

International Conference on
Computer Vision and Graphics

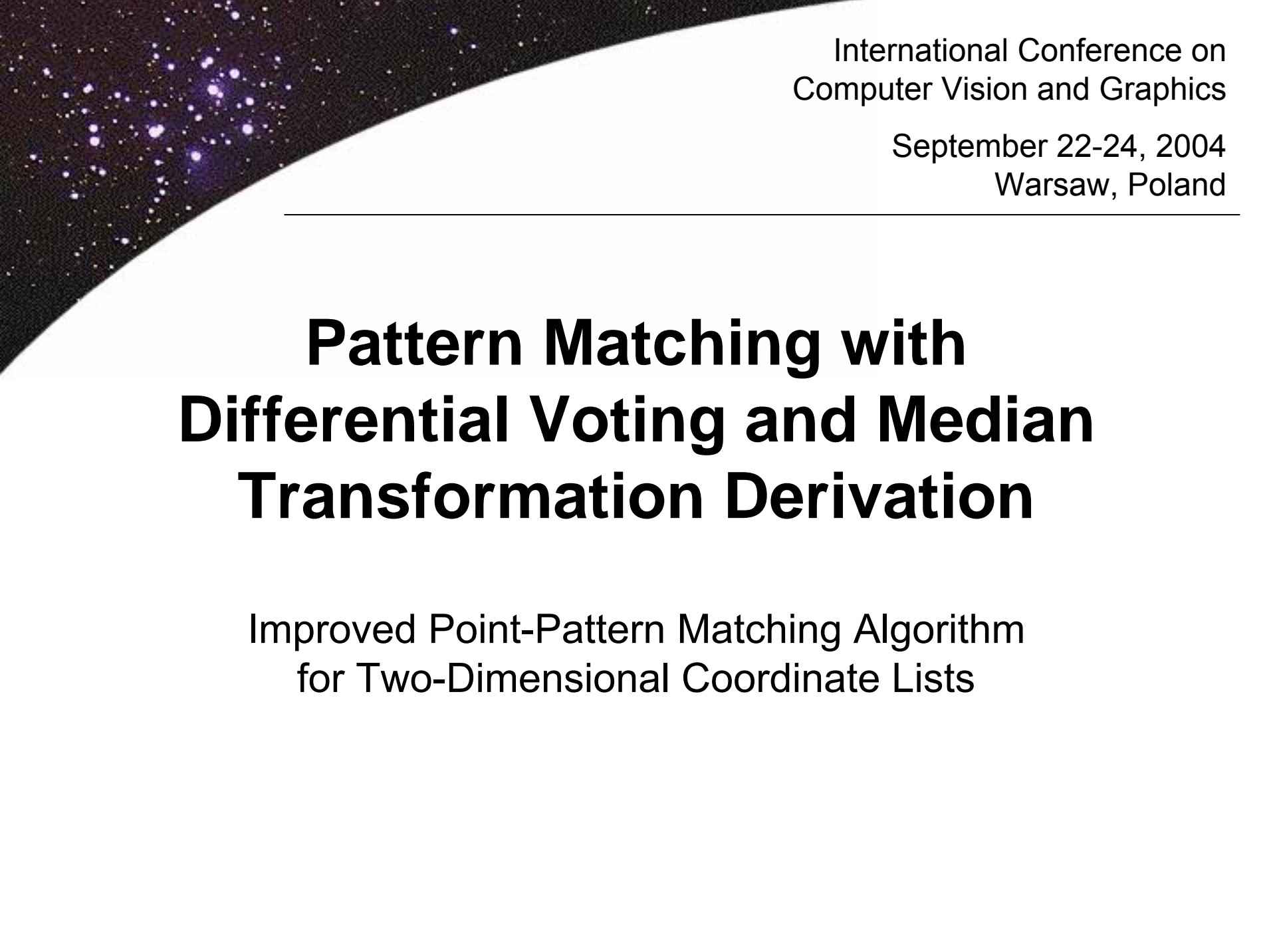
September 22-24, 2004
Warsaw, Poland

Pattern Matching with Differential Voting and Median Transformation Derivation

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A decorative background on the left side of the slide, featuring a dark, starry night sky with numerous small, bright stars and a few larger, more prominent ones. The stars are scattered across the dark field, creating a sense of depth and vastness. The background is partially obscured by a white curved shape that frames the top and right sides of the slide.

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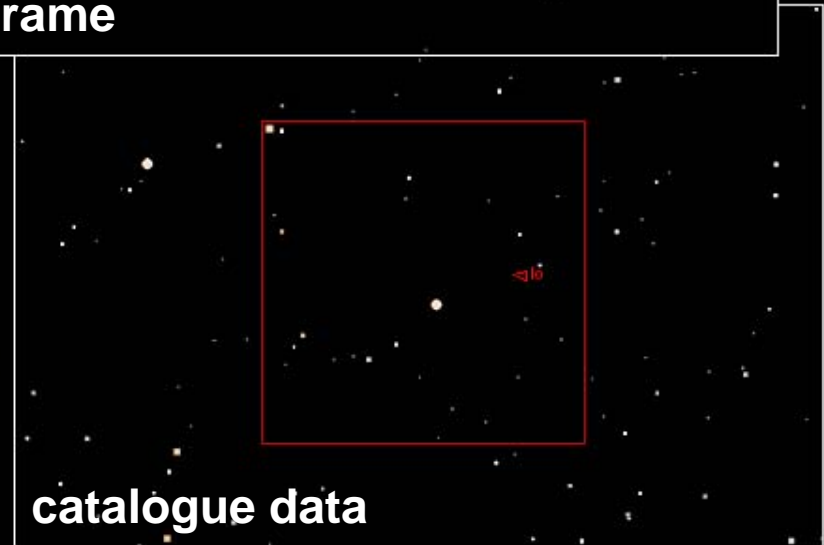
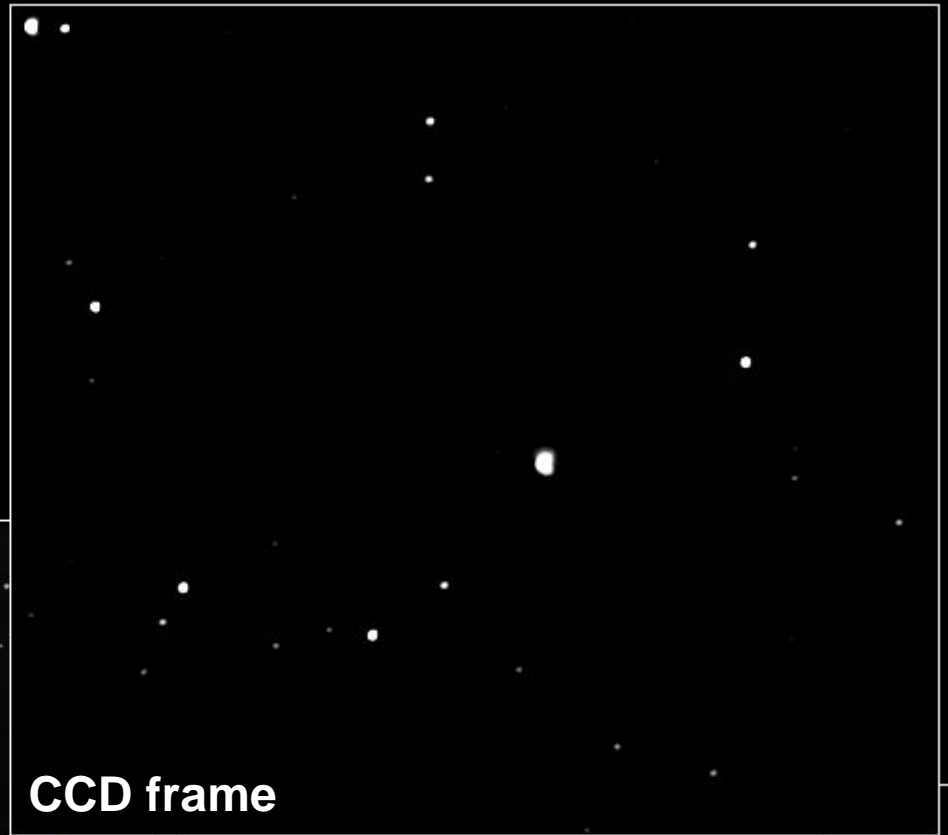
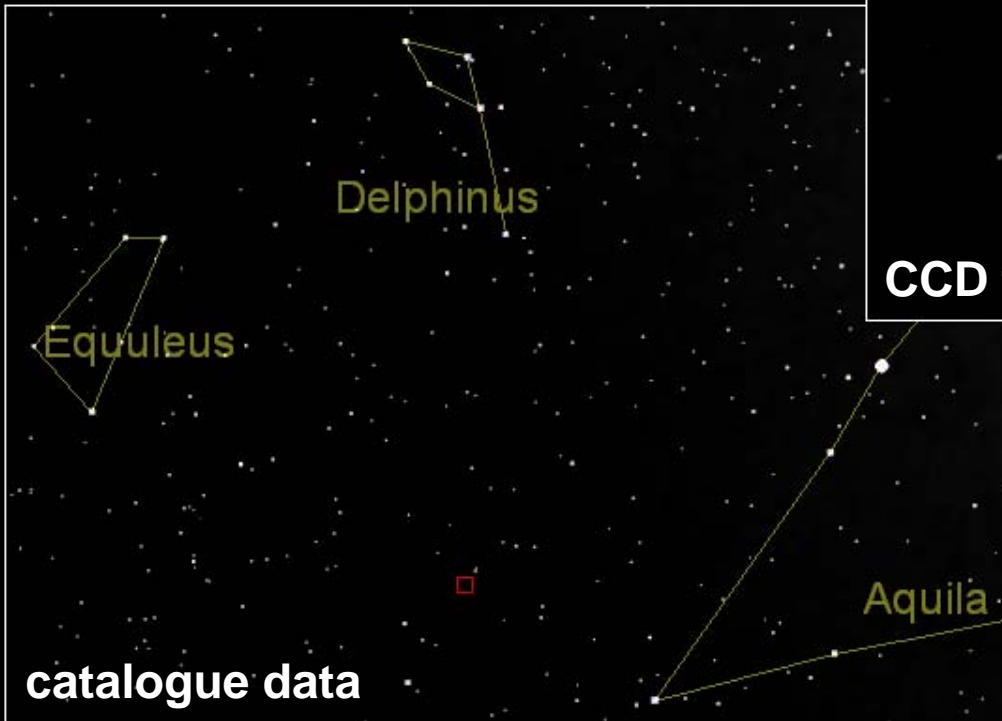
Improved Point-Pattern Matching Algorithm
for Two-Dimensional Coordinate Lists

SkySpy goals

- Fully automated sky survey system
- Image acquisition
- Preprocessing and stacking
- Star detection
- Performing astrometry and photometry
- **Star identification and data comparison**
- Mismatch reporting

Planetoid Io (85)

"Nadwarciański Gród", August 20 22:10 GMT 2003



Identification prerequisites

- Detected stars list
 - positions (in frame coordinates)
 - brightnesses (aperture photometry)
- Rough estimation of field of view
 - calculated from provided equipment parameters
- Rough estimation of observed sky region
 - stars movement observation during synchronization phase
- Querable star database (star catalogue)
 - positions (in celestial coordinates)
 - brightnesses (in magnitudo scale)

Problems to overcome

- CCD star positions are in frame coordinates but catalogue star positions are in celestial coordinates
 - we must deal with a transformation consisting of translation, rotation, scaling and flipping
- Frame data and catalogue data may be partially overlapping
 - we expect random star additions and deletions
- We expect random perturbations
 - star positions and brightnesses are measured with some random error

Triangles method (1/3)

Triangles method was originally developed in parallel by Groth and Stetson. It was later heavily improved by Valdes

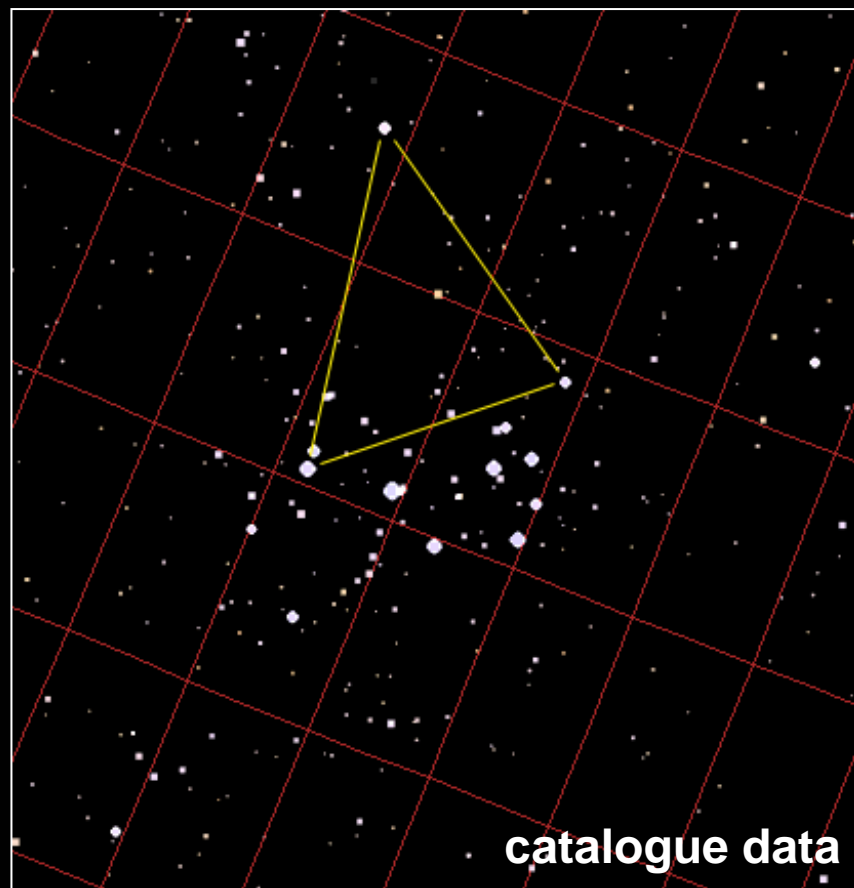
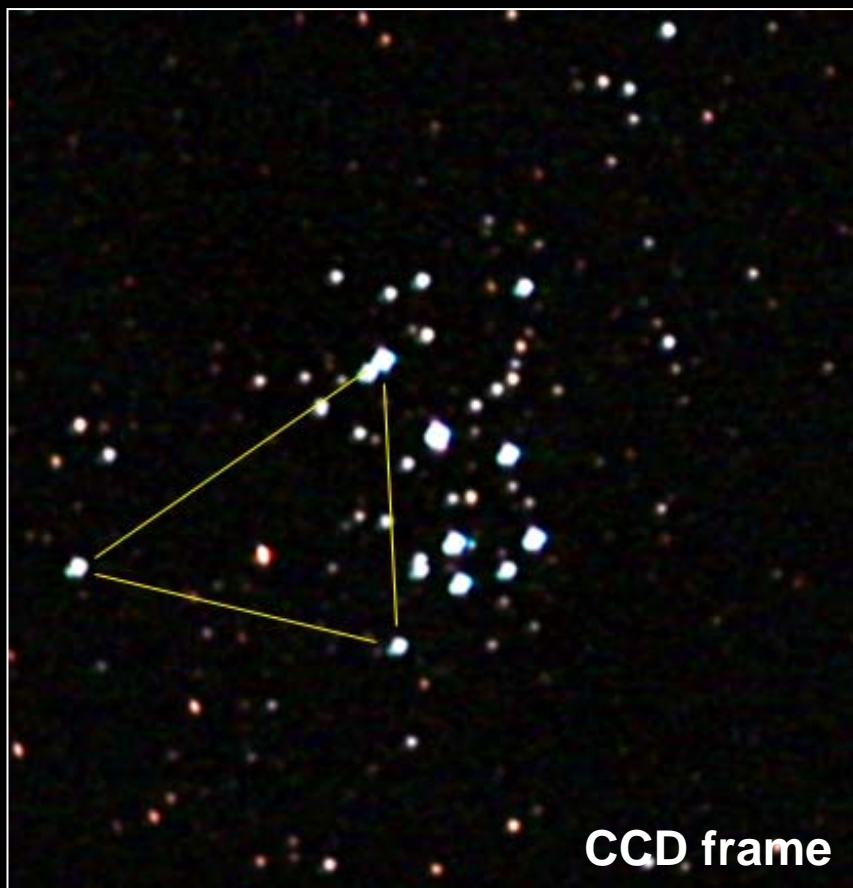
- Prepare the two lists containing the brightest objects of those to be matched
 - limit the number of stars found on a CCD frame to m
 - query a catalogue to choose the n brightest stars from an area expected to be covered by the frame
- For each list construct all possible triangles
 - for n stars we construct $n(n-1)(n-2)/6$ star triangles
- Represent the triangles in **triangle space**
 - similar triangles are located close to each other in triangle space

Triangle space

- A triangle is represented as a two-dimensional point (x,y)
 $x = a / b, \quad y = b / c$ where a, b and c are triangle sides in decreasing order
- Constructing and searching the triangle space may be optimized
 - distances between objects on the lists may be precalculated (Groth's optimization)
 - triangles may be presorted by one coordinate, so that we can use a moving window to reduce the number of neighbor candidates (our improvement)

Triangles method (2/3)

- Find similar triangles in triangle space
 - we are interested in finding similar triangles, because those are immune to translation, rotation, scaling and flipping
- Perform voting
 - each found triangle pair votes for three vertices pairs it consists of
- Apply **differential voting** correction
 - for each vertex pair subtract from a number of votes the highest number of votes that was received by another pair with the same member



New solution: differential voting

- Why differential voting?
 - in fact we would expect one-to-one matching of objects in the two lists
 - if object from one list is associated with two (or more) objects on the second list, we do not want to trust neither of the associations
- How is it applied?
 - we propose to apply a correction to the original voting table filled during traditional voting method

$$v'(m, n) = v(m, n) - \max\left(\max_{k \neq m}(v(k, n)), \max_{l \neq n}(v(m, l))\right)$$


Triangles method (3/3)

Direction cosines and matrix method for coordinates transformation derivation was originally proposed by Taki

- Choose highest vote getters and derive transformation parameters
 - from the highest vote getters we can construct triangles and derive individual transformation parameters using direction cosines and matrix method
 - we have chosen a simple and robust way to determine global transformation parameter values by choosing a median value of individual parameter values
- Use transformation parameters to quickly match all the stars from the CCD frame with the catalogue

Conclusion

- For pattern matching algorithms with voting, a differential voting approach is proposed
- Differential voting exploits the fact that one-to-one matching should be expected
- Differential voting shows its usefulness in triangles method of matching two-dimensional coordinate lists
- Differential voting correction may be applied to existing applications with no computational penalties
- From matched pairs transformation parameters may be derived and median value may be used to derive a global transformation parameters



Thank you
for your attention

Differential voting example

Table 1a. Vote array before correction. Six highest vote getters were marked bold. Note the obvious mismatch in the upper-left corner.

17	5	2	1	0	0	3	2
16	6	2	1	0	0	4	2
6	15	1	1	2	0	5	3
0	1	20	5	2	0	1	9
0	0	4	5	2	2	0	2
0	0	8	3	3	31	0	10
0	6	2	0	22	1	3	5
1	3	0	1	0	2	15	4
0	2	13	1	4	2	3	22
1	2	1	1	6	1	3	2

Table 1b. Vote array after correction. Six highest vote getters were marked bold. Pairs that received negative number of votes were zeroed.

1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	9	0	0	0	0	0	0
0	0	7	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	21	0
0	0	0	0	0	16	0	0
0	0	0	0	0	0	0	10
0	0	0	0	0	0	0	9
0	0	0	0	0	0	0	0