WORDOKU SOLVER

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EENG510

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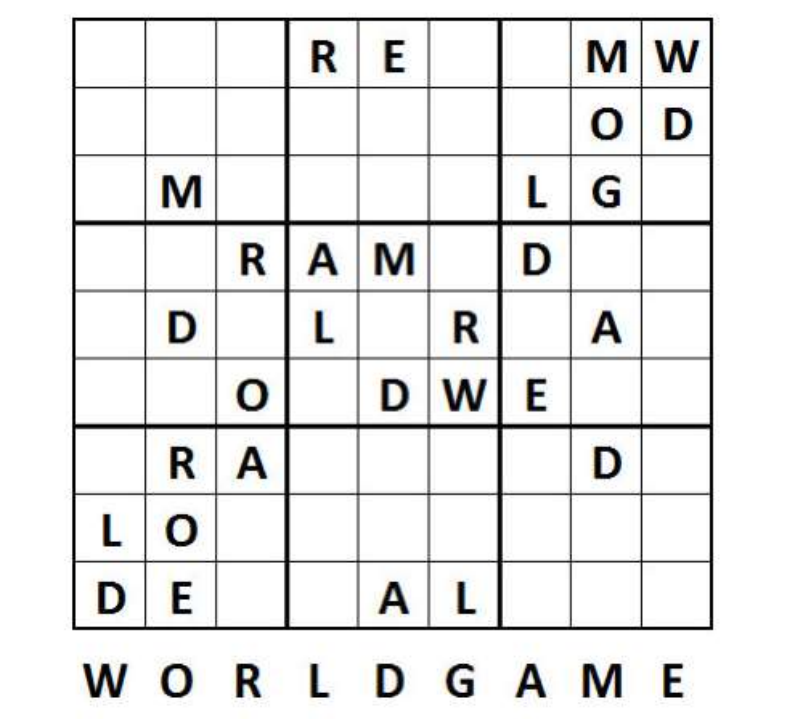
Outline

- Background
- Goal
- Steps to solve
- Algorithm used for each step
- Testing and Results
- Future work
- Questions

Background

- A wordoku puzzle is similar to a sudoku, but uses alphabets instead of numbers.
- A **keyword** is given at the bottom of each puzzle, consists of 9 alphabets that will be used to solve the puzzle.



			R	E			M	W
							O	D
	M					L	G	
		R	A	M		D		
	D		L		R		A	
		O		D	W	E		
	R	A					D	
L	O							
D	E			A	L			

W O R L D G A M E

Goal

- For any given wordoku puzzle (with **any font**), solve the puzzle and display the solution image.

			R	E			M	W
							O	D
	M					L	G	
		R	A	M		D		
	D		L		R		A	
		O		D	W	E		
	R	A					D	
L	O							
D	E			A	L			

W O R L D G A M E

O	G	L	R	E	D	A	M	W
A	W	E	M	L	G	R	O	D
R	M	D	O	W	A	L	G	E
G	L	R	A	M	E	D	W	O
E	D	W	L	O	R	G	A	M
M	A	O	G	D	W	E	L	R
W	R	A	E	G	O	M	D	L
L	O	G	D	R	M	W	E	A
D	E	M	W	A	L	O	R	G

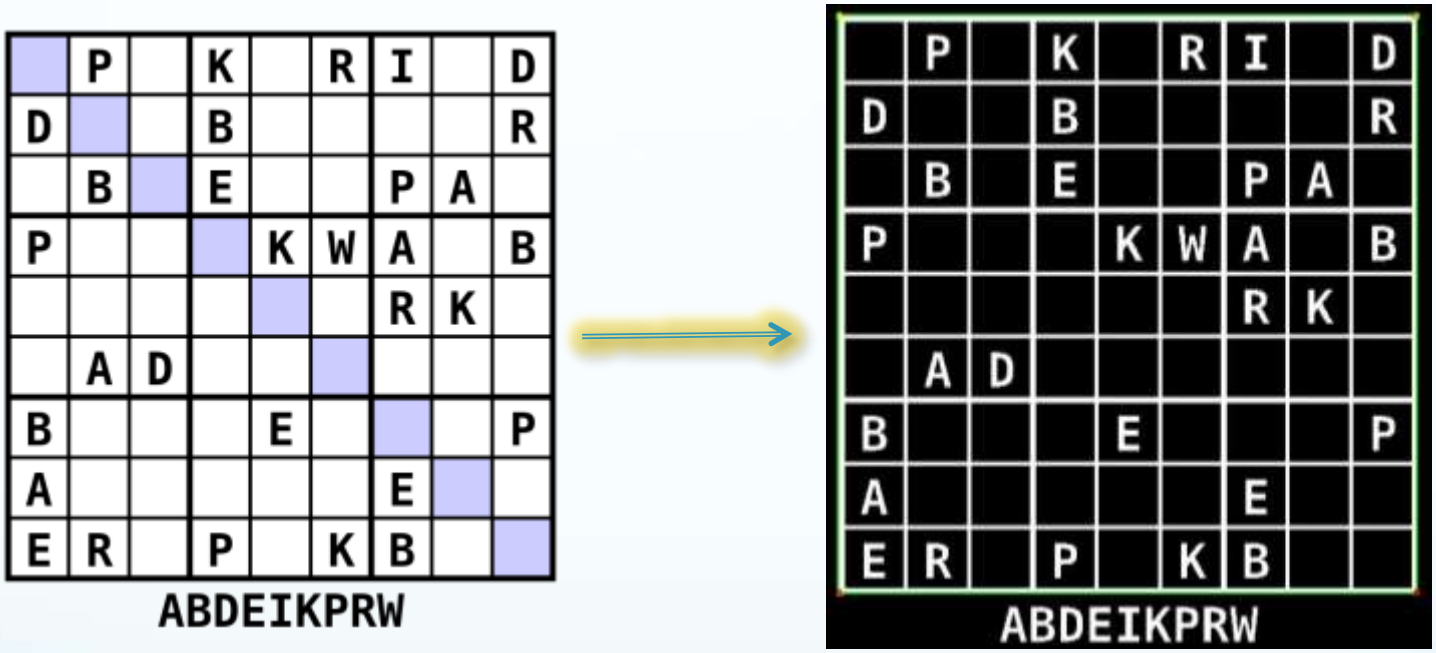
W O R L D G A M E

Steps Involved

1. **Separate the keyword and grid**
2. **Extract elements**
3. **Find Matches**
4. **Solve as a sudoku**
5. **Paste the solution back**

Step1: Separation

- First, threshold and use Hough transform to find boundary.



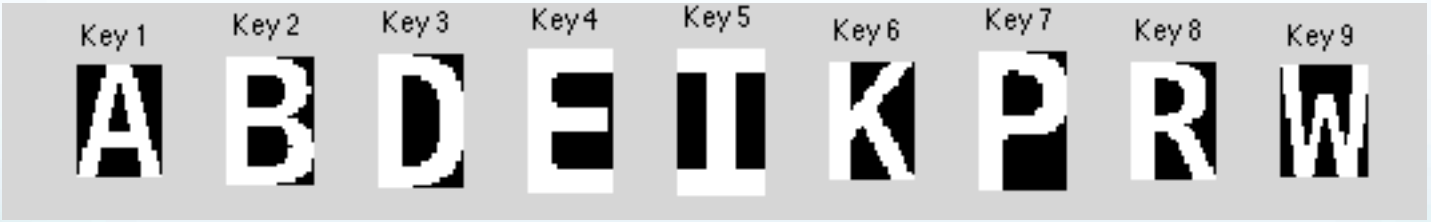
Extracted keyword

ABDEIKPRW

Step2: Extraction

1) Keyword :-

- Got rid of any small noises by using *imopen* and *imclose* commands.
- Used the *regionprops* extract the individual characters.
- Assigned values.



Step2: Extraction

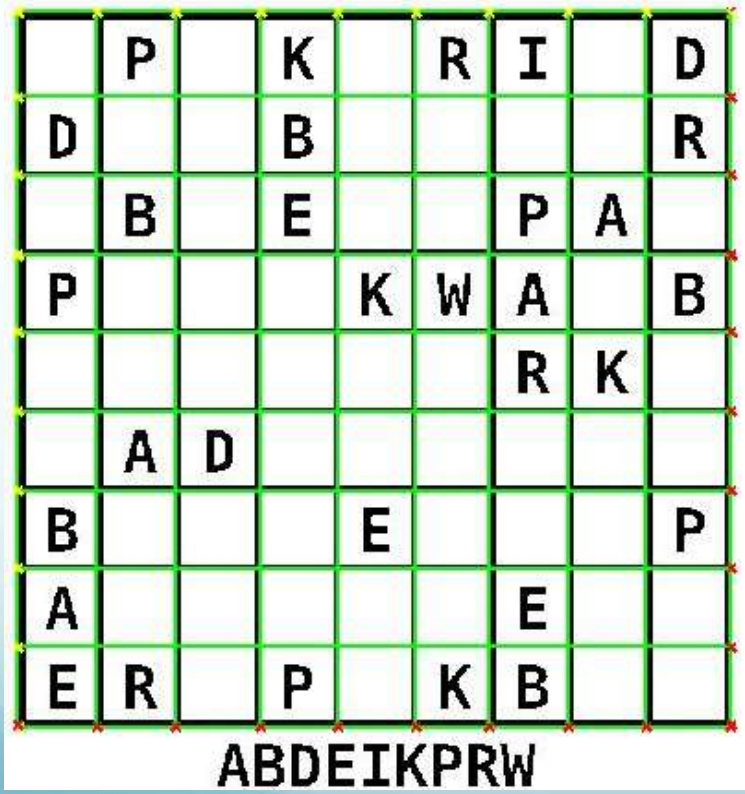
2) Puzzle Elements :-

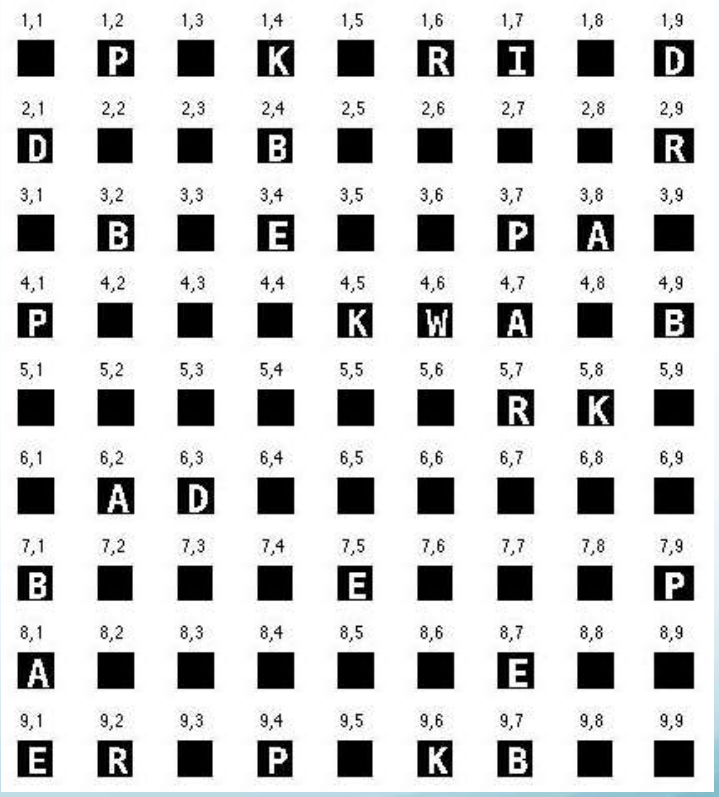
- Used the ***houghlines*** to extract 20 lines .
- The lines were in random order and it was necessary to sort them.
- Some of the puzzles had thick and thin grid lines. So, I created a new set of lines with average of distances.

Step2: Extraction

2) Puzzle Elements :- (cont…)

- Cropped each element between intersections and stored separately.
- Also, region properties of each element was extracted.





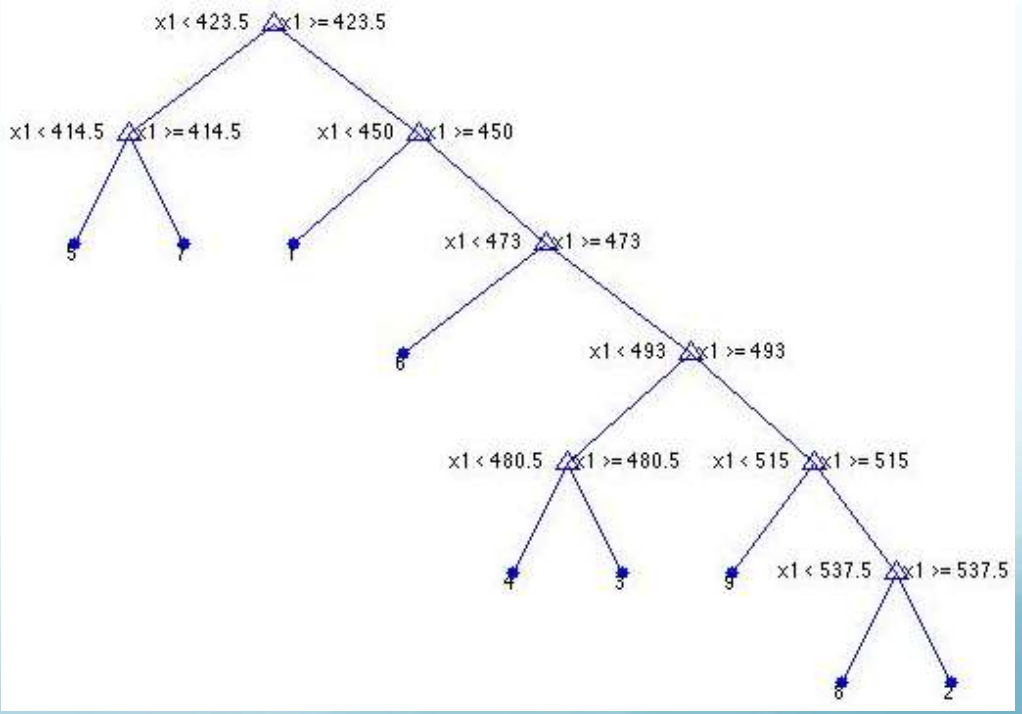
Step3: Matching

1) Classification Tree:

- Use various region properties (area, centroid, axis lengths) to create a decision tree.

- Used this tree to predict the classes(1-9).

This classification gave wrong matches in cases where two or more letters had almost *similar areas and axis lengths.*



Step3: Matching

2) Normalized Cross-Correlation:

- The max scores when each element of the puzzle was cross-correlated with all the 9 key characters was calculated and the max score among these was used to predict the class(1-9) of that element.

-- Eroding before using the cross-correlation gave better results.

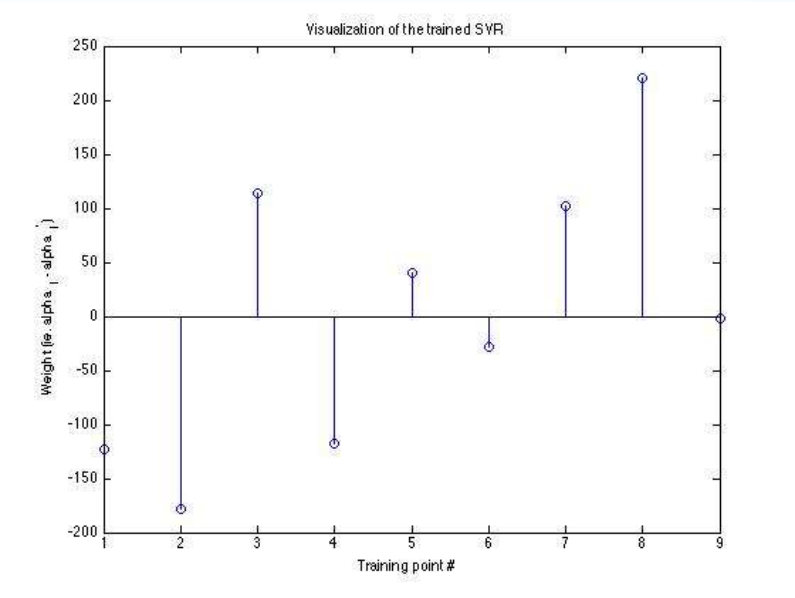
-- Limitation : When one letter could completely fit inside another letter, there was a chance for wrong detection.

Step3: Matching

3) Support Vector Regression:

- I used different region properties of key characters as a training set to train an SVR algorithm .
- The predictions I found were more accurate and reliable.

-- Limitation: This still depends on the properties like Area, Axis lengths of each element and how much they vary between the different characters used.



[1] Ronnie Clark , “A Matlab implementation of SVR”, MATLAB Central File Exchange
http://www.mathworks.com/matlabcentral/fileexchange/43429-support-vector-regression

Solution?

Combining algorithm -

- All the max cross-correlated scores > 0.68 are stored as the closest matches.

- And use support vector regression prediction to further narrow down the value.

-- Combining both of the algorithms matched 10 different puzzles with 100% accuracy. However, it significantly increases computational time.

Step4:Solving

- The location matrix reduces the problem to a sudoku.
- Using a MATLAB script I found which recursively solves for all possible values for every blank cell in the matrix.

UNSOLVED

0	7	0	6	0	8	5	0	3
3	0	0	2	0	0	0	0	8
0	2	0	4	0	0	7	1	0
7	0	0	0	6	9	1	0	2
0	0	0	0	0	0	8	6	0
0	1	3	0	0	0	0	0	0
2	0	0	0	4	0	0	0	7
1	0	0	0	0	0	4	0	0
4	8	0	7	0	6	2	0	0

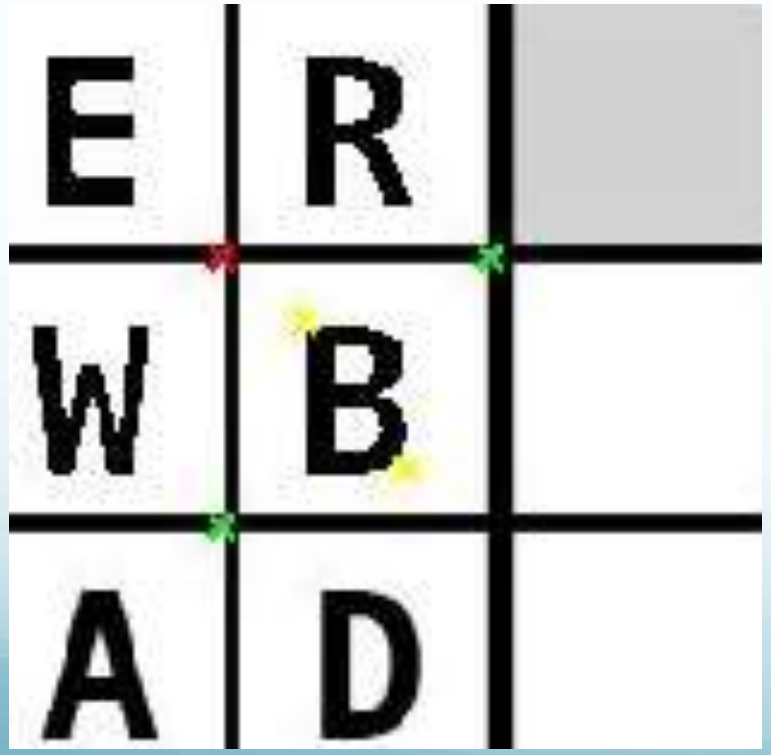
SOLVED

9	7	4	6	1	8	5	2	3
3	5	1	2	9	7	6	4	8
8	2	6	4	5	3	7	1	9
7	4	8	5	6	9	1	3	2
5	9	2	3	7	1	8	6	4
6	1	3	8	2	4	9	7	5
2	6	9	1	4	5	3	8	7
1	3	7	9	8	2	4	5	6
4	8	5	7	3	6	2	9	1

[1] G.M. Boynton, “MATLAB Sudoku Solver,” MATLAB Central File Exchange, 2005
http://www.mathworks.com/matlabcentral/fileexchange/8083-matlab-sudoku-solver

Step5:Printing

- I used the sorted hough-lines to find their intersection points using *polyxpoly,* and hence, width and height of each cell separately.
- Paste according to the dimensions of the element.
- Used the amount of black color in each character as reference to print.



W	P	E	K		R	I		D
D	I	A	B					R
R	B	K	E			P	A	
P	E	R		K	W	A		B
I	W	B				R	K	
K	A	D						
B	K			E				P
A	D					E		
E	R		P		K	B		

ABDEIKPRW

FINAL SOLUTION

	P		K		R	I		D
D			B					R
	B		E			P	A	
P				K	W	A		B
						R	K	
	A	D						
B				E				P
A						E		
E	R		P		K	B		

ABDEIKPRW

W	P	E	K	A	R	I	B	D
D	I	A	B	W	P	K	E	R
R	B	K	E	I	D	P	A	W
P	E	R	I	K	W	A	D	B
I	W	B	D	P	A	R	K	E
K	A	D	R	B	E	W	P	I
B	K	W	A	E	I	D	R	P
A	D	P	W	R	B	E	I	K
E	R	I	P	D	K	B	W	A

ABDEIKPRW

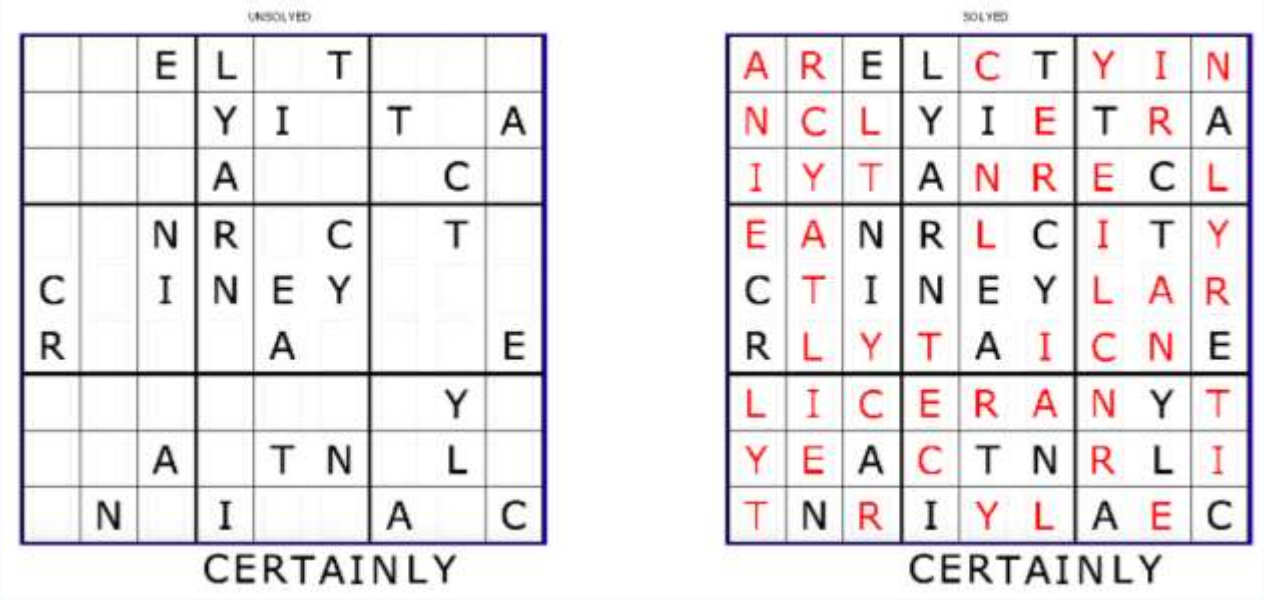
	D	U						O
G			L			U		A
	S						D	L
	U			D	L			G
			A		G			
D			U	O			A	
E	L						U	
U		D			S			H
S						G	E	

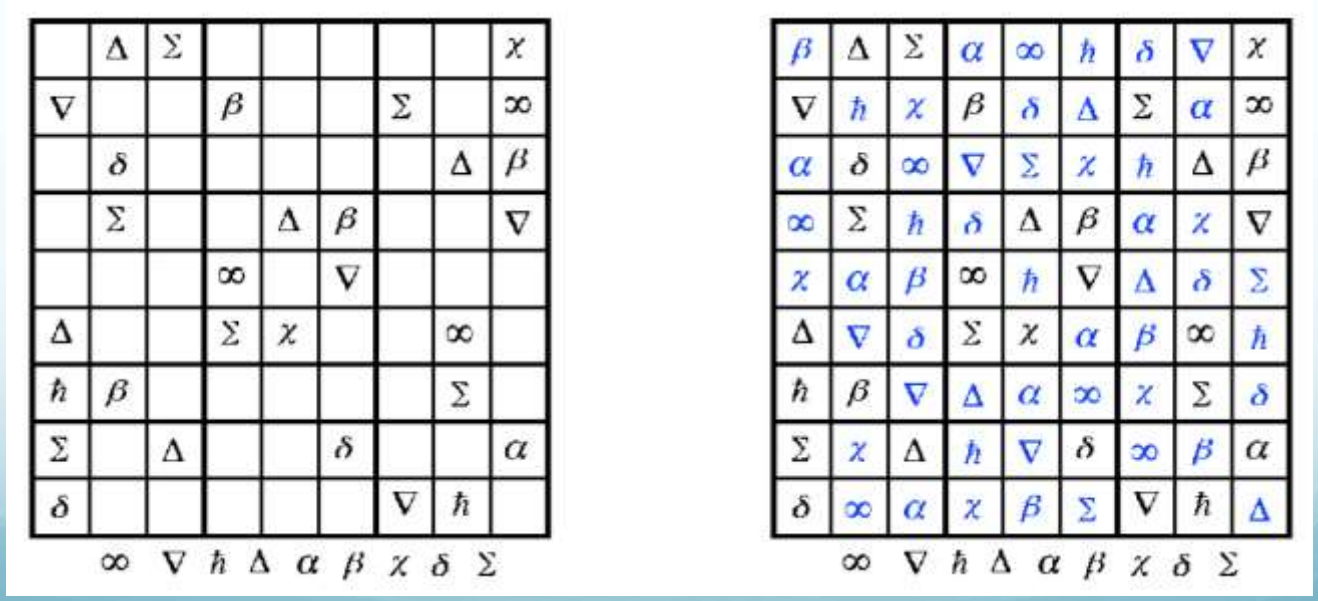
A D E G H L O S U

L	D	U	H	A	E	S	G	O
G	E	O	L	S	D	U	H	A
H	S	A	G	U	O	E	D	L
A	U	E	S	D	L	H	O	G
O	H	L	A	E	G	D	S	U
D	G	S	U	O	H	L	A	E
E	L	G	D	H	A	O	U	S
U	O	D	E	G	S	A	L	H
S	A	H	O	L	U	G	E	D

A D E G H L O S U

Step 5 : Testing/results

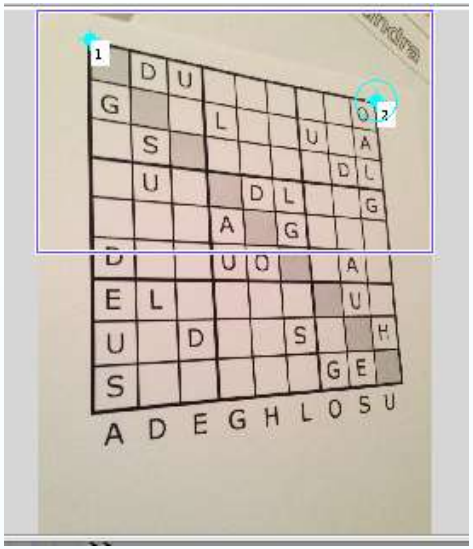


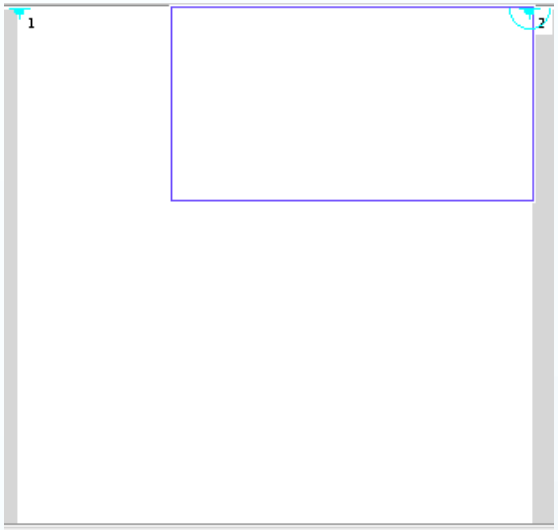


Step 5 : Testing/results

Real Images had Real problems -

1) Had to use *cpselect* to manually project the onto a sqaure template

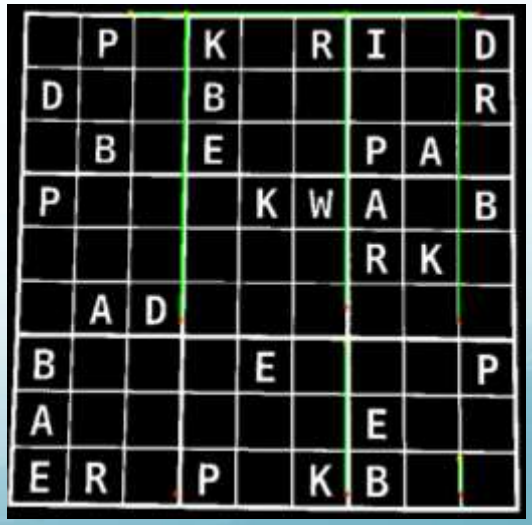




2) Problems with thresholding and detecting houghlines

Tweaking the algorithm-

1) Divide the grid into equal parts and extract.



Needs more testing -

Matching was successful for 1 out images out of 2 images.

Conclusions:

- Able to handle a tilt up to 10 degrees without user interaction.
- It could solve the puzzle for any given font.
- It could solve when lines were missing in the puzzle.
- Has 90 percent (10/11) accuracy.

Limitations:

- Keyword characters need to be separated.
- Could not handle real images without user interaction.
- Noise/thresholding issues for real images.

Future Work

- To optimize the algorithm to handle varying size of keyword and puzzle elements.
- To extend this algorithm to solve for real images with thresholding issues.

QUESTIONS