

ANALYSIS OF USER TRAJECTORIES BASED ON DATA DISTRIBUTION AND STATE TRANSITION: A Case Study with a Massively Multiplayer Online Game Angel Love Online

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Background

- Trajectory analysis
 - Feature extraction
 - Trajectory comparison
 - Behavior prediction



The next step is

Similar to shoplifting's behavior.



Analysis

His behavior is suspect.

Research Problems

- Traditional model
 - The state set is definite
 - Over-approximate trajectories
 - Cannot expressed exactly
- small movements

time series state transition

$$t \quad (x, y) \rightarrow \text{State}$$

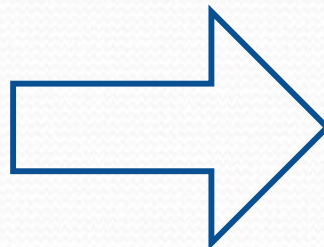
$$1 \quad (x_1, y_1) \rightarrow h_1$$

$$2 \quad (x_2, y_2) \rightarrow h_2$$

$$3 \quad (x_3, y_3) \rightarrow h_3$$

⋮

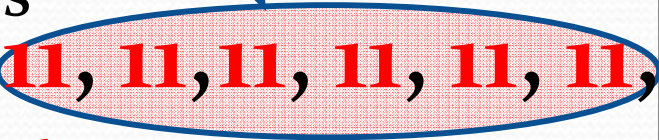
1	2	5	6
3	4	7	8
9	10	13	14
11	12	15	16



State series

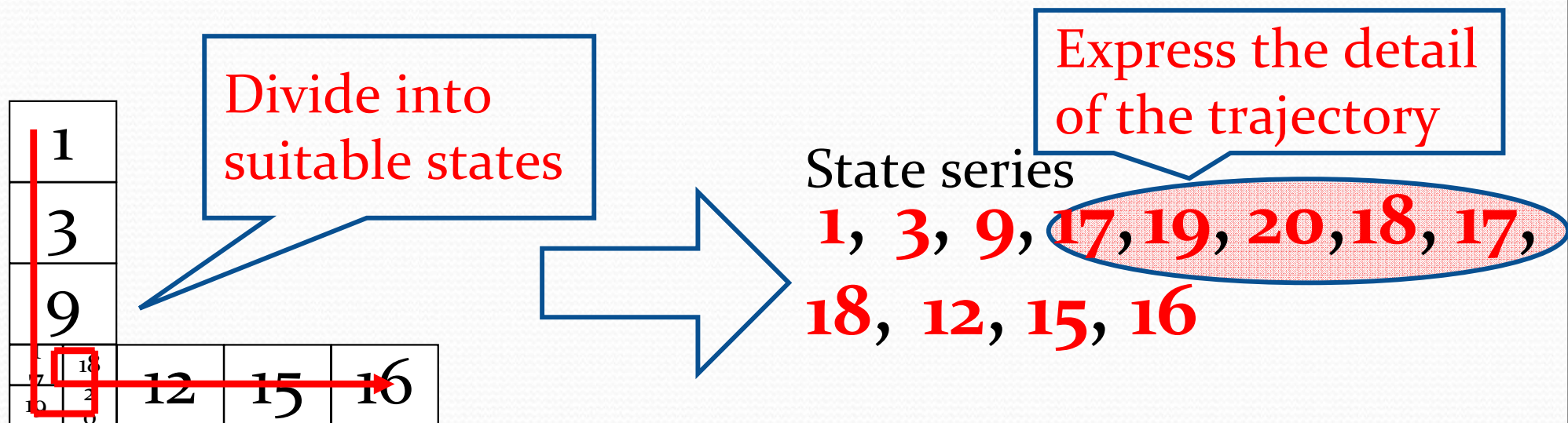
1, 3, 9, 11, 11, 11, 11, 11, 11,
12, 15, 16

Lost features

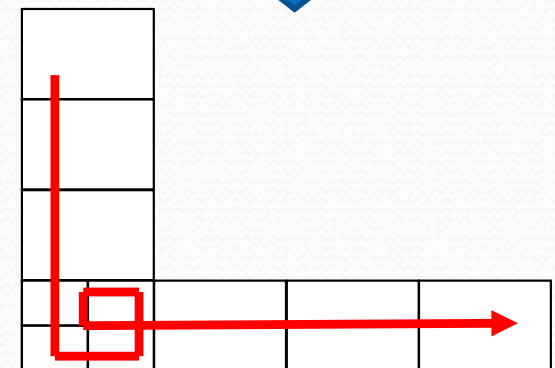
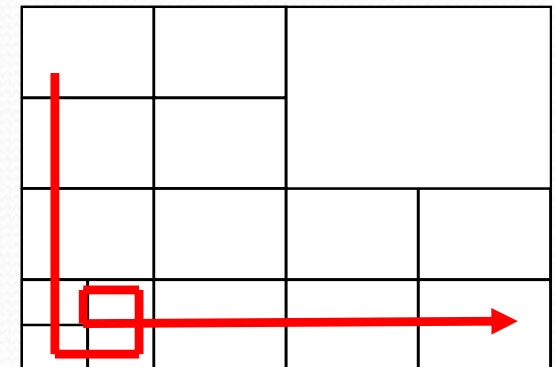
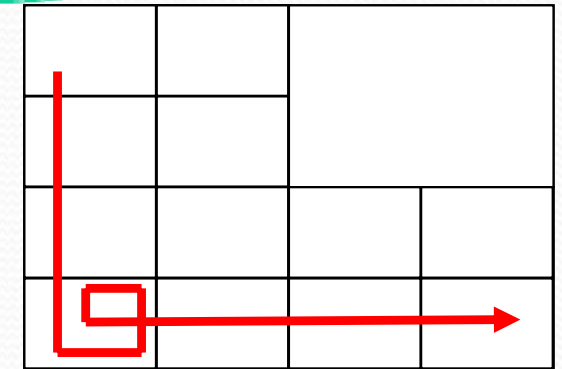
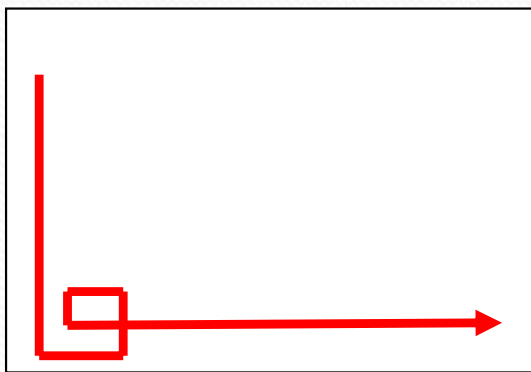


The way of coping

- Divide into suitable states for each trajectory
- Need the method comparing trajectories expressed by transitions in different state sets.
- The comparing method based on **data distribution**
- The comparing method based on **state transition**

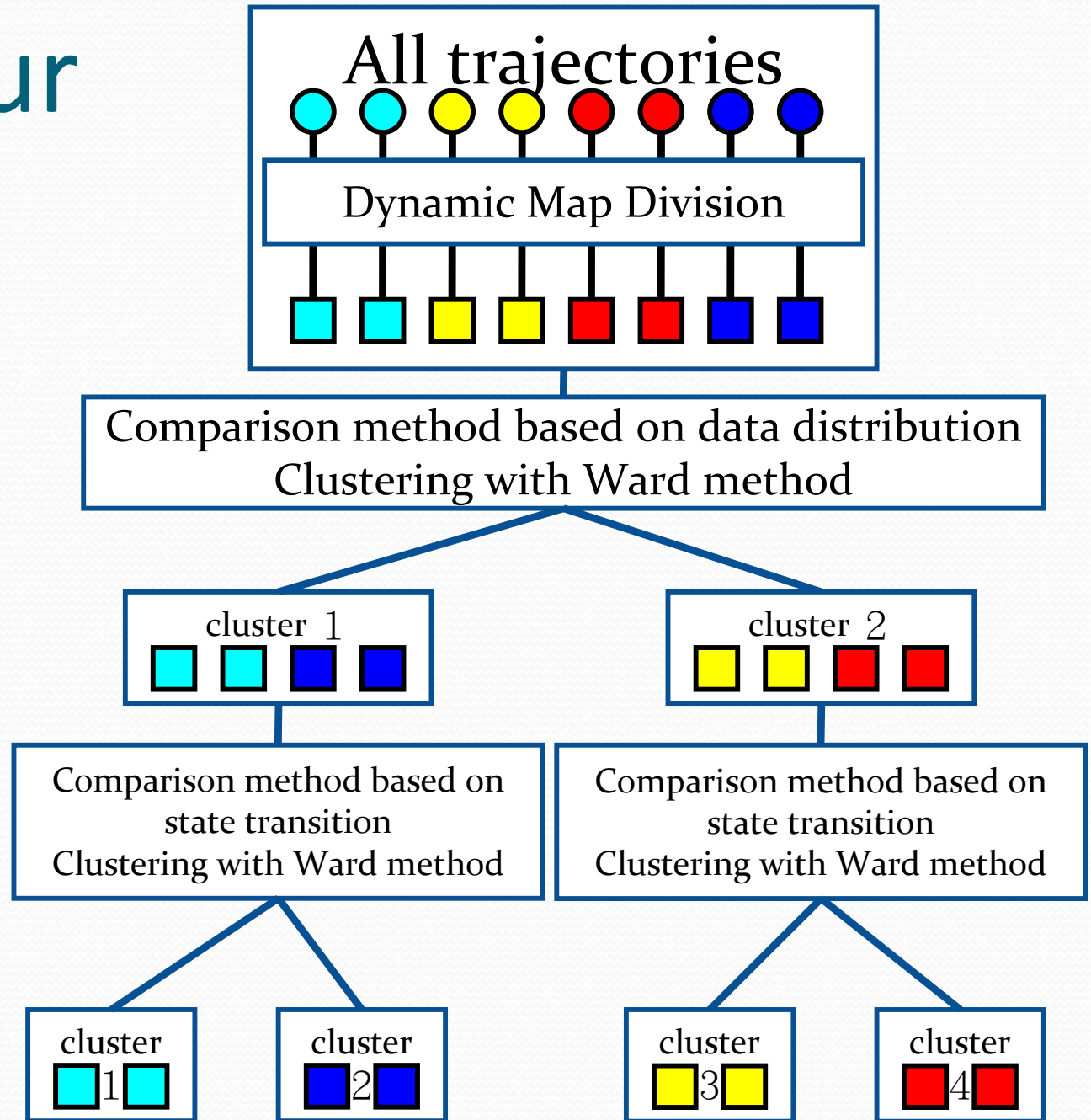
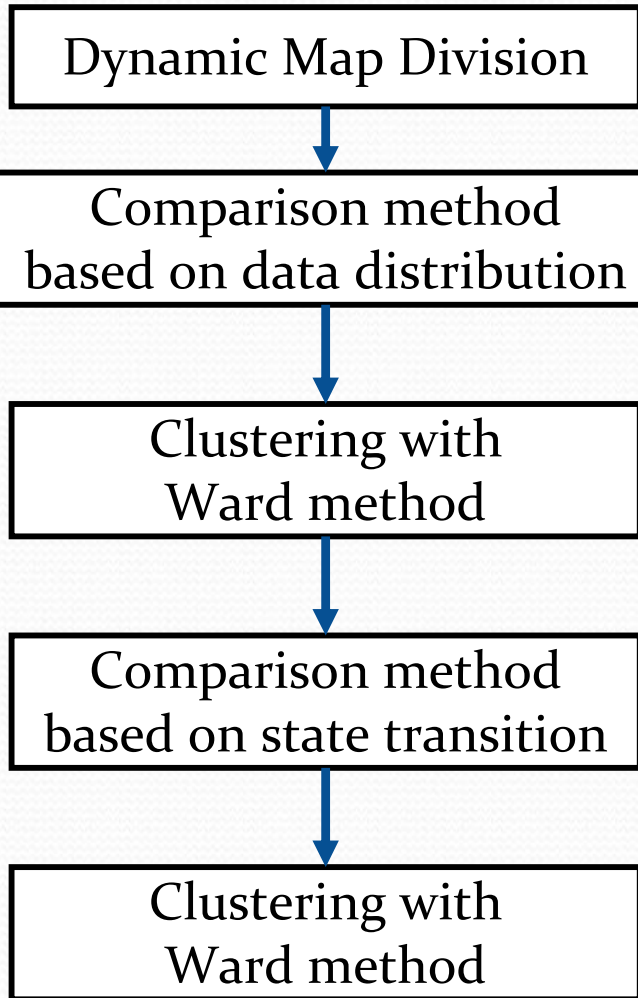


Dynamic Map Division



- Repeat the following
 - ① Evaluate the density in the area
 - ② Divide the area into 4 areas if the density is higher than the threshold.
- Delete areas which don't have trajectory data

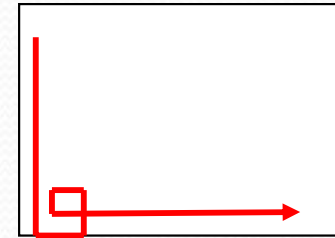
Outline of Our Approach



The initial state



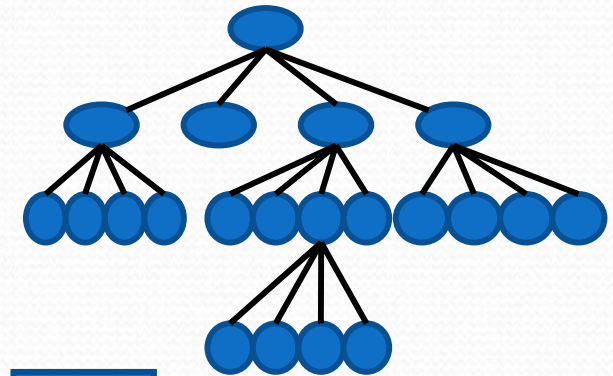
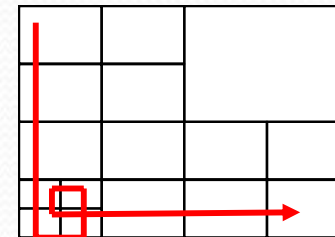
Divide the space



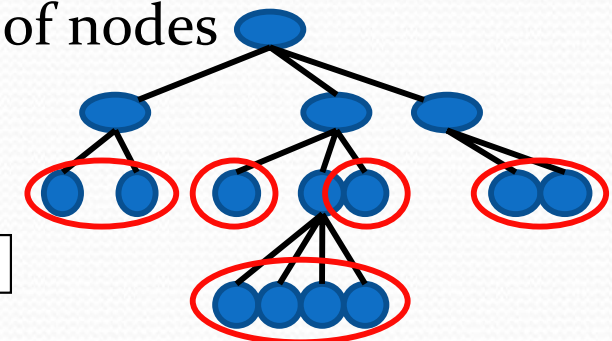
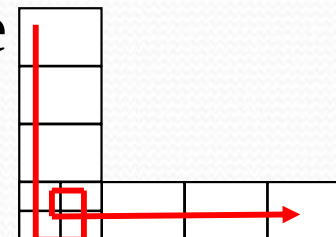
- Implemented by quadtree

- Extension of the tree corresponds to division of the area.
- Deletion of nodes corresponds to deletion of areas.
- Left areas correspond to leaf nodes.
- The number of area corresponds to the number of node.

Extension of the tree



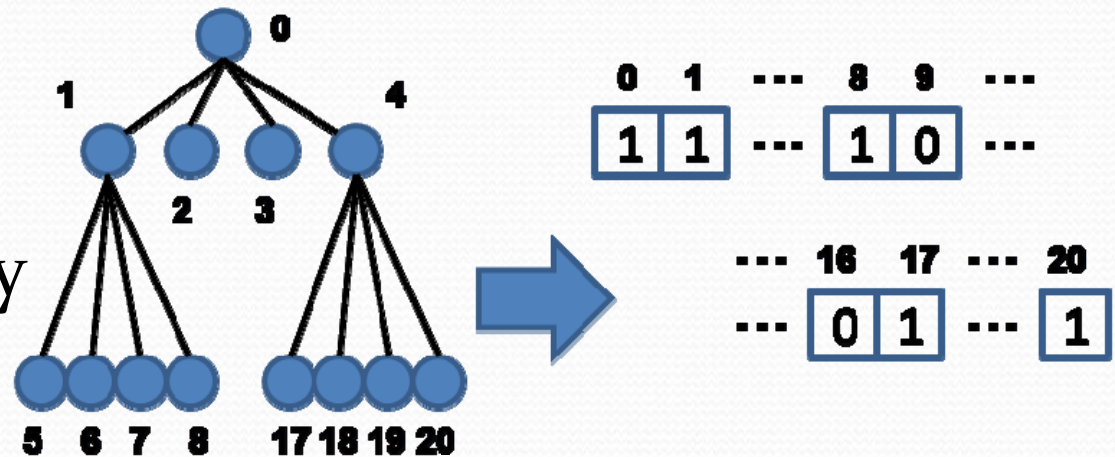
Deletion of nodes



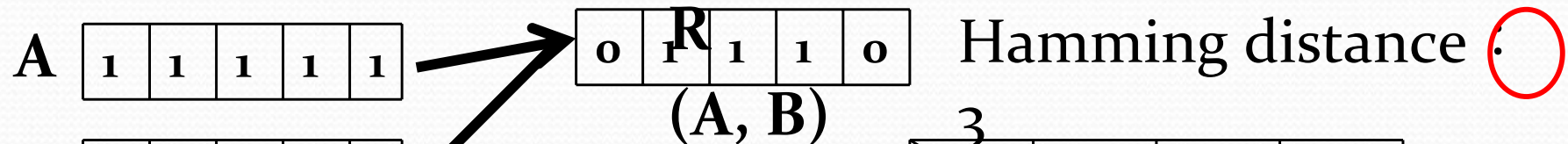
- Comparison based on coordinate data is to compare structures of quadtree.

Comparison Method based on Data Distribution

- Represented by bit sequences
- Evaluate difference by Hamming distance



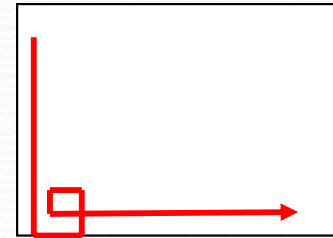
XO



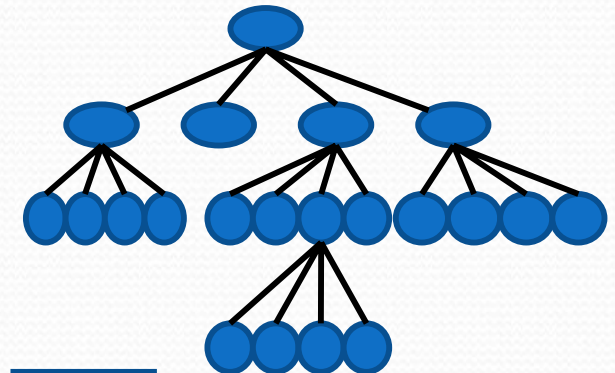
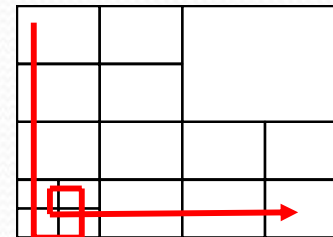
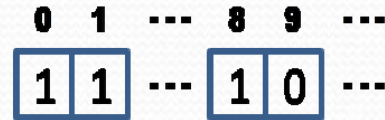
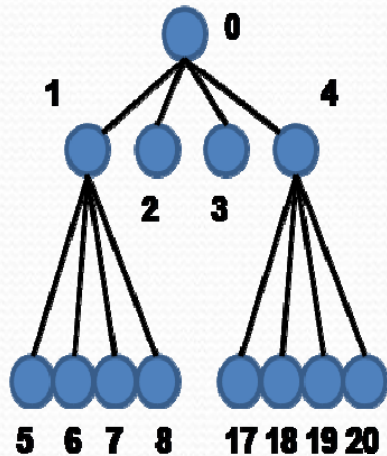
3	A	B	C
B	3		
C	2	1	
D	1	2	1

Hamming distance of quadtree

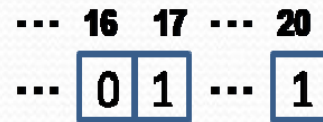
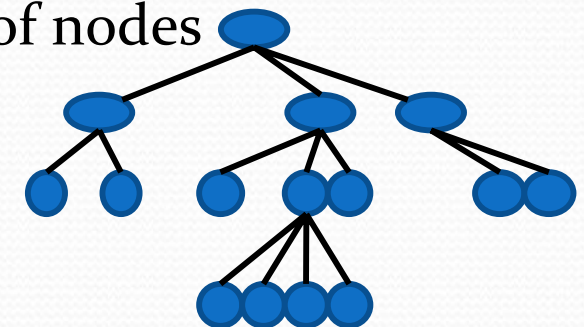
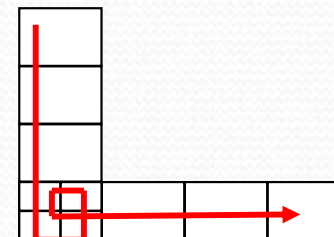
The initial state



Extension of the tree



Deletion of nodes



	A	B	C
B	3		
C	2	1	
D	1	2	1

A 1 1 1 1 1

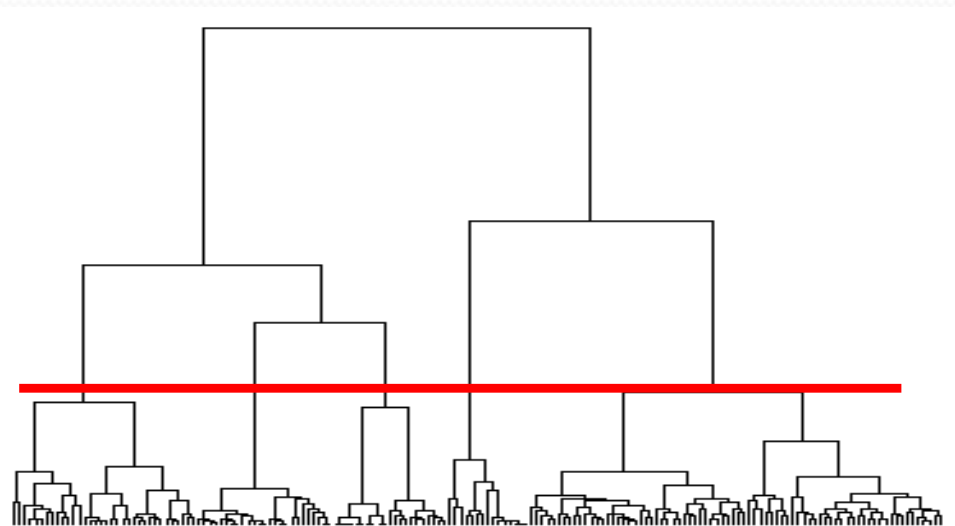
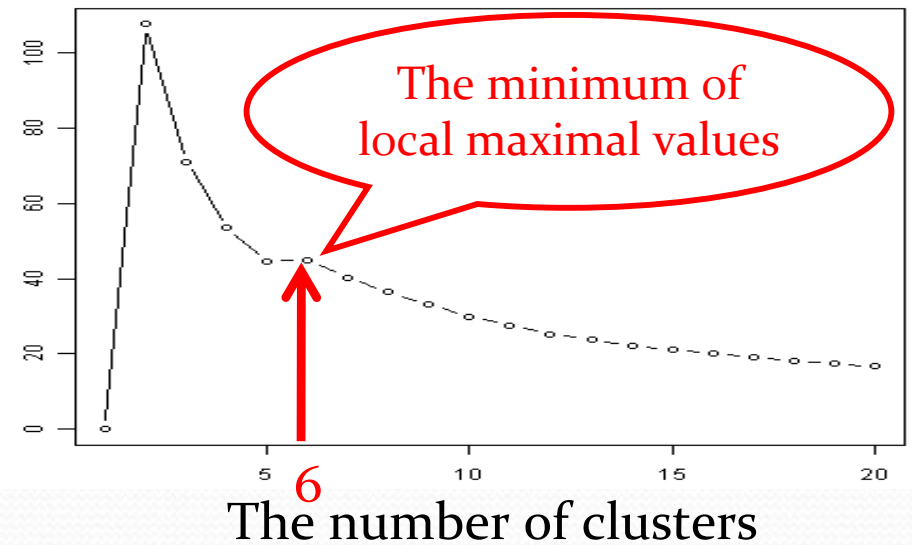
B 1 0 0 0 1

C 1 1 0 0 1

D 1 1 1 0 1

Clustering

- The Ward clustering
- Decide the number of clusters.
 - Show the graph of the proportion of internal variance of the cluster to external variance of all clusters
 - Adopt the number of clusters with the minimum of local maximal values



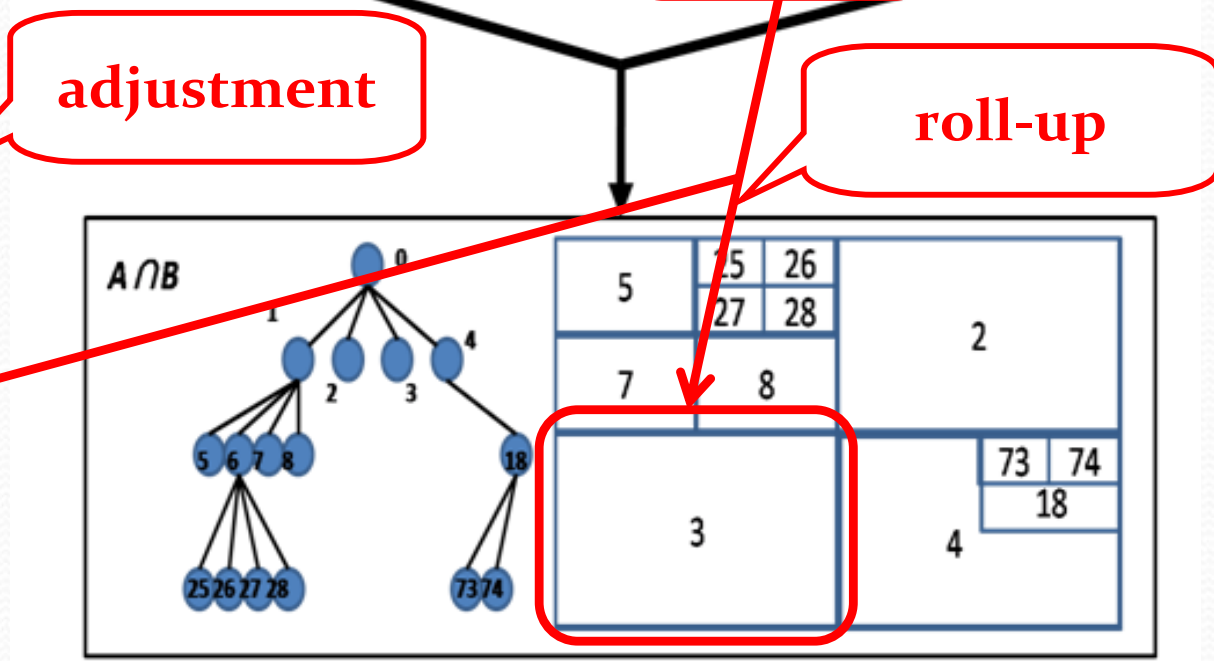
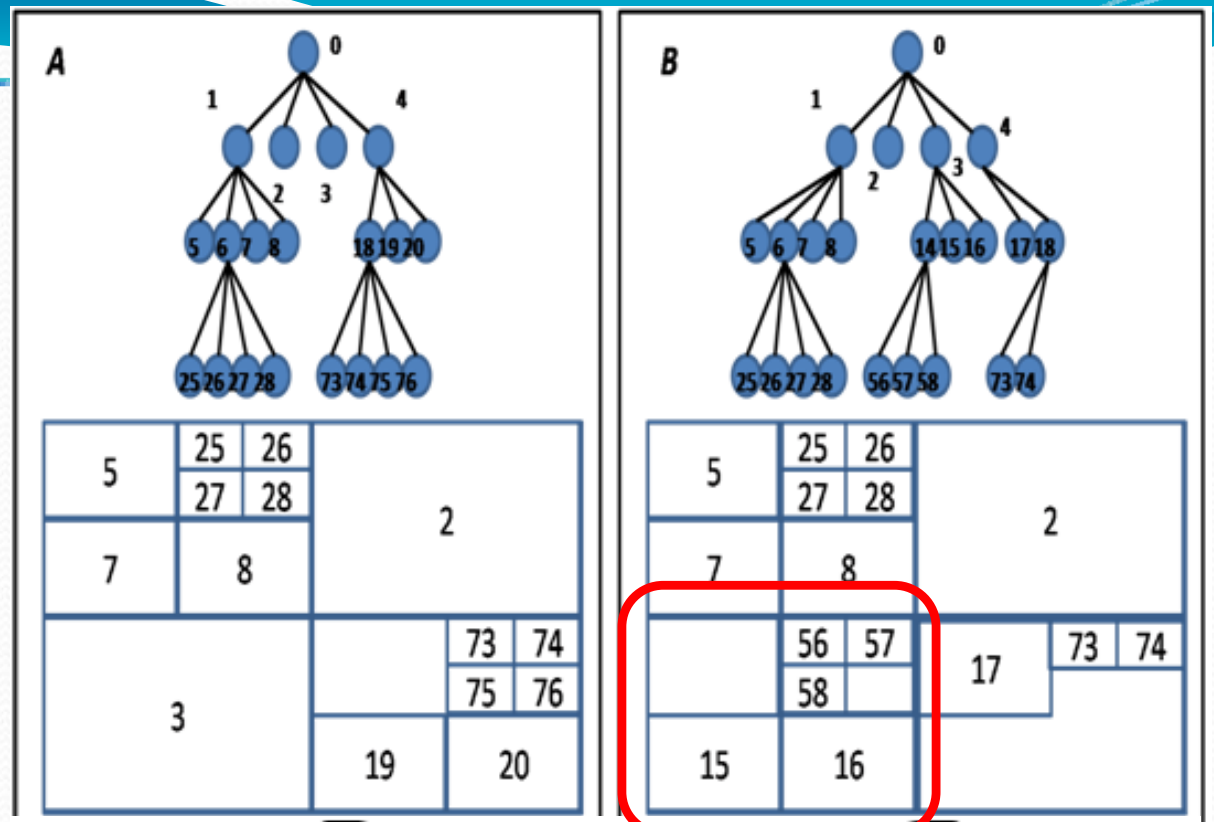
time series transition

state

$$\begin{aligned}
 t & (\mathbf{x}, \mathbf{y}) \rightarrow \text{state} \\
 1 & (x_1, y_1) \rightarrow h_1 \\
 2 & (x_2, y_2) \rightarrow h_2 \\
 3 & (x_3, y_3) \rightarrow h_3 \\
 & \vdots
 \end{aligned}$$



$a_{11}, a_{12}, \dots, a_{1n}$
 $a_{21}, a_{22}, \dots, a_{2n}$
 \vdots
 $a_{n1}, a_{n2}, \dots, a_{nn}$



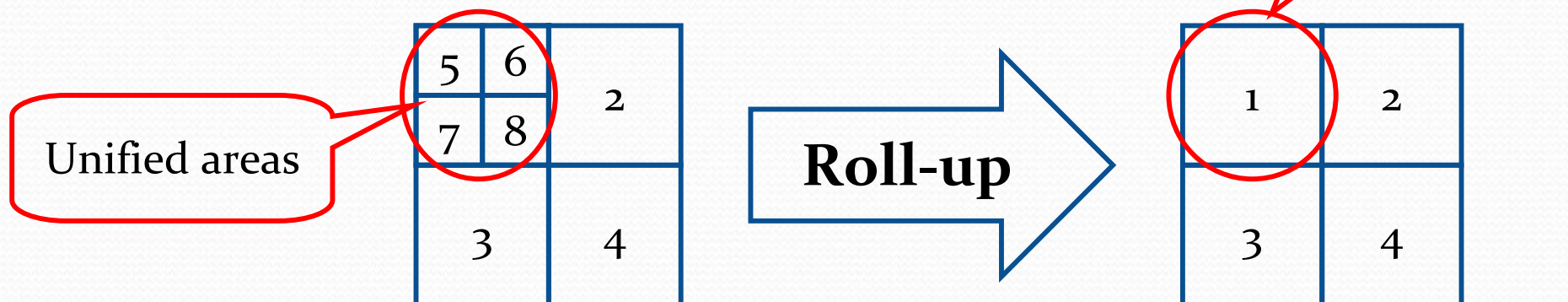
adjustment

roll-up

Comparison based on state transition

- Roll-up algorithm
 - Evaluate the transition probability of the derived states
 - ① Before and after transition areas are unified area.
 - ② Before transition area is unified area.
 - ③ After transition area is unified area.

Example



Comparison based on state transition

- Roll-up algorithm

① Before and after transition areas are unified area.

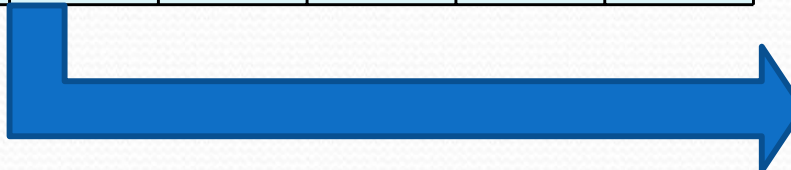
After

Before

	a5	a6	a7	a8	a2	a3	a4
a5	a55	a56	a57	a58	a52	a53	a54
a6	a65	a66	a67	a68	a62	a63	a64
a7	a75	a76	a77	a78	a72	a73	a74
a8	a85	a86	a87	a88	a82	a83	a84
a2	a25	a26	a27	a28	a22	a23	a24
a3	a35	a36	a37	a38	a32	a33	a34
a4	a45	a46	a47	a48	a42	a43	a44

$$a_{11} = (a_{55} + a_{56} + a_{57} + a_{58} + a_{65} + a_{66} + a_{67} + a_{68} + a_{75} + a_{76} + a_{77} + a_{78} + a_{85} + a_{86} + a_{87} + a_{88}) / 4$$

	a1	a2	a3	a4
a1	a11			
a2		a22	a23	a24
a3		a32	a33	a34
a4		a42	a43	a44



Comparison based on state transition

- Roll-up algorithm

② Before transition area is unified area.

After

Before

	a5	a6	a7	a8	a2	a3	a4
a5	a55	a56	a57	a58	a52	a53	a54
a6	a65	a66	a67	a68	a62	a63	a64
a7	a75	a76	a77	a78	a72	a73	a74
a8	a85	a86	a87	a88	a82	a83	a84
a2	a25	a26	a27	a28	a22	a23	a24
a3	a35	a36	a37	a38	a32	a33	a34
a4	a45	a46	a47	a48	a42	a43	a44

$$a_{12} = (a_{52} + a_{62} + a_{72} + a_{82}) / 4$$

$$a_{13} = (a_{53} + a_{63} + a_{73} + a_{83}) / 4$$

$$a_{14} = (a_{54} + a_{64} + a_{74} + a_{84}) / 4$$

	a1	a2	a3	a4
a1		a12	a13	a14
a2		a22	a23	a24
a3		a32	a33	a34
a4		a42	a43	a44

Comparison based on state transition

- Roll-up algorithm

③ After transition area is unified area.

After

Before

	a5	a6	a7	a8	a2	a3	a4
a5	a55	a56	a57	a58	a52	a53	a54
a6	a65	a66	a67	a68	a62	a63	a64
a7	a75	a76	a77	a78	a72	a73	a74
a8	a85	a86	a87	a88	a82	a83	a84
a2	a25	a26	a27	a28	a22	a23	a24
a3	a35	a36	a37	a38	a32	a33	a34
a4	a45	a46	a47	a48	a42	a43	a44

$$a_{21} = a_{25} + a_{26} + a_{27} + a_{28}$$

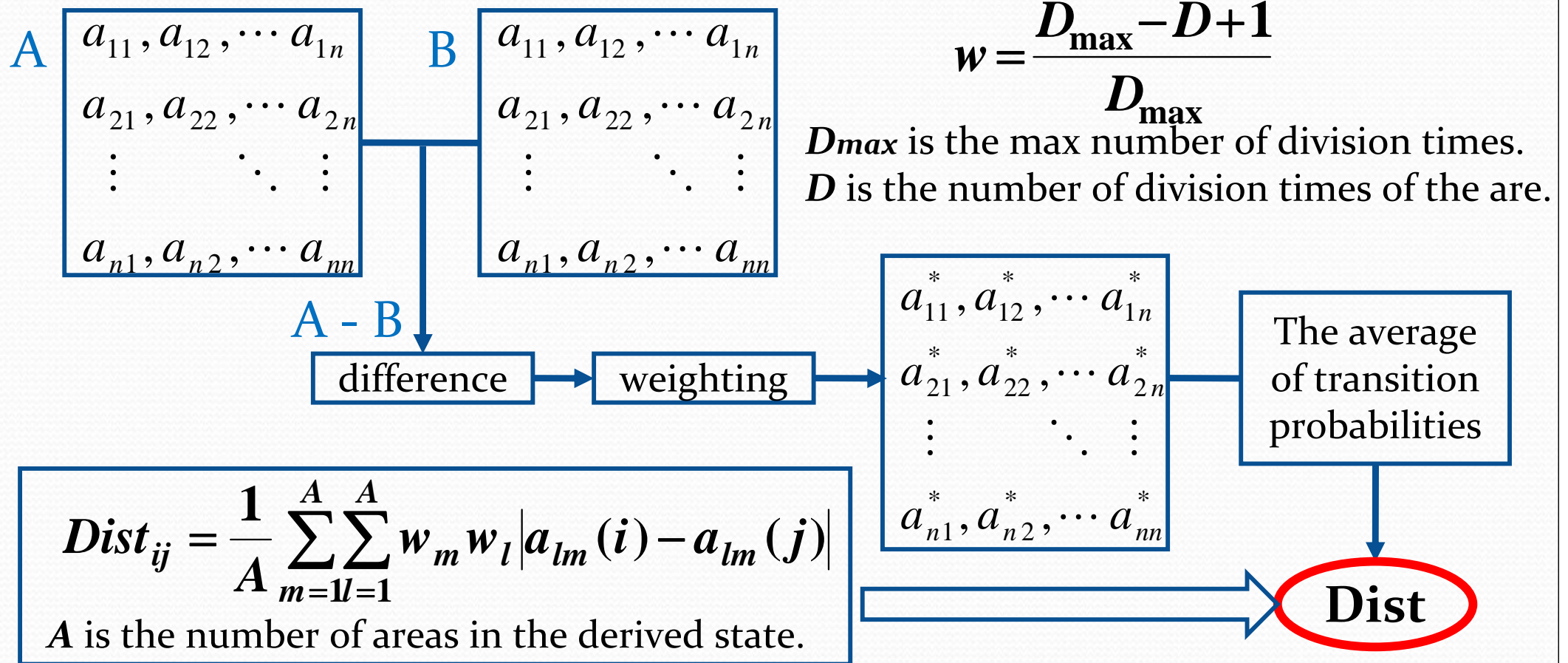
$$a_{31} = a_{35} + a_{36} + a_{37} + a_{38}$$

$$a_{41} = a_{45} + a_{46} + a_{47} + a_{48}$$

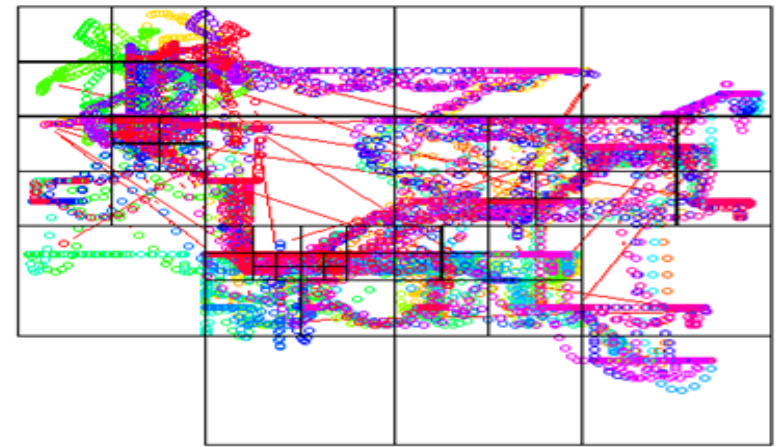
	a1	a2	a3	a4
a1				
a2	a21	a22	a23	a24
a3	a31	a32	a33	a34
a4	a41	a42	a43	a44

Comparison Method based on State Transition

- Difference in transition probability
 - Weighting in accordance with the size of area
 - The smaller the size of the area is, the heavier the weight is.



Experiment I

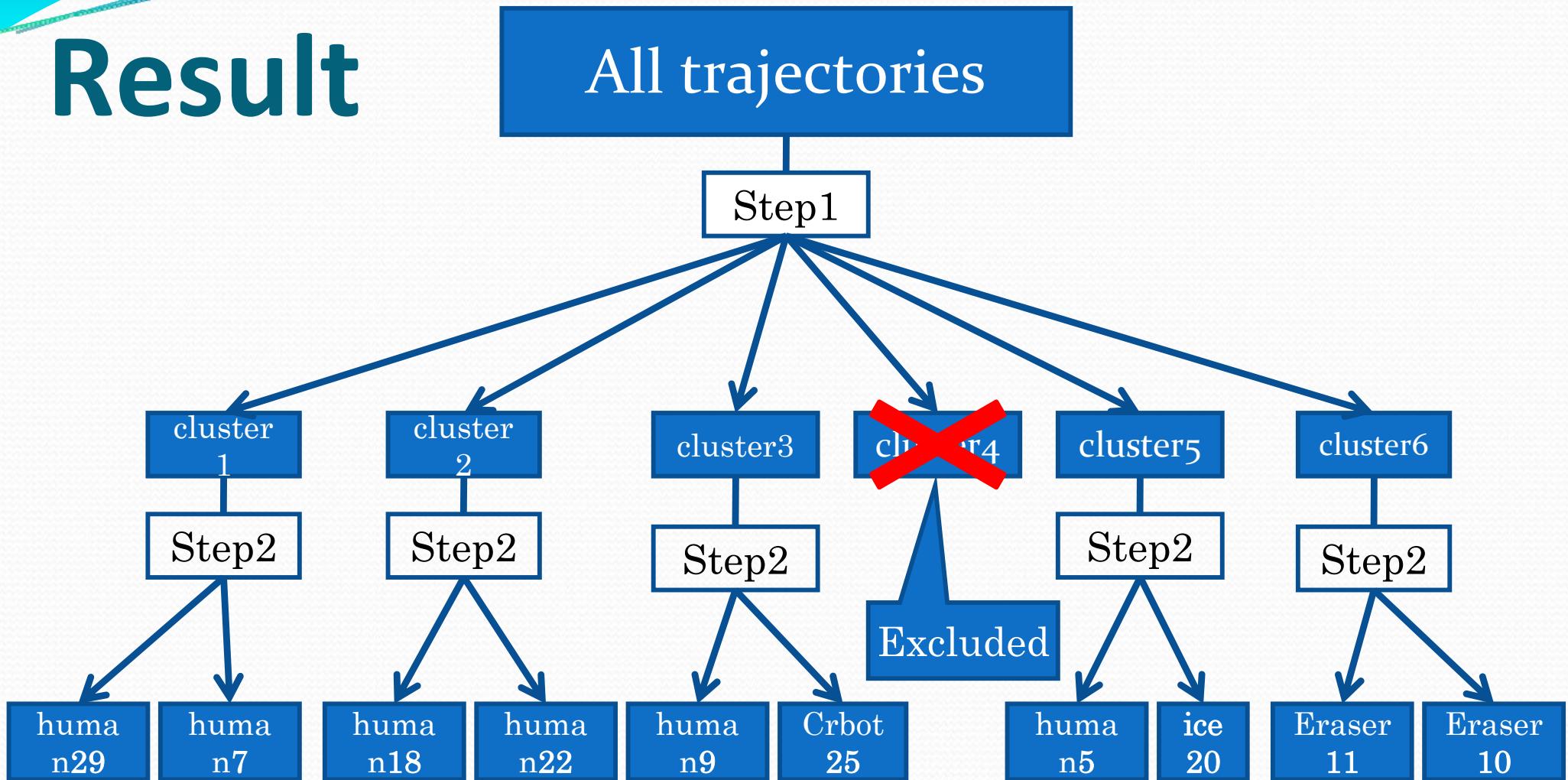


a human player trajectory

- Quake II
 - Trajectories of human player : 105
 - Trajectories of BOT : 66(Crbot : 25, Eraser : 21, ice : 20)
- Compared method
 - Dynamic map division with all trajectories
 - Divide a map from all trajectories data distribution

Evaluation	Method	Entropy
	Dynamic map division for all trajectory data	1.58
	Our method	0

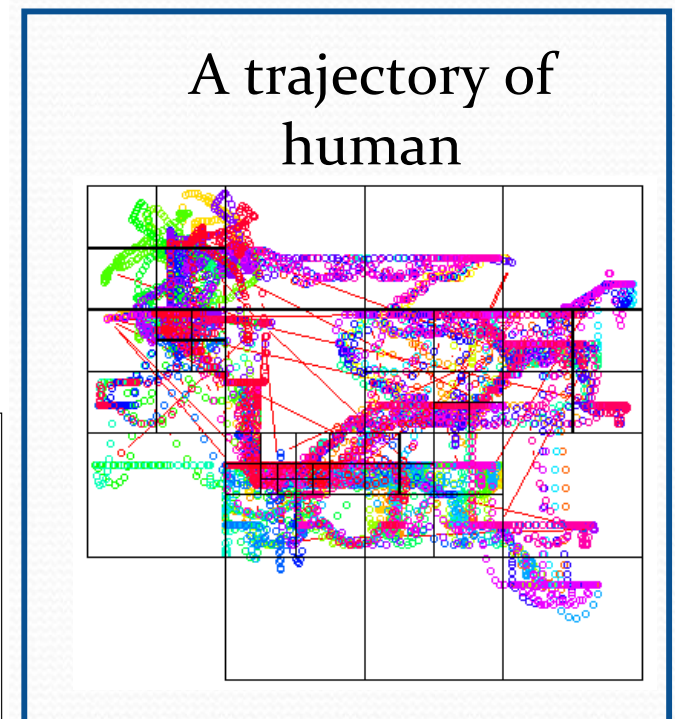
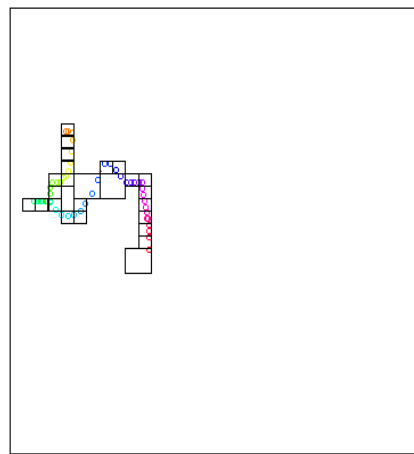
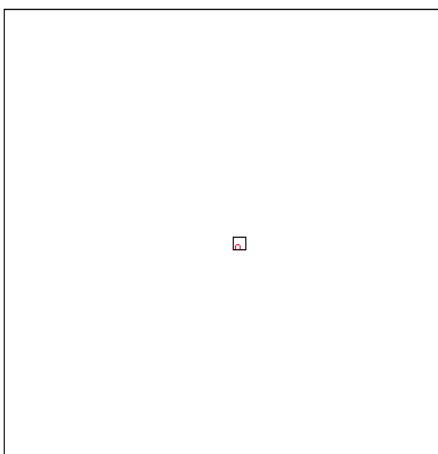
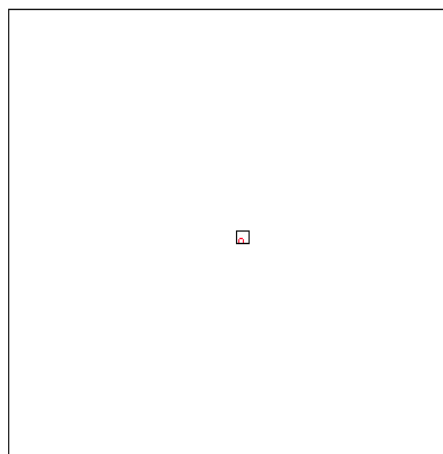
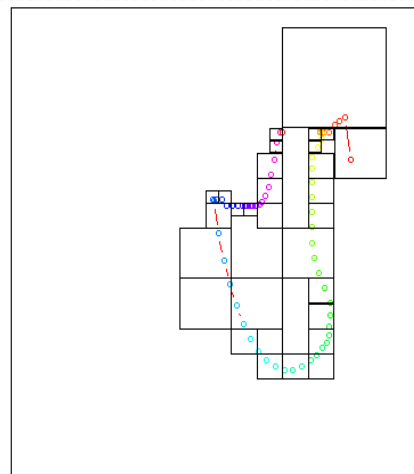
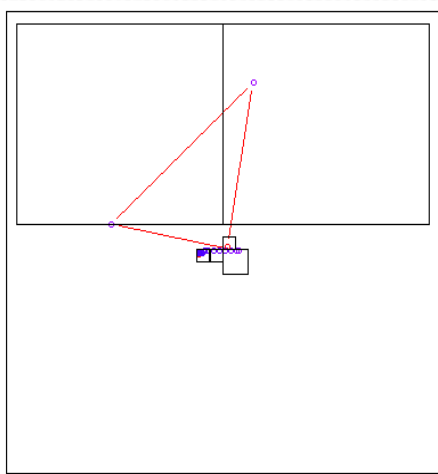
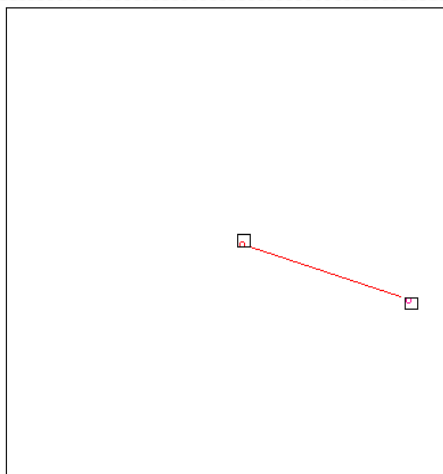
Result



- Step1: Comparison based on data distribution
- Step2: Comparison based on state transition

Result

- Errant trajectories

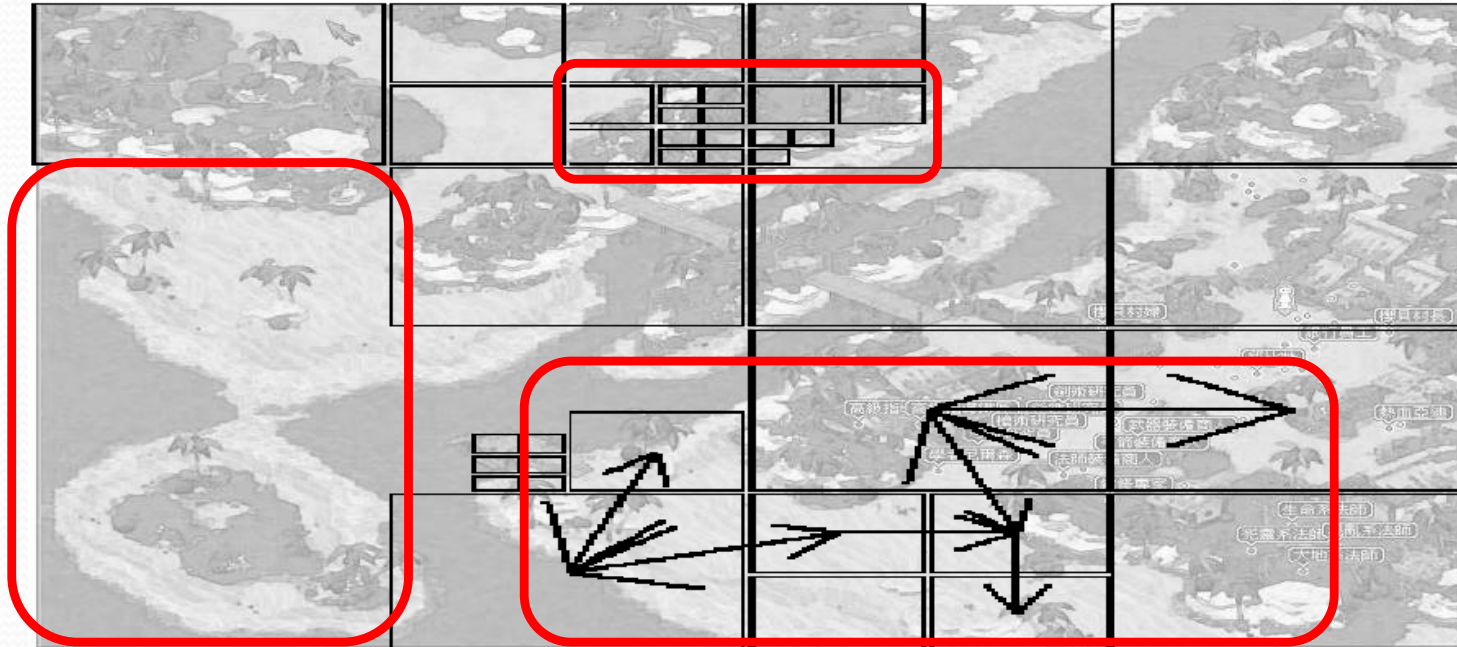


Experiment II

- Angel Love Online
 - About 70 hours
 - 394 trajectories
- Map
 - A facility to help
 - Distributed enemies
- Purpose
 - To give a case study in understanding players



Typical Result



- Cluster #2 (out of 21 clusters)
 - Map division and transitions
 - No movement in the left of map
 - A lot of transitions below the map
 - small rectangles and no arrow

Conclusions

- We proposed
 - Dynamic Map Division
 - Comparison Methods
 - Based on data distribution
 - Based on state transition
- We experimented with
 - Quake II
 - ALO