Improved Object Recognition -- The RoboCup 4 legged league

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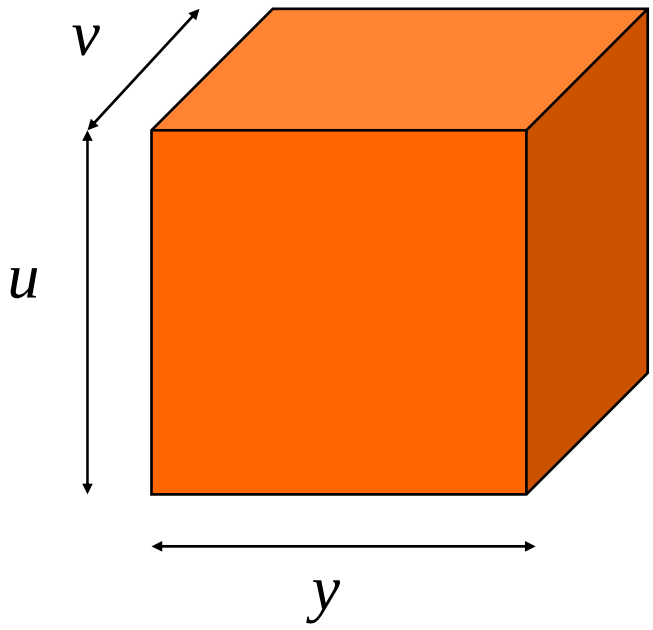
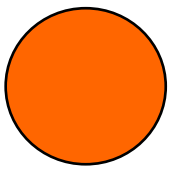
Classifier for One Color

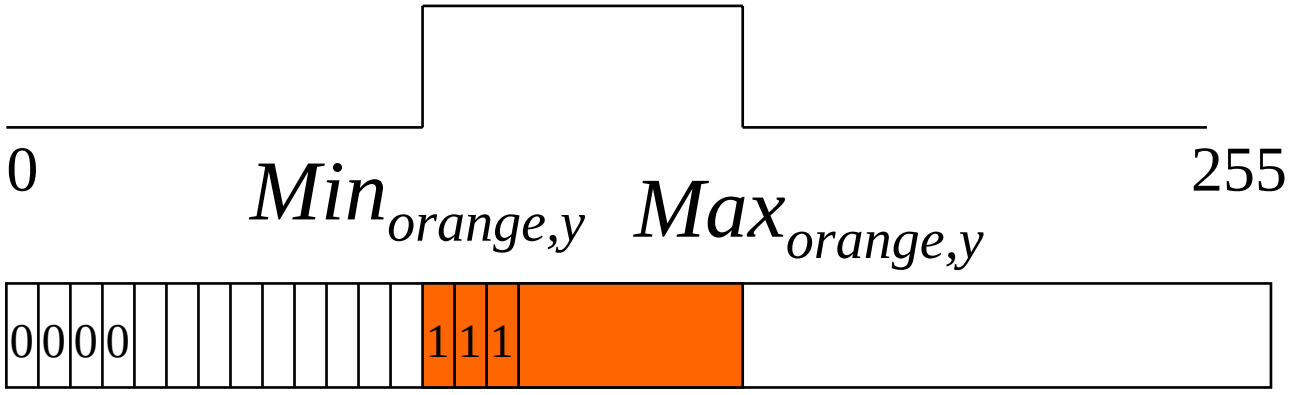


- Simplification for *Color_Orange*
- *If*
  - $Min_{orange,y} \leq y$ *AND* $y \leq Max_{orange,y}$
- *AND*
  - $Min_{orange,u} \leq u$ *AND* $u \leq Max_{orange,u}$
- *AND*
  - $Min_{orange,v} \leq v$ *AND* $v \leq Max_{orange,v}$
- *Then ORANGE*



The bit-Map for a color projection

- *If*
  - $Min_{orange,y} \leq y$ *AND* $y \leq Max_{orange,y}$

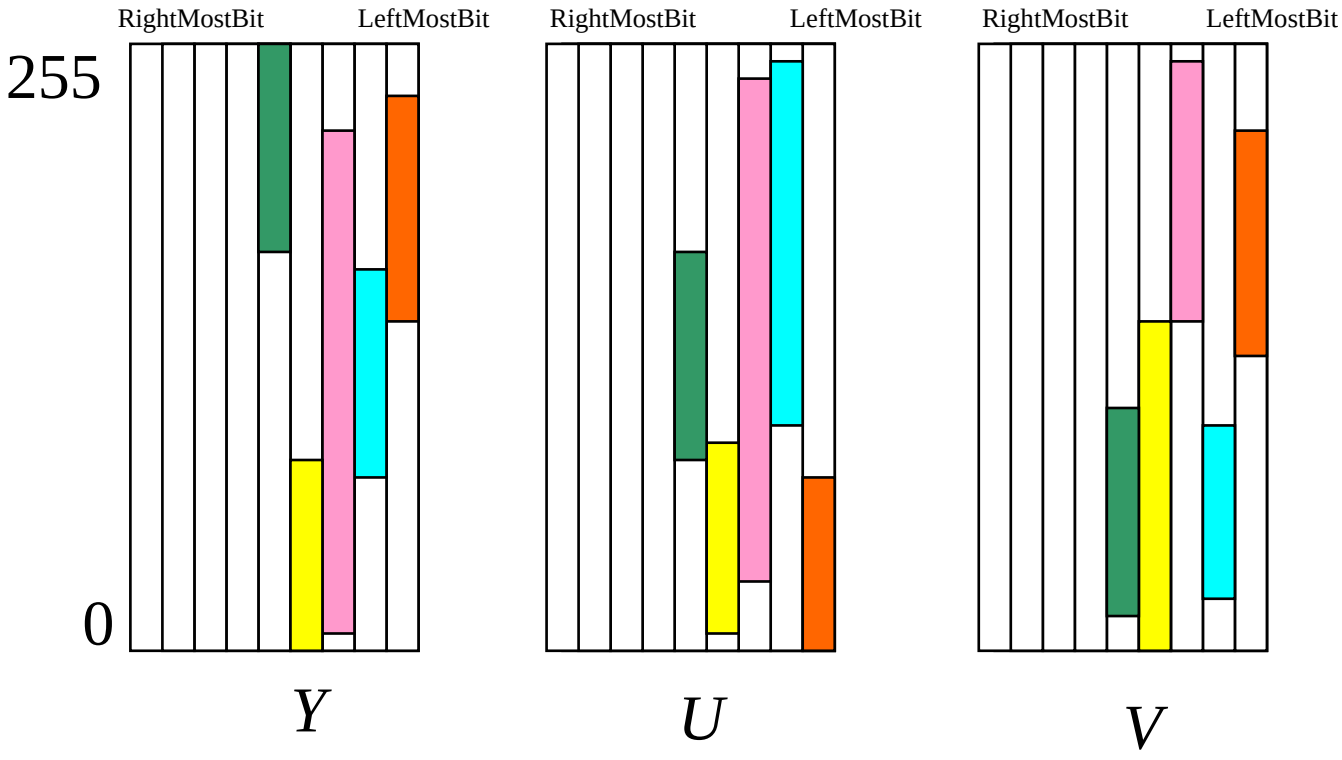


A classifier is a table look up

- C/C++ bit-wise AND operation

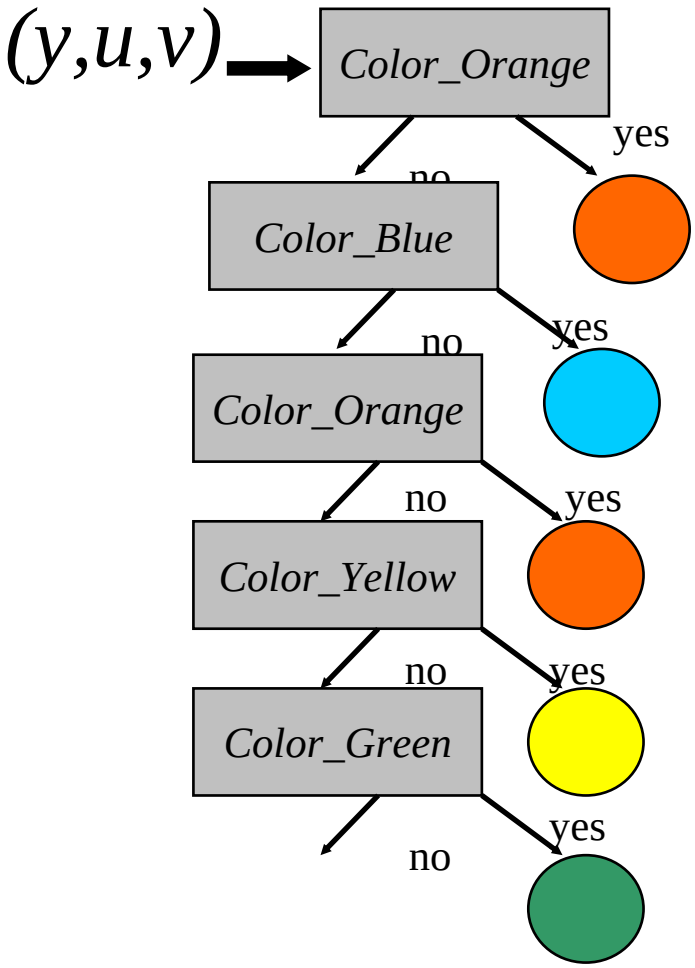
```
Color_Orange=Y[y]&U[u]&V[v]
```

A Decision List is a Scan through the Bits of a Memory Word




```
color=Y[y]&U[u]&V[v]
color_id=0
while (color & 1 == 0)
  { color>>=1; color_id++}
```

List Can Repeat Simple Classifiers



The RoboCup Competition

- Dynamic environment
- Very rapid analysis of images
- Legged-league
  - SONY Aibo robots
  - Image is 174x144 pixels
  - 25 frames a second
  - YUV format (3 bytes per pixel)

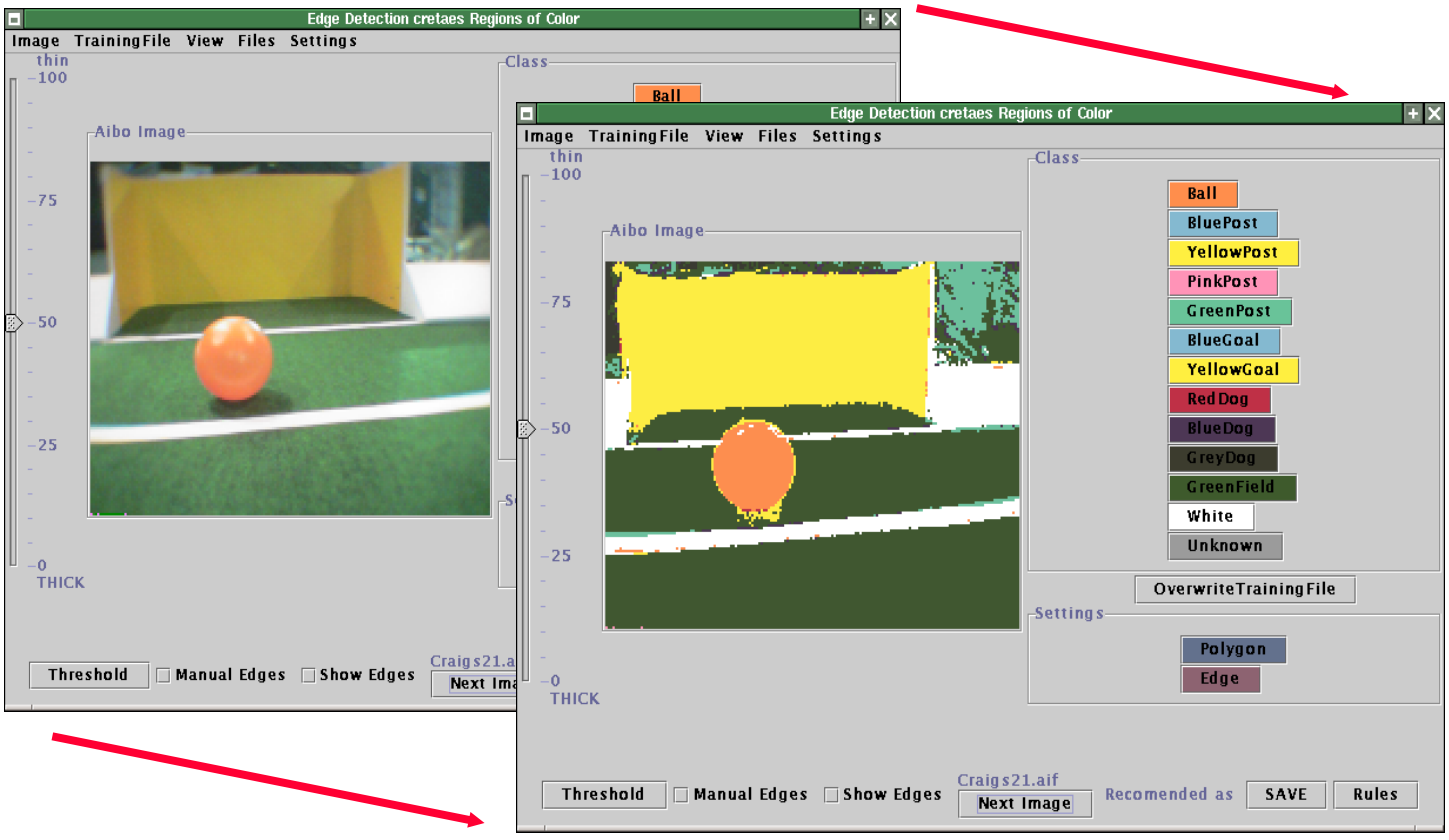
Image Segmentation

- Mapping is a classifier

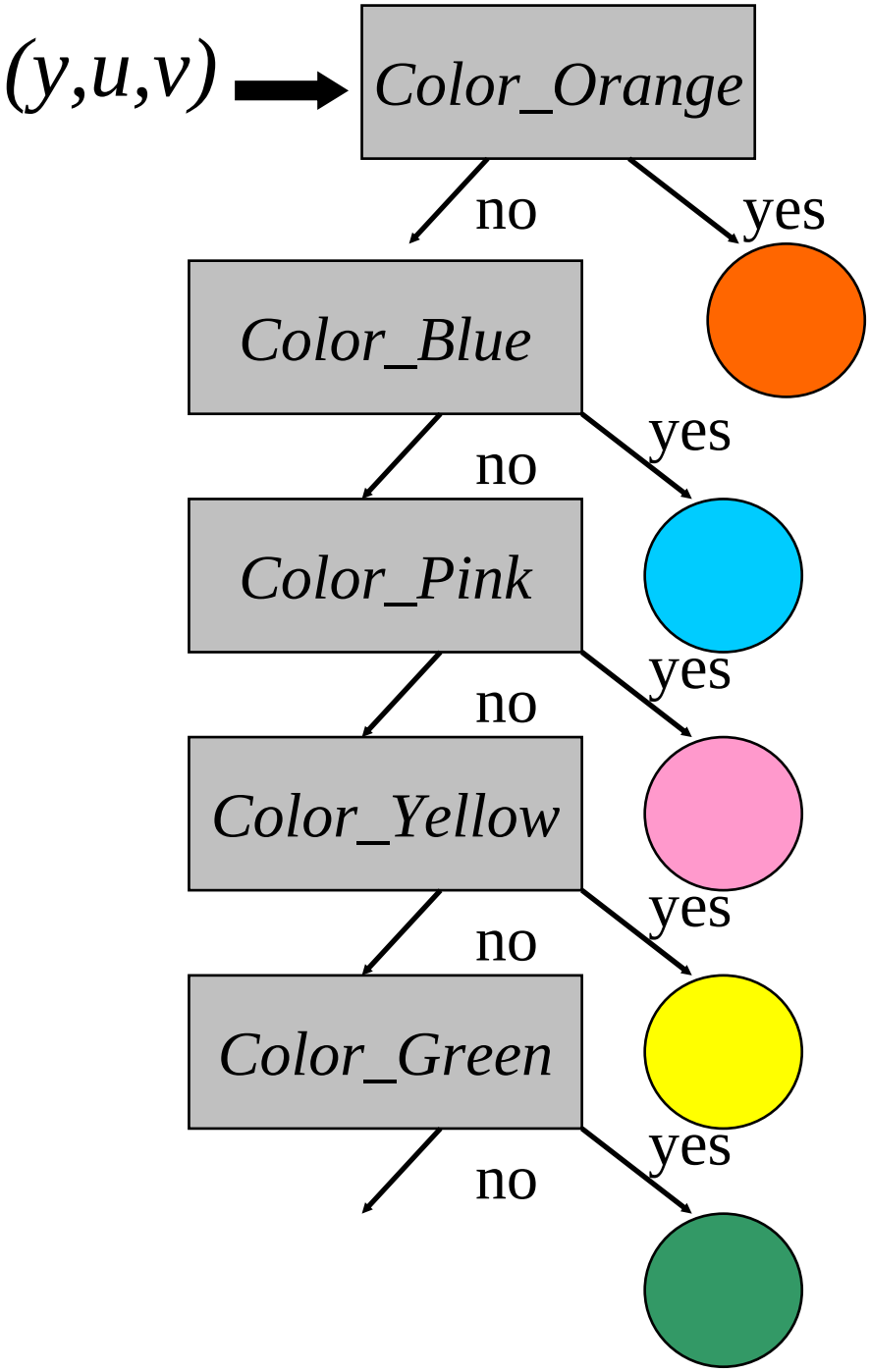
$$Color\_class: YxUxV \rightarrow Color$$

$$Color\_Class(y,u,v) = Orange$$

$$|Y| x |U| x |V| = 256^3$$



Decision List



Much faster than Artificial Neural Networks (ANN) or other classifiers k- Nearest neighbors (k-NN) and Decision Trees

- ANN using snns were 20K times slower
- *k*-NN with Quadtrees and DT (Weka) were 2K times slower

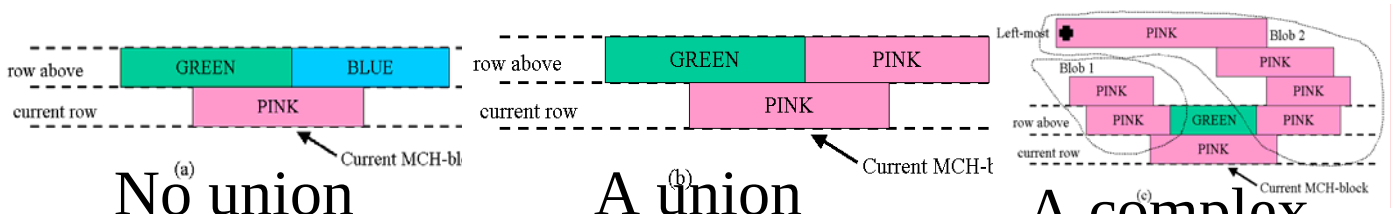
	DL	Look-up Table	Ratio
Maximum	2.87ms	2.46ms	1.16
Average	2.33ms	1.41ms	1.65
Minimum	2.08ms	1.27ms	1.63

Accuracy with Decision List is Marginally better

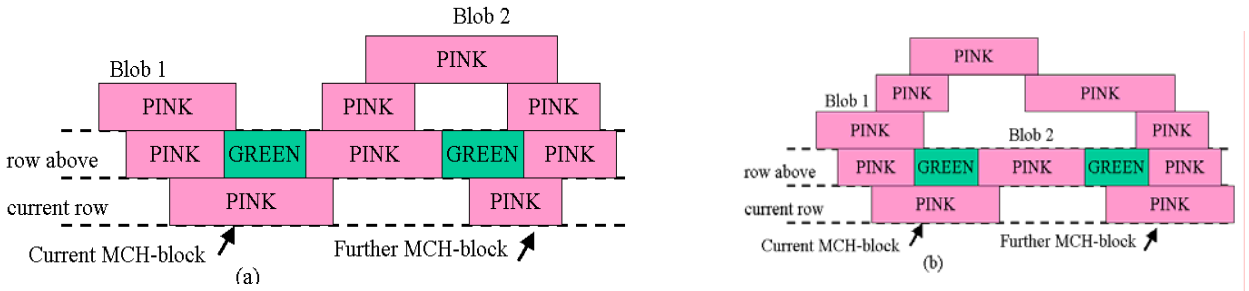
- ANN using snns were 20K times slower
- *k*-NN with Quadtrees and DT (Weka) were 2K times slower

Algorithm	10-fold accuracy	Lowest accuracy per class	Largest 2-class confusion	size	Learning time	Test set accuracy
PART	99.0%	96% (yellow goal)	10 blue dog Vs gray dog	26 Rules	1.15s	99.3%
k-NN	99.3%	97% (blue dog)	8 red dog Vs gray dog	*k*=3 6,226 Instances	0s	99.7%
DT	98.8%	95% (yellow goal)	10 red dog Vs gray dog	34 leaves 67 nodes	1.27s	99.6%
Look-up Table	71.6%	64% (yellow goal)	45 yellow goal vs orange ball	11 rules	manual	68.2%

Blob Forming – Bringing contiguous blocks together



No union A union A complex union



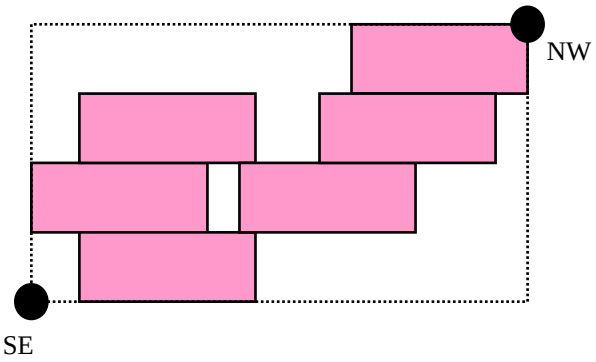
Merging needs to unify blob ids exposed in the row above

- We avoid UNION-FINF algorithms
- A data structure to process a row as we create run-length encoding

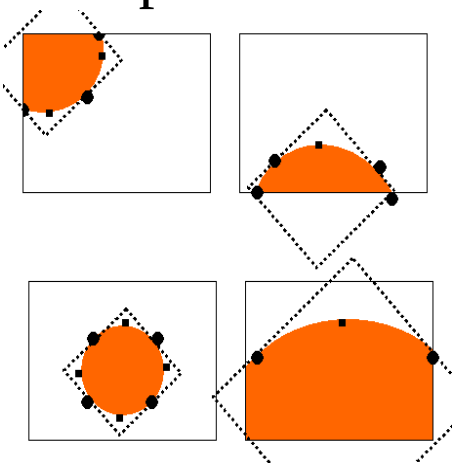
Blob information

Minimum bounding box

SE & NW (4 integers)



Special case



Data Structure for Current row

A sorted list of blobs exposed,

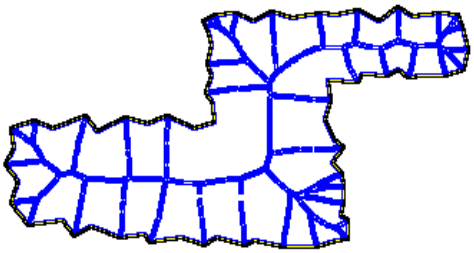
sorted by x-coordinate of left most pixel exposed in the current row

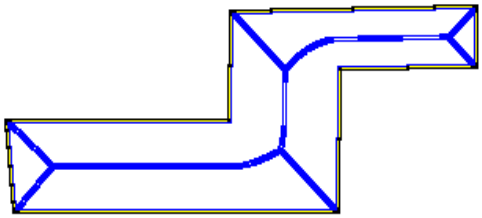
Processing a row is like merging sorted lists

Few blobs per line

Shape Finding

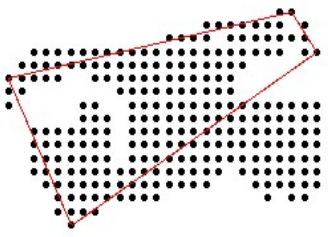
- We need a better boundary to use the skeleton (medial axis)

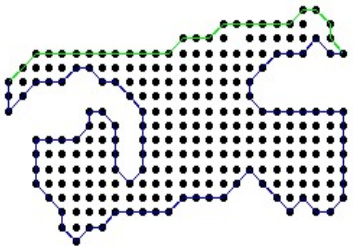


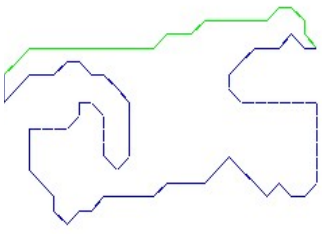


Sinuosity in boundary produces complex skeleton

- We need to find the boundary fast







Finding the boundary

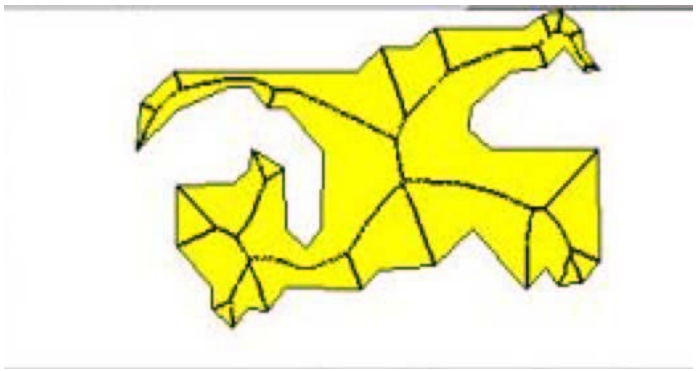
- Trace it
  - Time proportional to the number *b* of pixels in boundary

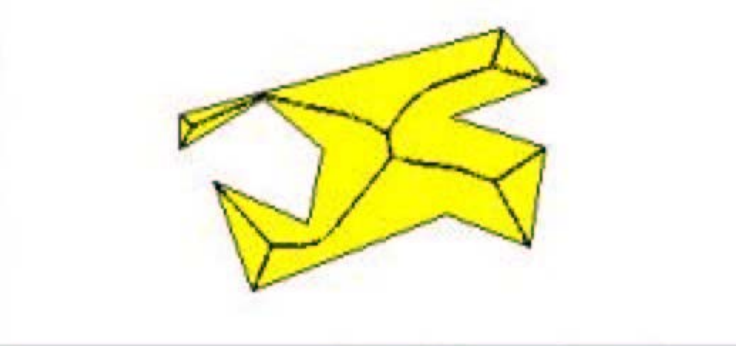
Simplify the boundary

- Douglas-Peucker Algorithm
- Time proportional to *b log b*

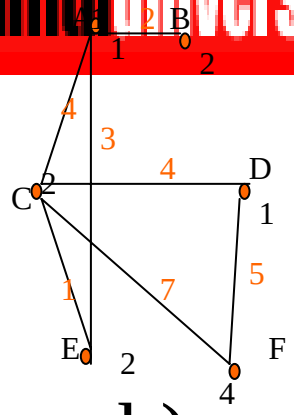
Find the skeleton

- Use Voronoi diagram of boundary segments
  - Time proportional to high level description of boundary
    - (less than *b*)



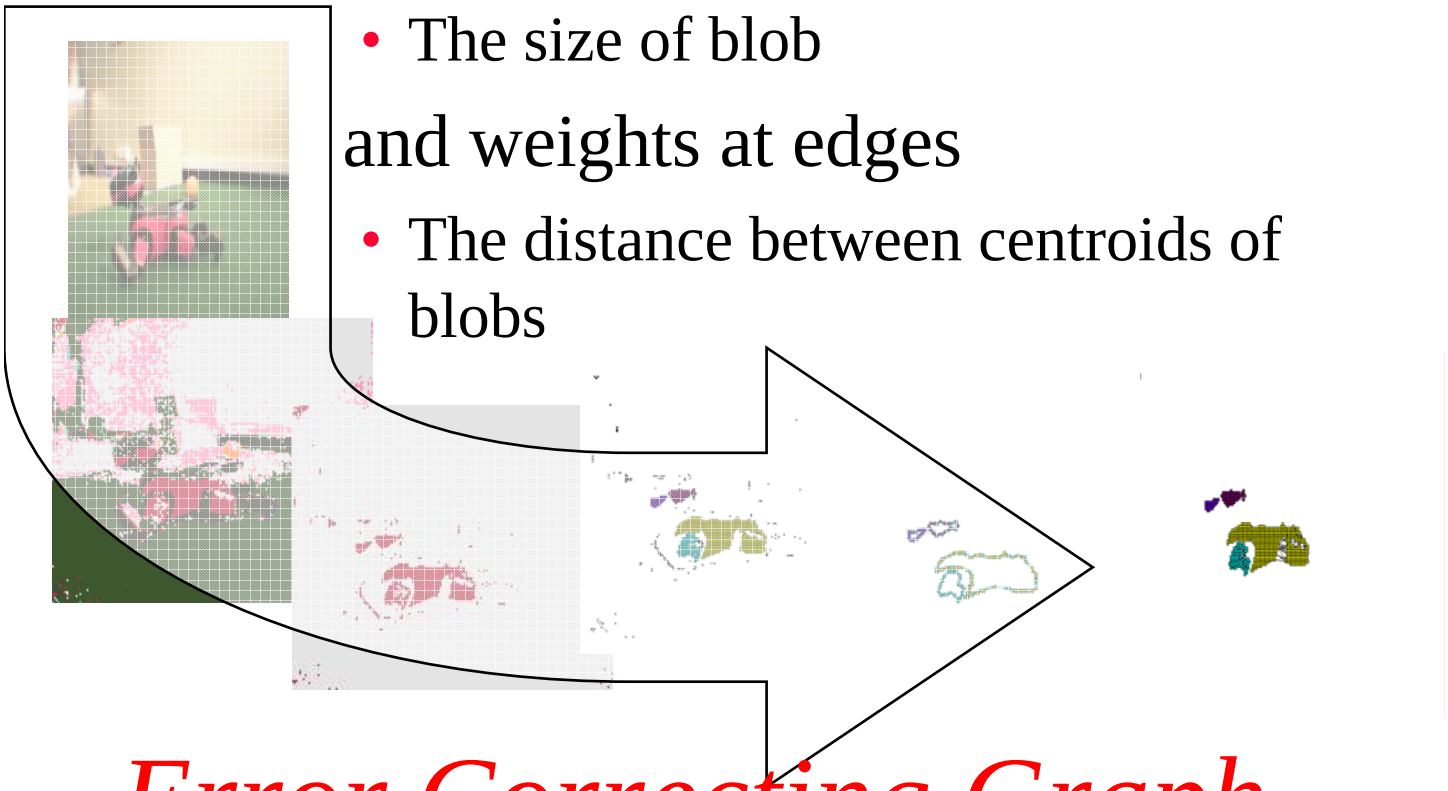


Attribute Oriented Graph



- Nodes and Edges (as a graph)
  - Weights at nodes
    - The size of blob

    and weights at edges
    - The distance between centroids of blobs



Error Correcting Graph Isomorphism

Input: Two attributed graphs

Output:
A permutation of the nodes that minimizes total dissimilarity

Limitations of the current attribute graph approach

The robot we see

- *must not be far*

  (the length of the field)

- *must not be to close*

  (we must see almost all parts)

- *must be by itself*

A difficult situation for identifying the red dog in the back