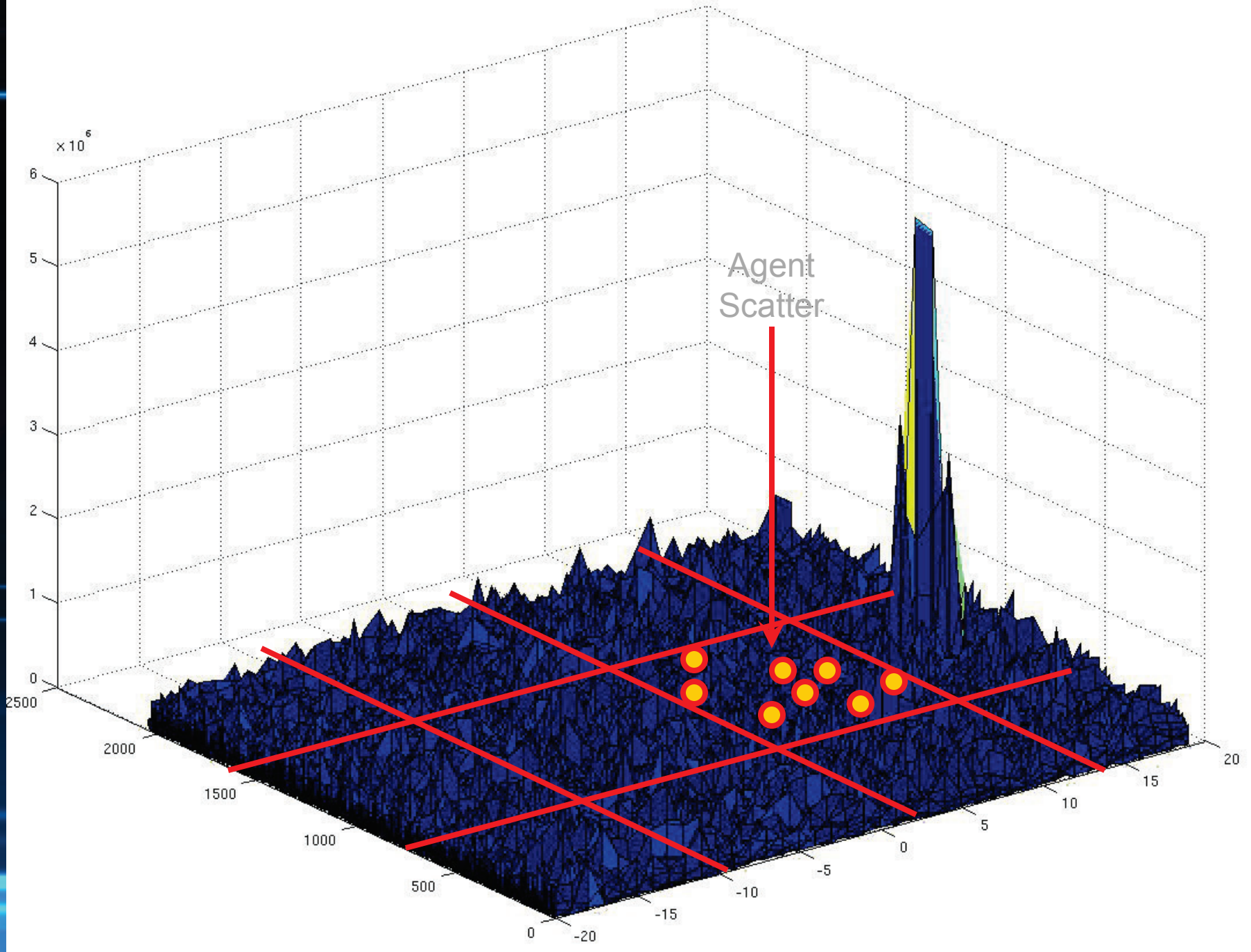
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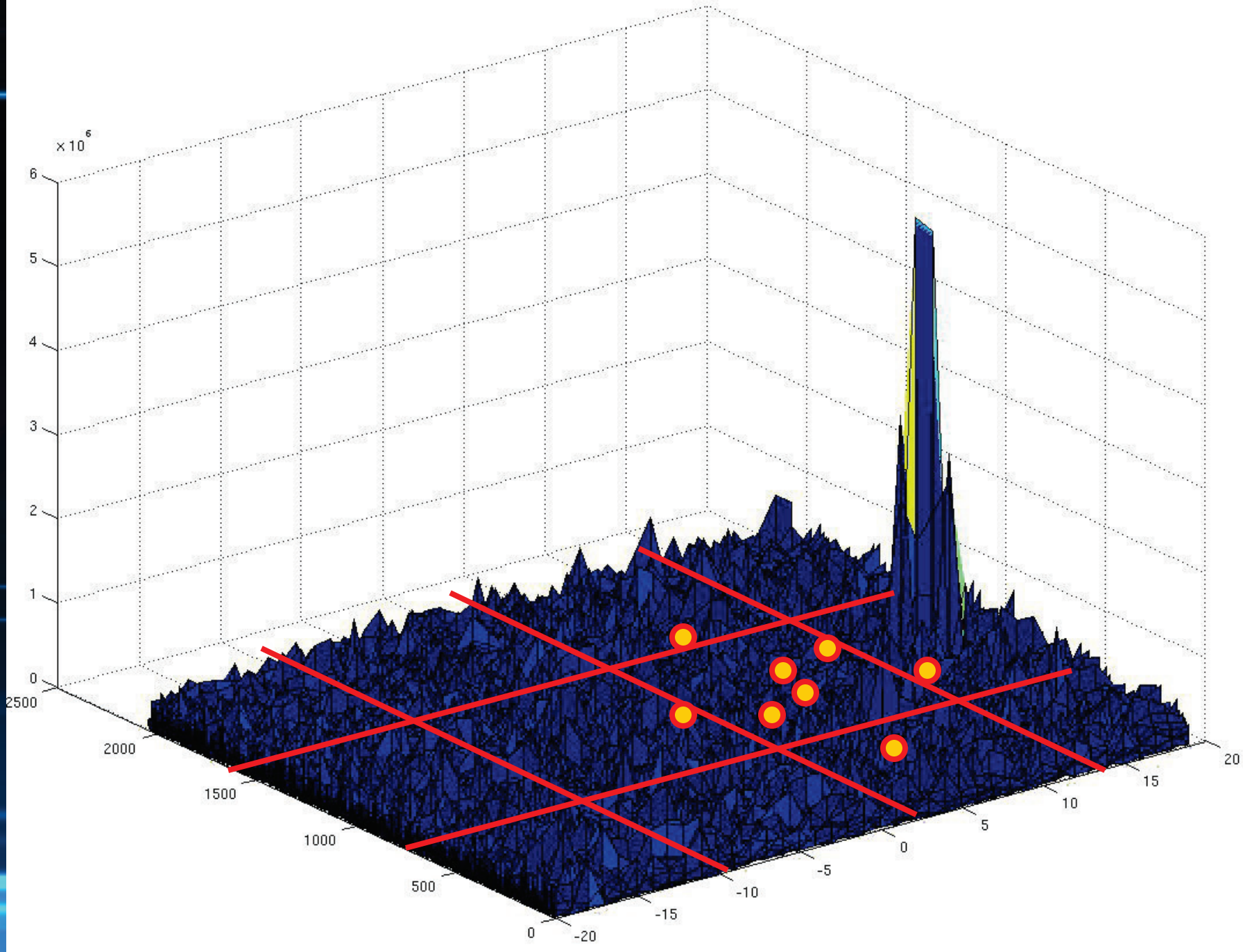
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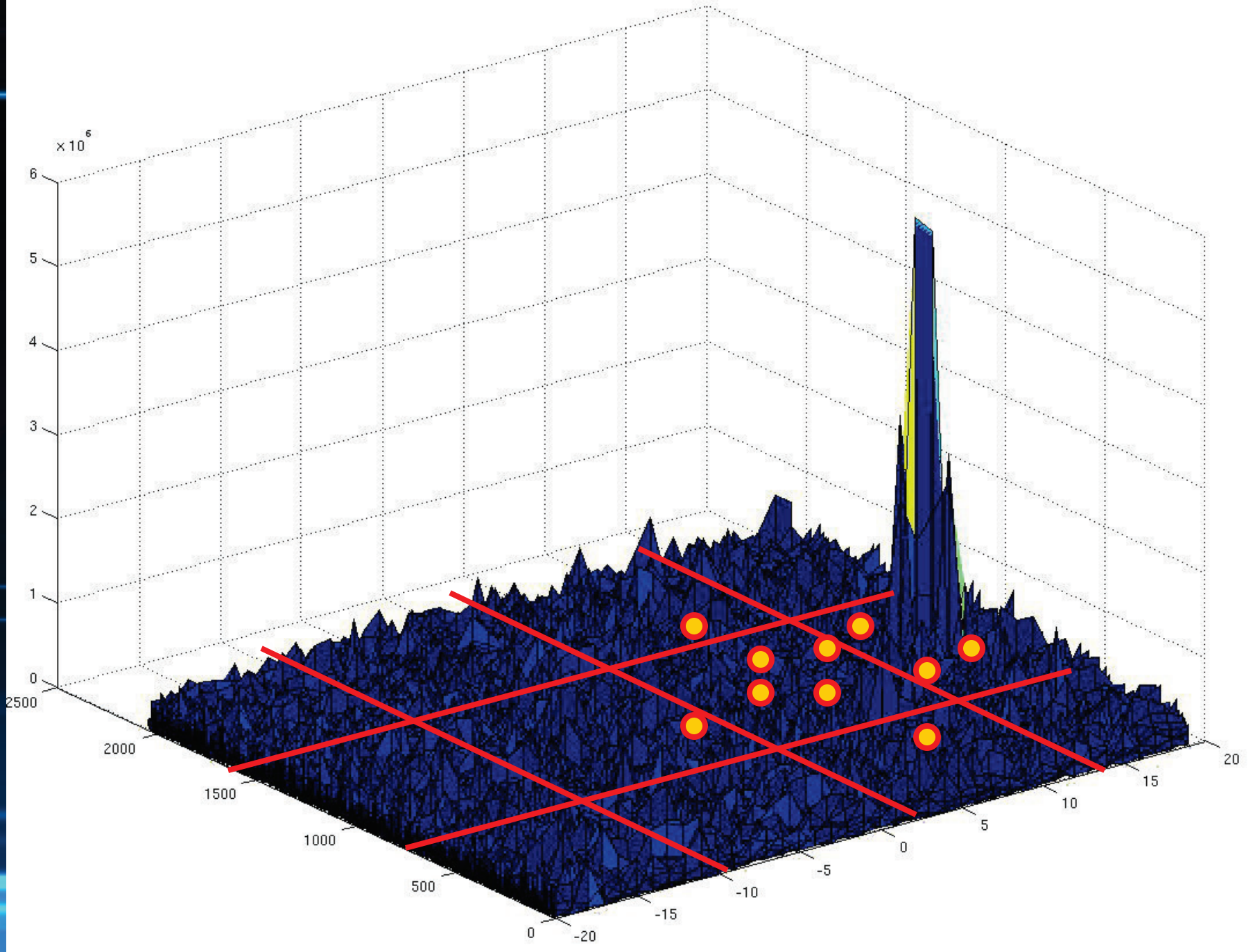
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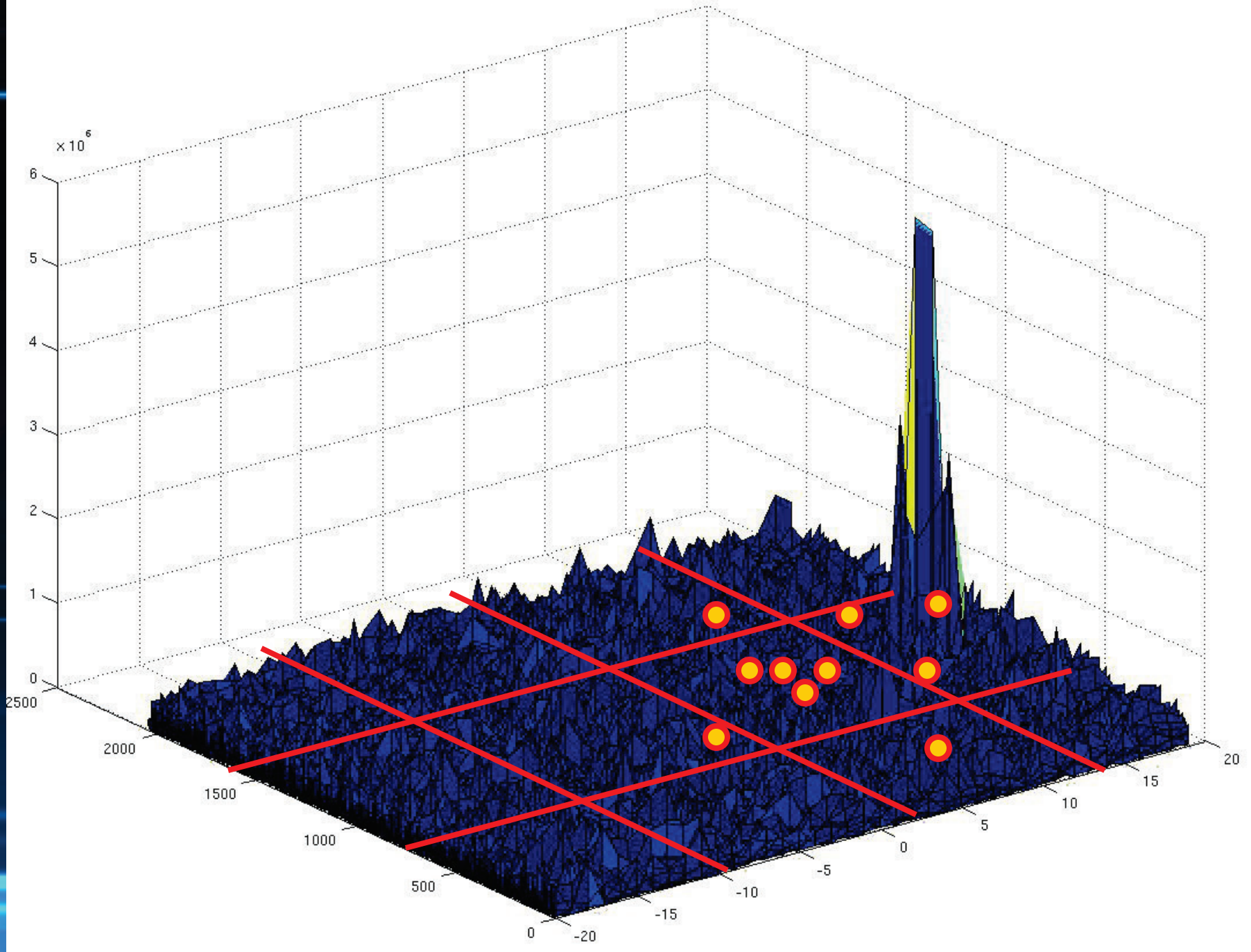
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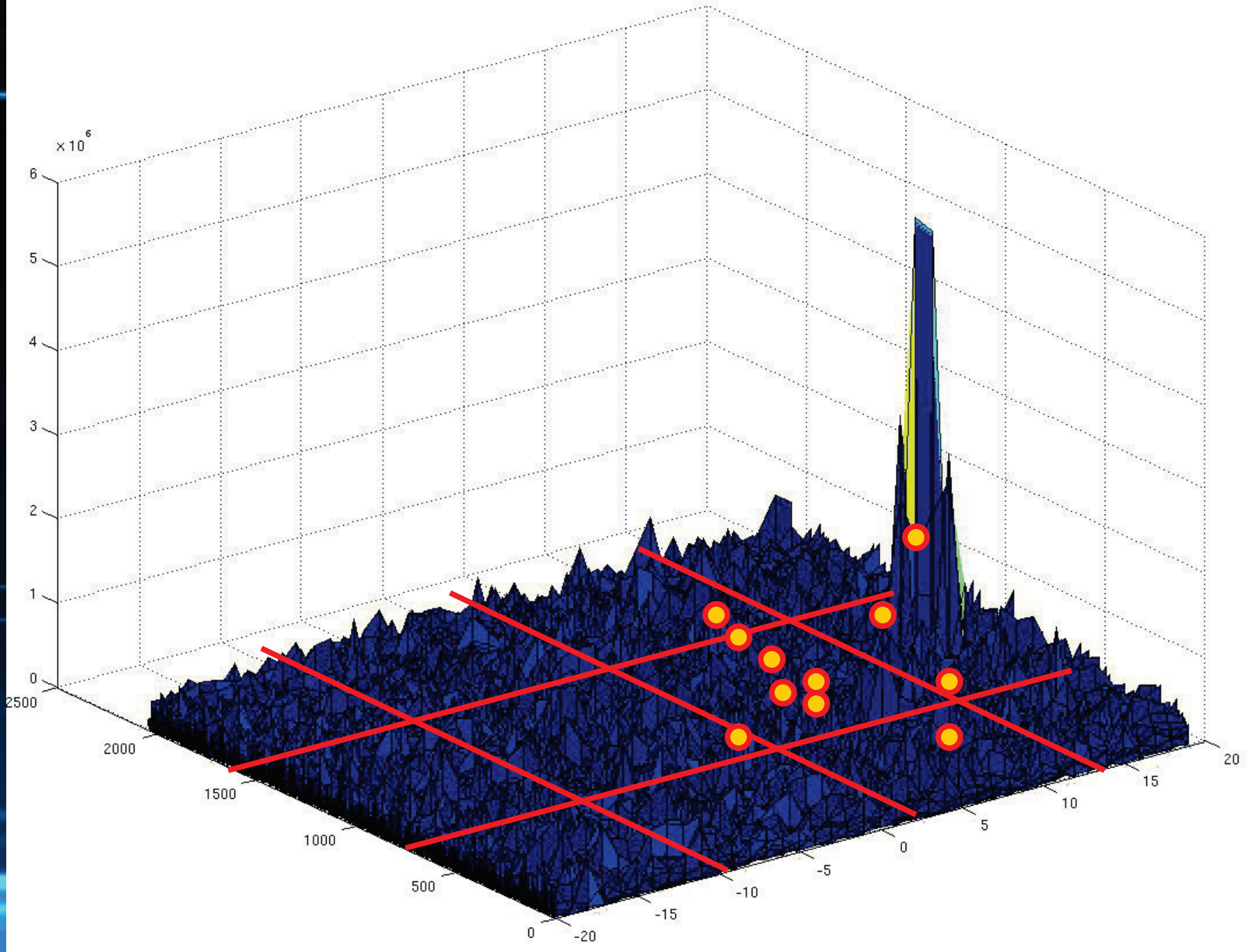
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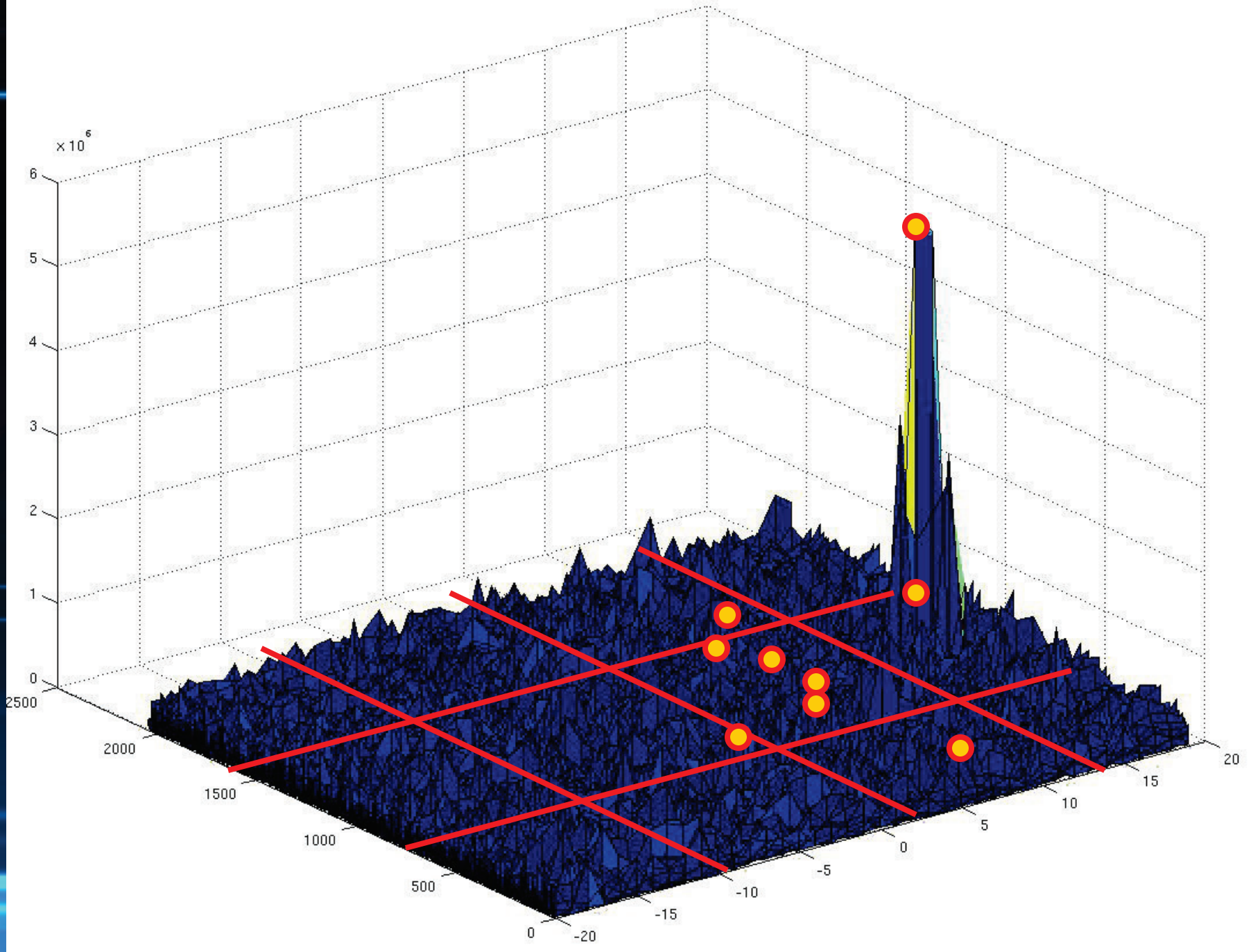
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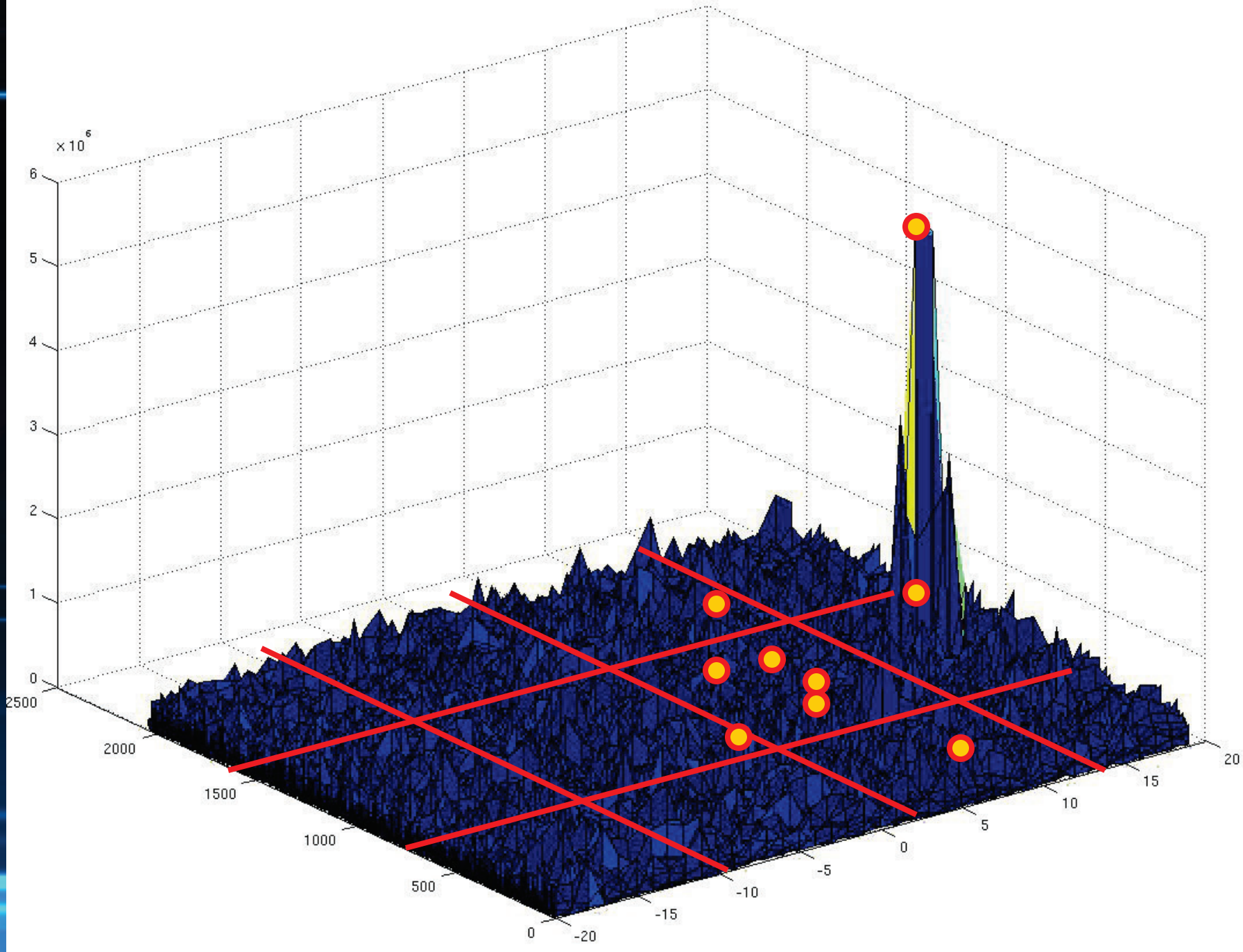
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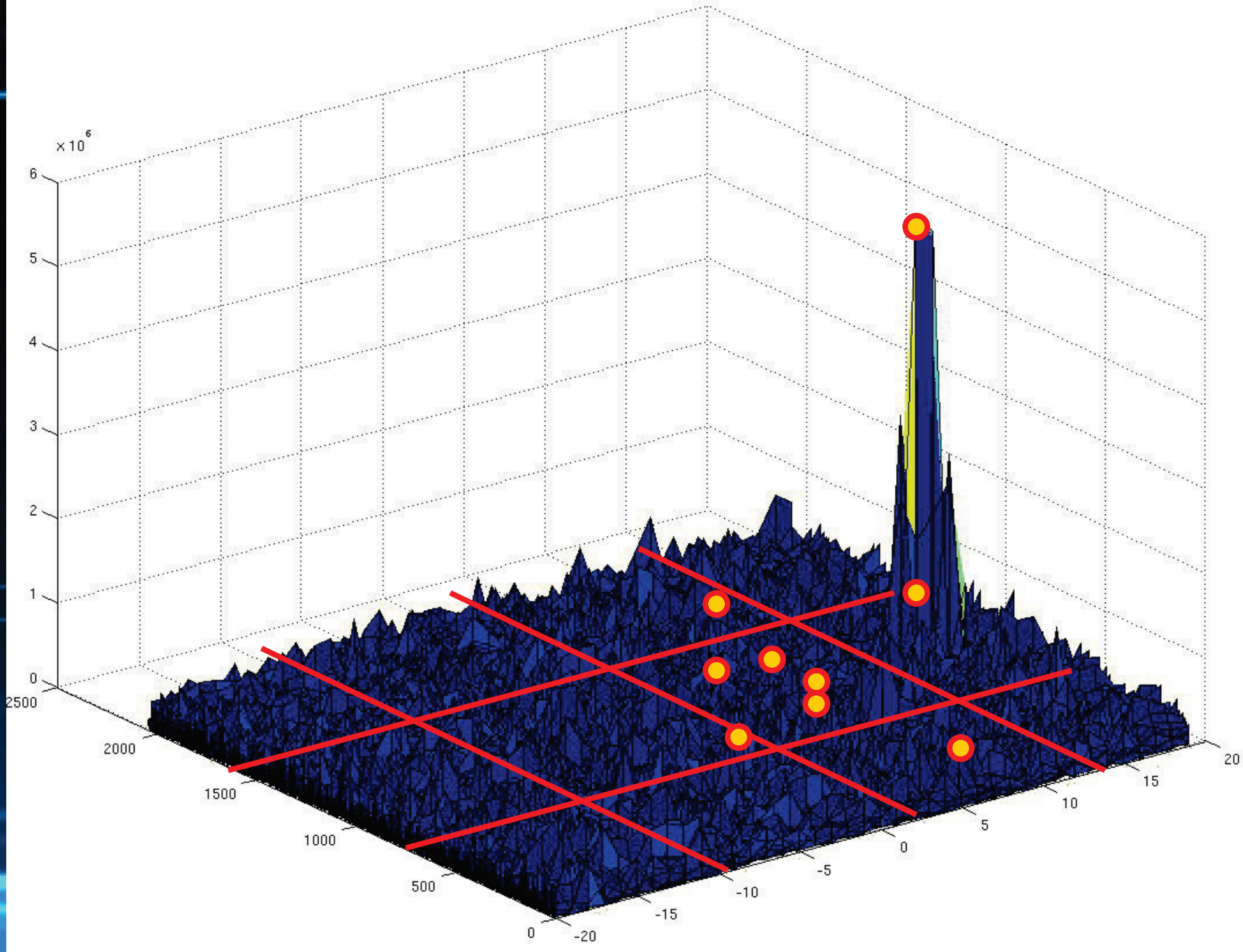
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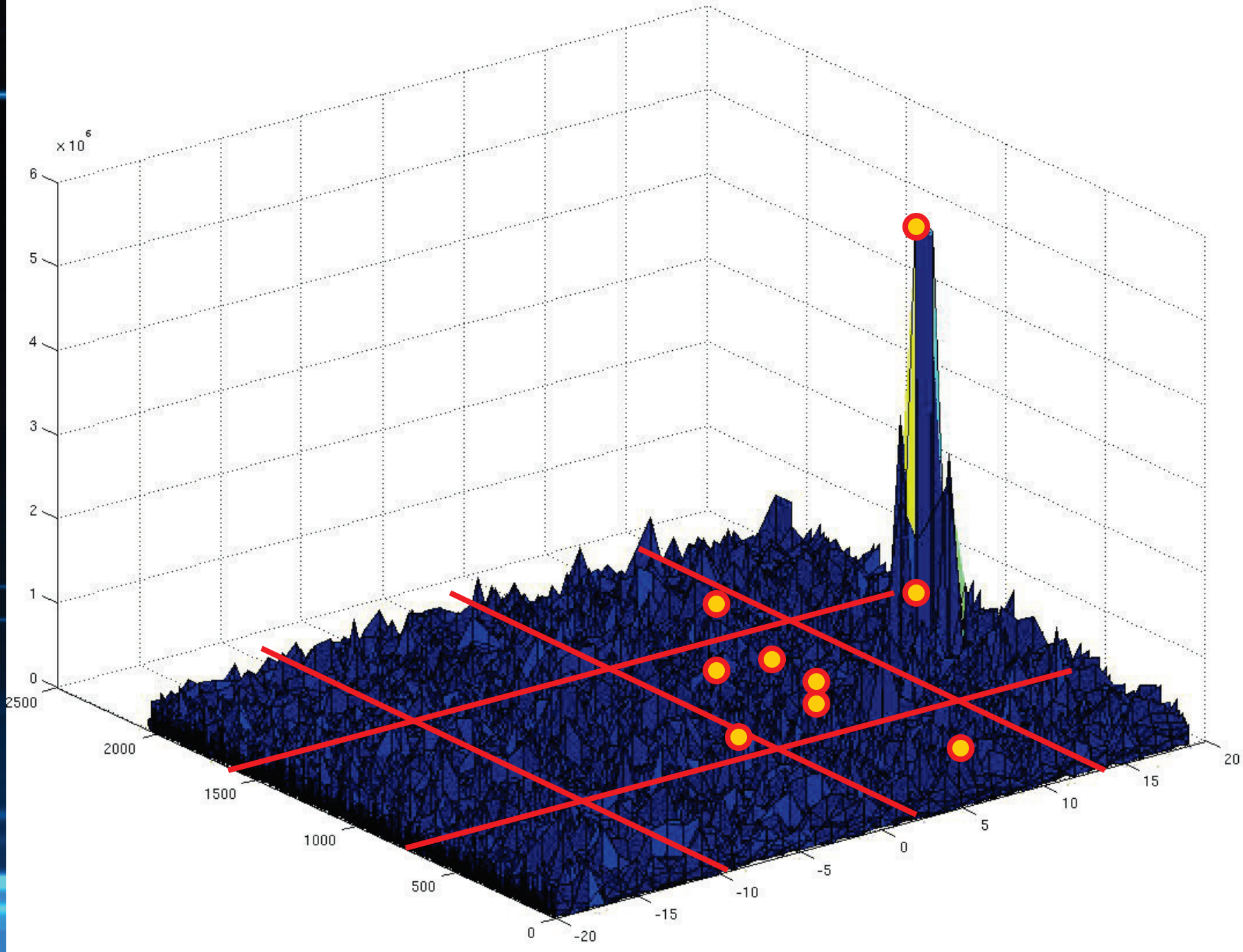
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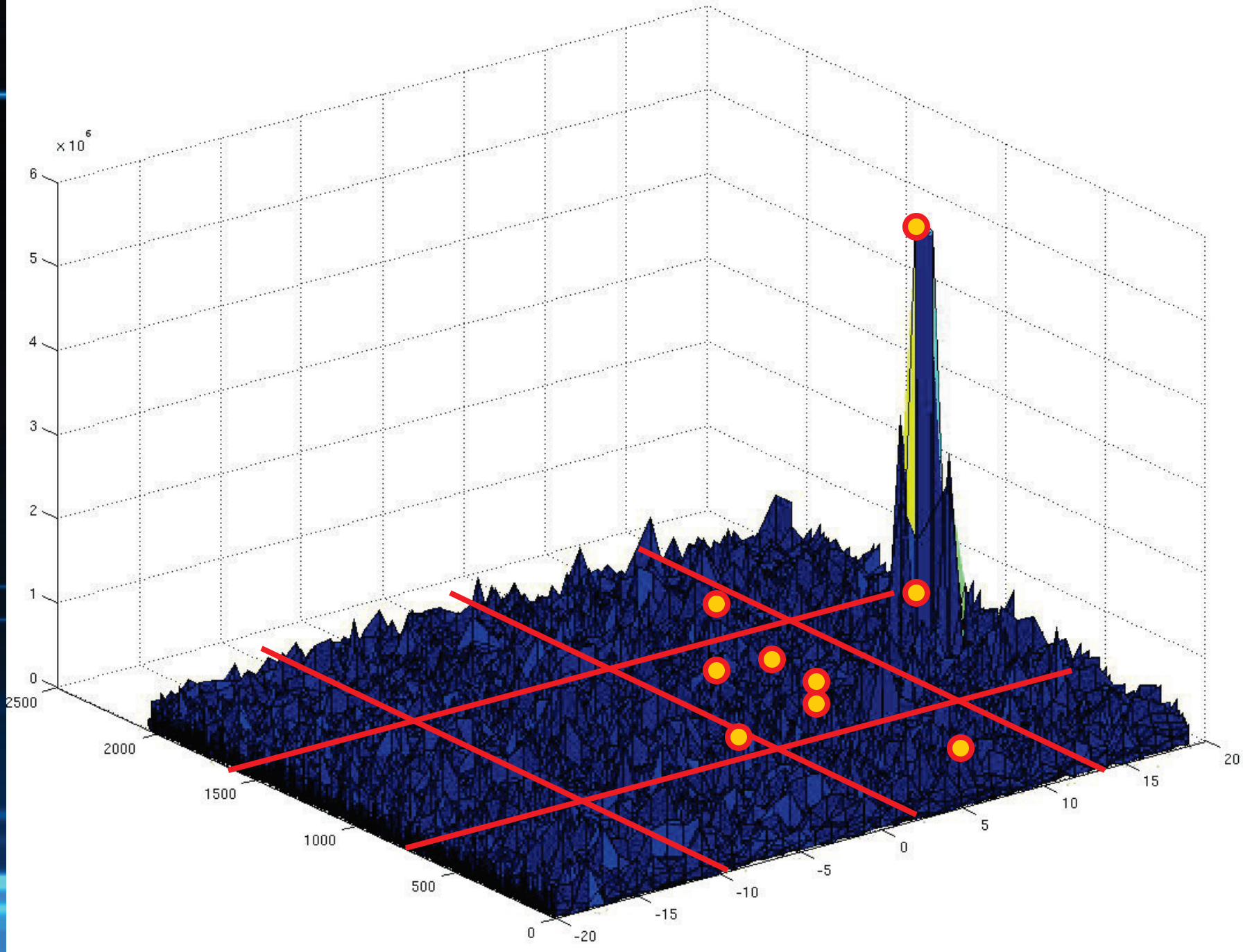
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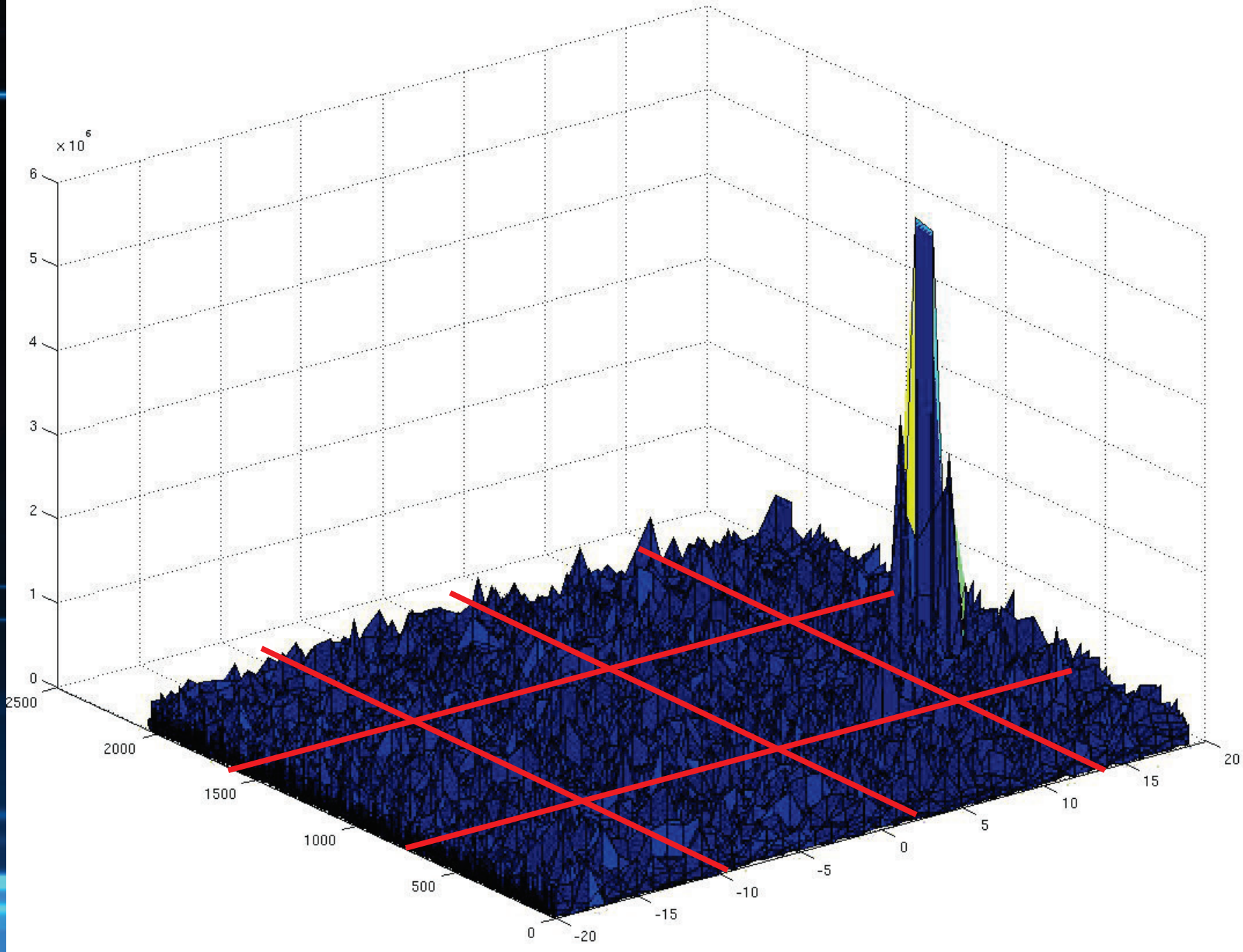
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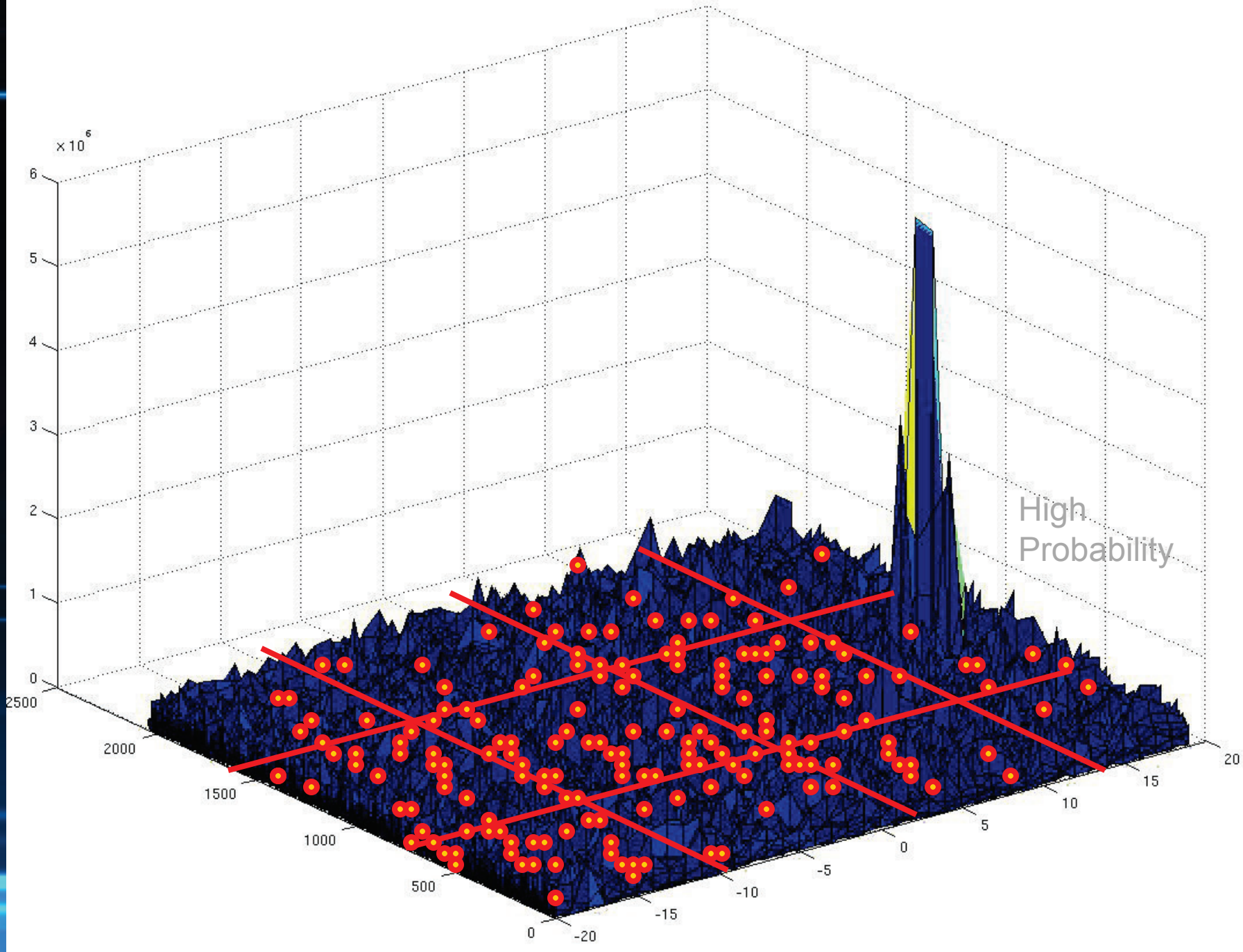
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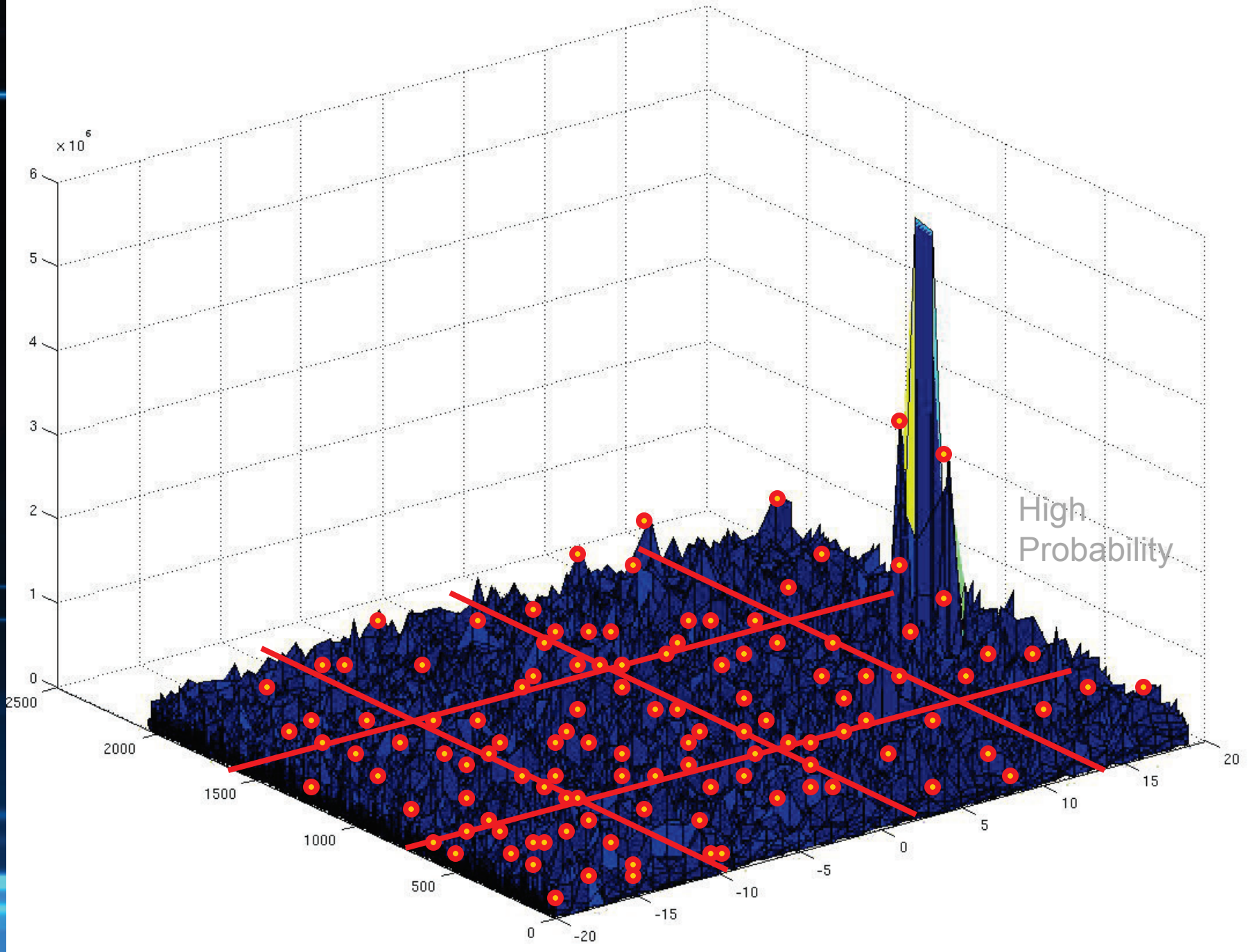
High
Probability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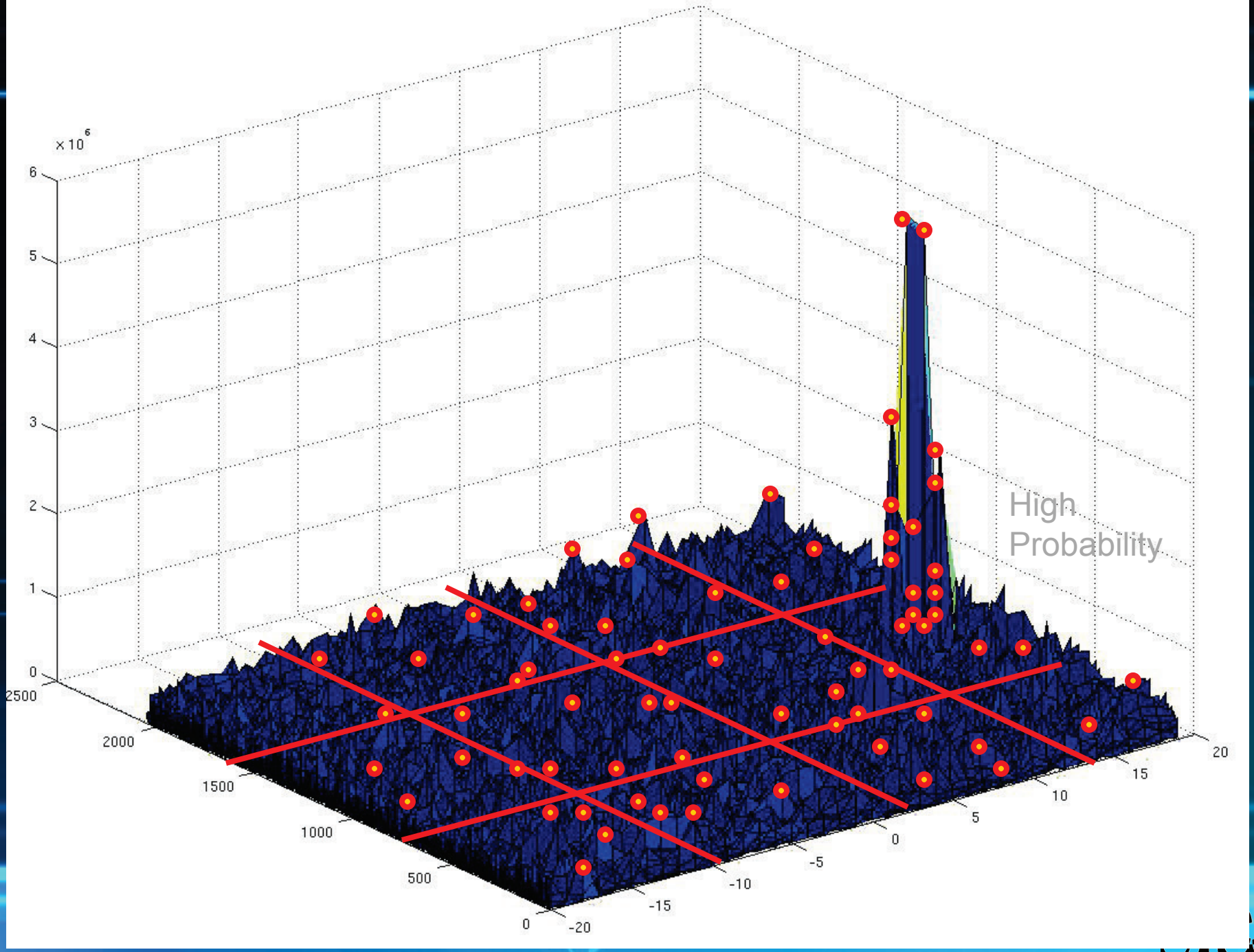
High
Probability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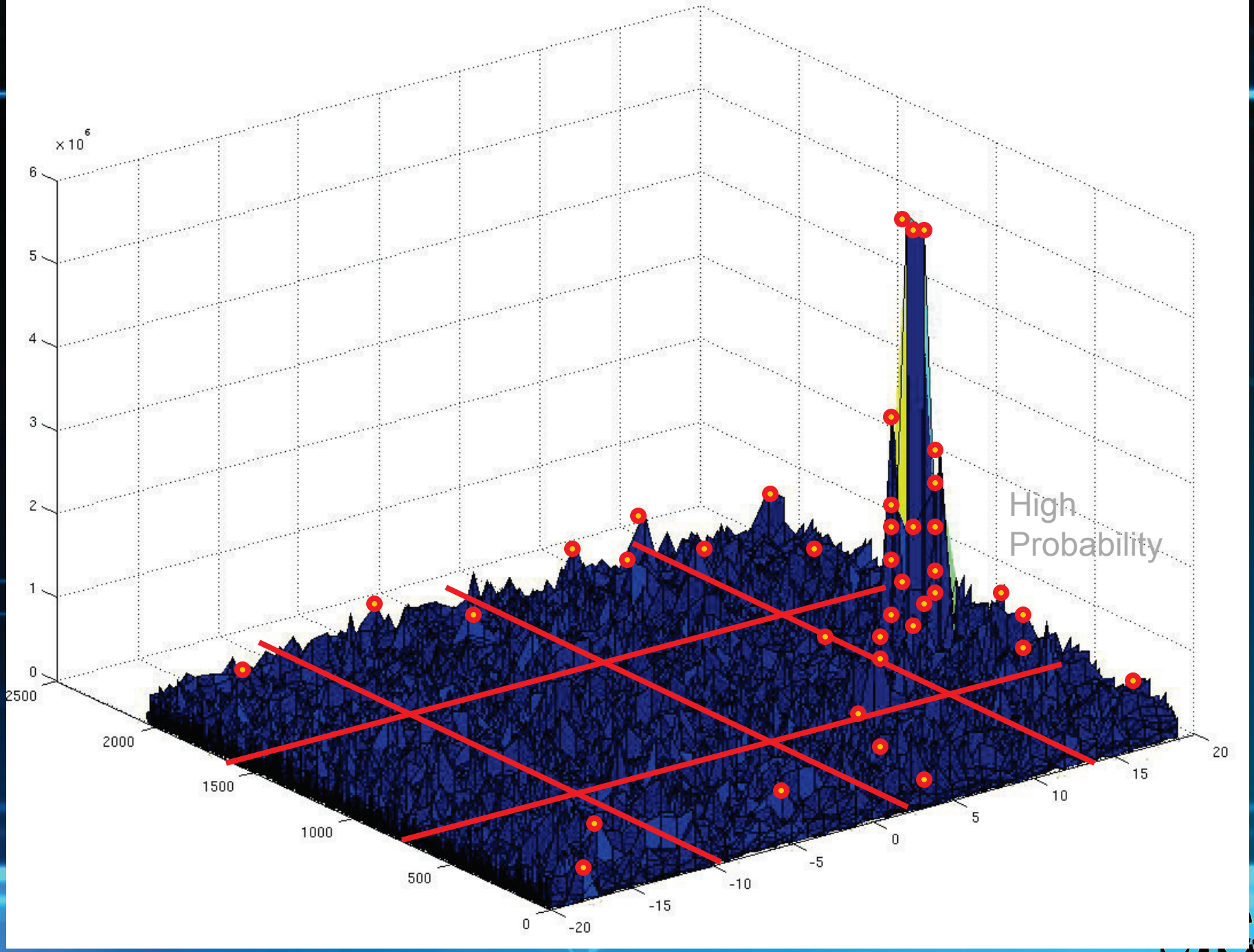
High
Probability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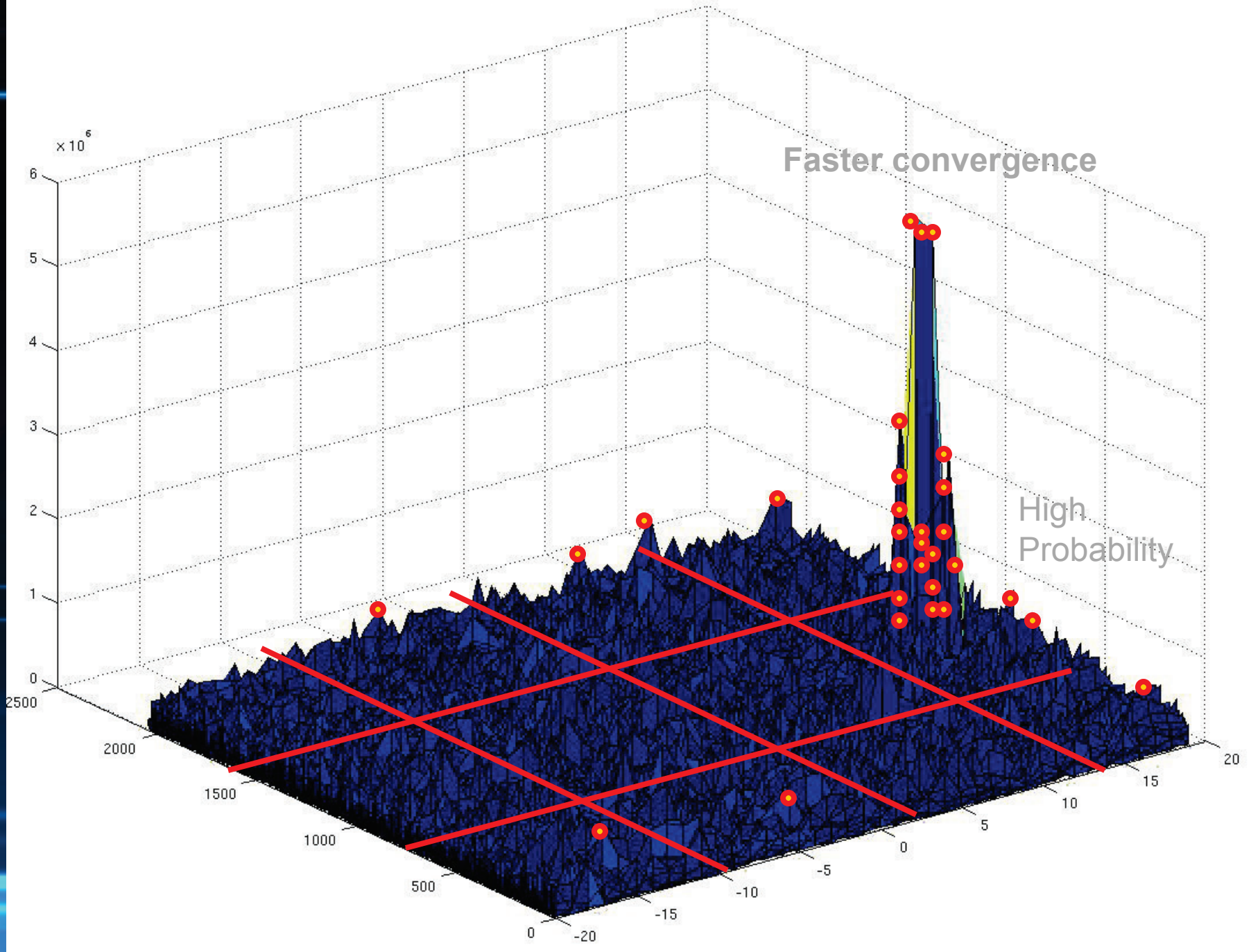
High
Probability


Faster convergence
High Probability
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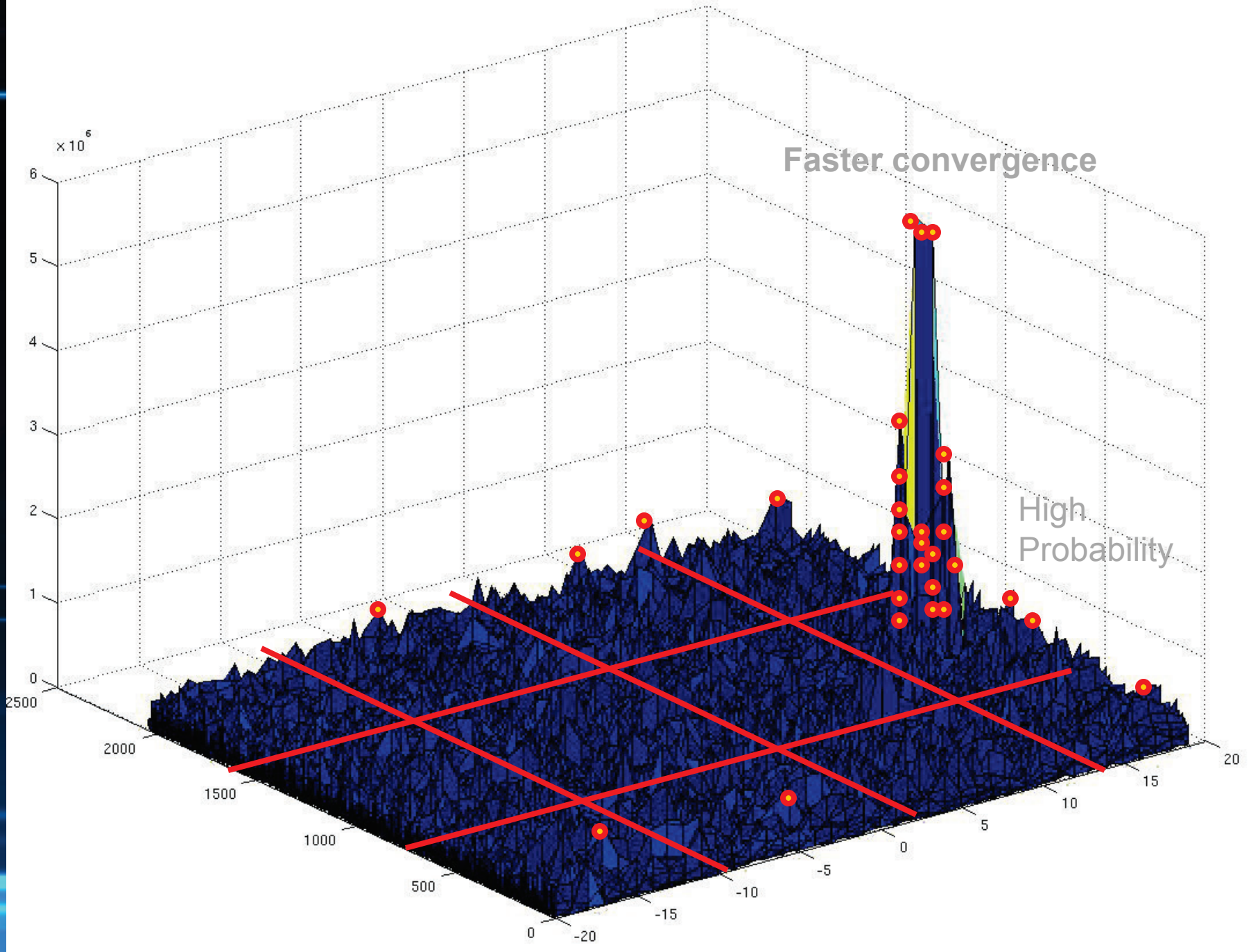
Faster convergence
High Probability
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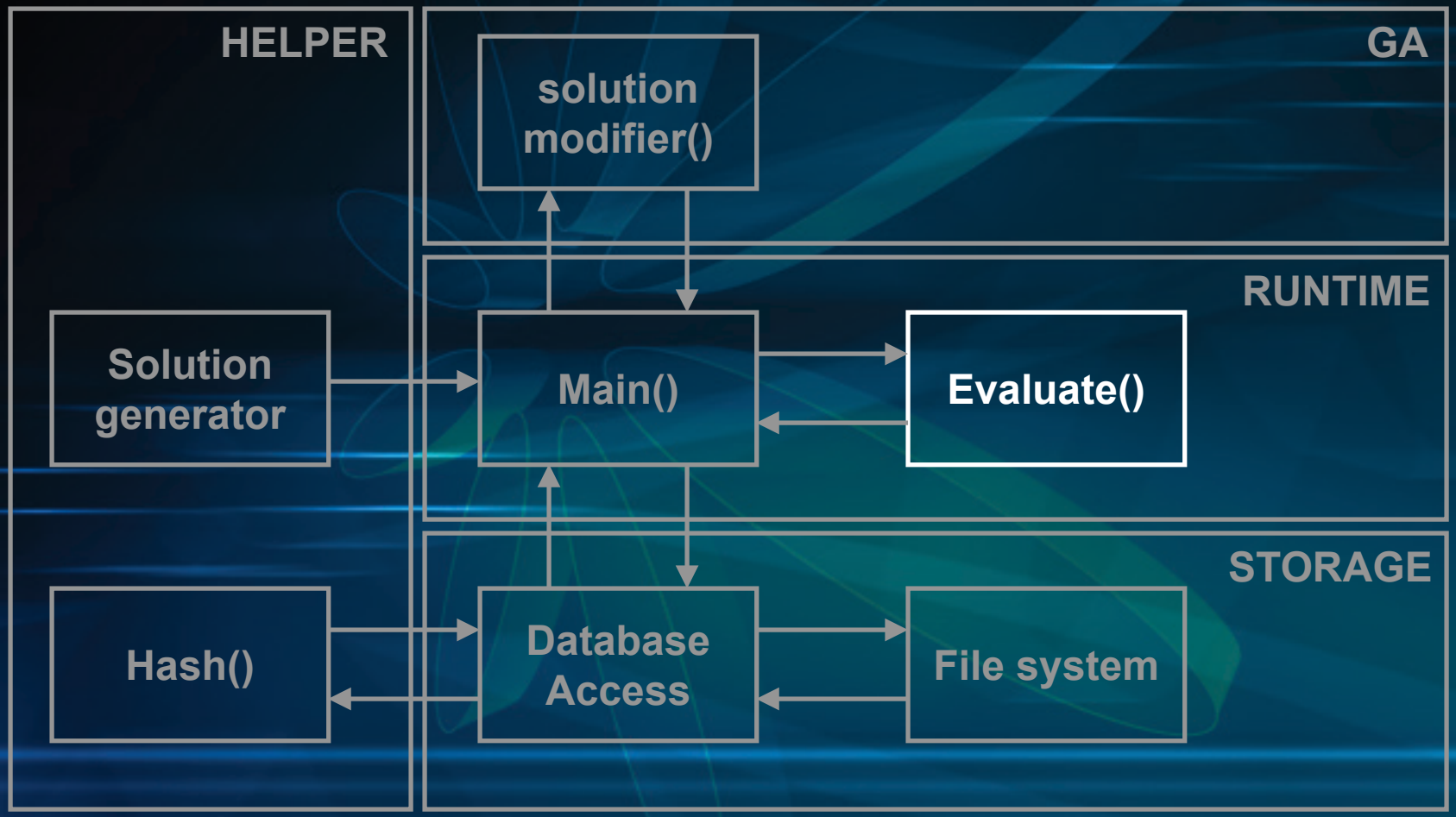
Simulation


HELPER
GA
solution modifier()
RUNTIME
Solution generator
Main()
Evaluate()
STORAGE
Hash()
Database Access
File system

Actuator Control

Command Data Packet:

	1 byte	1 byte	1 byte	1 byte
	Header	Data 1	Data 2	CHKSUM
(HEX)	F F	0-4 0-3	Pos: 00-FE	D1^D2&7F

	Command				Target Motor			
(BIN)	0	0	1	1	0	0	1	0

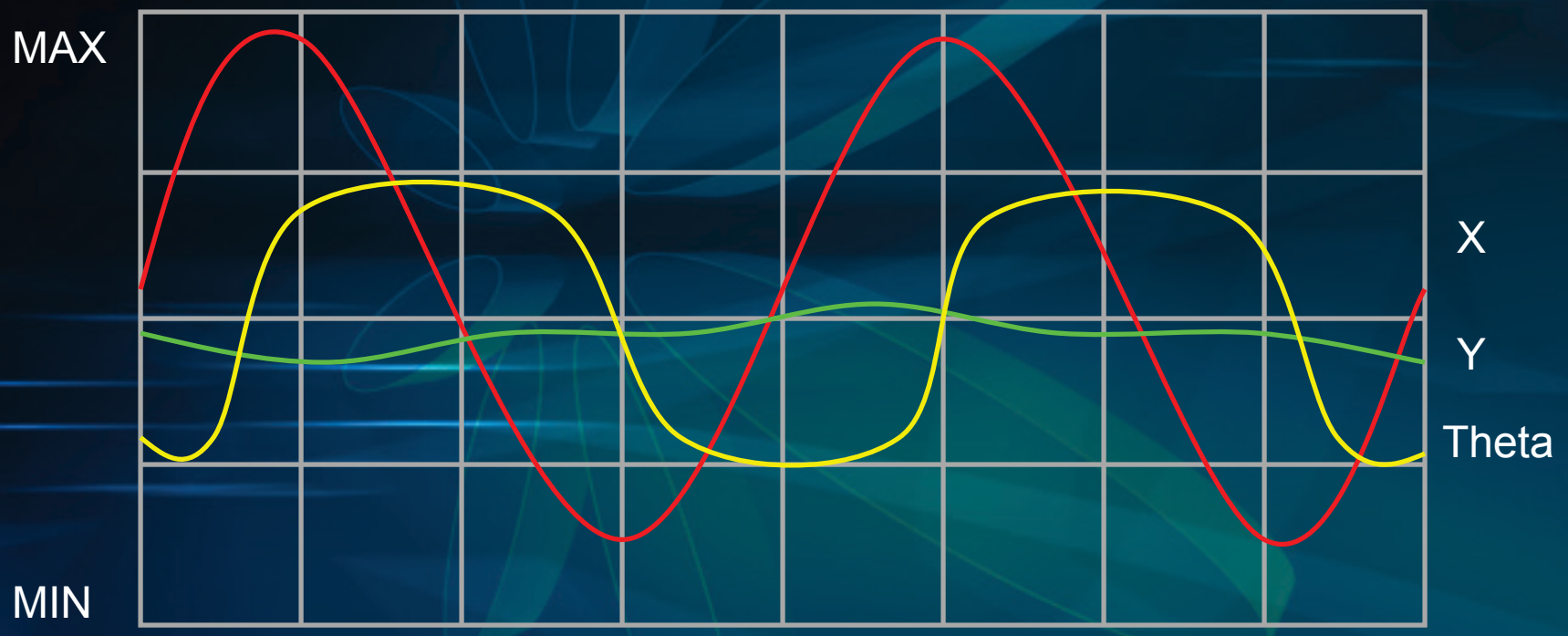
Control Matrix

DNA=[CMD1 POS1 T1 CMD2 POS2 T2 CMD3 POS3 T3 …]

Command (byte)	Position (byte)	Delay (byte)
Cmd 1	Pos 1	T1
Cmd 2	Pos 2	T2
Cmd 3	Pos 3	T3
…	…	…

SACS

Positioning Signals



Example (Analog signal)

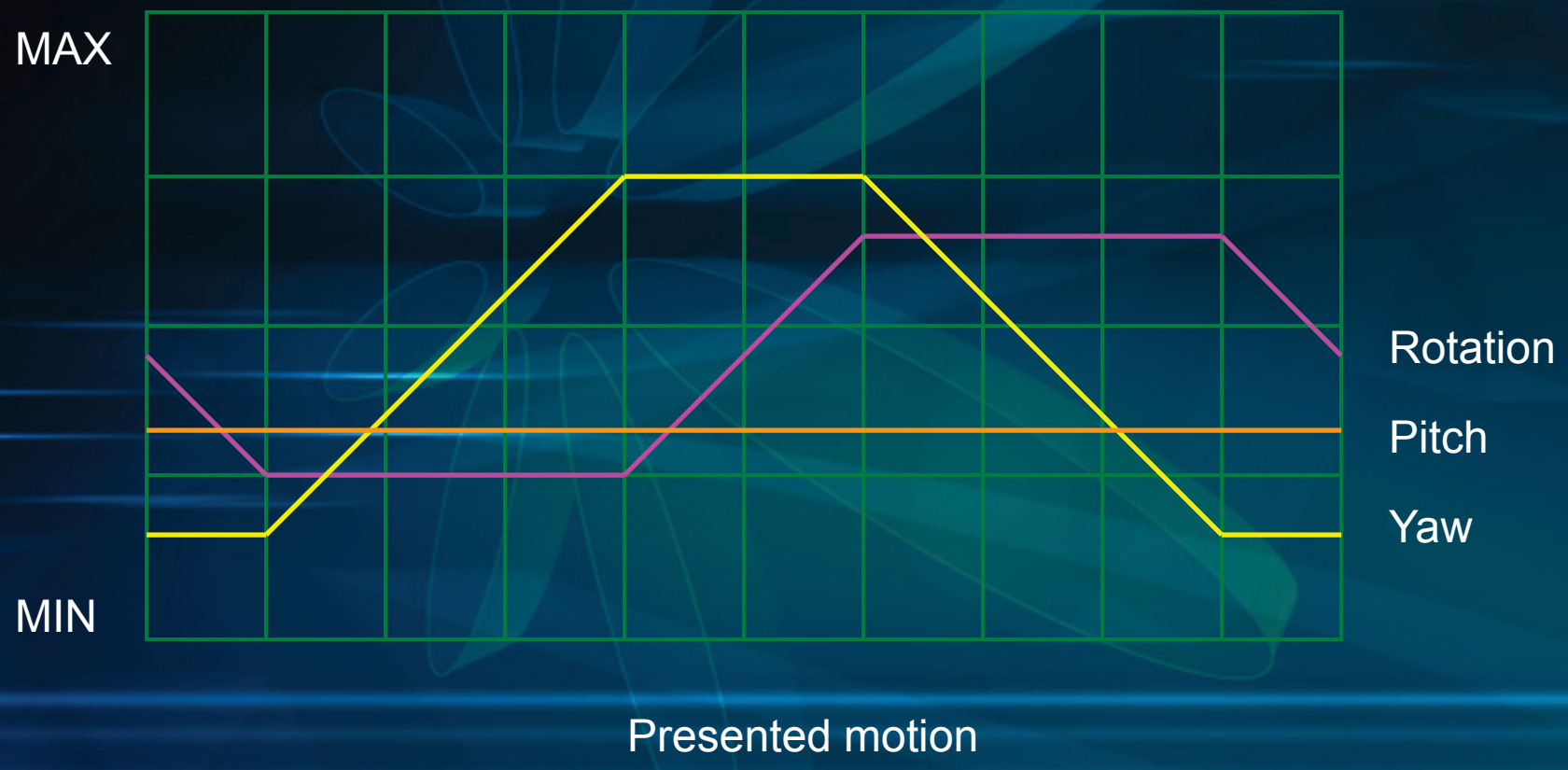
Example

CMD (h)	POS (h)	T (ms)	
20	50	300	**Chromosome 1**
22	40	200	**Chromosome 2**
20	B6	300	**Chromosome 3**
22	C0	200	**Chromosome 4**

DNA=20 50 30 22 40 20 20 B6 30 22 C0 20

x x x x

Digital Positioning Signals



Simulation

1st Mapping of matrix codes into vectors and movements

2nd Performance evaluation into simulated environment

3rd Classification and processing of partial solutions, applying GA

SACS

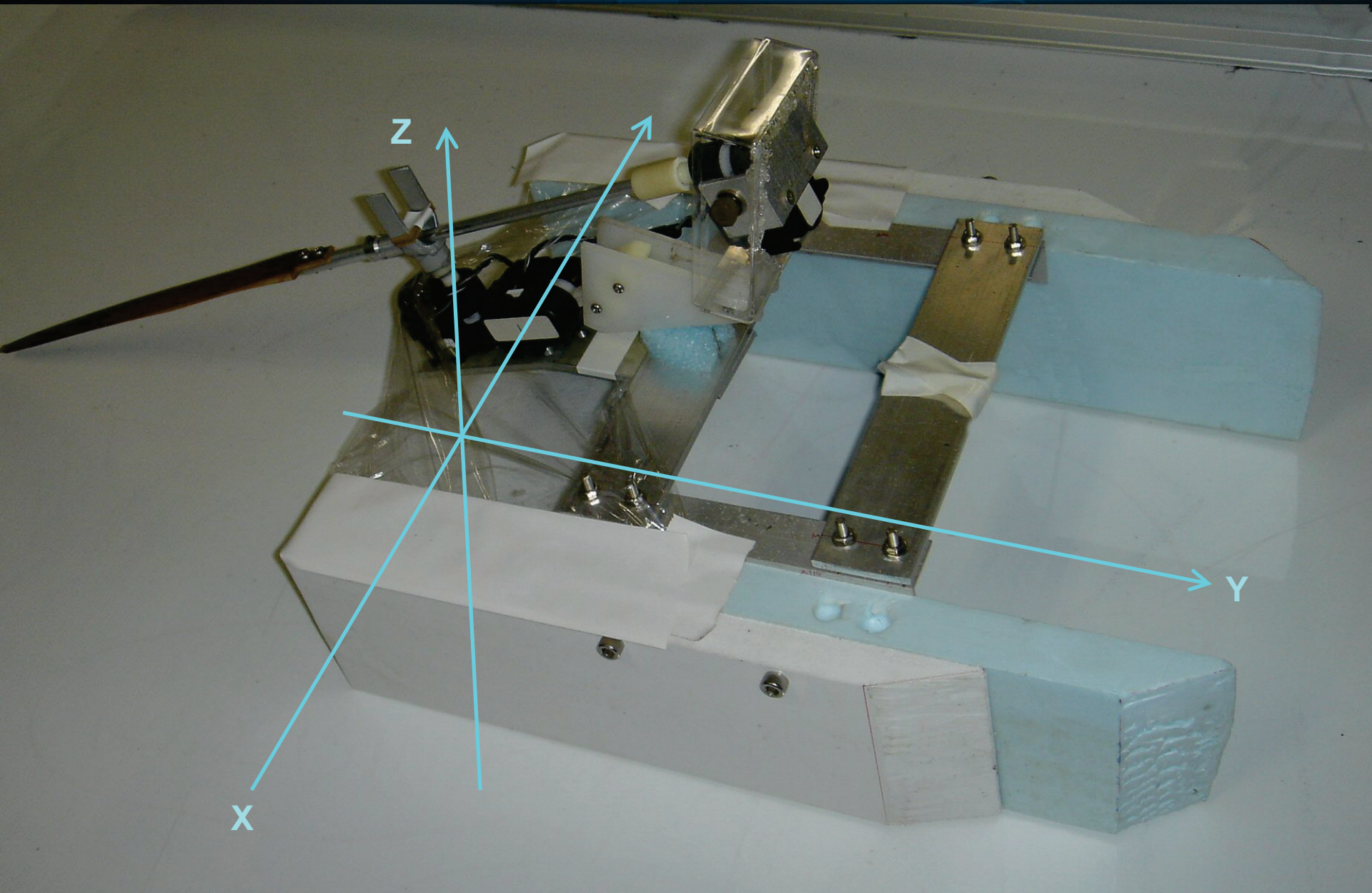
Simulation

To reduce computation time, the following approximations were done:

- Fixed position
- Considering always the steady state (fluid speed remains unchanged)
- Approach for infinitesimal transitions
- Angular speed is constant for all motors
- Considering a flat Ro surface on both sides

SACS

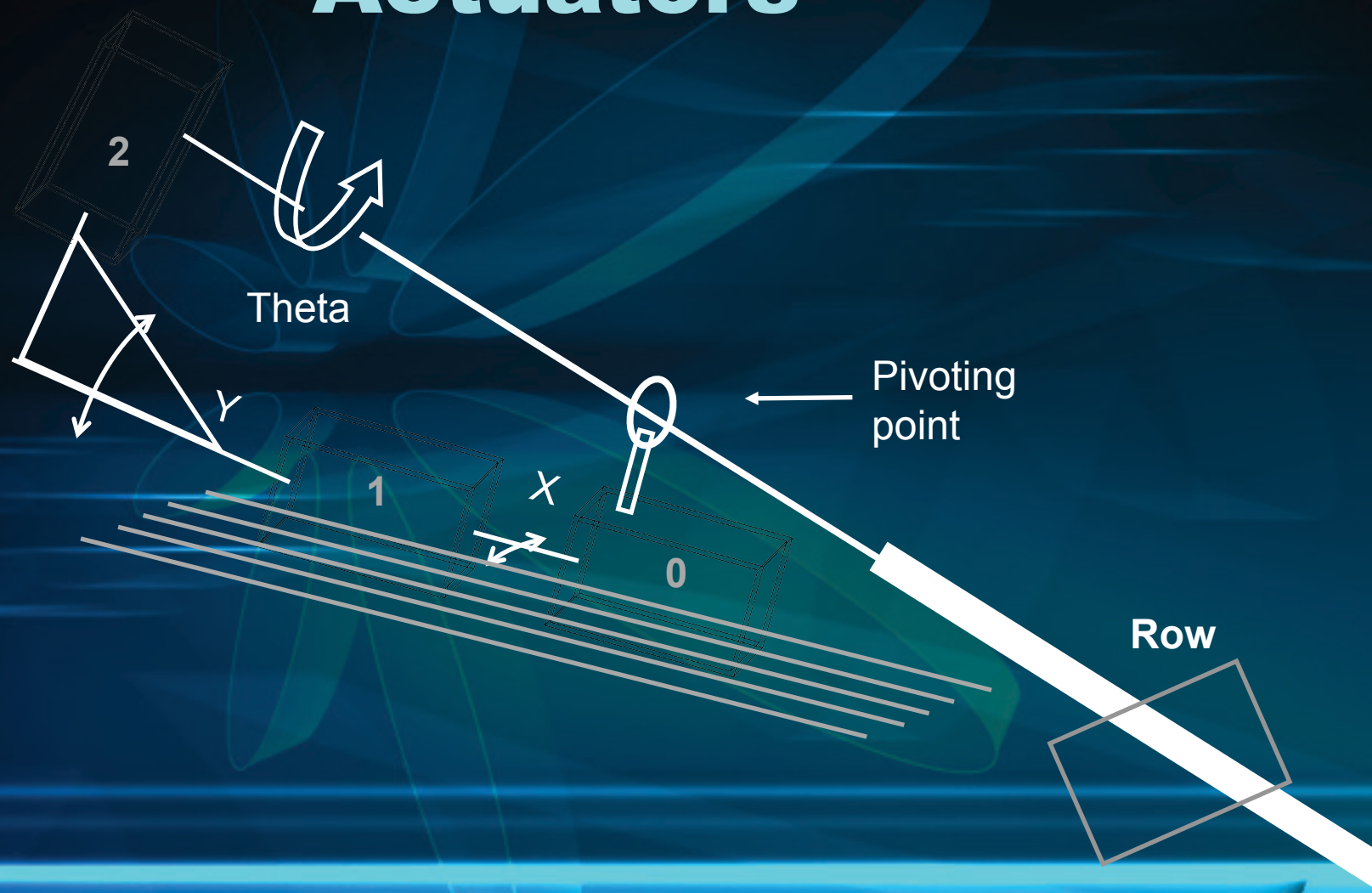
Coordinate System



Position Mapping

Motor	Vmin (hex)	Vmax (hex)	Vmin (dec)	Vmax (dec)	Positions	Min (rad)	Max (rad)	Aperture
0	40	C0	**64**	**192**	128	-0.62	0.62	71°
1	70	8A	**112**	**138**	26	-0.32	0	18 °
2	00	FE	**0**	**254**	255	-Pi	Pi	180 °

Actuators



Simulation

By the Bernoulli principle, we have:

$$\vec{F} = \left(\vec{L} + \vec{D}\right) = \oint_{\partial\Omega} p\vec{n}d\partial\Omega$$

Where:

F= (Thrust related) Force

L=Lift

D=Drag

p is the value of the pressure,

$\partial\Omega$ is the frontier of the domain,

$\vec{n}$ is the normal to the profile.

Simulation

By the Bernoulli equations, we have:

$$\vec{F}t = \left(\vec{L}t + \vec{D}t\right) = \sum_{T}\sum_{\Omega} p\vec{n}d$$

Where:

Ft= Total Impulse

Lt= Total Lift

Dt=Total Drag

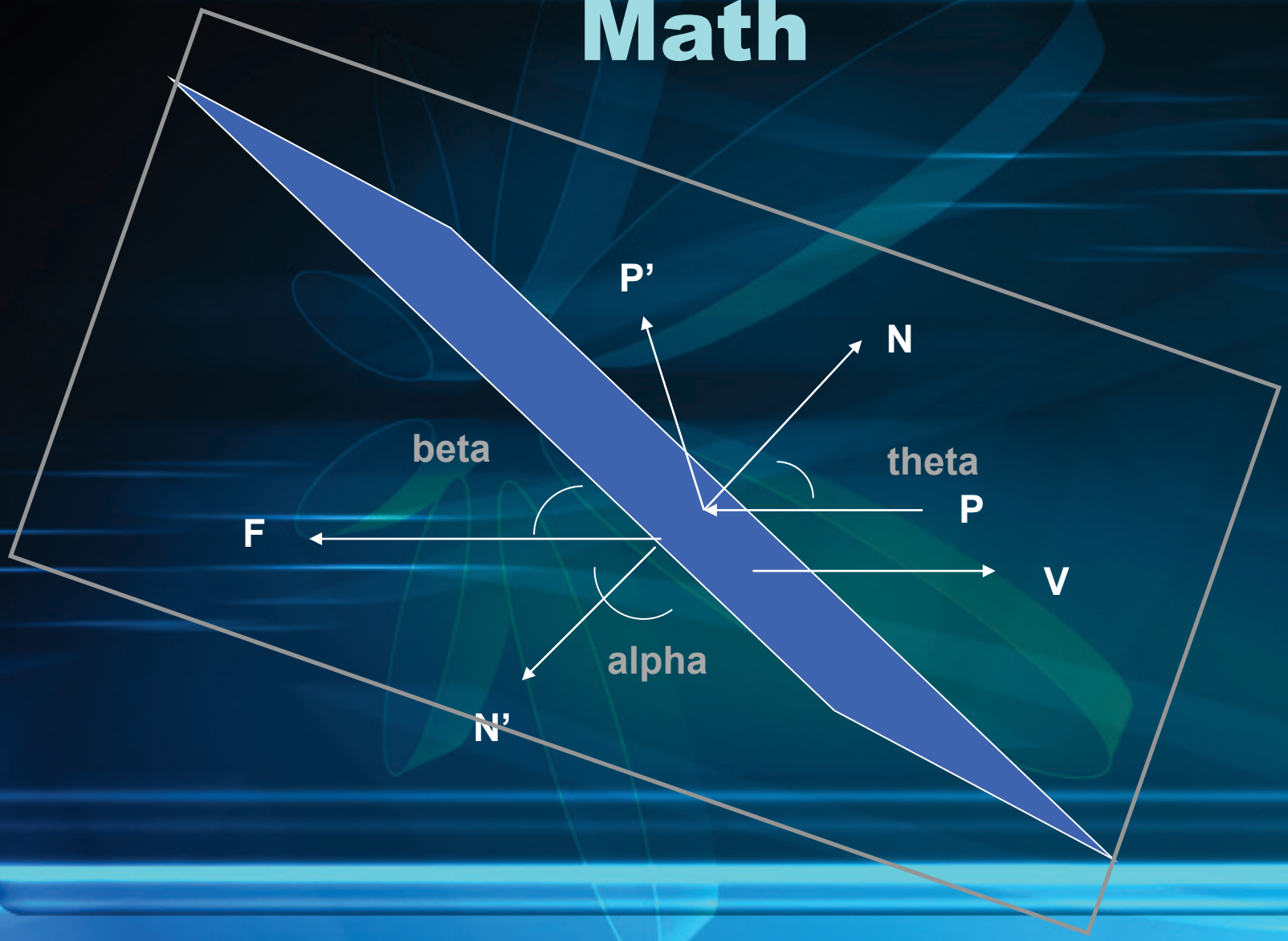
p is the value of the pressure,

Ω is evaluated segment,

$\vec{n}$ is the normal to the profile.

SACS

Math



Translation

$$\text{alpha} = \frac{\text{M0-127}}{89.141} \text{ radians}$$

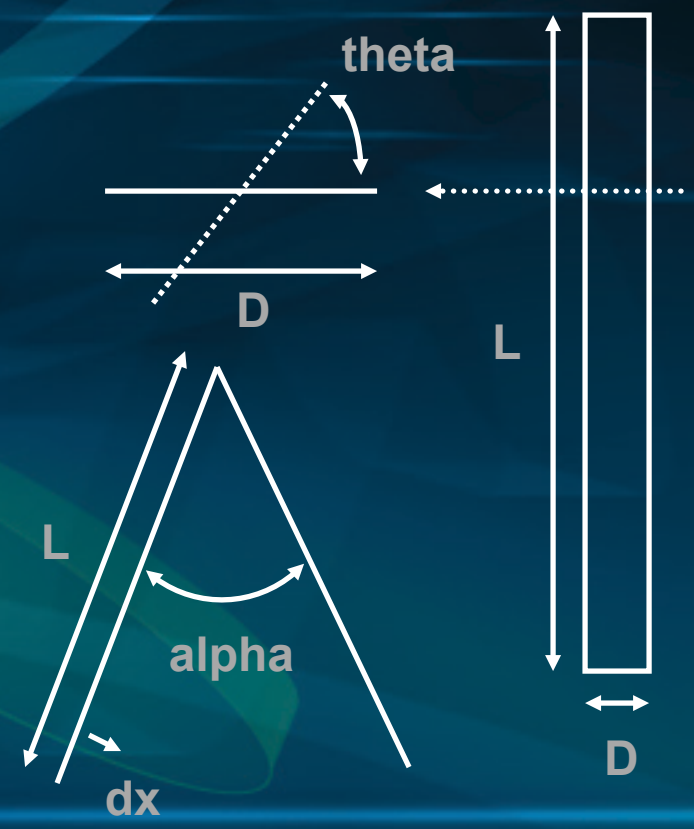
$$\text{beta} = -(\text{M1-112})*\text{pi}/180$$

$= -\ 0.7854$ radians

$$\text{theta} = \frac{\text{M2-127}}{84.667} \text{ radians}$$

$$d(t) = p(t=t)-p(t=t-1)$$

$$r = \text{sum}([L*D]*\sin(\text{theta})*dx)$$



Translation

M1 X-axis rotation

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta_x & -\sin\theta_x & 0 \\ 0 & \sin\theta_x & \cos\theta_x & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

beta

M2 Y-axis rotation

$$\begin{bmatrix} \cos\theta_y & 0 & \sin\theta_y & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta_y & 0 & \cos\theta_y & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

M0 Z-axis rotation

$$\begin{bmatrix} \cos\theta_z & -\sin\theta_z & 0 & 0 \\ \sin\theta_z & \cos\theta_z & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

alpha

$\vec{n}$ = (0, 0, 1)*RY*RX*RZ

$$\vec{F} = \sum_n \frac{\hat{n} \bullet \vec{w}}{\hat{n} \bullet \hat{n}} * \hat{n}$$

$$Impulse = \|\vec{F}\|$$

$$Direction = \hat{F}$$

Translation

X-axis rotation

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta_x & -\sin\theta_x & 0 \\ 0 & \sin\theta_x & \cos\theta_x & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Y-axis rotation

$$\begin{bmatrix} \cos\theta_y & 0 & \sin\theta_y & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta_y & 0 & \cos\theta_y & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Z-axis rotation

$$\begin{bmatrix} \cos\theta_z & -\sin\theta_z & 0 & 0 \\ \sin\theta_z & \cos\theta_z & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

beta

alpha

Y-ROT

X=sin(th)

Y=0

Z=cos(th)

X-ROT

X=sin(th)

Y=-cos(th)*sin(bt)

Z=cos(th)*cos(bt)

Z-ROT

X=sin(th)cos(aph)+cos(th)sin(bt)sin(aph)

Y=sin(th)sin(aph)-cos(th)sin(bt)cos(aph)

Z=cos(th)cos(bt)

Translation

M1 X-axis rotation

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta_x & -\sin\theta_x & 0 \\ 0 & \sin\theta_x & \cos\theta_x & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

beta

M2 Y-axis rotation

$$\begin{bmatrix} \cos\theta_y & 0 & \sin\theta_y & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta_y & 0 & \cos\theta_y & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

M0 Z-axis rotation

$$\begin{bmatrix} \cos\theta_z & -\sin\theta_z & 0 & 0 \\ \sin\theta_z & \cos\theta_z & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

alpha

$\vec{p}(t) = (0, 1, 0)*RX*RZ$

$\vec{d} = \vec{p}(t)-\vec{p}(t-1)$

Translation

X-axis rotation

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta_x & -\sin\theta_x & 0 \\ 0 & \sin\theta_x & \cos\theta_x & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

beta

X-ROT

X=0

Y=cos(bt)

Z=sin(bt)

Y-axis rotation

$$\begin{bmatrix} \cos\theta_y & 0 & \sin\theta_y & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta_y & 0 & \cos\theta_y & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Z-ROT

X=-cos(bt)sin(aph)

Y=cos(bt)cos(aph)

Z=sin(bt)

Z-axis rotation

$$\begin{bmatrix} \cos\theta_z & -\sin\theta_z & 0 & 0 \\ \sin\theta_z & \cos\theta_z & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

alpha

SACS

Simulation

The simulation returns a 3D vector for total thrust over time (Ft):

$$\vec{F}t = \sum_{T} \left(F_X, F_Y, F_Z \right) = \left(X_T, Y_T, Z_T \right)$$

Integral over time of all produced thrust for T (simulated period)

Fitness

The fitness for each direction is obtained projecting the vector into the desired direction

$$Fitness = \sum_{T} \vec{F} \cdot \hat{d} = \vec{F}t \cdot \hat{d}$$

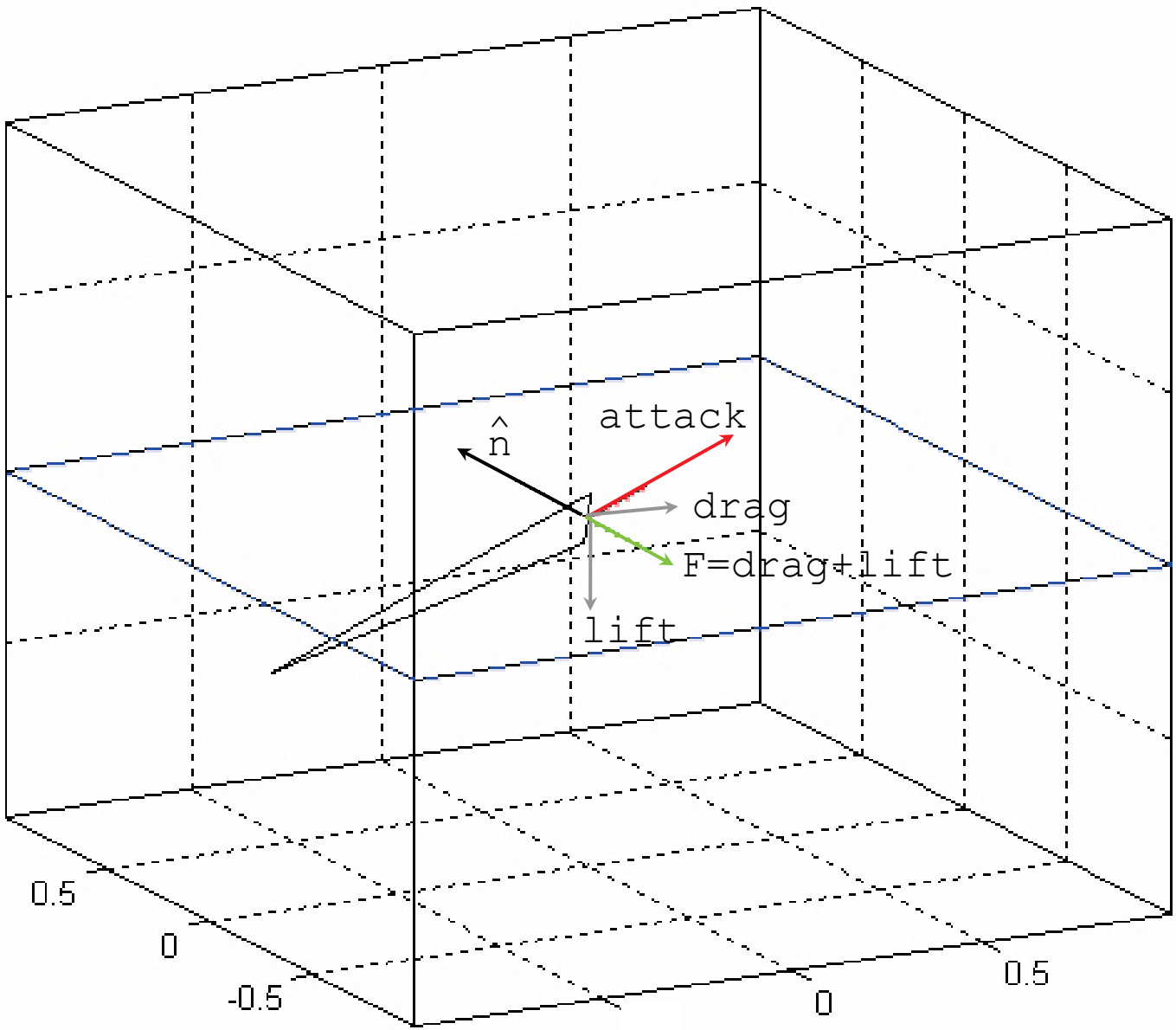
Where

Ft=Total Thrust over time

F=Resulting force

d=unitary vector in the direction of evaluation

SACS


n̂
attack
drag
F=drag+lift
lift
0.5
0
-0.5
0
0.5

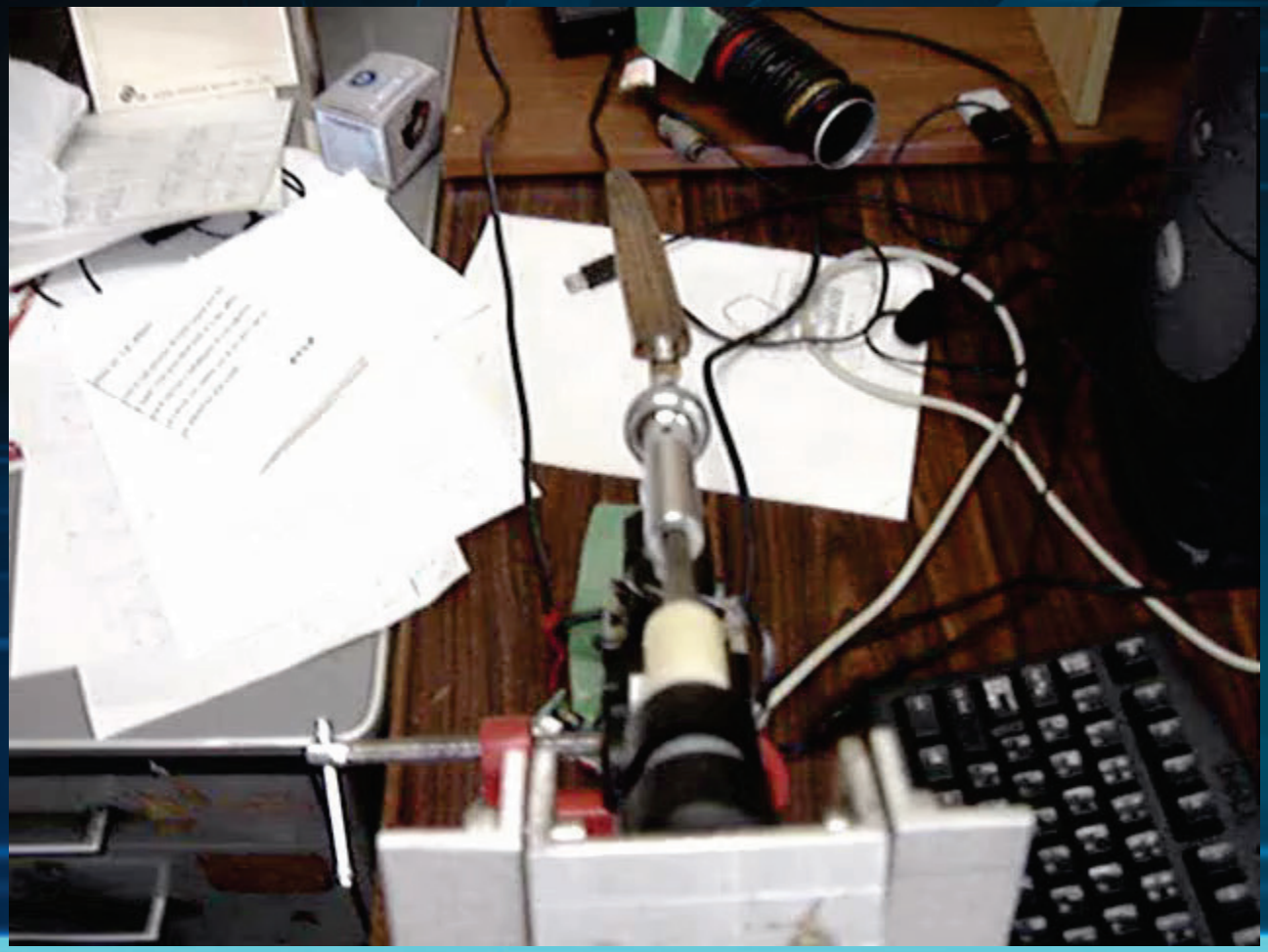
Validation

- To validate the simulated model, we compare the thrust generated by one control in the simulation to the one generated by the same control in the actual model

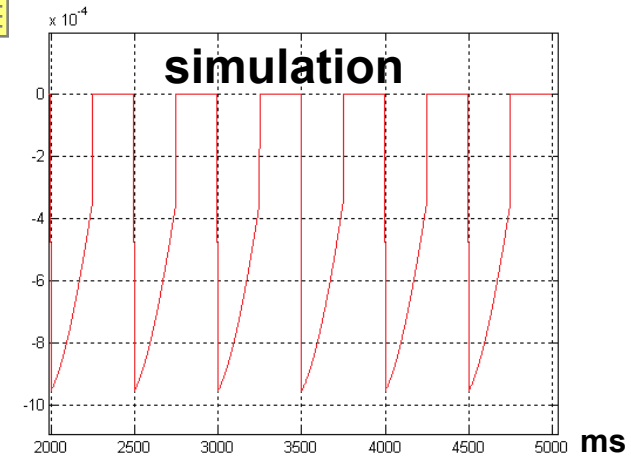
SACS

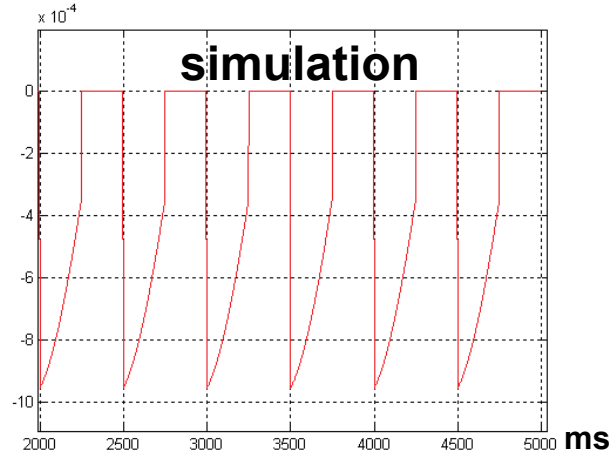
Calibrating

Rowing

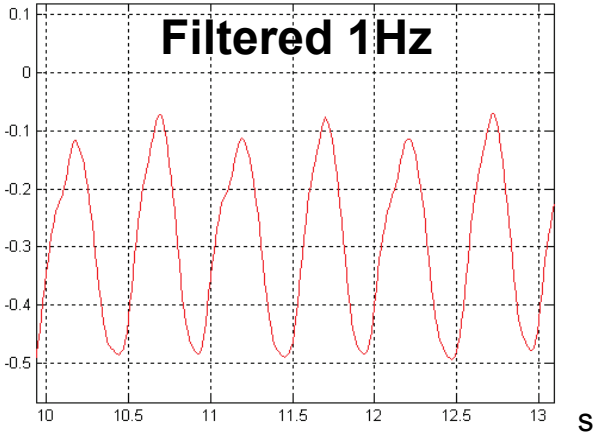


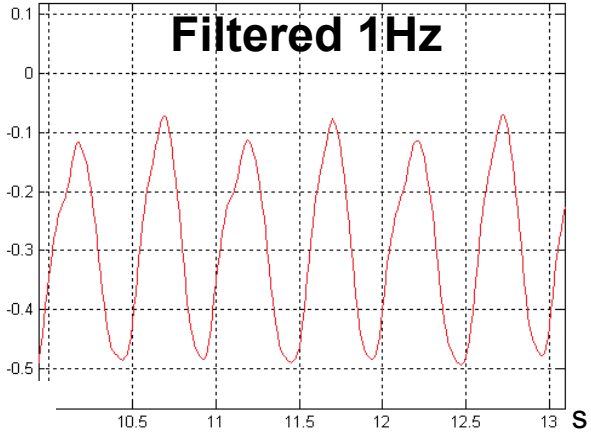
Analysis





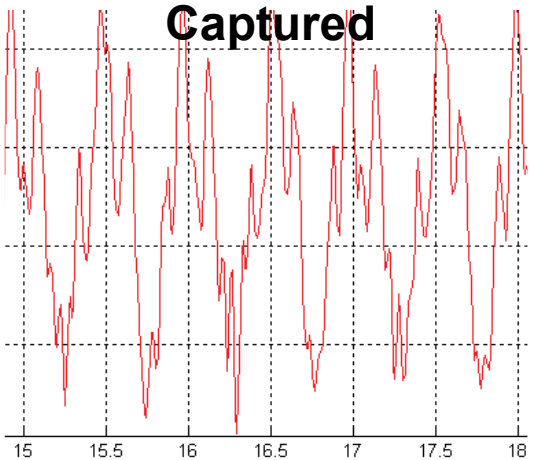
Simulation
Frequency = 1Hz
1 cycle = 2 attacks (left and right)
Matches Experiment

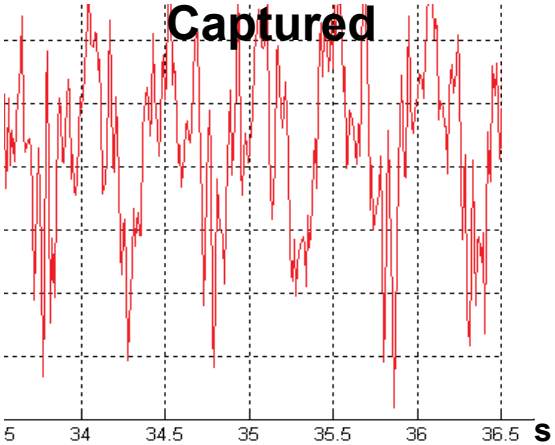




1Hz Filter
Frequency = 1Hz
1 cycle = 2 attacks

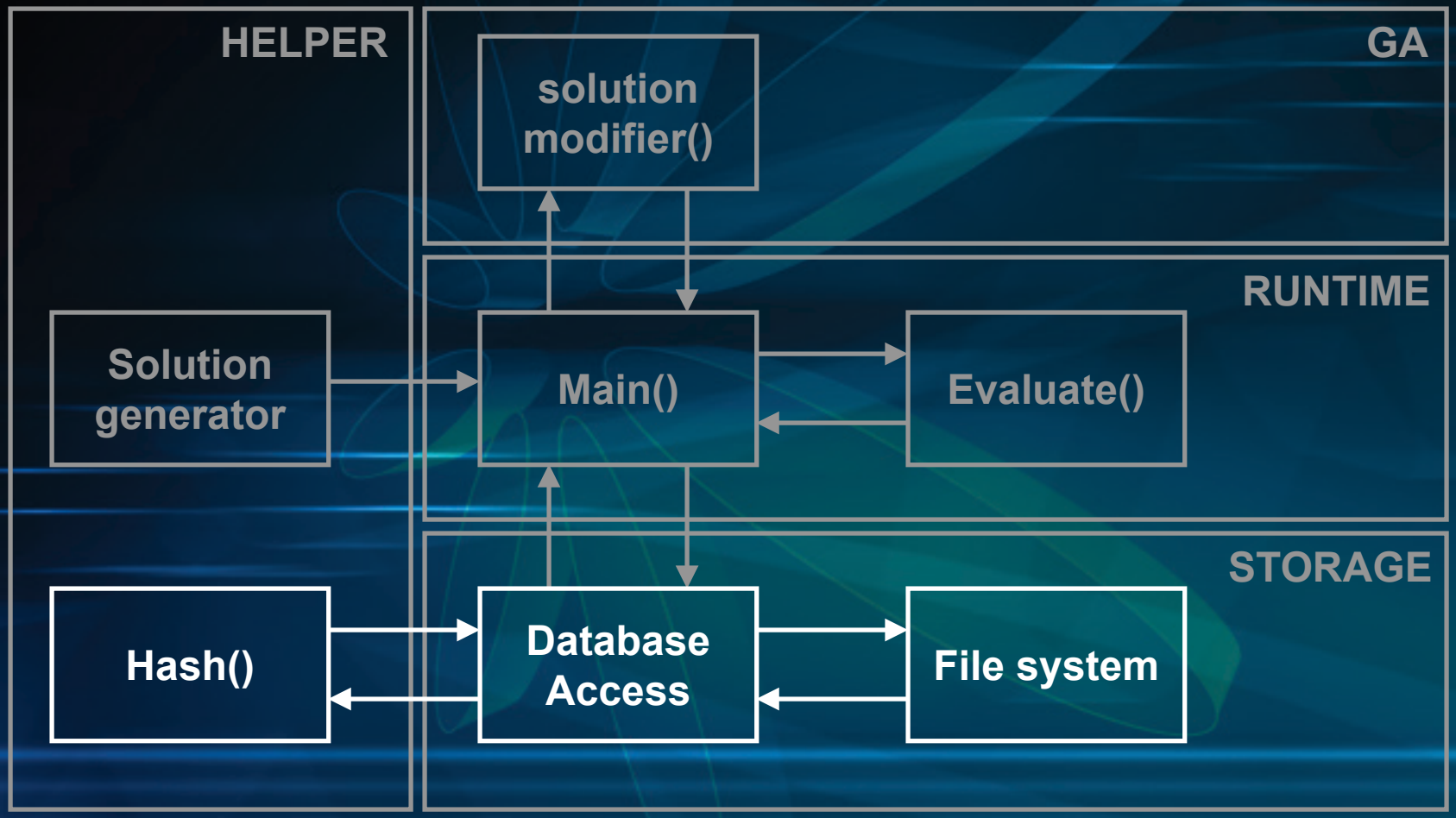
Mean waveform





10Hz Filter/No Filter
Frequency = 1Hz
1 cycle = 2 attacks
Hi frequency noise and inertia distortions

Database


HELPER
GA
solution modifier()
RUNTIME
Solution generator
Main()
Evaluate()
STORAGE
Hash()
Database Access
File system

Solution Database

- Each matrix has a unique hash
- A file, named by the hash code, contains the calculated efficiency
- A file check avoids redundant calculations

[0] [00] [1000]
[1] [FF] [0200] = A0002FF1FA02
[2] [A0] [1500]

SACS

Results

- MAS was executed in different scenarios
- The obtained results were benchmarked in the actual model mounted in a catamaran-style ship
- The results were compared by efficiency
- The method advantage was analyzed computationally

SACS

Multi-vector control

- Stores solutions with hi trust in different directions
- The control only reproduce stored signals

Windows Task Manager

File Options View Shut Down Help

Applications | Processes | Performance | Networking | Users

CPU Usage: 97 %

CPU Usage History

PF Usage: 975 MB

Page File Usage History

Totals	
Handles	7250
Threads	371
Processes	24

Physical Memory (K)	
Total	1046840
Available	319060
System Cache	373356

Commit Charge (K)	
Total	999232
Limit	3073872
Peak	1244916

Kernel Memory (K)	
Total	118992
Paged	61676
Nonpaged	57316

Processes: 24 | CPU Usage: 97% | Commit Charge: 975M / 3001M

MASM-E\main.exe

```
.1426    -0.4085    -0.8983

 best : (Ef=1.0692)  89D25D1248C118C1150022021012 3B60 Saved.
.0692    -0.2794    -0.3183

 best : (Ef=0.54154)  1E625B6028C185005751764172B208C1 Saved.
.8425     0.5415     0.3273

 best : (Ef=0.54974)  67D06641093031F208C125007B605C6216412B6078D0 Saved.
.5796    -0.5497    -0.9302

 best : (Ef=0.48616)  16414AC22F423891367015003ED237A256410891 Saved.
.3452    -0.6540    -1.5030

 best : (Ef=0.65396)  16414AC22F423891367015003ED237A256410891 Saved.
.3452    -0.6540    -1.5030

 best : (Ef=1.2345)  3500212296417B605B5258C168C1964118C12D222B60317245C2 S

.2345     0.2516     0.0092

 best : (Ef=1.0058)  08C139729500864156411500288002F27B6018C17500 Saved.
.0058     0.0939     0.0836
```

```
 best : (Ef=0.54974)  67D06641093031F208C125007B605C6216412B6078D0 Saved.
.5796    -0.5497    -0.9302

 best : (Ef=0.48616)  16414AC22F423891367015003ED237A256410891 Saved.
.3452    -0.6540    -1.5030

 best : (Ef=0.65396)  16414AC22F423891367015003ED237A256410891 Saved.
.3452    -0.6540    -1.5030

New E best : (Ef=1.2345)  3500212296417B605B5258C168C1964118C12D222B60317245C2 S
aved.
    1.2345     0.2516     0.0092

New W best : (Ef=1.0058)  08C139729500864156411500288002F27B6018C17500 Saved.
   -1.0058     0.0939     0.0836
```

```
614 tested, 250 not modified , data saved.
[1135] Generation, time elapsed: 2853.6516 mins, sorting index...
Performing genetics...
628 tested, 250 not modified , data saved.
[1136] Generation, time elapsed: 2856.3369 mins, sorting index...
Performing genetics...
630 tested, 250 not modified , data saved.
[1137] Generation, time elapsed: 2858.9942 mins, sorting index...
Performing genetics...
613 tested, 250 not modified , data saved.
[1138] Generation, time elapsed: 2862.0635 mins, sorting index...
Performing genetics...
609 tested, 250 not modified , data saved.
```

QR.gif

serial2.zip

start | C:\MASM\main.exe | C:\MASM-E\main.exe | C:\MASM-S\main.exe | Windows Task Mana... | EN | 4:23 PM

Windows Task Manager

File Options View Shut Down Help

Applications | Processes | Performance | Networking | Users

CPU Usage: 97 %

CPU Usage History

PF Usage: 975 MB

Page File Usage History

Totals	
Handles	7250
Threads	371
Processes	24

Physical Memory (K)	
Total	1046840
Available	319060
System Cache	373356

Commit Charge (K)	
Total	999232
Limit	3073872
Peak	1244916

Kernel Memory (K)	
Total	118992
Paged	61676
Nonpaged	57316

Processes: 24 | CPU Usage: 97% | Commit Charge: 975M / 3001M

MASM-E\main.exe

```
.1426    -0.4085    -0.8983

 best : (Ef=1.0692)  89D25D1248C118C11[illegible]2021[illegible]Sa
.0692    -0.2794    -0.3183

 best : (Ef=0.54154)  1E625B6028C185[illegible]764[illegible]B20[illegible]ed.
.8425     0.5415     0.3273

 best : (Ef=0.54974)  67D06641093031F20[illegible]250[illegible]605[illegible]2B6[illegible]ave
.5796    -0.5497    -0.9302

 best : (Ef=0.48616)  16414AC22F4238913[illegible]1500[illegible]256[illegible]Sa
.3452    -0.6540    -1.5030

 best : (Ef=0.65396)  16414AC22F4238913670150 03ED237A256410891 Saved.
.3452    -0.6540    -1.5030

 best : (Ef=1.2345)  3500212296417B605B5258C168C1964118C12D222B60317245C2 S
.2345     0.2516     0.0092

 best : (Ef=1.0058)  08C1397295008641564115002880 02F27B6018C17500 Saved.
.0058     0.0939     0.0836
```

```
 best : (Ef=0.54974)  67D06641093031F20[illegible]2500[illegible]216[illegible]78D0
.5796    -0.5497    -0.9302

 best : (Ef=0.48616)  16414AC22F4238[illegible]150[illegible]D23[illegible]5[illegible]089[illegible]Sa[illegible]
.3452    -0.6540    -1.5030

 best : (Ef=0.65396)  16414AC22F4238913[illegible]150[illegible]D23[illegible]5[illegible]089[illegible]Sa[illegible]
.3452    -0.6540    -1.5030

New E best : (Ef=1.2345)  3500212296417B605B[illegible]8C16[illegible]18C[illegible]60[illegible]S
aved.
    1.2345     0.2516     0.0092

New W best : (Ef=1.0058)  08C1397295008641564115002880 02F27B6018C17500 Saved.
   -1.0058     0.0939     0.0836
```

```
614 tested, 250 not modified , data saved.
[1135] Generation, time elapsed: 2853.6516 m[illegible], so[illegible]nde
Performing genetics...
628 tested, 250 not modified , data saved
[1136] Generation, time elapsed: 2856.336[illegible], s[illegible]ing[illegible]d[illegible]..
Performing genetics...
630 tested, 250 not modified , data saved.
[1137] Generation, time elapsed: 2858.9942 m[illegible], s[illegible]ing[illegible]d[illegible]..
Performing genetics...
613 tested, 250 not modified , data saved.
[1138] Generation, time elapsed: 2862.0635 m[illegible], so[illegible]nde
Performing genetics...
609 tested, 250 not modified , data saved.
```

1000

1000

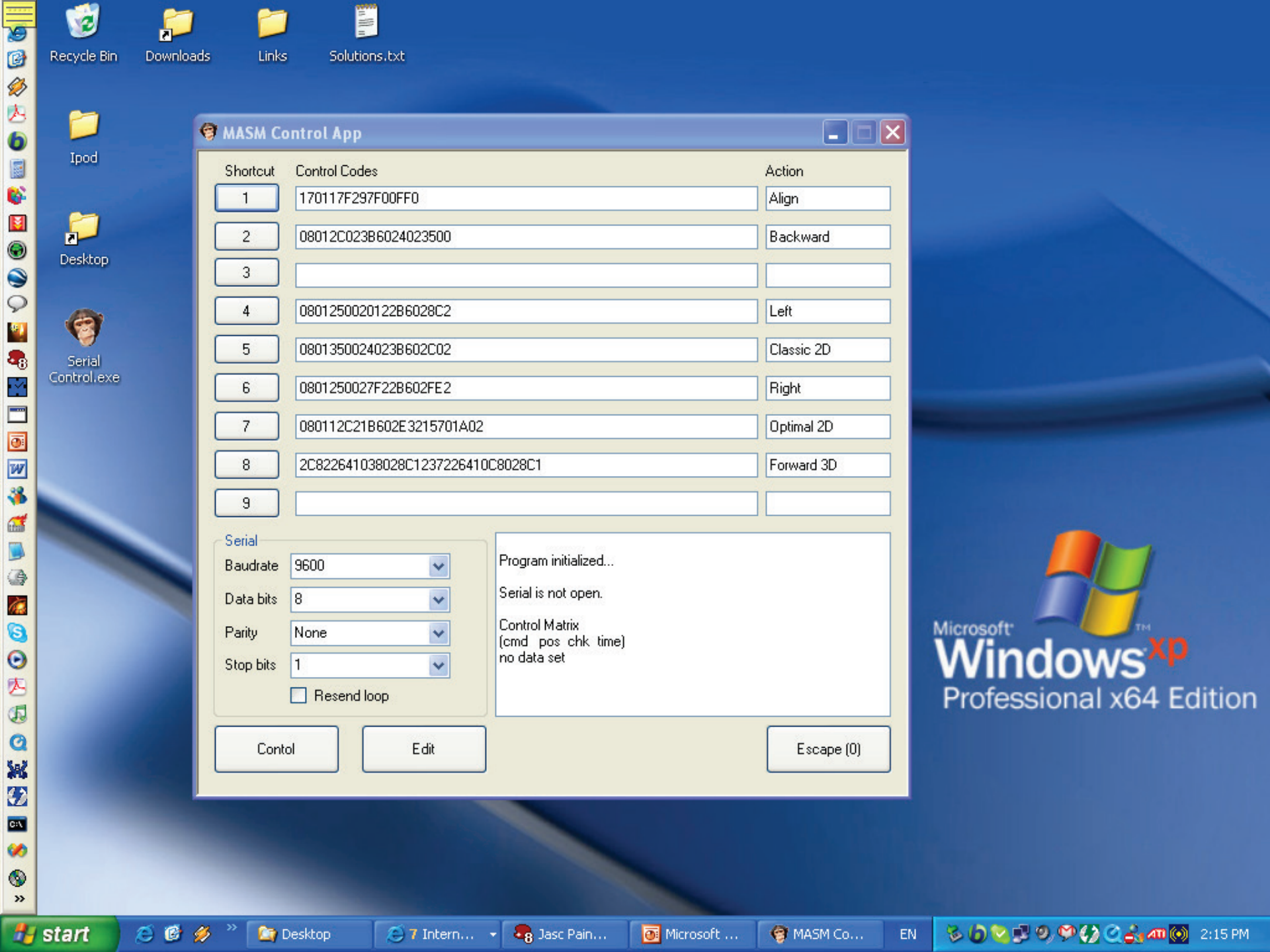
1000

100% CPU

QR.gif

serial2.zip

start | C:\MASM\main.exe | C:\MASM-E\main.exe | C:\MASM-S\main.exe | Windows Task Mana... | EN | 4:23 PM


Recycle Bin
Downloads
Links
Solutions.txt
Ipod
Desktop
Serial Control.exe
MASM Control App
Shortcut
Control Codes
Action
1
170117F297F00FF0
Align
2
08012C023B6024023500
Backward
3
4
0801250020122B6028C2
Left
5
0801350024023B602C02
Classic 2D
6
0801250027F22B602FE2
Right
7
080112C21B602E3215701A02
Optimal 2D
8
2C822641038028C1237226410C8028C1
Forward 3D
9
Serial
Baudrate
9600
Data bits
8
Parity
None
Stop bits
1
Resend loop
Program initialized...
Serial is not open.
Control Matrix
(cmd pos chk time)
no data set
Contol
Edit
Escape (0)
Microsoft Windows xp
Professional x64 Edition
start
Desktop
7 Intern...
Jasc Pain...
Microsoft ...
MASM Co...
EN
2:15 PM

CONTROL CODES

ACTION NAME

MASM Control App

Shortcut	Control Codes	Action
1	170117F297F00FF0	Align
2	08012C023B6024023500	Backward
3		
4	0801250020122B6028C2	Left
5	0801350024023B602C02	Classic 2D
6	0801250027F22B602FE2	Right
7	080112C21B602E3215701A02	Optimal 2D
8	2C822641038028C1237226410C8028C1	Forward 3D
9		

Serial

Baudrate 9600

Data bits 8

Parity None

Stop bits 1

Resend loop

Program initialized...

Serial is not open.

Control Matrix
(cmd pos chk time)
no data set

Contol

Edit

Escape (0)

Recycle Bin

Downloads

Links

Solutions.txt

Ipod

Desktop

Serial Control.exe

Microsoft Windows xp Professional x64 Edition

start

Desktop

7 Intern...

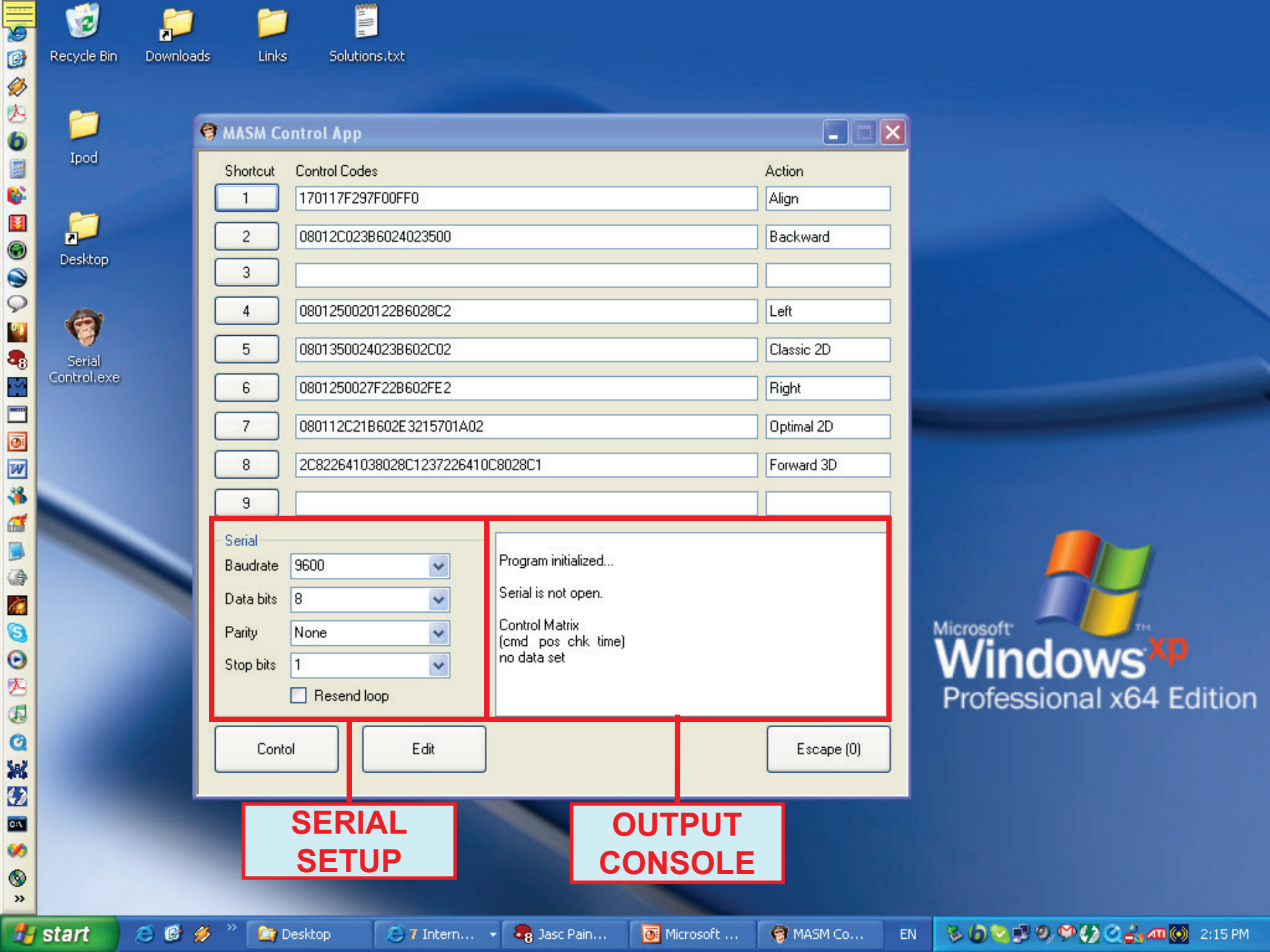
Jasc Pain...

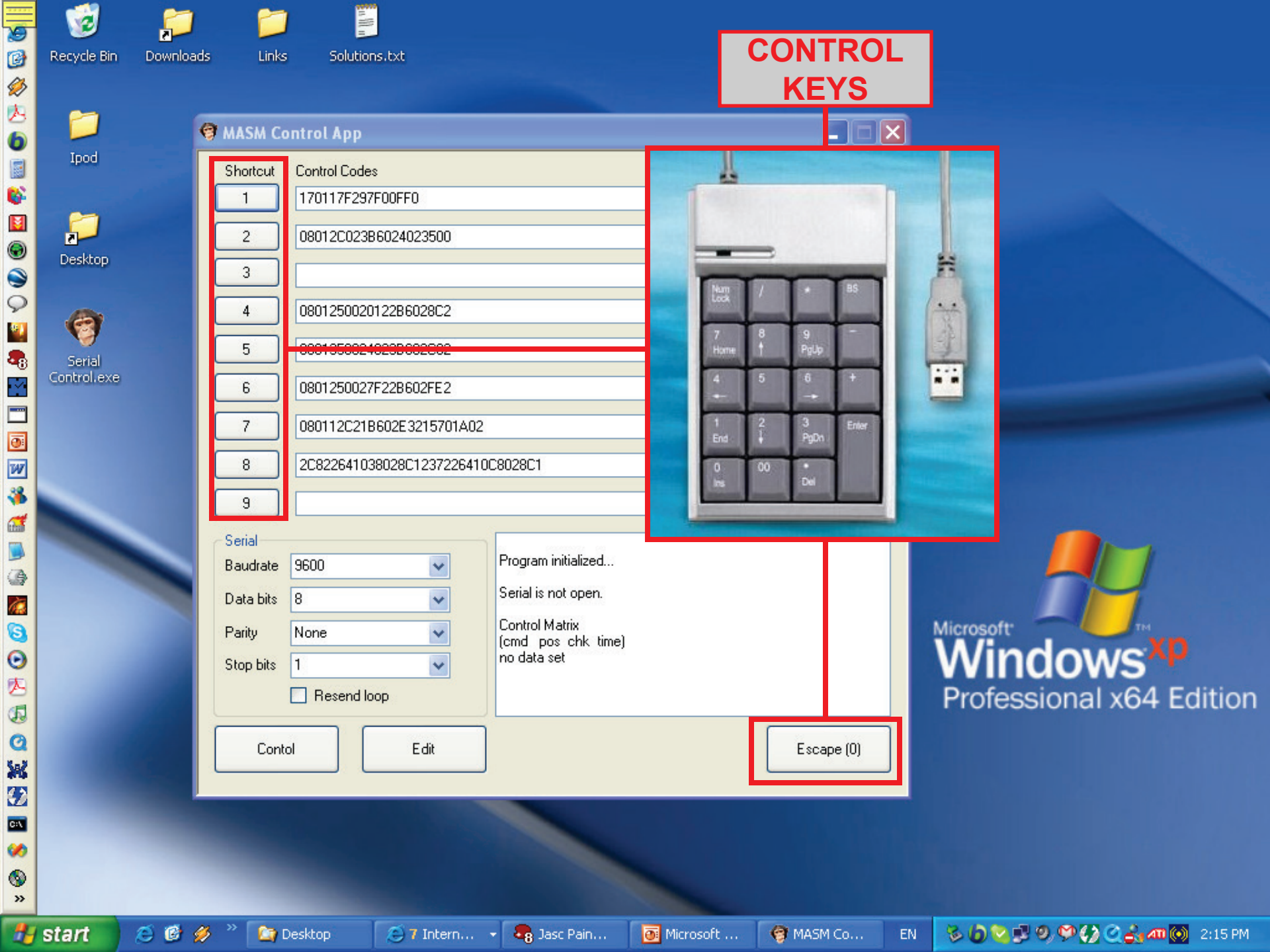
Microsoft ...

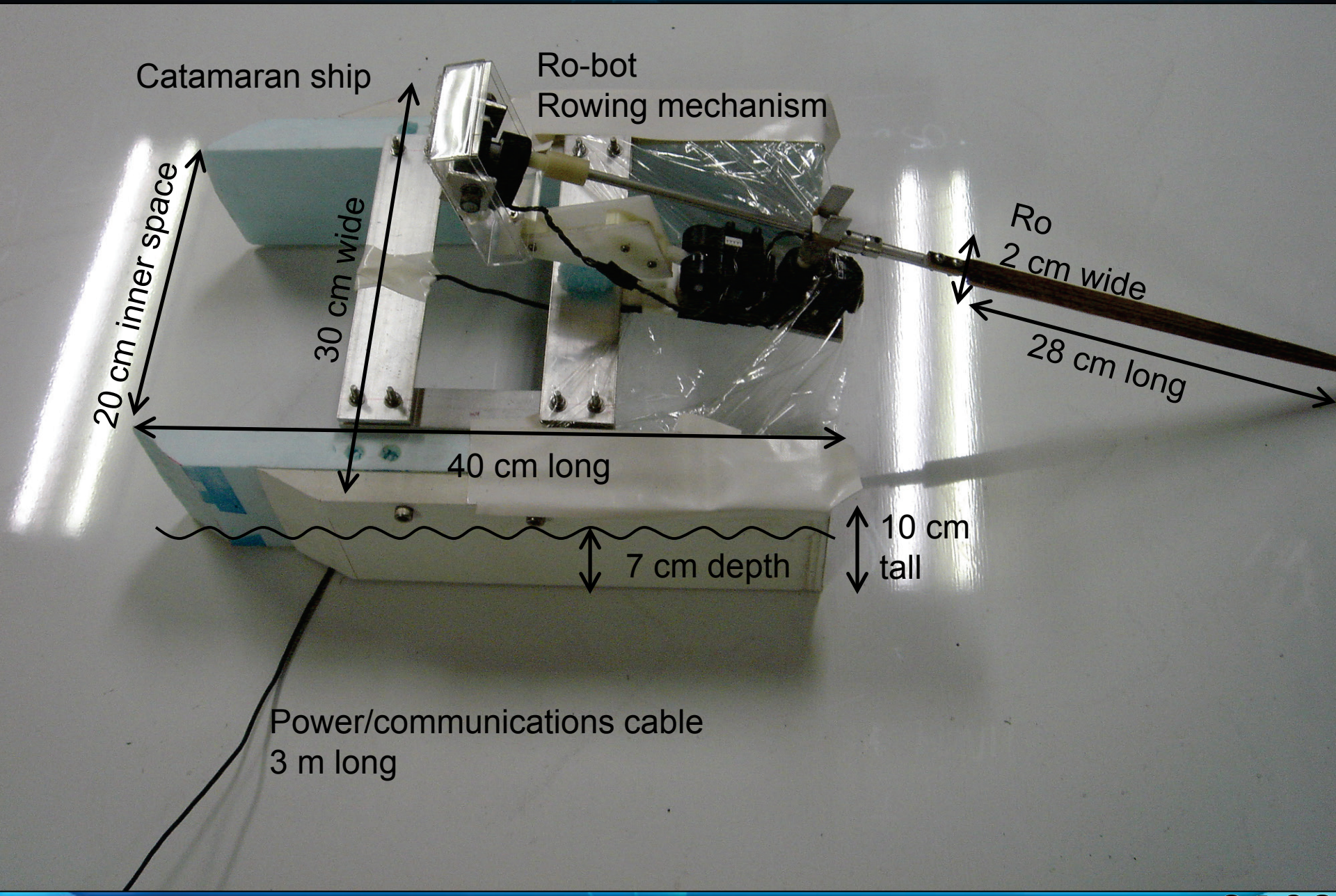
MASM Co...

EN

2:15 PM

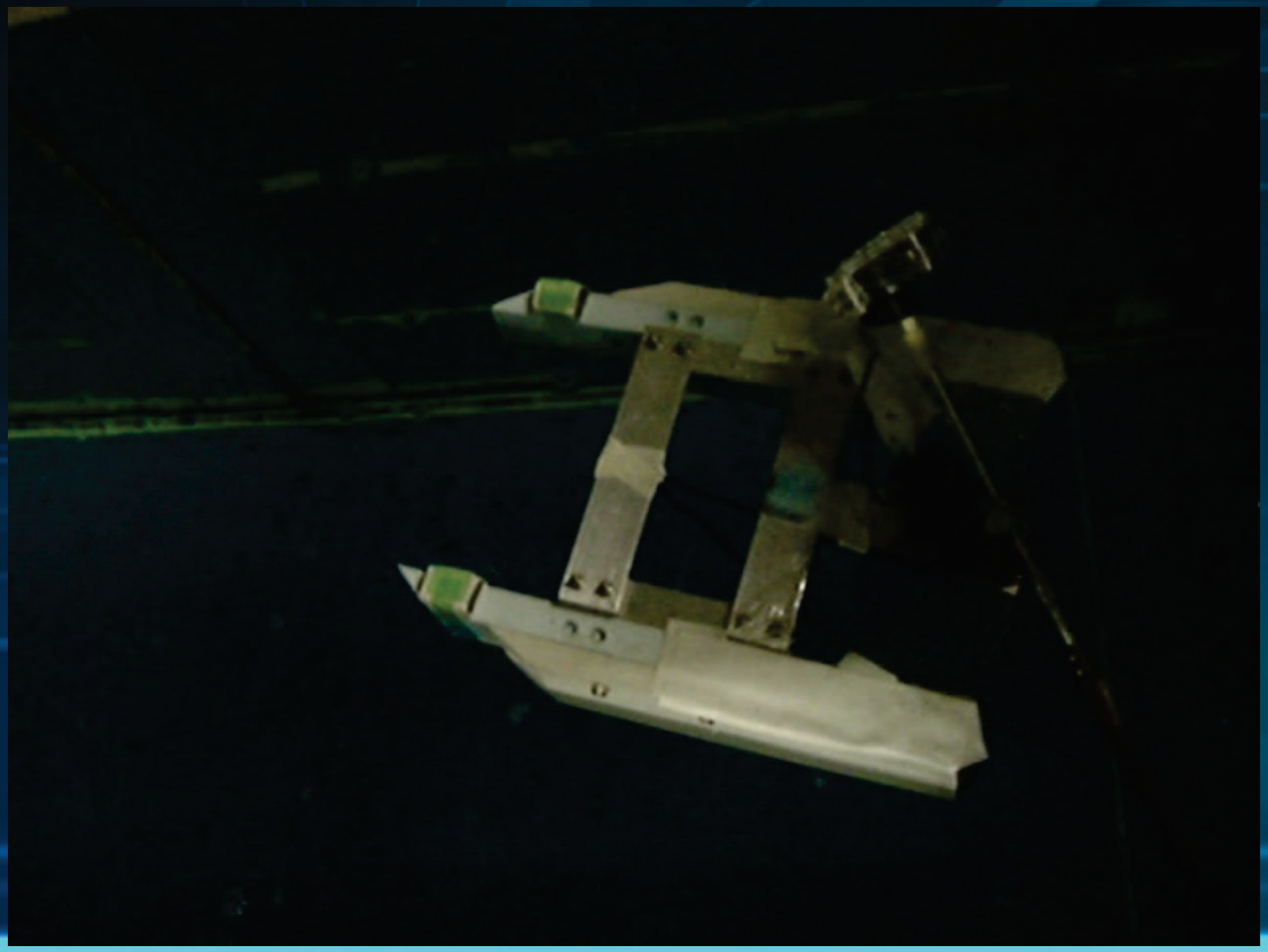

Recycle Bin
Downloads
Links
Solutions.txt
Ipod
Desktop
Serial Control.exe
MASM Control App
Shortcut
Control Codes
Action
1
170117F297F00FF0
Align
2
08012C023B6024023500
Backward
3
4
0801250020122B6028C2
Left
5
0801350024023B602C02
Classic 2D
6
0801250027F22B602FE2
Right
7
080112C21B602E3215701A02
Optimal 2D
8
2C822641038028C1237226410C8028C1
Forward 3D
9
Serial
Baudrate
9600
Data bits
8
Parity
None
Stop bits
1
Resend loop
Program initialized...
Serial is not open.
Control Matrix
(cmd pos chk time)
no data set
Contol
Edit
Escape (0)
SERIAL SETUP
OUTPUT CONSOLE
Microsoft Windows xp
Professional x64 Edition
start
Desktop
7 Intern...
Jasc Pain...
Microsoft ...
MASM Co...
EN
2:15 PM


CONTROL KEYS
MASM Control App
Shortcut
Control Codes
1
170117F297F00FF0
2
08012C023B6024023500
3
4
0801250020122B6028C2
5
6
0801250027F22B602FE2
7
080112C21B602E3215701A02
8
2C822641038028C1237226410C8028C1
9
Serial
Baudrate
9600
Data bits
8
Parity
None
Stop bits
1
Resend loop
Program initialized...
Serial is not open.
Control Matrix
(cmd pos chk time)
no data set
Contol
Edit
Escape (0)
Recycle Bin
Downloads
Links
Solutions.txt
Ipod
Desktop
Serial Control.exe
Microsoft Windows xp
Professional x64 Edition
start
Desktop
Jasc Pain...
Microsoft ...
MASM Co...
EN
2:15 PM


Catamaran ship
Ro-bot
Rowing mechanism
20 cm inner space
30 cm wide
Ro
2 cm wide
28 cm long
40 cm long
10 cm
tall
7 cm depth
Power/communications cable
3 m long

Solution testing

Solution testing



Solution testing

Solution testing

Timing speeds

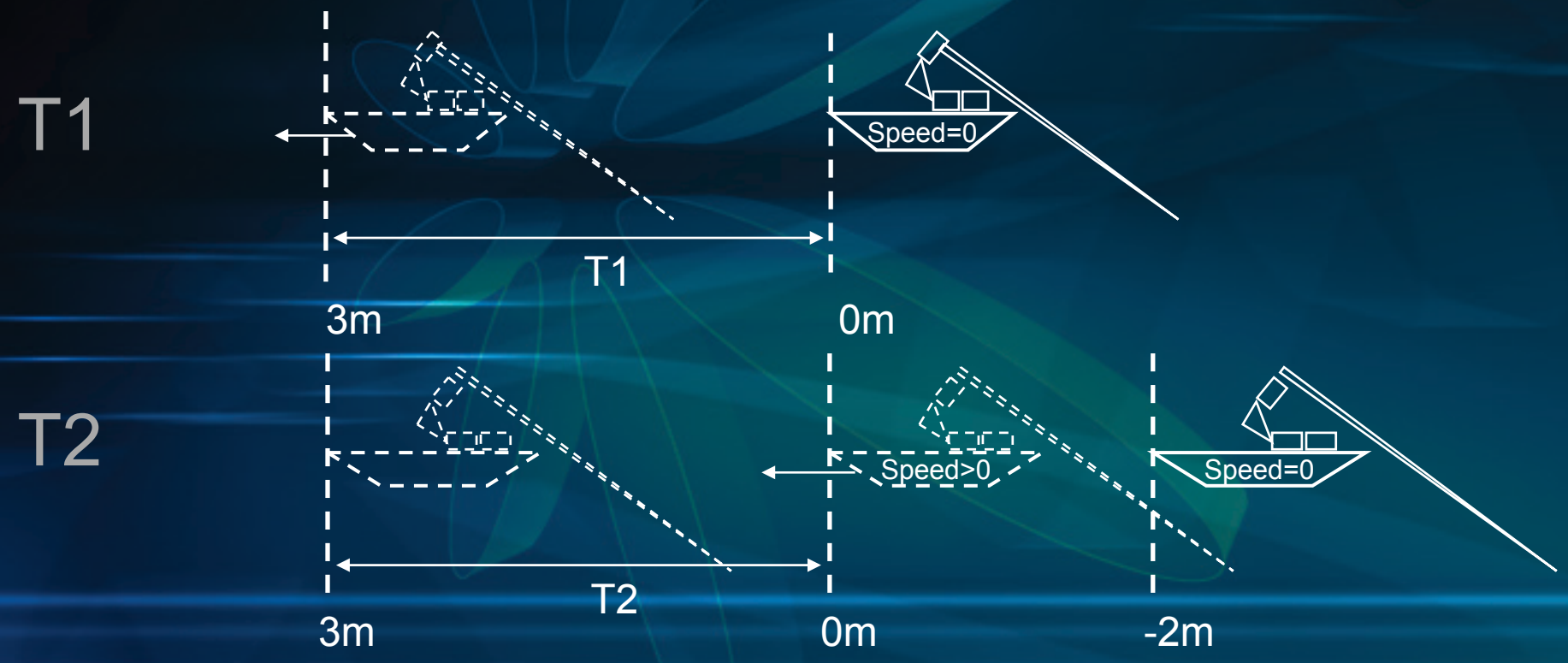


Table View

Model	Simulation	Course Time T1
2DF: Classic	3.2	12.0
2DF: Optimized	4.6	10.5
2DF: Rotated	2.9	11.5
3DF: X	6.56	11.4
3DF: M	5.6	12.0

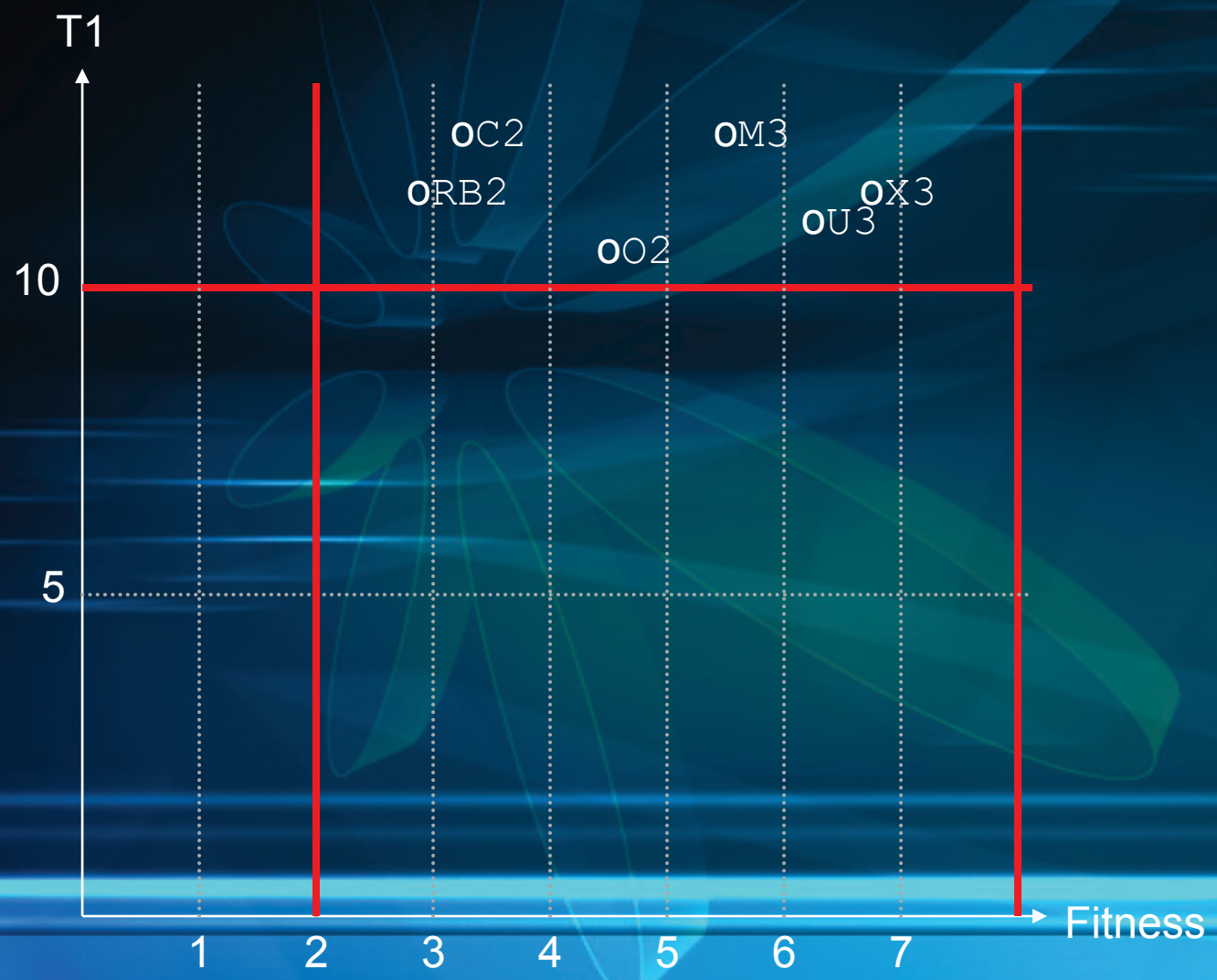
SACS

Table View

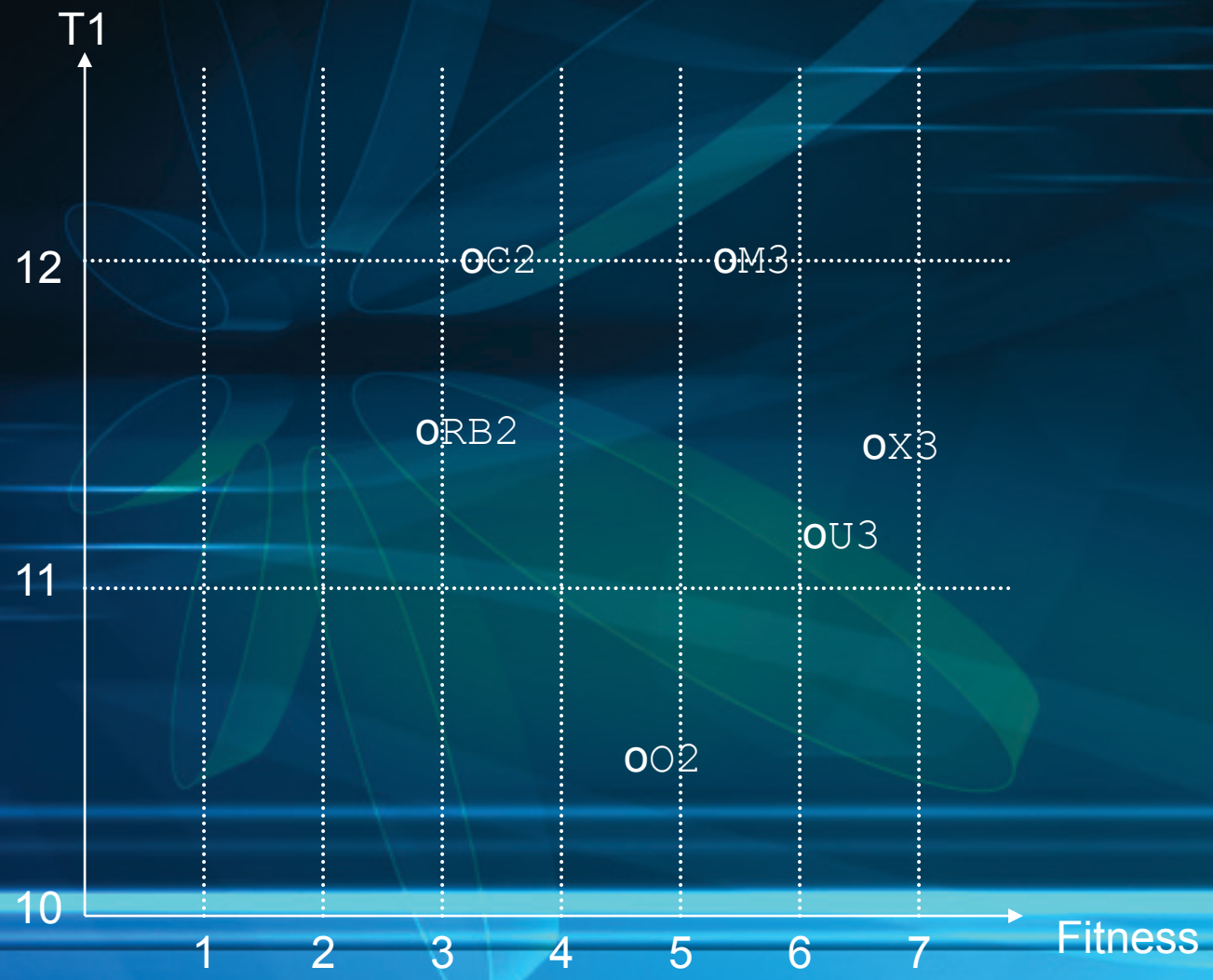
Model	Simulation	Course Time T2
2DF: Classic	3.2	10.5
2DF: Optimized	4.6	9.6
2DF: Rotated	2.9	10.2
3DF: X	6.56	10.5
3DF: M	5.6	11

SACS

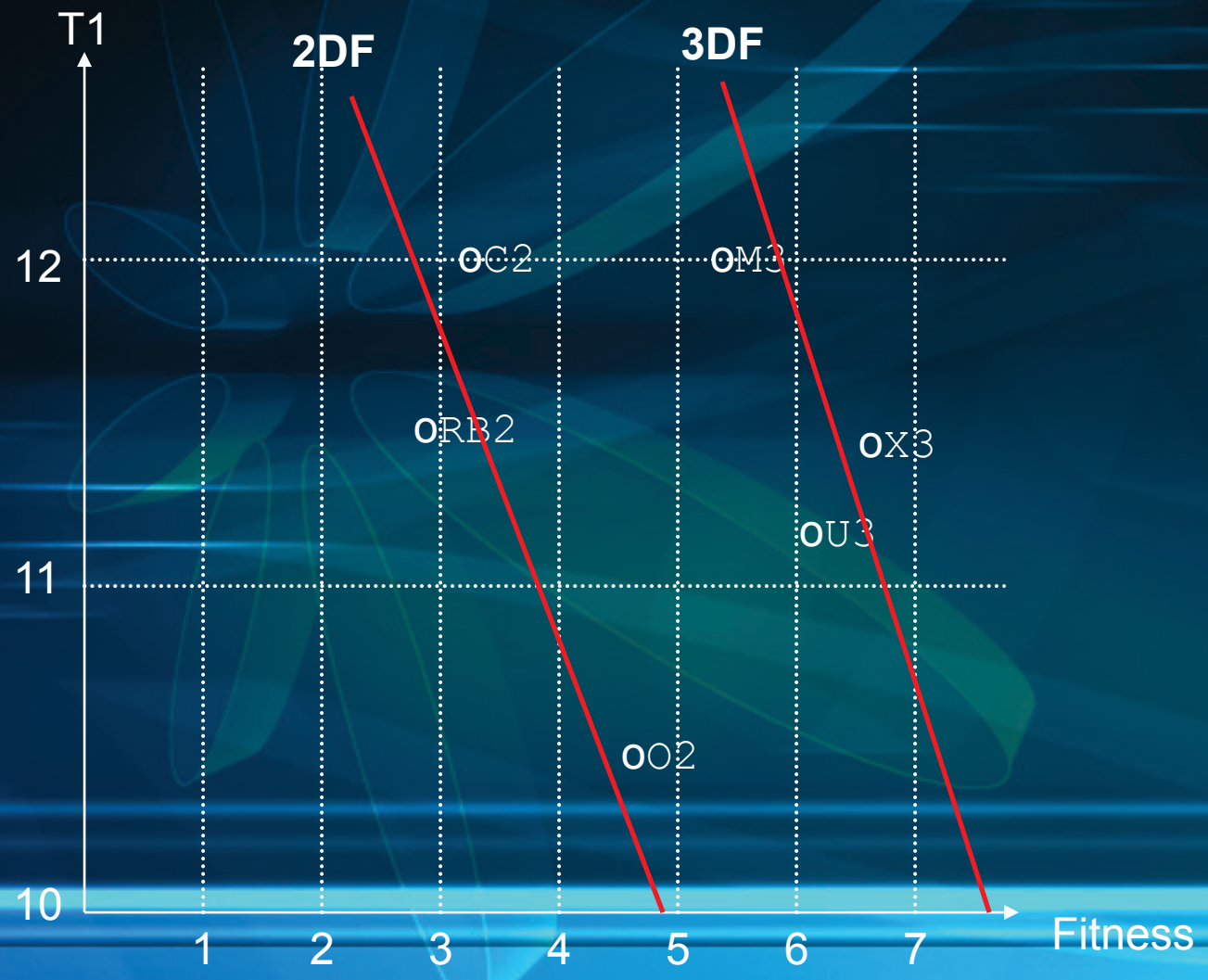
T vs. Fitness



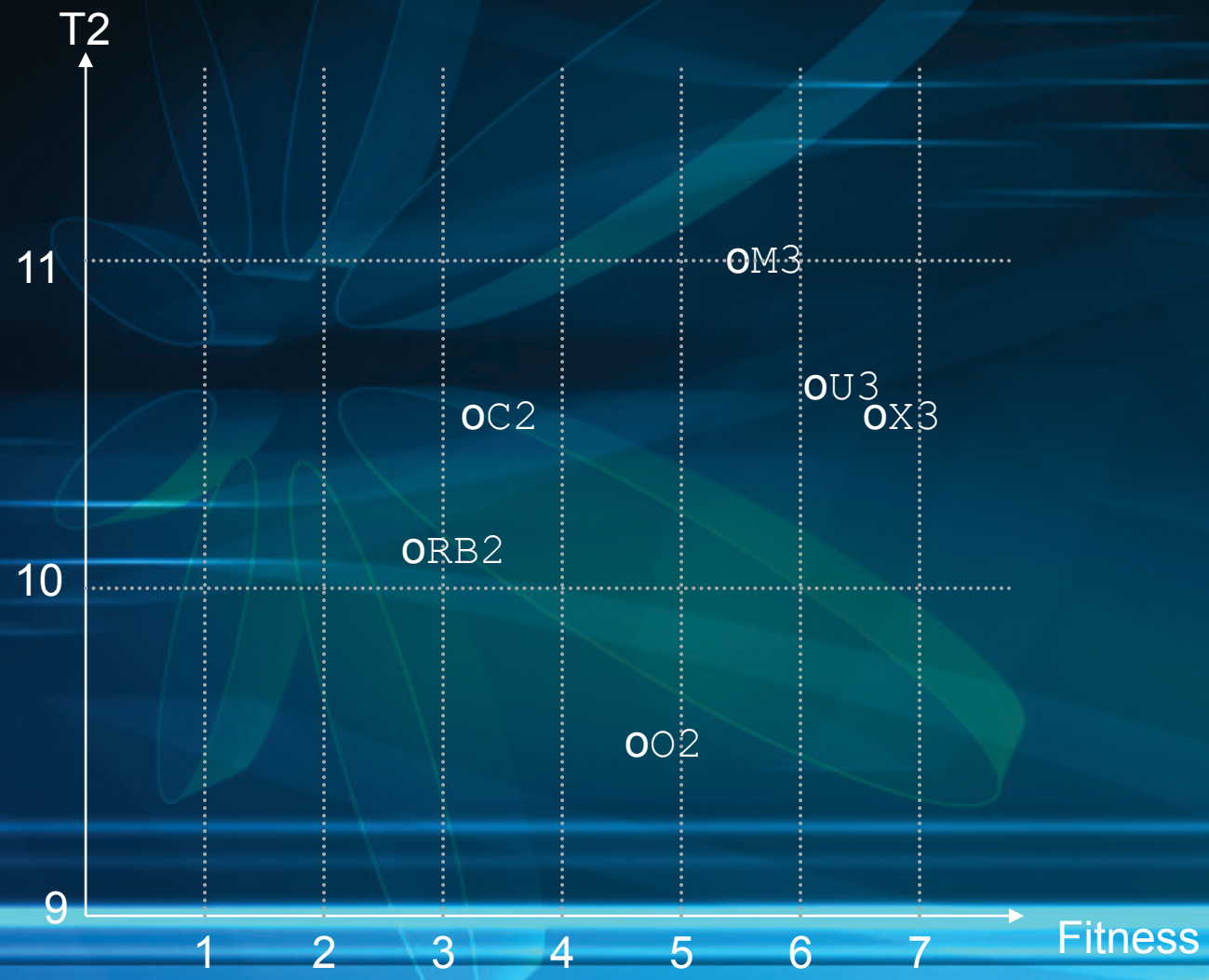
T1 vs. Fitness



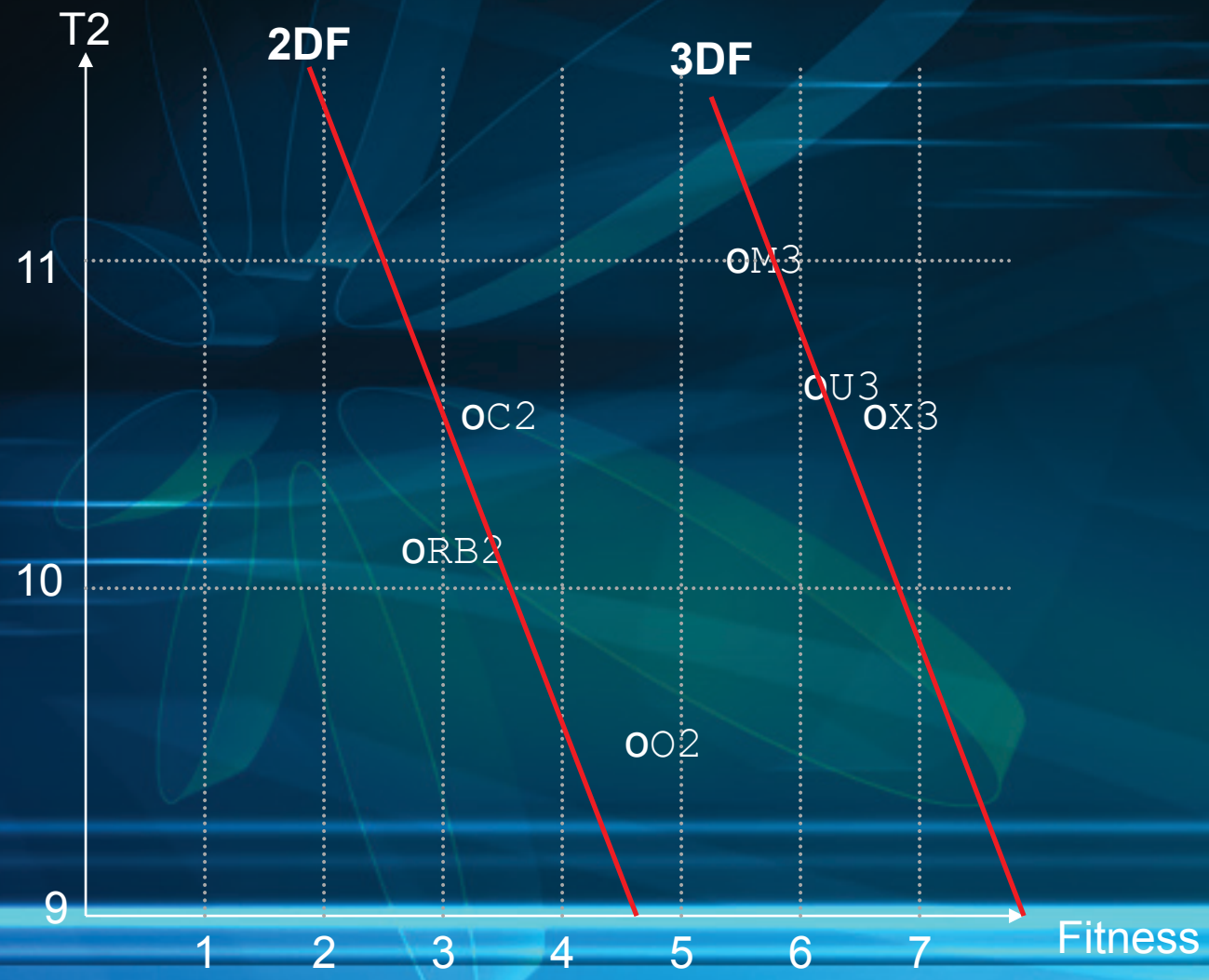
T1 vs. Fitness



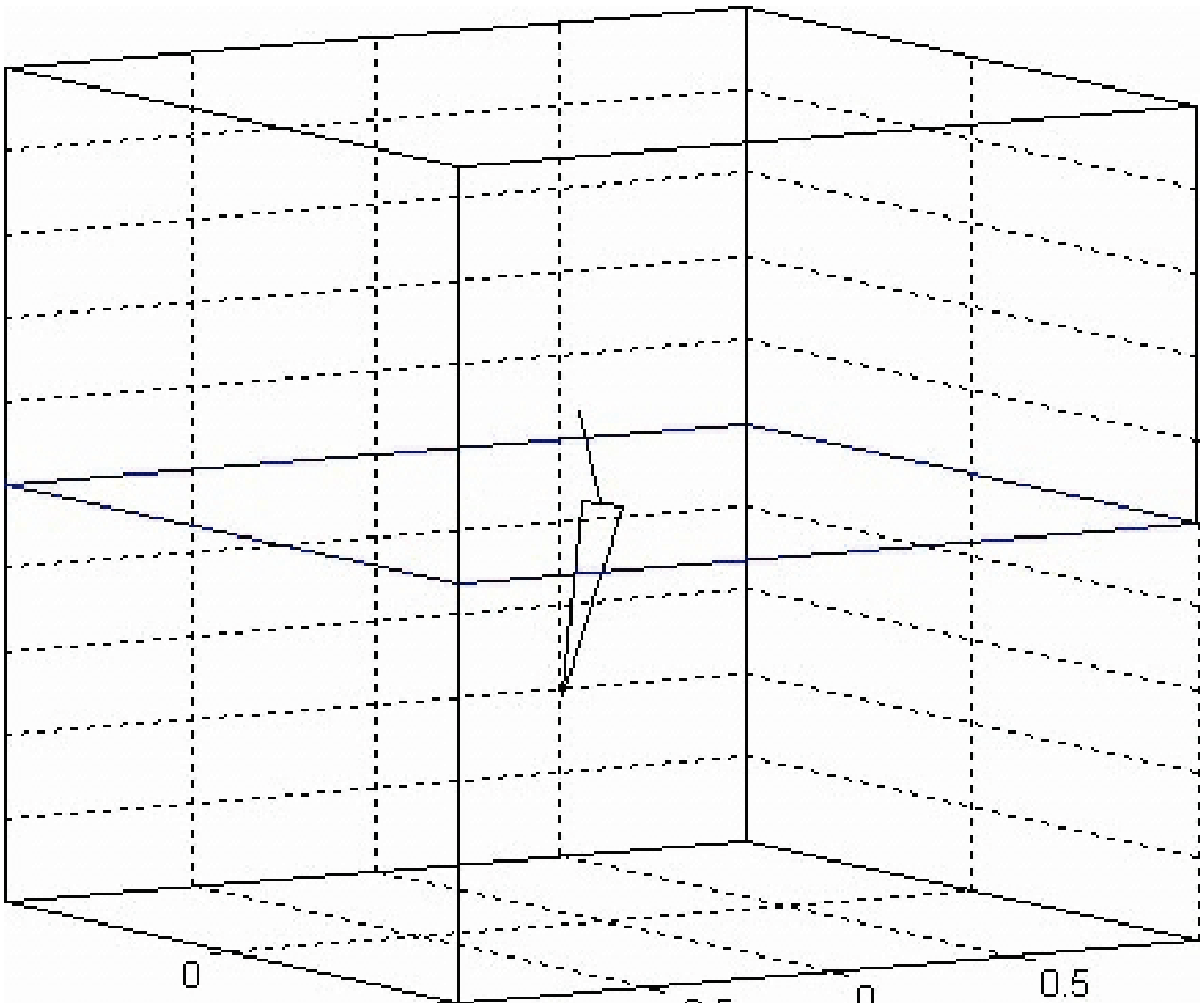
T2 vs. Fitness



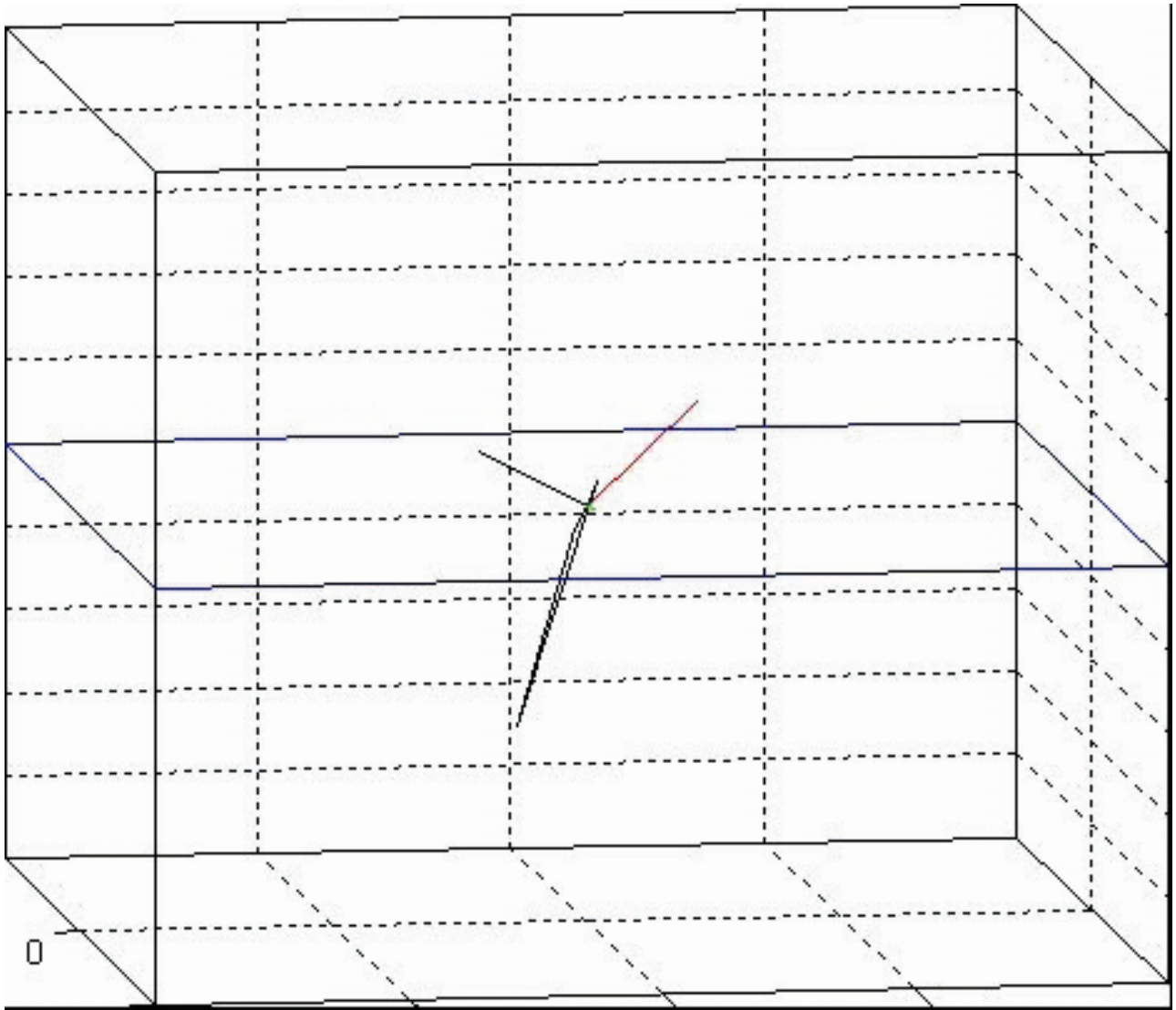
T2 vs. Fitness



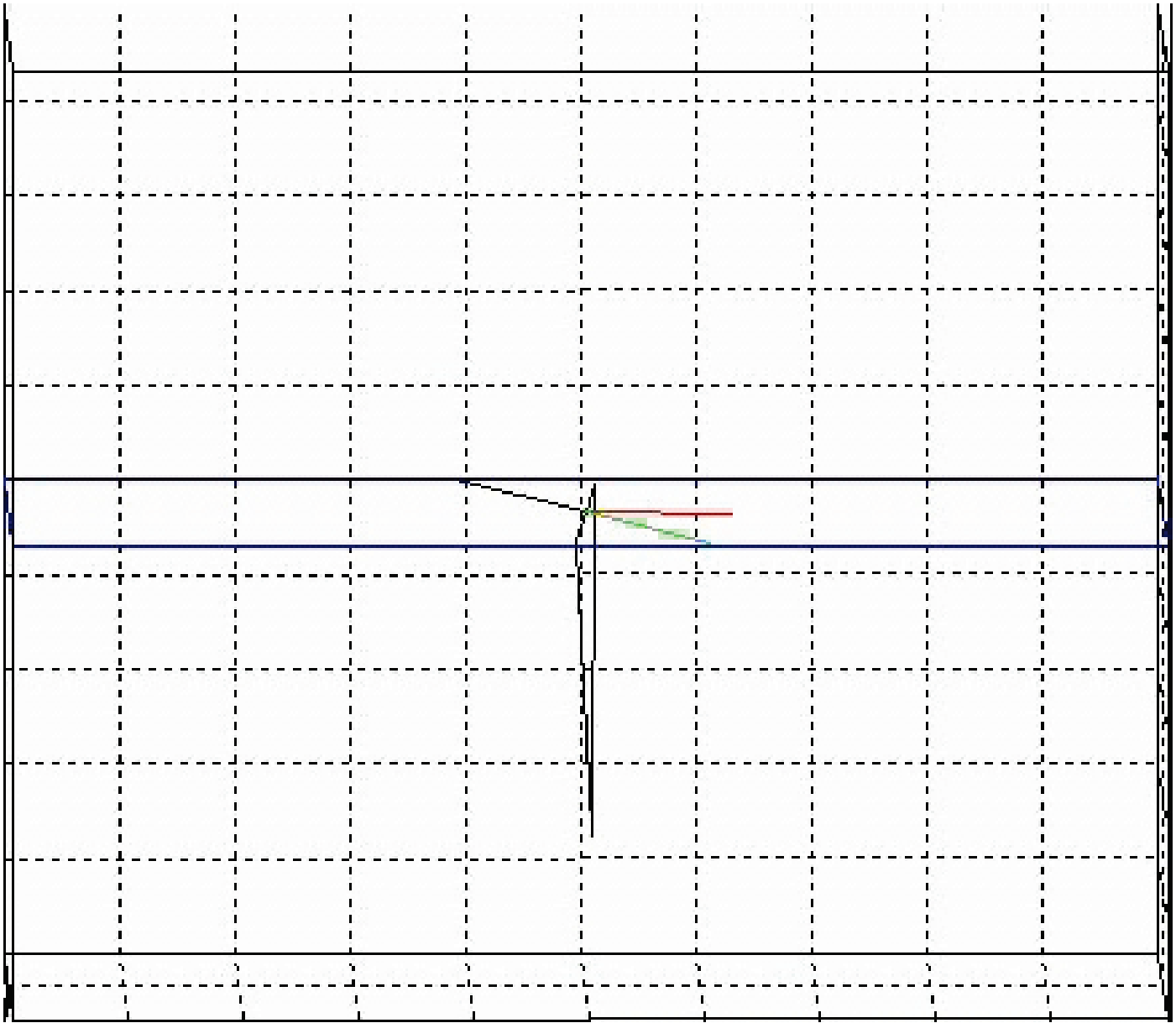
Optimized 2DF Rowing



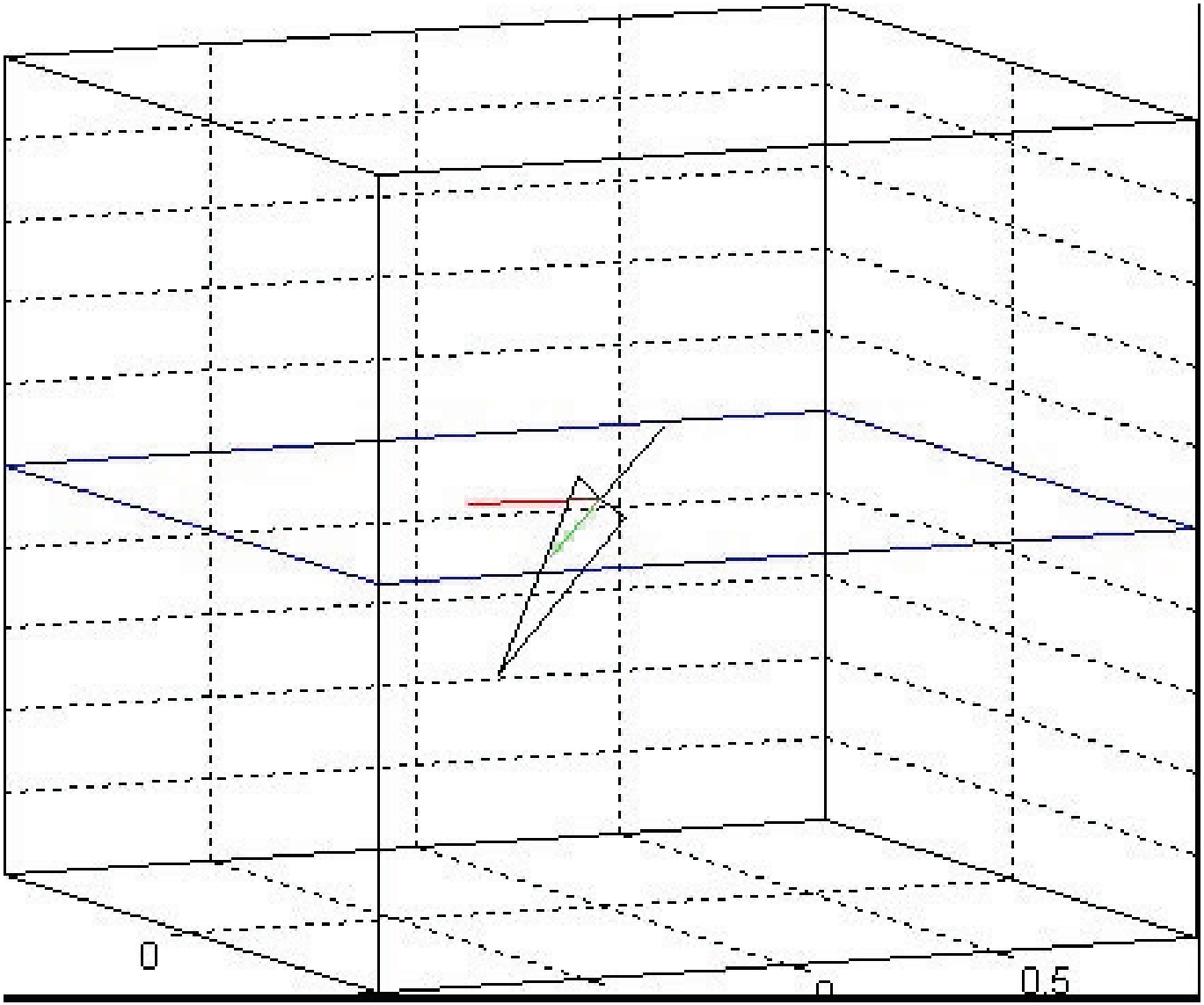
Optimal X-3DF Rowing



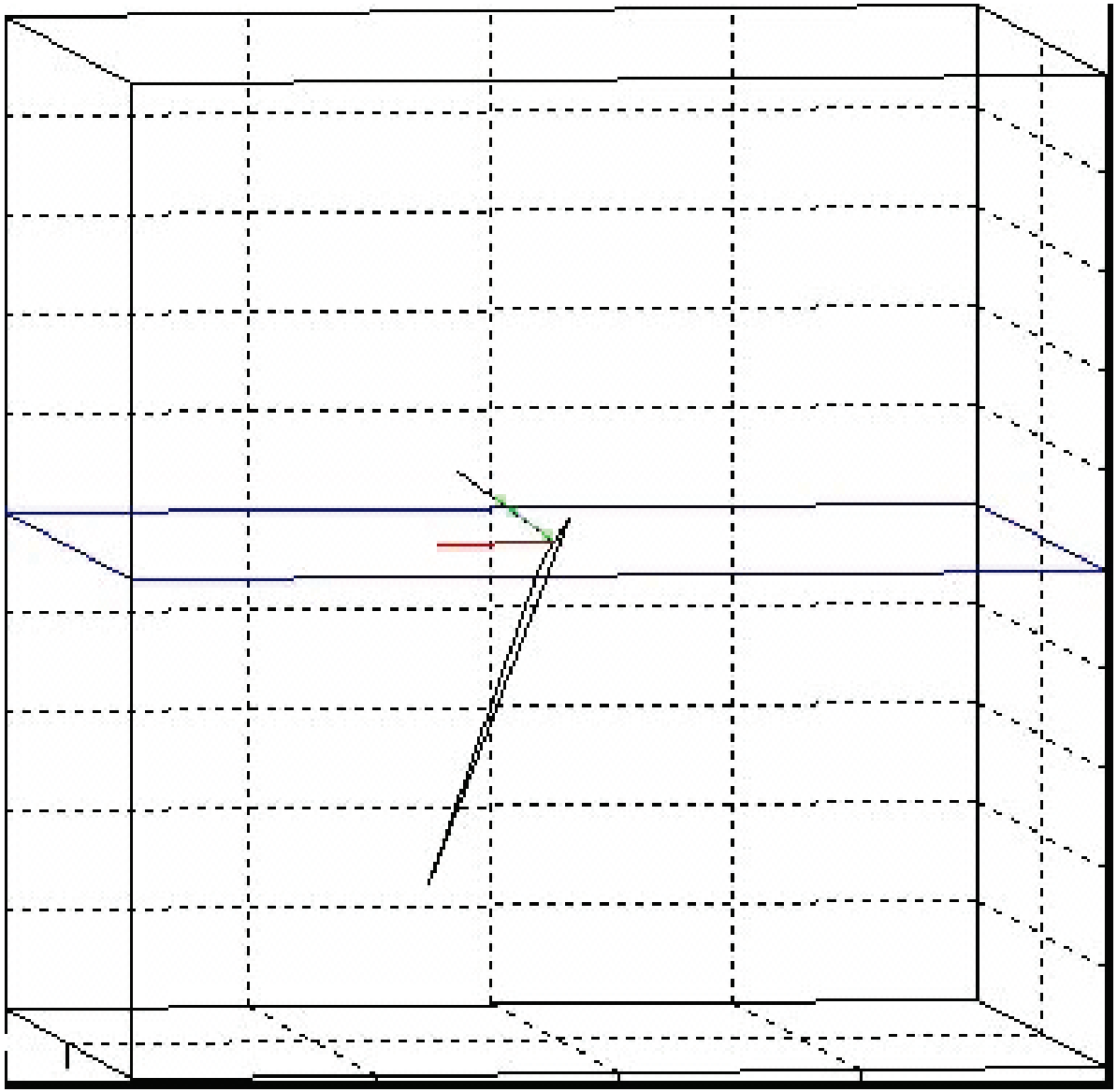
U-3DF Rowing



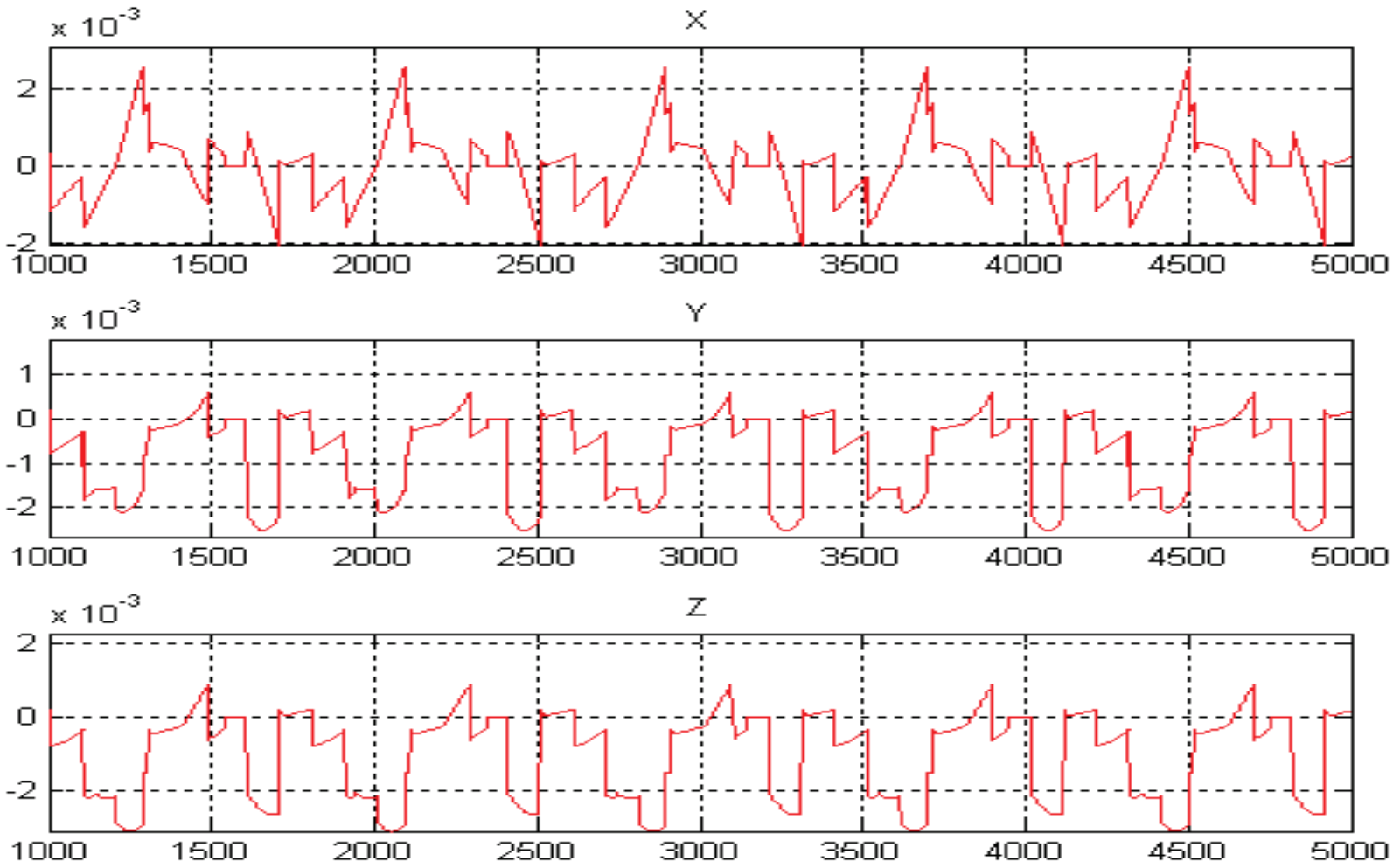
M-3DF Rowing

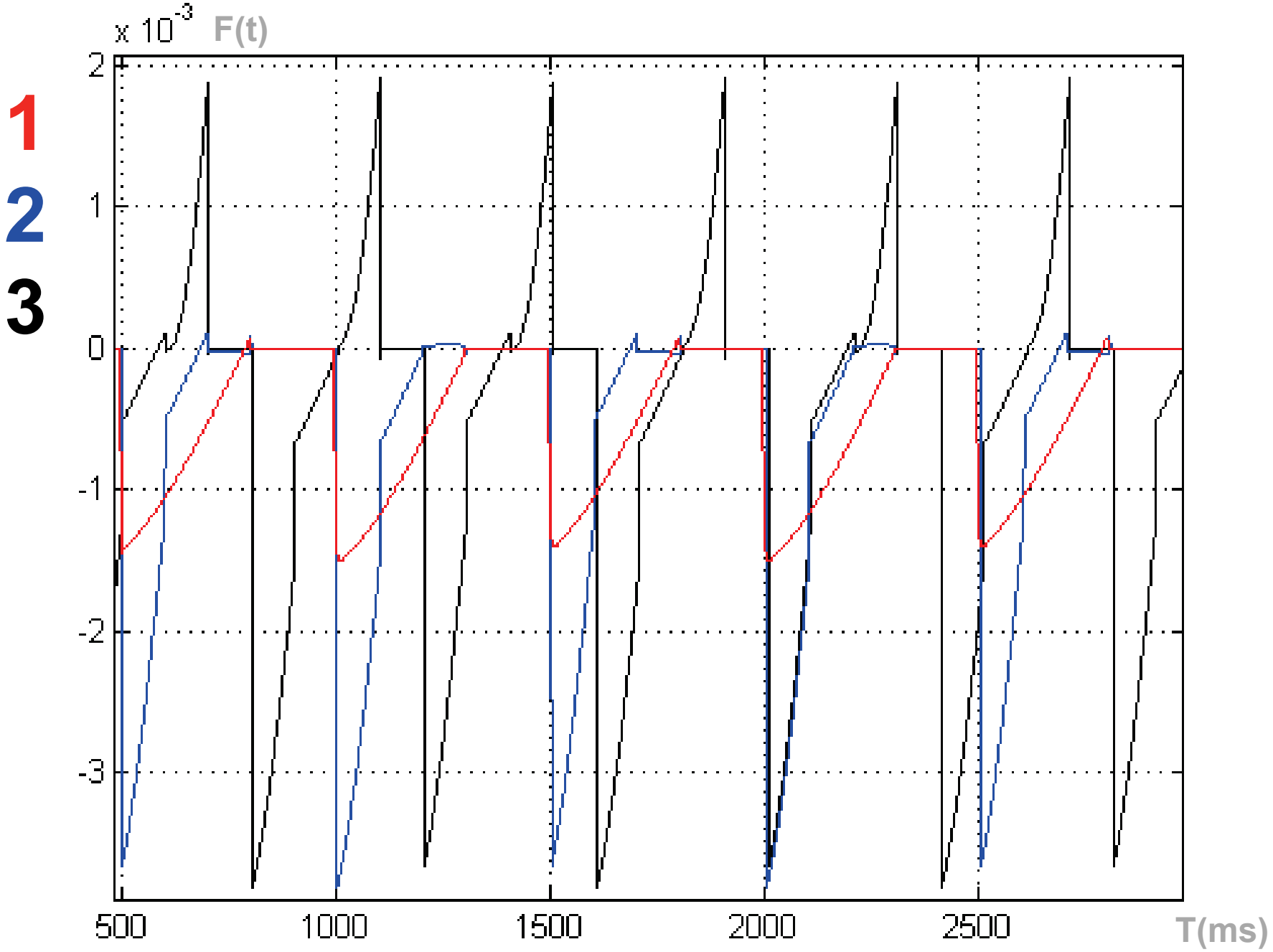


Back Rowing

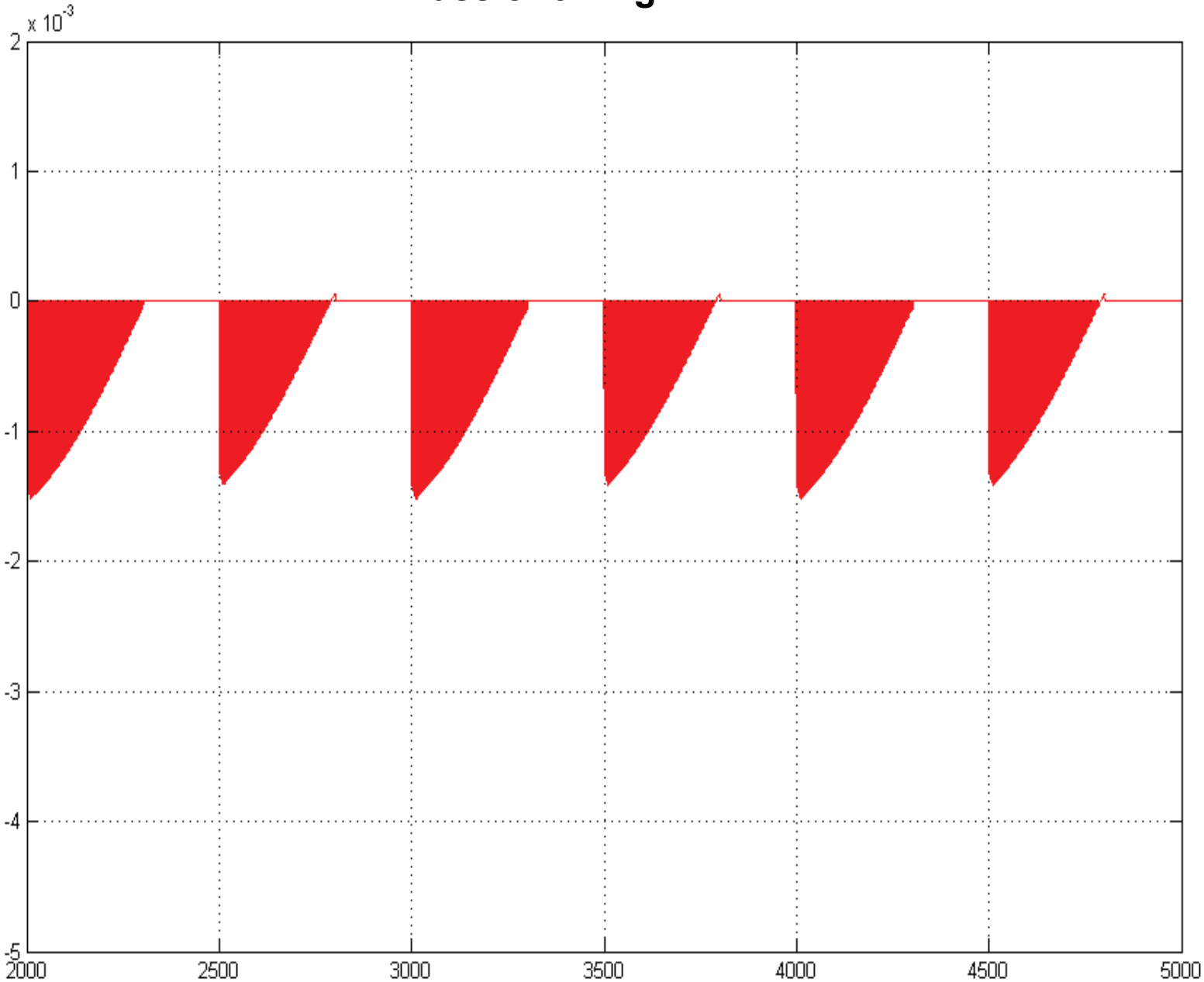


3D Impulse


x 10^-3
X
2
0
-2
1000
1500
2000
2500
3000
3500
4000
4500
5000
x 10^-3
Y
1
0
-1
-2
1000
1500
2000
2500
3000
3500
4000
4500
5000
x 10^-3
Z
2
0
-2
1000
1500
2000
2500
3000
3500
4000
4500
5000

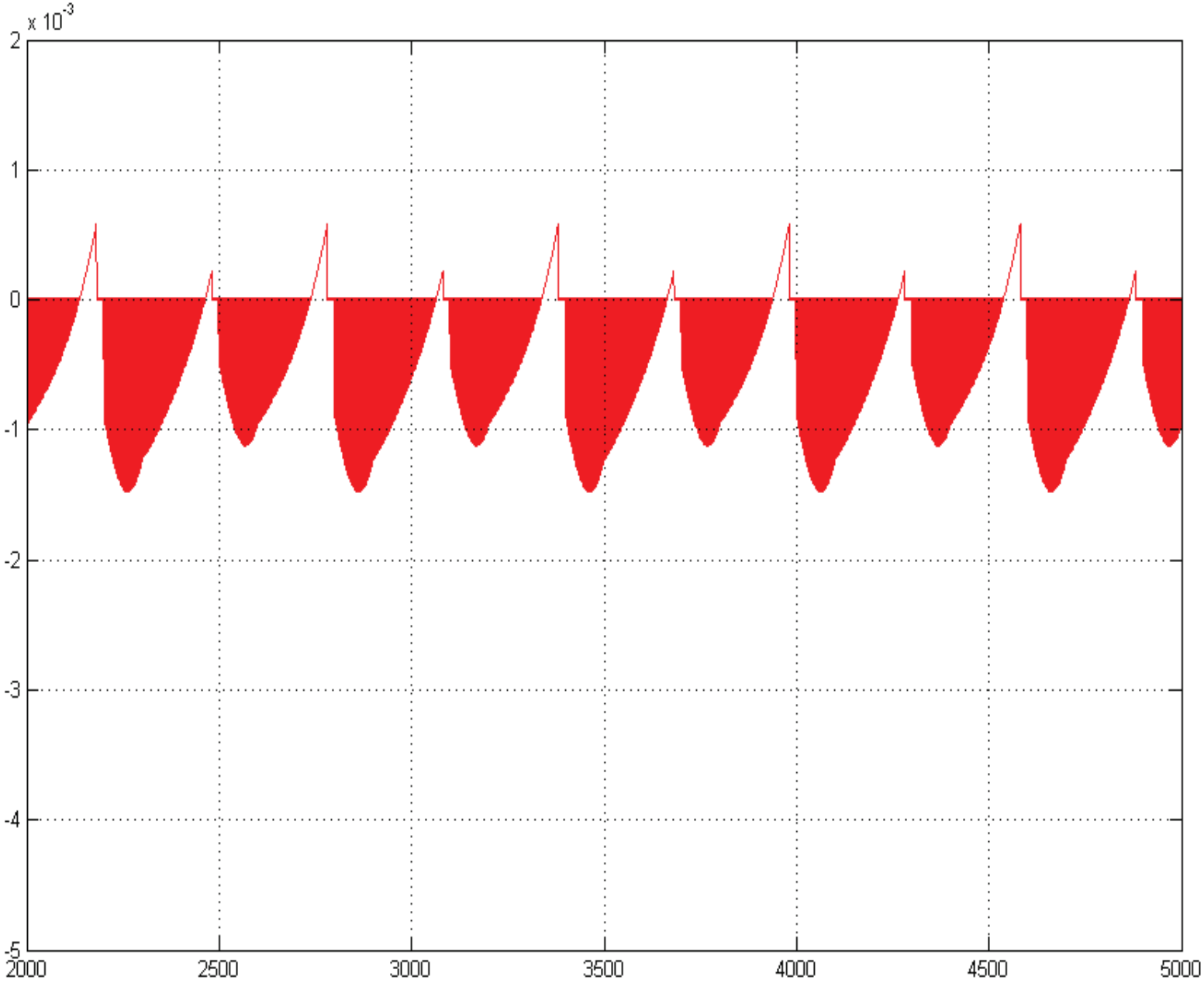

x 10^-3
F(t)
1
2
3
2
1
0
-1
-2
-3
500
1000
1500
2000
2500
T(ms)

Classic rowing C-2DF



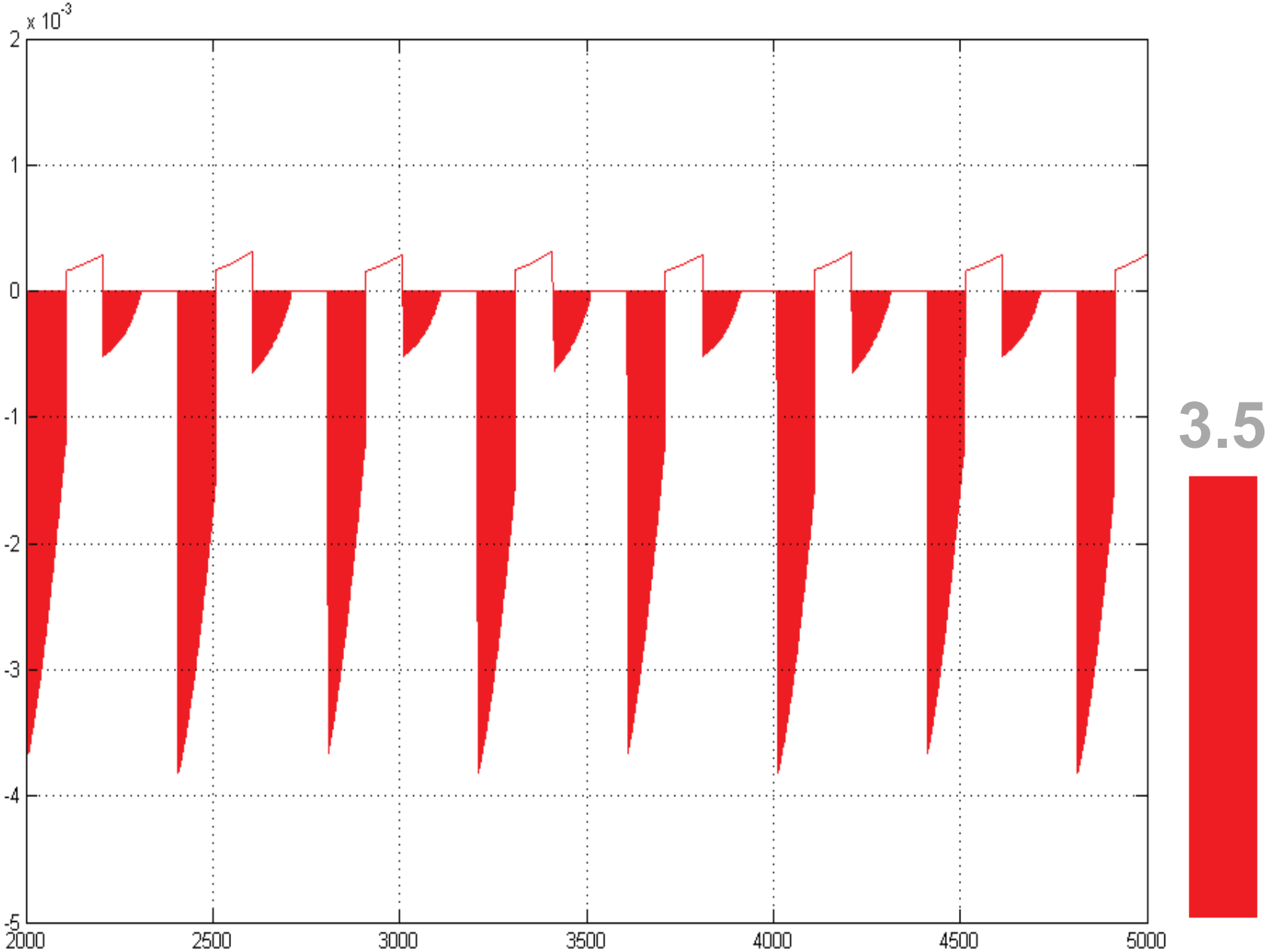
2.2

OPTIMIZED 0-2DF

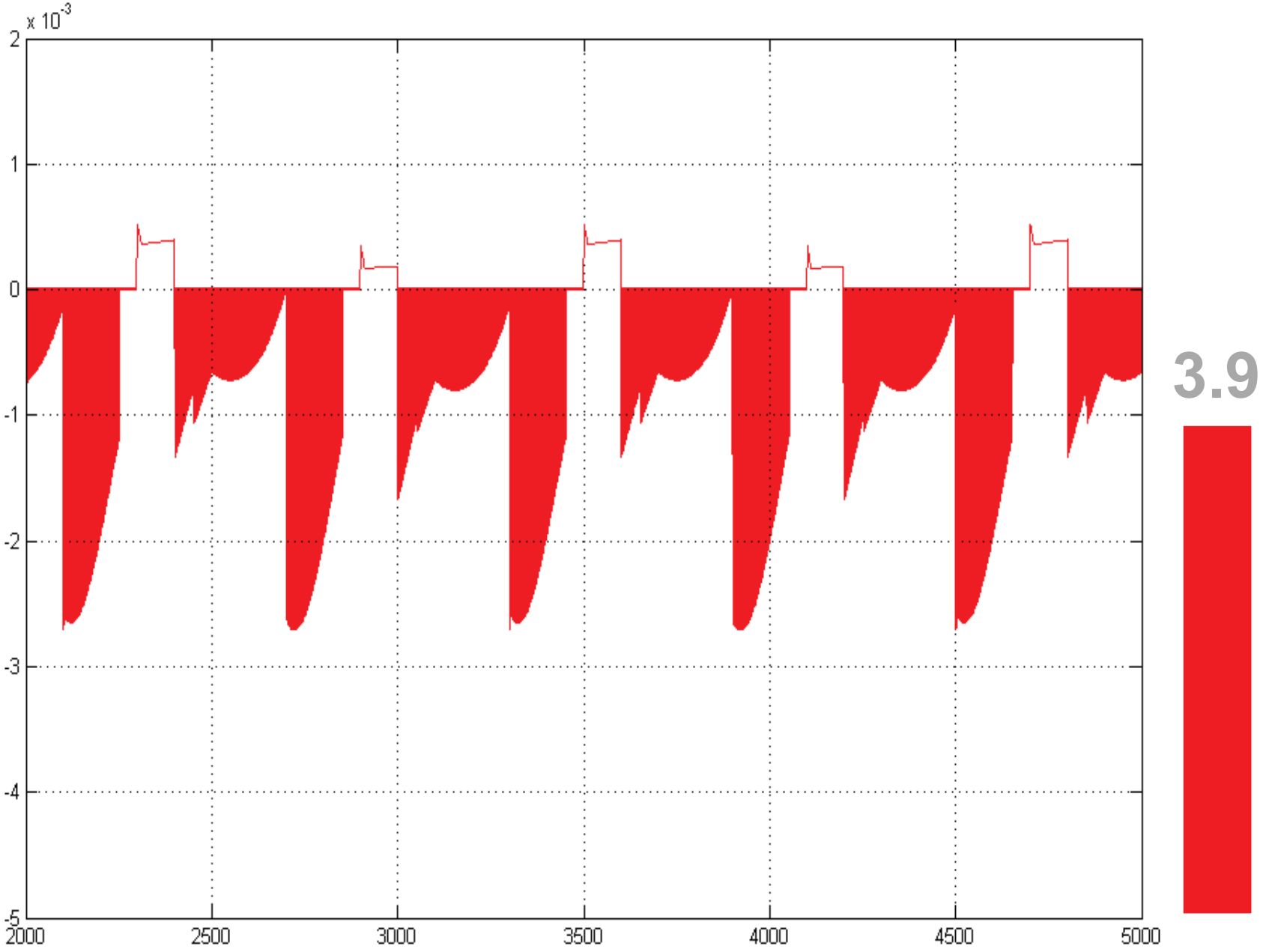


3.2

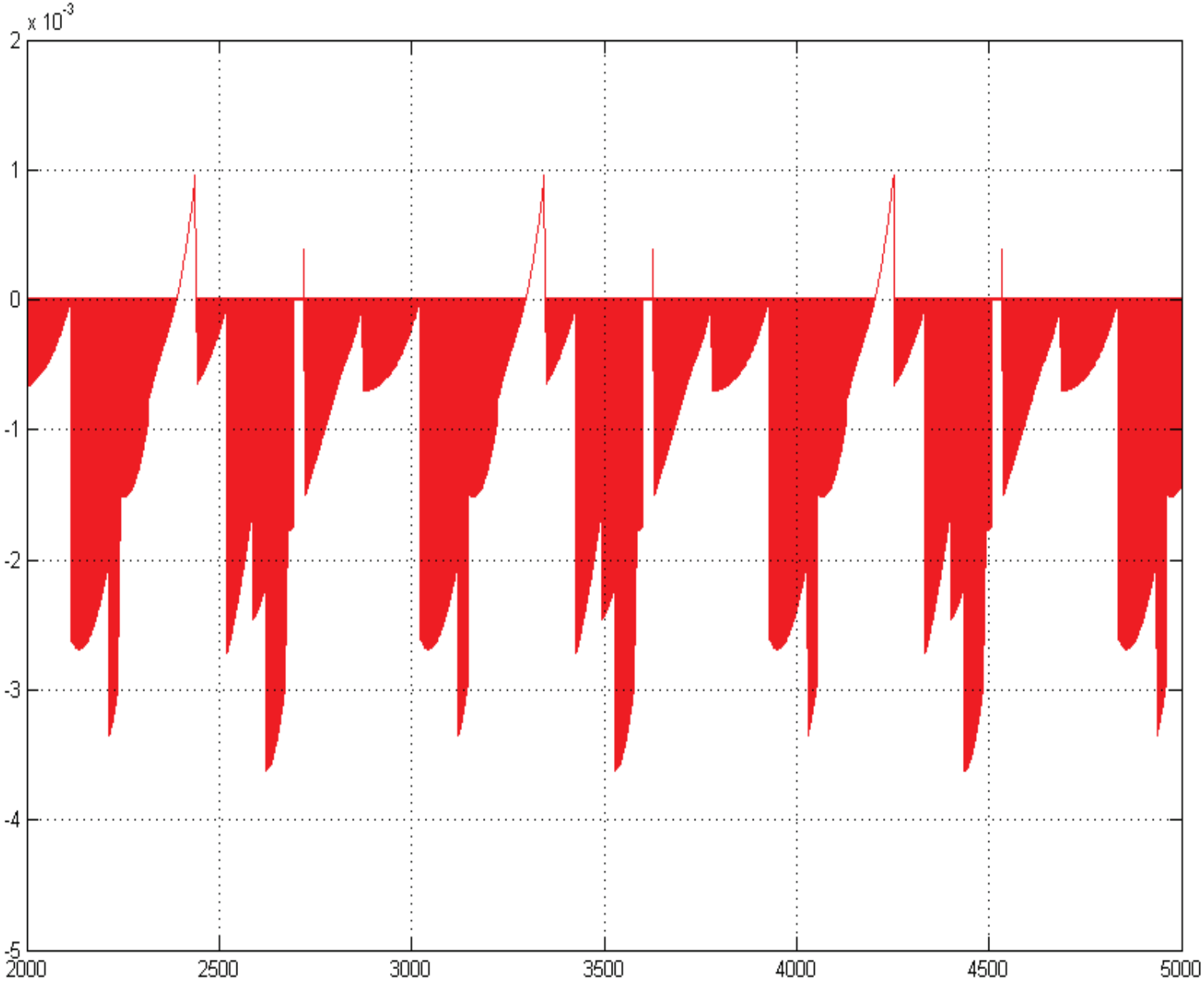
3D MODE A-3DF



3D MODE M-3DF

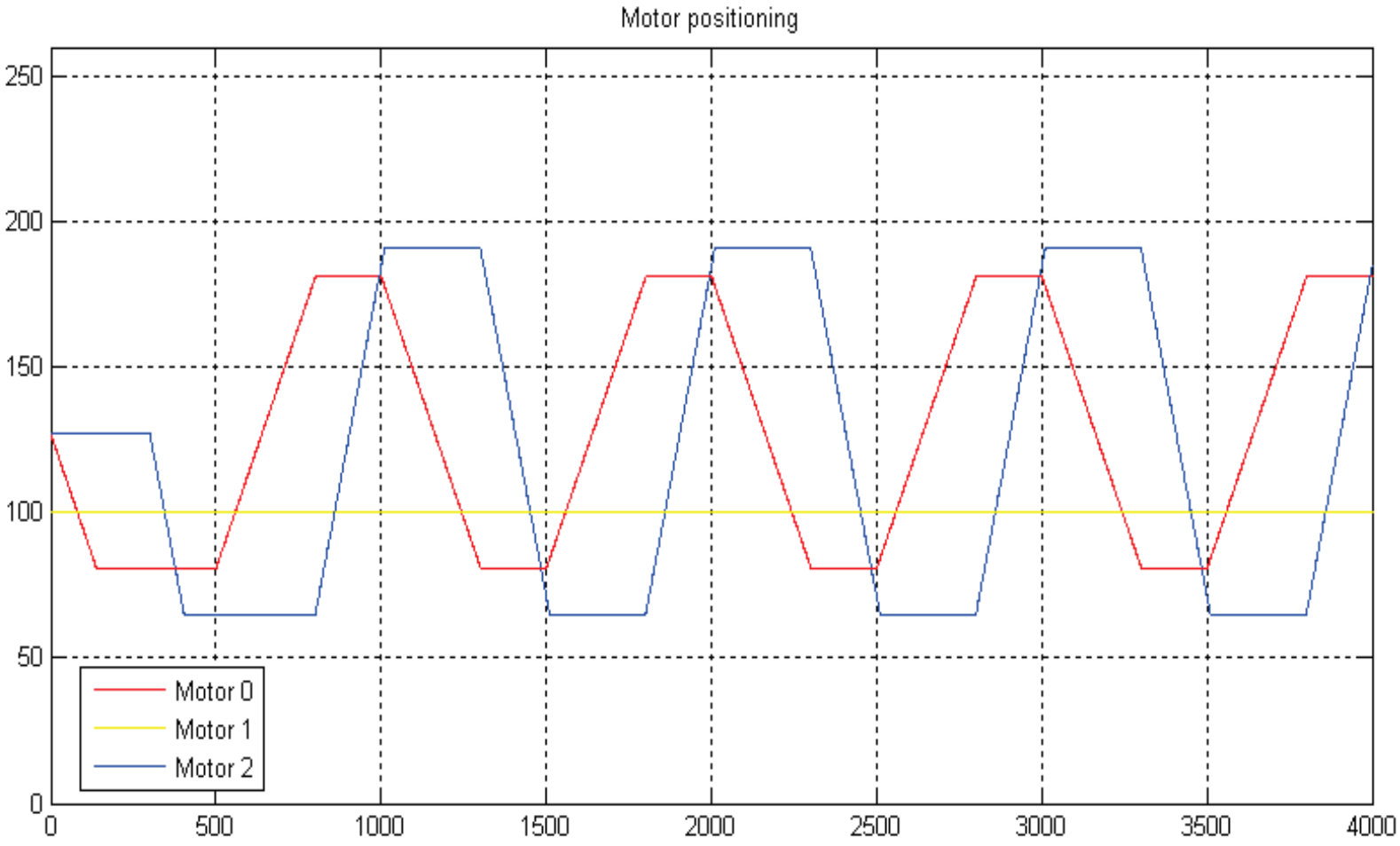


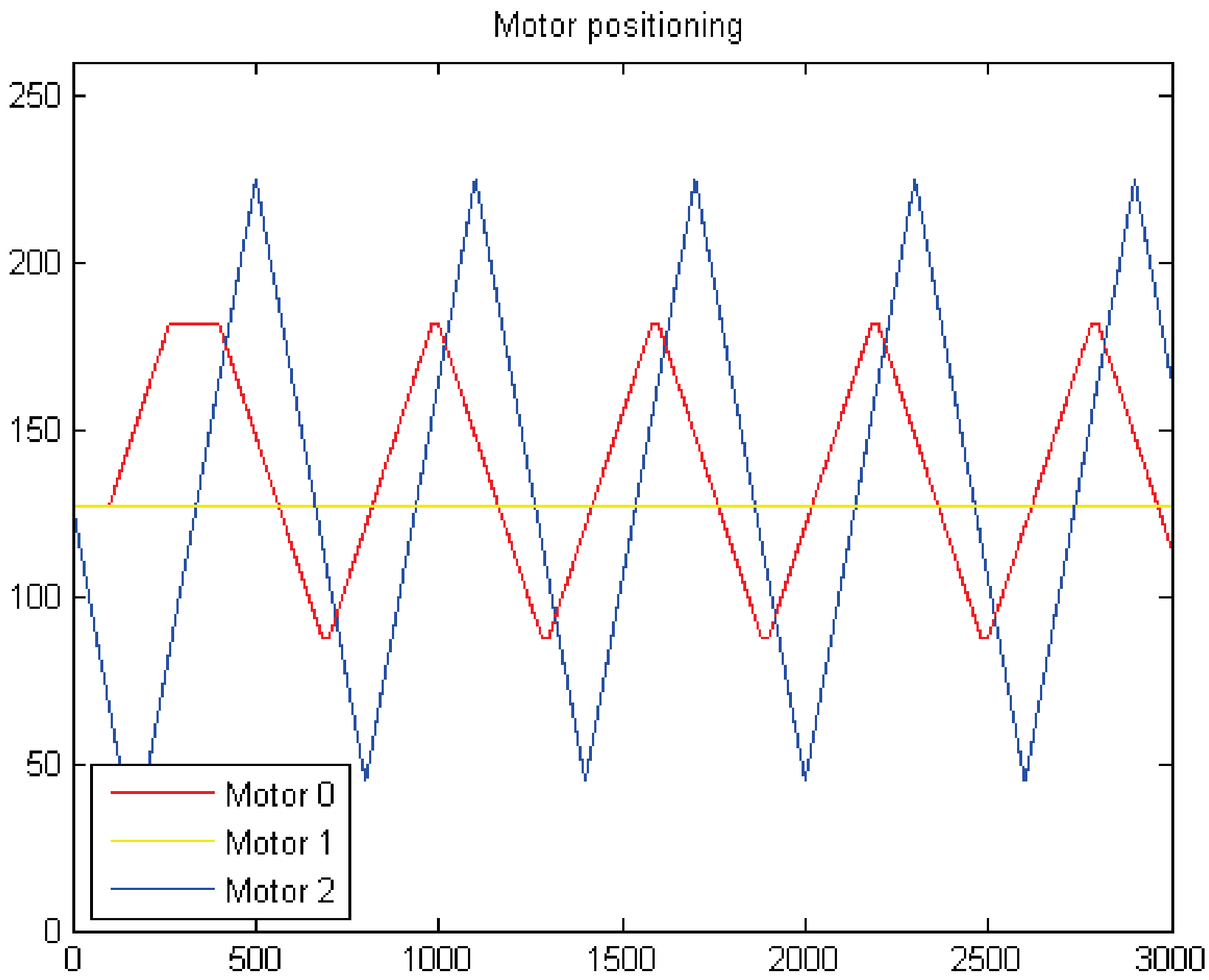
3D MODE X-3DF

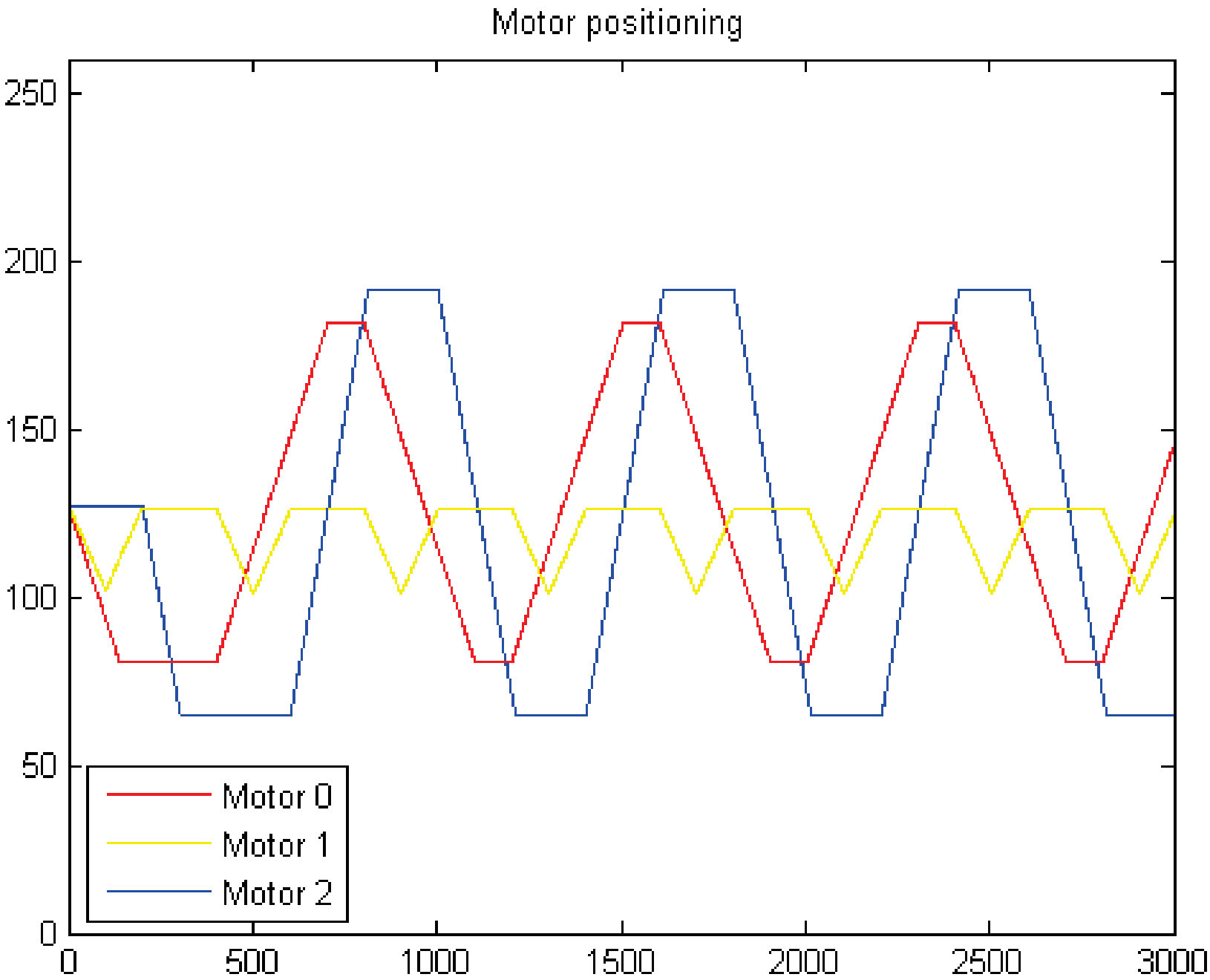


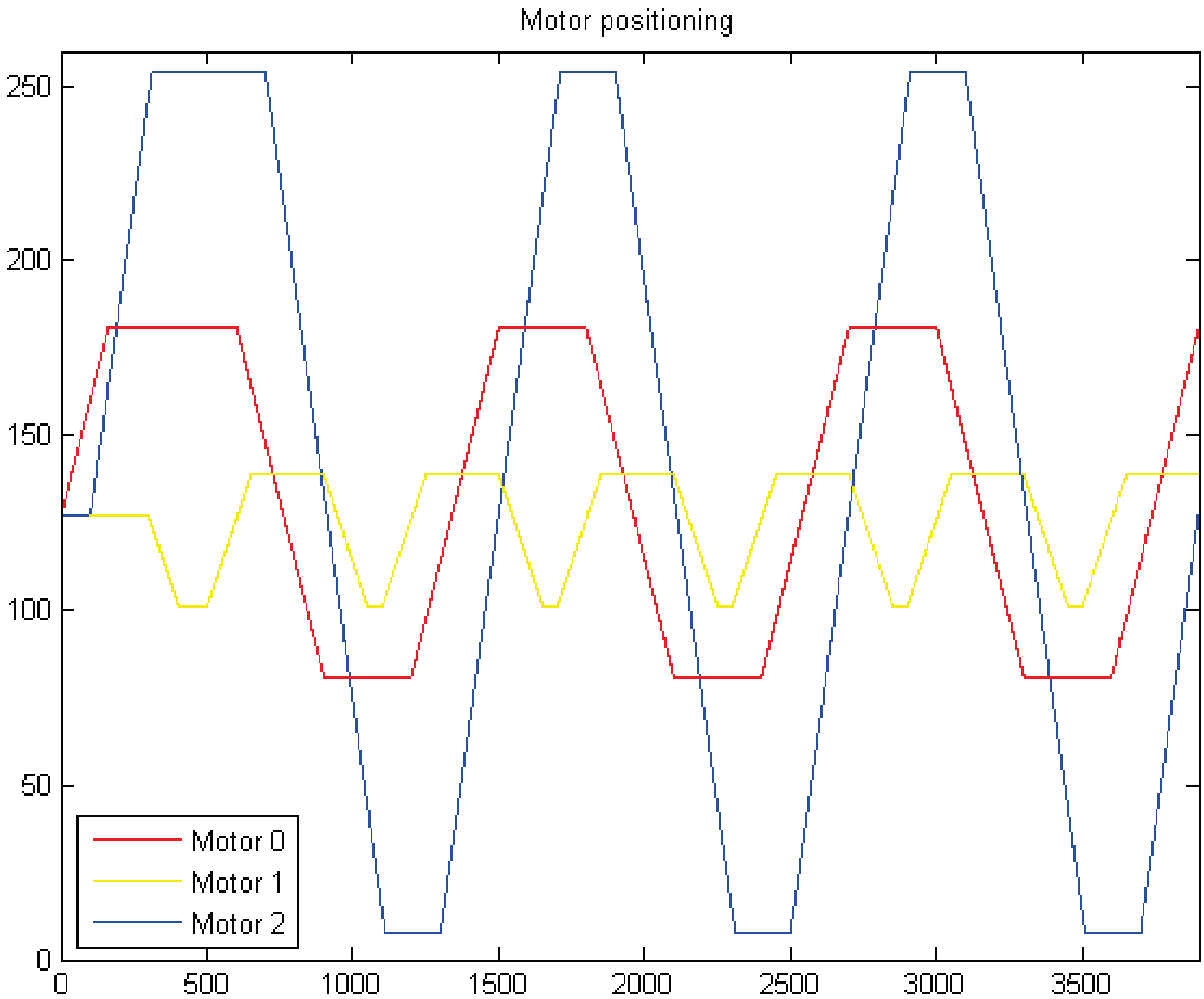
5.6

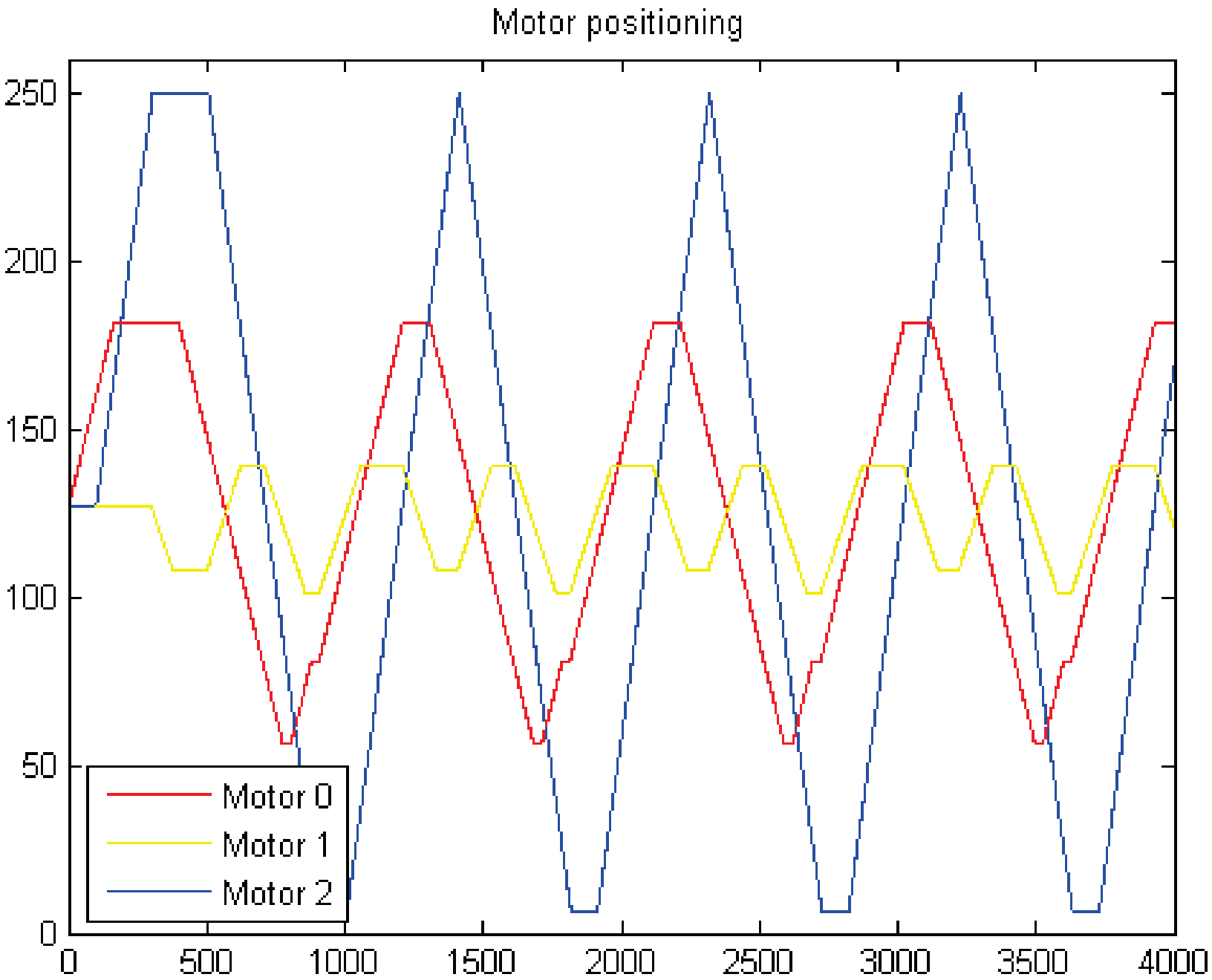
Motor Positioning




Motor positioning
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
Motor 0
Motor 1
Motor 2

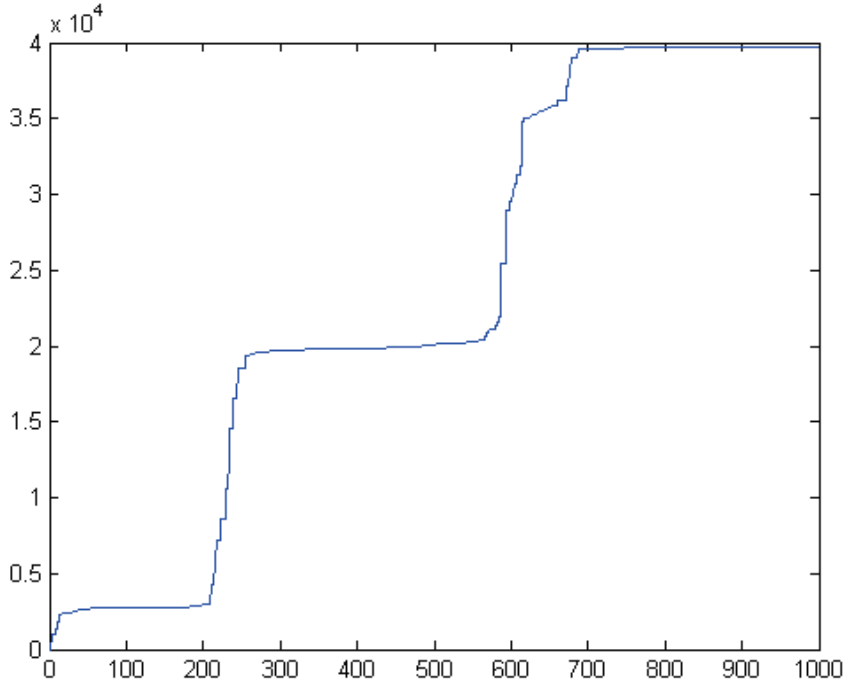

Motor positioning
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
Motor 0
Motor 1
Motor 2

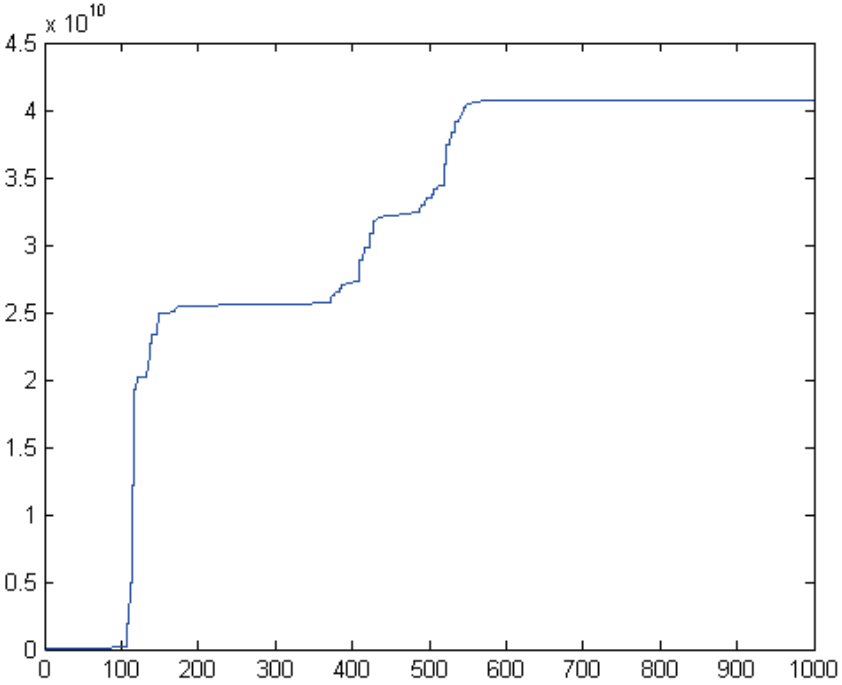

Motor positioning
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
Motor 0
Motor 1
Motor 2


Motor positioning
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
4000
Motor 0
Motor 1
Motor 2

Progress in time

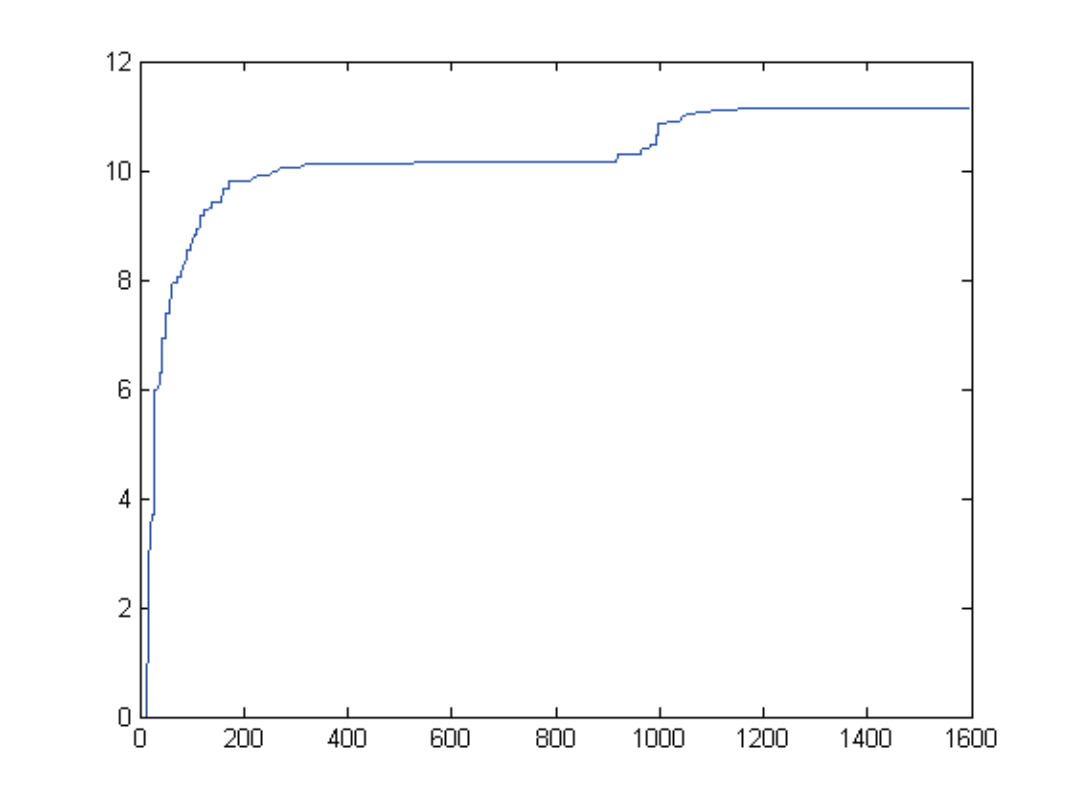
- Overall time evolution of maximum fitness





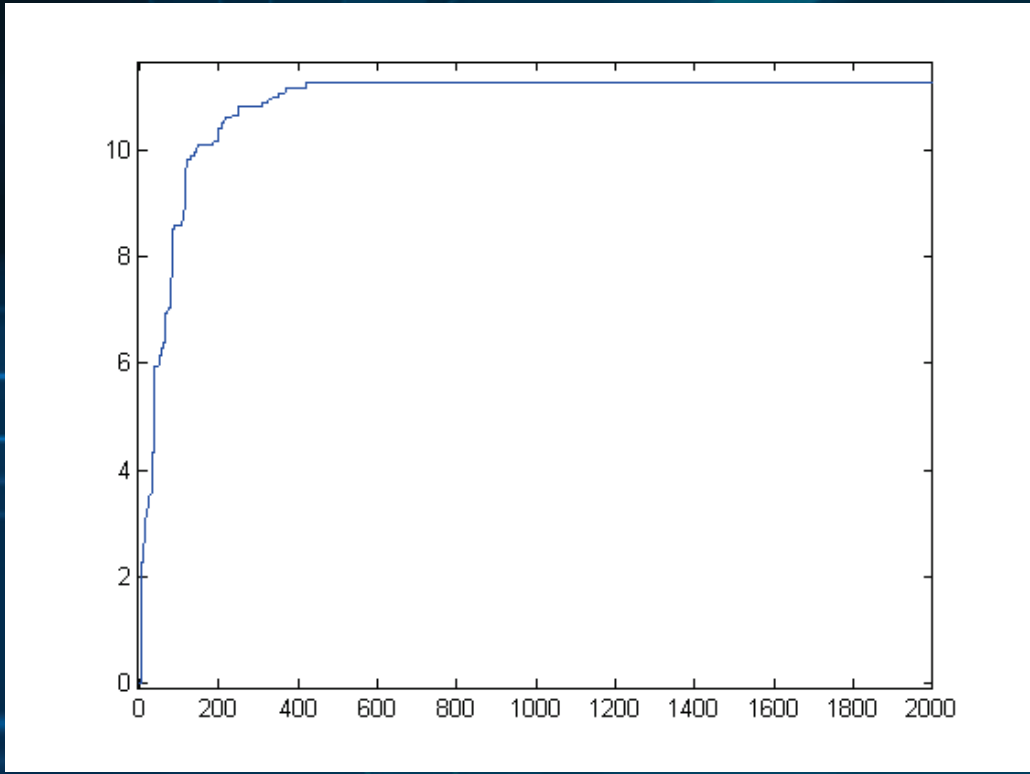
Progress in time

- Multi-Agent stand-alone application (1 proc.)

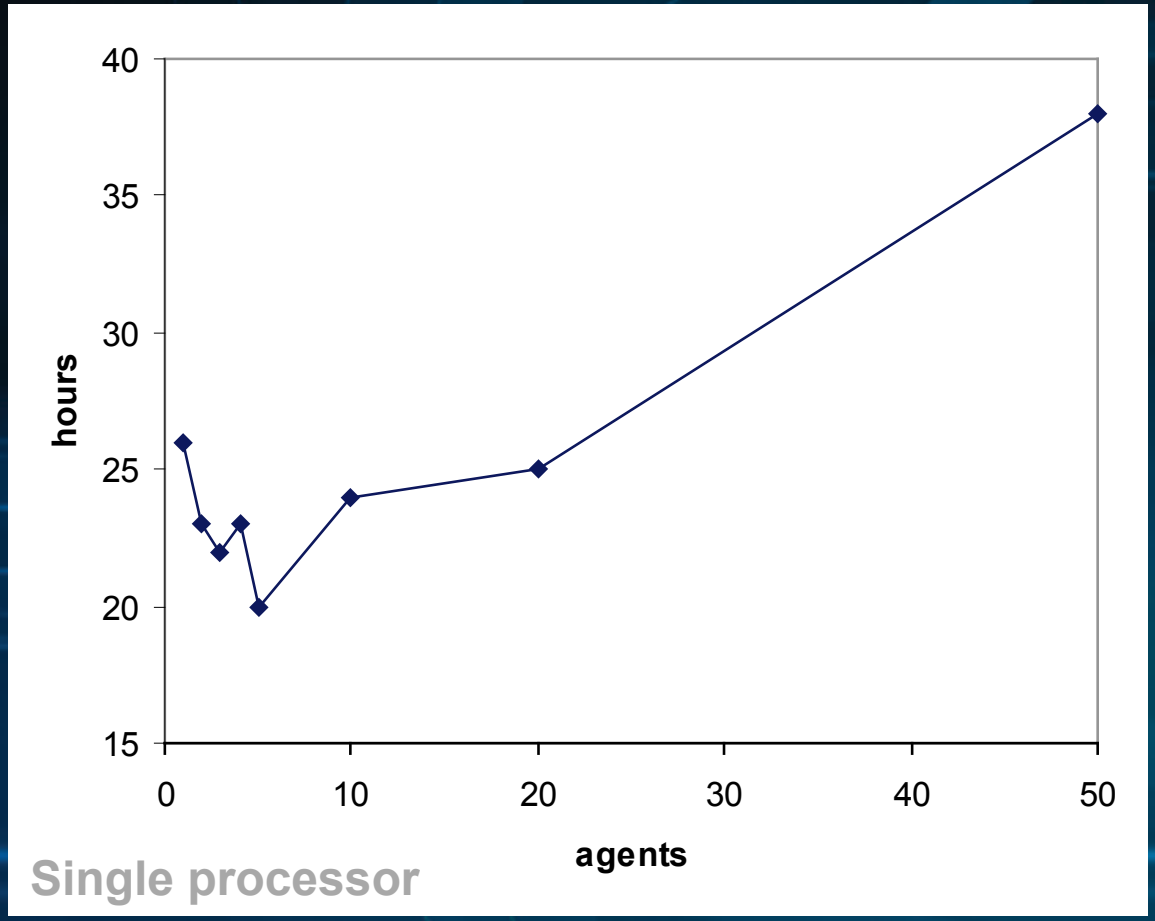


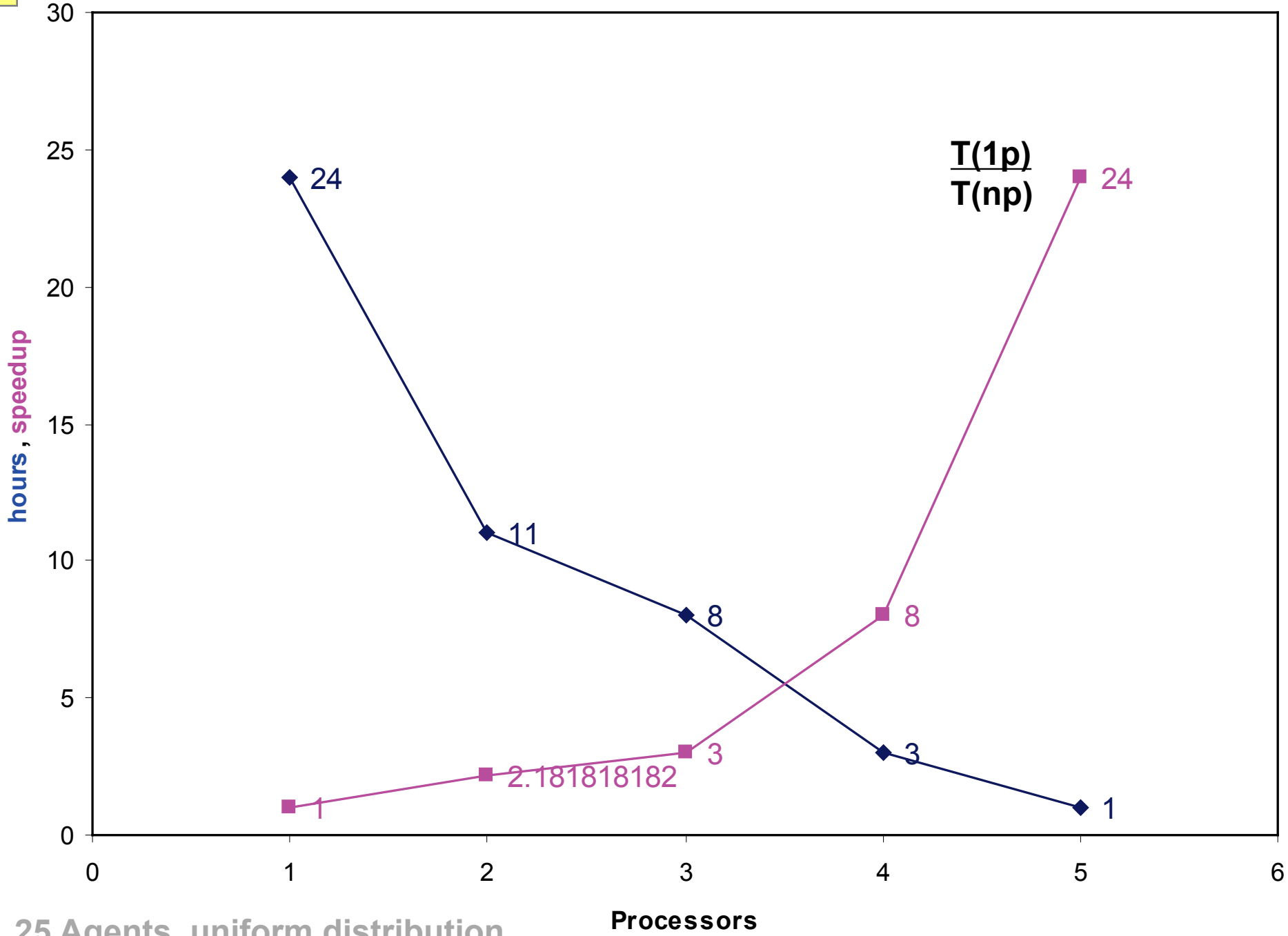
Parallel model

- Multi-Agent stand-alone application (2 proc.)



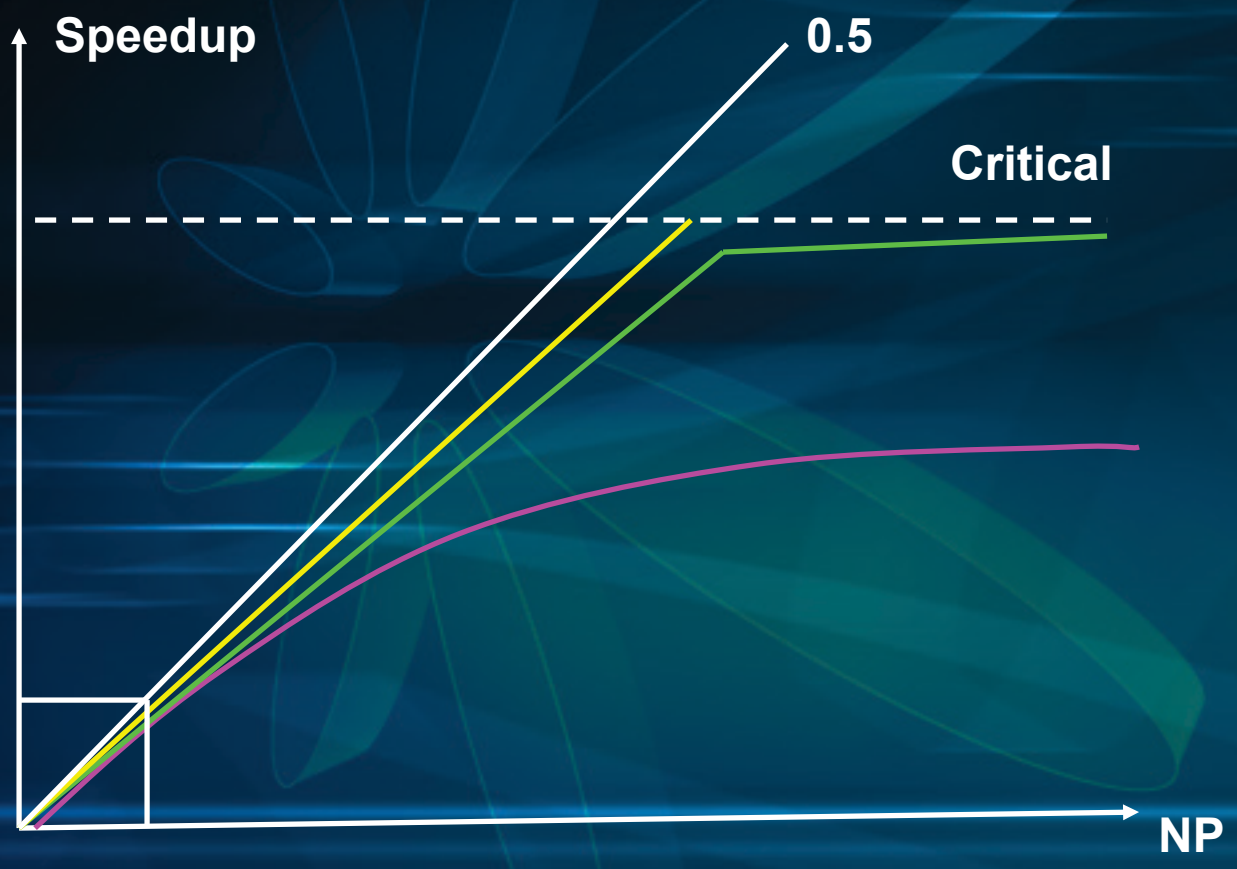
Benchmarking





25 Agents, uniform distribution

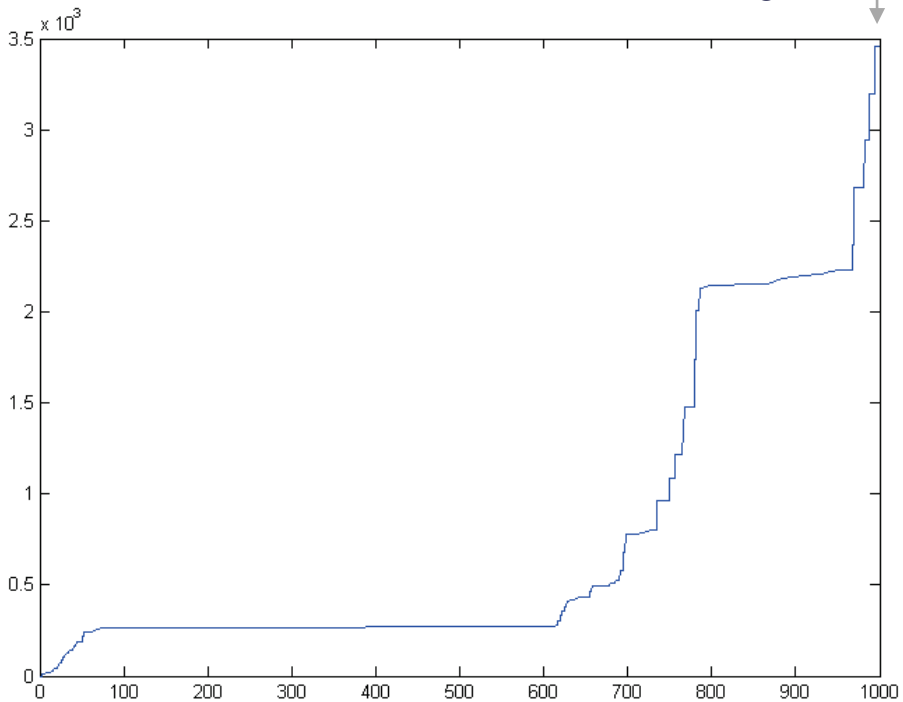
Usual speedups



Comparison

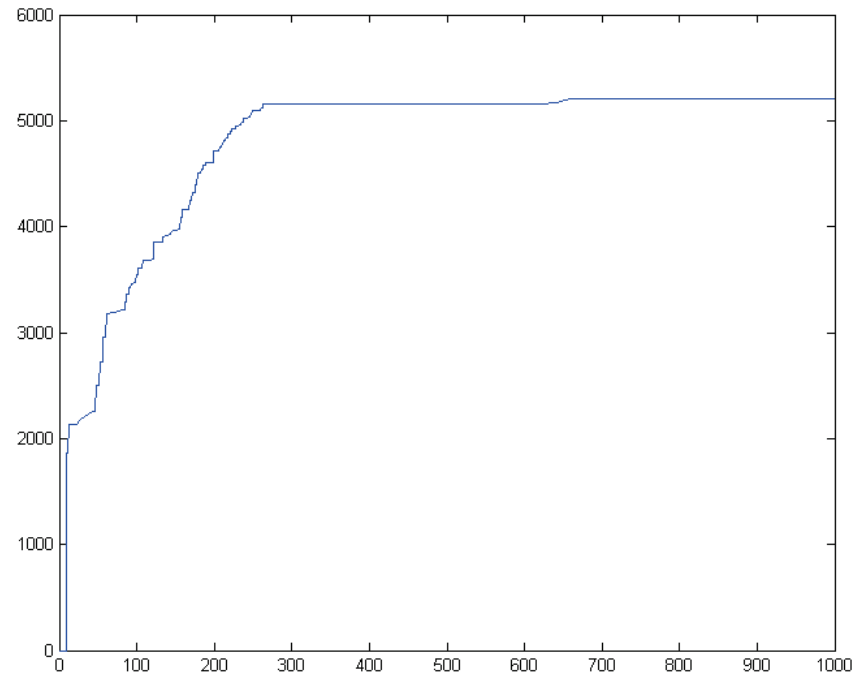
Graphic analysis Maximum fitness (Fm) vs. Generation for 1000 generations

Fm=3.4K



Single-thread model
1 Agent, 1 processor
~26h total time

Fm=5.2K



Multi-thread model
3 Agents, 2 processors
5h 30 min

Conclusions
Ro

- The method were able to identify new rowing modes for Ro
- The method optimized the conventional Ro operation
- New solutions are non-intuitive, being hard to achieve by the conventional method
- The results could be verified in the actual model

SACS

Conclusions
Parallel computing

- The agent-oriented approach solved the problem in fractions of original time
- Increasing the number of processors (NP), the time consumed in the multi-threaded model (Tm) compared to the single-threaded model (Ts) is usually Tm<<Ts/np (~90% cases)
- The speedups behave in a super-linear fashion, by exploring simultaneously several different regions of the multi-dimensional space

SACS

Conclusions
MAS

- Allowed the use of alternate distributed topologies
- Distributed computer systems and networks are becoming cheap and more accessible, allowing a broader application of the described method.
- The method can be extended to more complex control problems, such ship navigation, collision avoidance or docking

SACS

Algorithm Optimization

CMD	POS	T (100ms steps)
20, 21 or 22	00-FF (255)	0-1000 (400)
20, 21 or 22	00-FF (255)	0-1000 (400)
20, 21 or 22	00-FF (255)	0-1000 (400)
…	…	…

(3*255*10)E(n Lines)
7650 E (n Lines) solutions

SACS

Algorithm Optimization

(Front rowing)

7650 E (n Lines) solutions

Actual GA (max) 14 lines = 4.02 E46 solutions

Approx ~ 40E16 tested

Test rate before = 18 tests / minute = 1000 tests/hour *
Test rate now = ~ 200 tests / minute = 18000 tests/hour

SACS

Suggestion for future works

- Implement a full-scale simulation of the water-borne experiment
- Apply the MAS approach to other control problems in engineering
- Experiment with different network topologies

SACS

Used equipment

1. Athlon64 3800+ X2, Windows XP x64
   1GB RAM, LAN Drive
2. Athlon64 3200+, Linux 64
   1GB RAM, Dual Speed RAID-0 Array
3. Pentium IV 2.2GHz, Windows XP
   512MB RAM, LAN Drive
4. Pentium III 1.8Ghz, Windows XP
   512MB RAM, LAN Drive
5. Pentium III 900Mhz, Windows XP
   256MB RAM, LAN Drive

SACS

Time Schedule 2005

Jan Feb Mar April May June July Aug Sep Oct Nov Dec

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- Prof. Tsugukiyo Hirayama
- Sea and Air Control Systems Lab's crew
- Special thanks to professor

Yoshiaki Hirakawa

(Model construction, assistance and support)

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Questions

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