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AI Cruciverbalist - Artificial Intelligence for Grid Based Word Puzzle Generation

Master's Thesis

to achieve the university degree of
Diplom-Ingenieur

Master's degree programme:
Software Engineering and Management

submitted to

Graz University of Technology

Supervisor

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Institute for Interactive Systems and Data Science
Head: Stefanie Lindstaedt, Univ.-Prof. Dipl.-Inf. Dr.

Graz, 2020

Interactive Slides at:
<https://oskar.bechtold.work>

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Agenda

- Introduction
- Problem Statement
- Results
- Method
- Evaluation

Introduction

What is a Puzzle?

"Puzzles are rule-based systems, like games, but the goal is to find a solution, not to beat an opponent."

Chris Crawford

Grid-Based Word Puzzles

Puzzle Types

Kreuzwörterrätsel für Profis

Erraten Sie alle senkrecht gesuchten Begriffe wie gewohnt. Der Pfiff liegt im Kreuzwort. Den Standort der waagrecht gesuchten Wörter müssen Sie selbst herausfinden, die Abfragen stehen nicht in der richtigen Reihenfolge!

Waagrecht:

- 1. rager, mager • sauber, unbeschmutzt • Registrator • Frau Jakobs im Alten Testament • Gaststätte • dreist, vorlaut • Unterkunft, Wohnung • unverdientes Glück (ugs.) • zünftig, kernig, originell • männliches Borsenfleisch • Lasten bewegen • Hüter von Hausdauern beim Weidgang • heftiger Schlag • sehr fache Sevierunterlage • persönliches Fürwort (offizielle Person) • Durchfahrt, Durchgang • saloppe Umgangssprache; Jargon • Sammlung abstrakter Dichtung • ein streptophones Gesangs • Gastpavillon • Feld- und Wiesentier • Truhnen • Fisch-, Vogelfanggerät • Einspruch, Einspruch • Haushaltplan • Wasservogel, Natter • Sohn Isaaks • postisch: Adler • dreist, originell (englisch)

Senkrecht:

- 1. salopp; unglaublich, 2. abstrakte Erzählung in Prosa, 3. fählich, 4. Krankheitssemer, 5. Stadt und Fluss in Böhmen, 6. ausgenommen, frei von, 7. Himmelsrichtung, 8. literarisches Gedicht, 9. Fähigkeit zur Wahrnehmung, 10. ein Pflanz, 11. Kordweil (Maler), 12. Hauptstrom Vorderindien, 13. französischer Komponist (Daniel-François-Esprit), 14. Talschaft des Inns in der Schweiz, 15. helteres musikalische Bühnenwerk, 16. Lebensbund, 17. Stadt an der Murg, in Baden-Württemberg, 18. Staat in Nahost, Persien, 19. breitarige Spitze, 20. Stadteil von Berlin, 21. kleines Knechtel, 22. Unglück, Missgeschick, 23. Blutgerüst, 24. Aufguss, 25. großer Becher, Behälter aus Stoff, 26. Hingel-, Saugraum

Stück für Stück durchs Gitter

Können Sie die nachfolgenden Wörter so in das Gitter einsetzen, dass sich ein vollständiges Rätsel ergibt?

- 5 Buchstaben: ADLER – MONET – JUMPS – PRIMA – REIBE – SPAET – UMBAU
- 6 Buchstaben: GRIPPE – LEGION – MEDUSA
- 7 Buchstaben: BADENER – LAMELLE – REMONTE – TOMBOLA
- 8 Buchstaben: EGERLING – NOTATION – ZÖGERND
- 9 Buchstaben: ERBANLAGE – FLUTWELLE – HARTKASE – STUETZUNG – TITELSONG
- 10 Buchstaben: INTOLERANZ – LIEGESTUHL – SPORTLERIN – STEIGERSEN – TELGEBIET – UNGEHOERIG
- 11 Buchstaben: BOMBASTISCH – EBENUEBTIG – ELEKTROKID – EROETERUNG – RASTSTAETTE

Wabenrätsel

Bilden Sie um die Textfelder sechsbuchstellige Wörter, die im Pfeilfeld beginnen und sich in Pfeilrichtung drehen. Viel Spaß beim Raten!

Text boxes and arrows indicate the start and direction of the words:

- Kreuzfeld
- getreidesähnliche Krebse
- Oberer Teil am Stiefel
- vor flügeligen Insekten (flut)
- den Menschen haben
- langhaariger Rasen
- Dachshund
- von geringem Gewicht
- starrer Mensch (ugs.)
- Südsee
- unterirdischer Kirchenraum
- Staat in Nahost
- Flugkörper
- musikalischer Indus
- Platz (italienisch)
- Insel vor dem Golf von Neapel

Zur Schnecke gemacht

Die Wörter beginnen bei einer Zahl und enden bei der nächsten Zahl, sodass jeweils der Endbuchstabe gleichzeitig der Anfangsbuchstabe des folgenden Wortes ist. Das letzte Wort endet am Schneckenkern. Die unterlegten Felder ergeben – von außen nach innen gelesen – die Schlusslösung.

1 Kurs, Seminar (englisch) 2 geistiger Diebstahl 3 indische Streitzahl 4 Freund, Gefährte 5 Schustergerät; Art des Schemels 6 Linie 7 Glücksspiel (Kurzwort) 8 Störnschreck 9 übelnagel, brummig 10 heessche Stadt 11 umhüllen, einschließen 12 Überovorteilung im Preis 13 Spätrupp; Streife

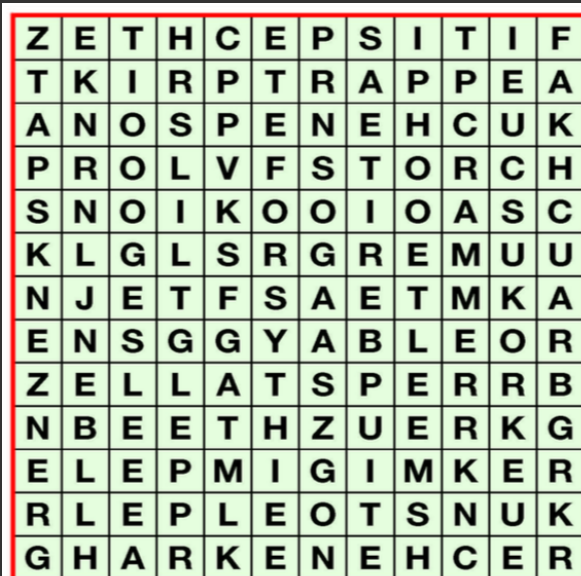
Grid content (row by row):

- 1 K I E F S I O G I
- 2 V O L K S F E S T B E R G F I N K
- 3 M I E T E A U G U S T I R A N
- 4 P S A U G E R S T O R N O L E
- 5 M E N S U R G E S E L I N A T
- 6 T E A M E N T A A E C K E
- 7 B E L L O N A E H R U N G A T
- 8 N E K I T T D N E S S I G
- 9 S T I L L E N T S W A L L I S E R
- 10 T E E P O C H E I I I
- 11 T H E I S S O H S U E D S E E
- 12 O R B I T S T R A E H N E I B
- 13 E T T O R E R O N R A N N E
- 14 G R O T T E N A T O M E N U E
- 15 S P I E R E U P F A U L L N
- 16 P M U N K E U C E L F E
- 17 S I E B N T R A S T H O F L O
- 18 E R R E G E R P R E F E I N
- 19 L I E D A U F F O R D E R N
- 20 L N I S O L I E R T S T A T T
- 21 H E N G S T L A T Z H H
- 22 S E O E L E N C O R A N G E
- 23 P R I N T E O B H U T R E I S
- 24 C E N T S E K T T E E K A N N E

Grid content (row by row):

- 1 UN KE WA
- 2 RU LU RE
- 3 HE LE NA
- 4 GA LA
- 5 AU TO MO BIL
- 6 LA BI
- 7 SPIE LE REI
- 8 I GEL BE
- 9 EI RE
- 10 MI TI DE
- 11 DI A NA
- 12 ME RO
- 13 O RI NO KO
- 14 KA KO
- 15 KEI NER LEI
- 16 FEN SE MI

Wordsearch and Swedish Puzzles



Wörtersuchen

Wir haben 31 Begriffe in diesem Buchstaben-Wirrwarr versteckt. Die Wörter können in jede Richtung laufen, auch diagonal, rückwärts oder von unten nach oben.

AMMER – AURORA – BEET – BRAUCH – EISVOGEL – FITIS – FLORA – FORSYTHIE – GIMPEL – GRENZEN – HAGEL – HARKE – IMKER – KNOSPE – KOLKRABE – KREUZ – KROKUS – KUCHEN – KUNST – LENZ – MEISE – NEST – PASSION – PFORTE – RECHEN – SPATZ – SPECHT – STALL – STORCH – TOELPEL – TRAPPE



Spruch gesucht

Wenn Sie richtig geraten haben, ergibt sich ein Spruch aus den gelb unterlegten Feldern. Also dann: Viel Spaß!

Three stages in Puzzle Creation

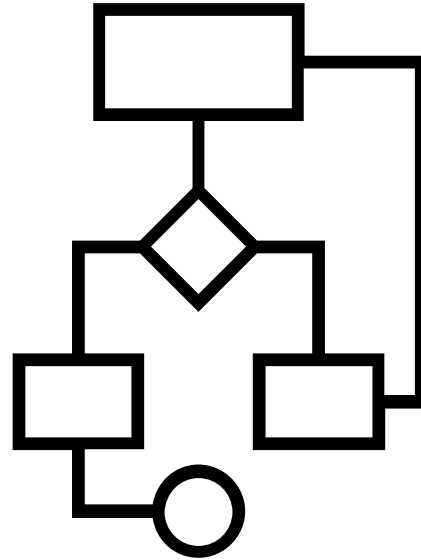
1. Text and Vocabularies
2. Generating Puzzles
 - Placing words
 - Generating grids
 - Filling empty grids
 - Assigning clues
3. Quality Assurance

Problem Statement

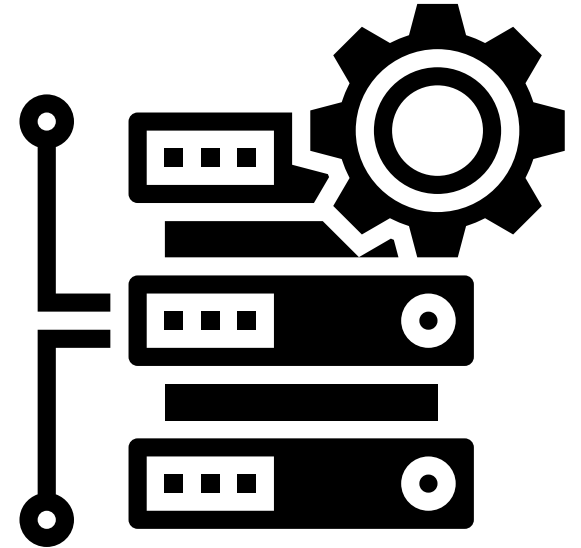
Use Case



Puzzle Editor



Algorithm



Microservice
in Cloud

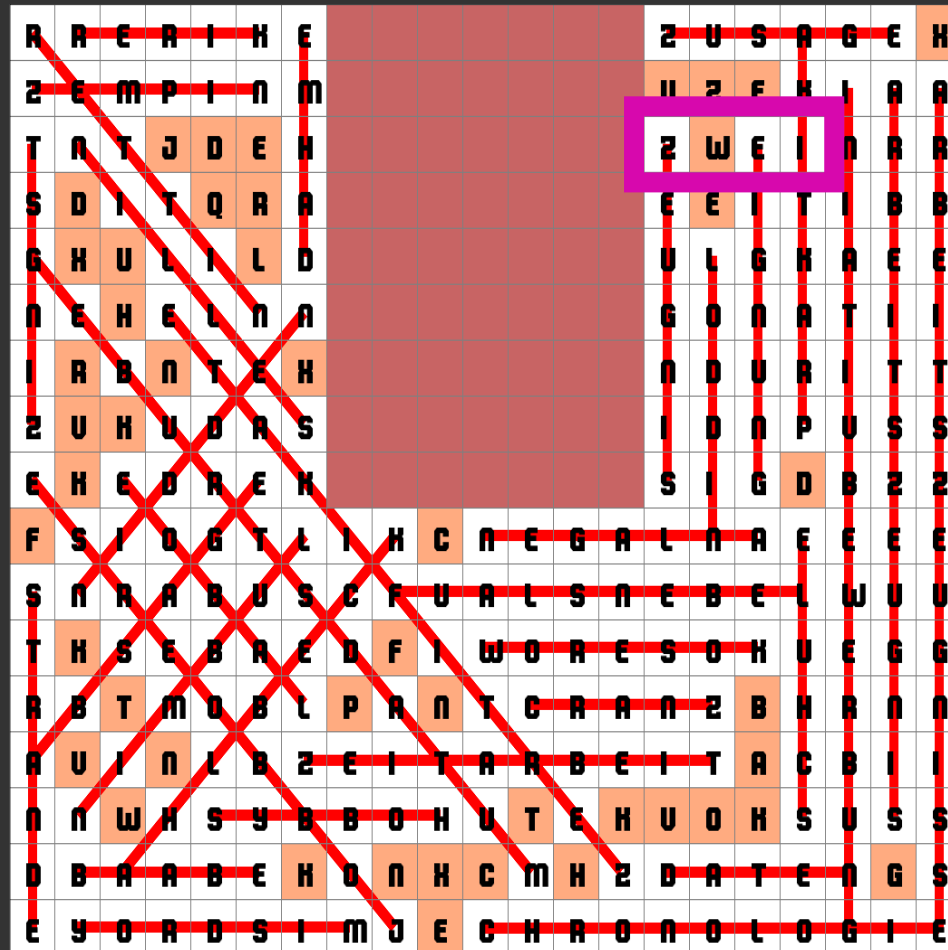
Requirements

by Krupion GmbH

Grids

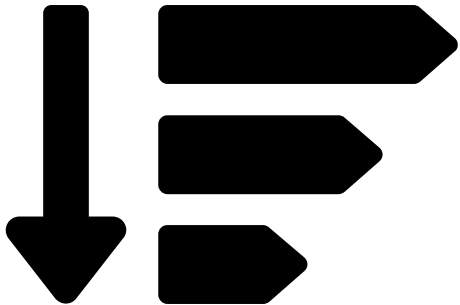
Requirements

Puzzles

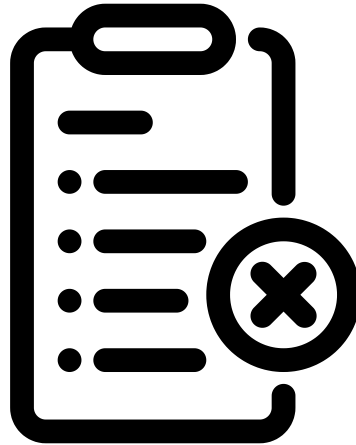


Requirements

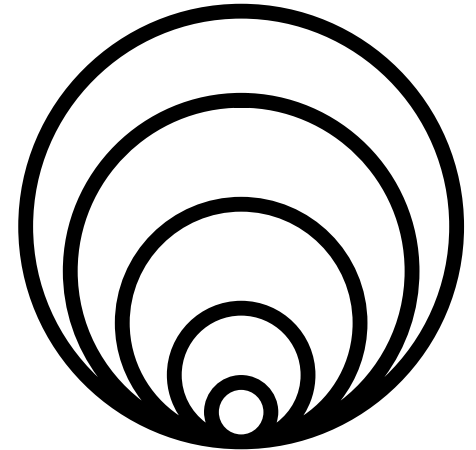
Vocabularies



Company
Medical
Austria



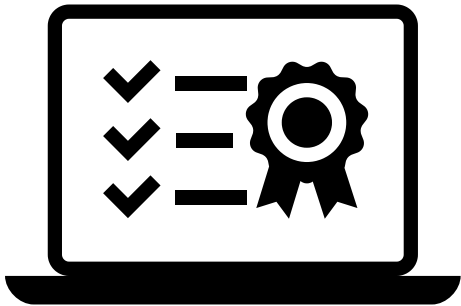
Mom
X
Mother



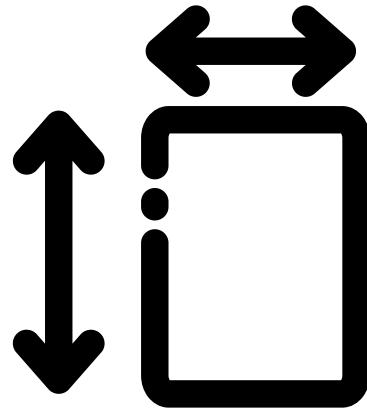
40 - 40.000
Words

Requirements

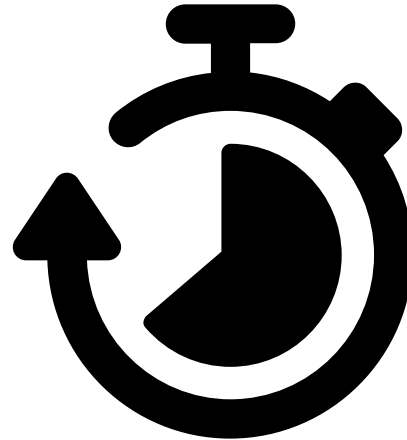
Algorithm



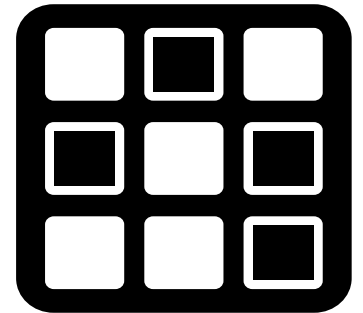
High
Quality



Arbitrary
Size

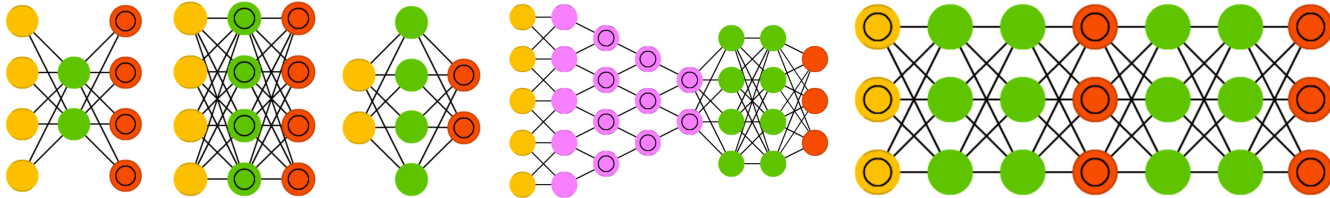


Acceptable
Runtime



Predefined
Fields

Approaches



- DNN
- CNN
- (v)AE
- CSP
- COP

- (c)GAN
- RL
- NTM
- DNC

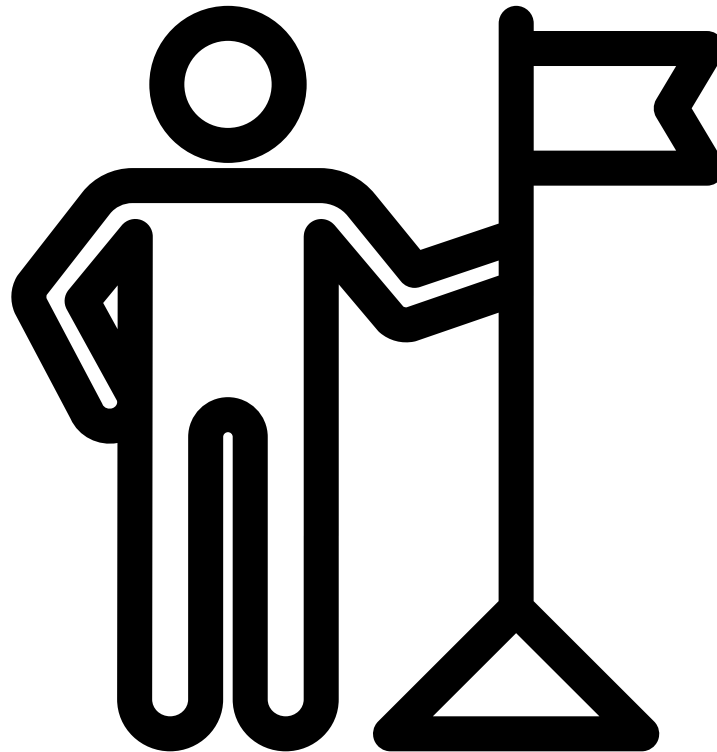
Result

Domain Expert Approved



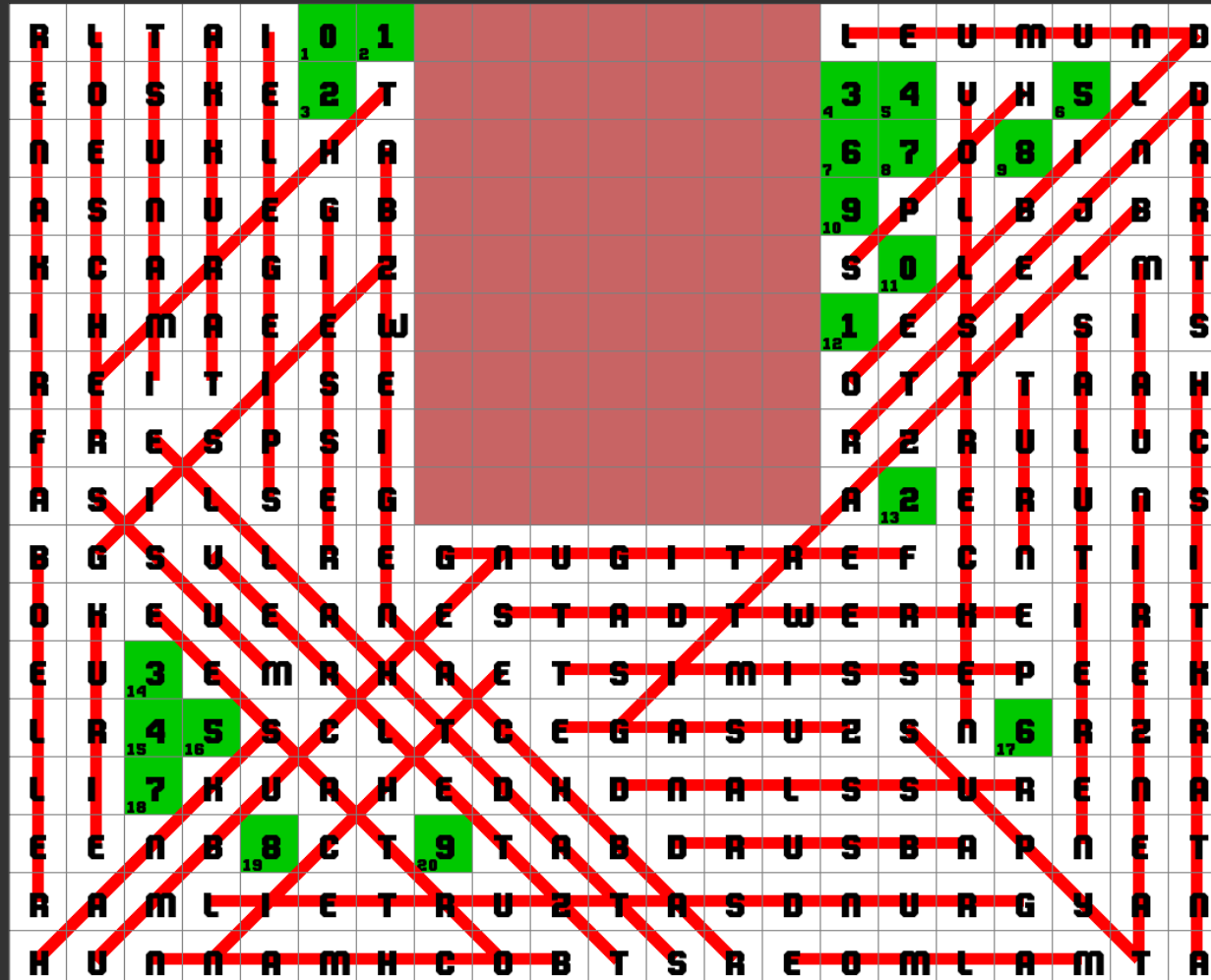
Constraint Programming:

Excellent Results



Constraint Programming:

Excellent Results



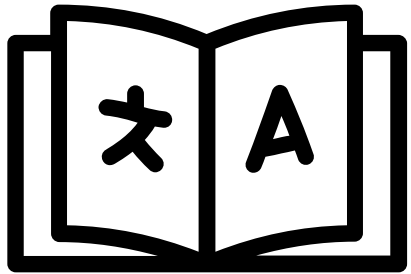
Neural Networks:

Unsuitable

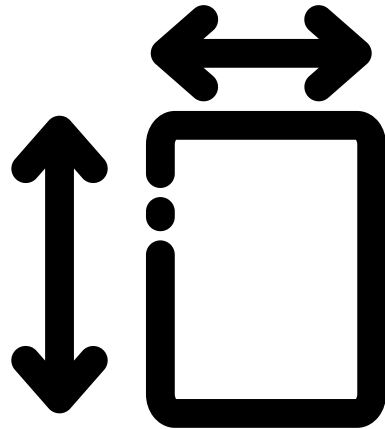


Neural Networks:

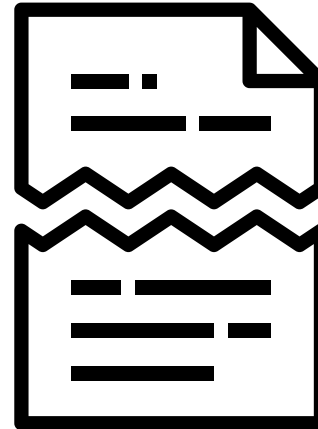
Unsuitable



No Vocab
Encoding



No Variable
Size Output

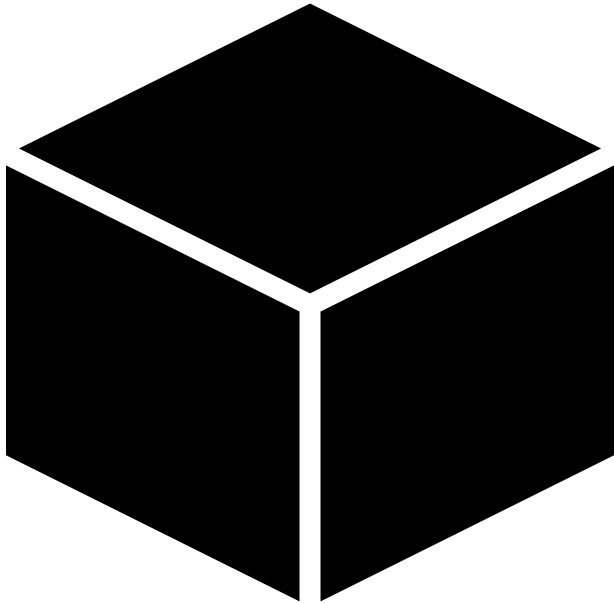


Not Accurate
Enough

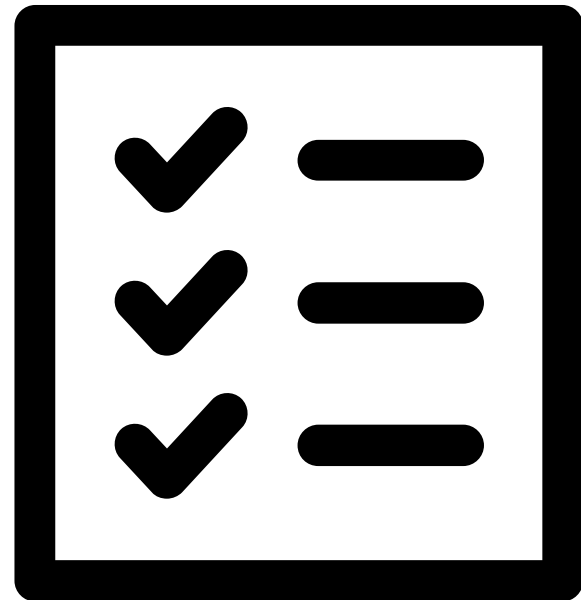


Too Much
Data Needed

NN vs. CSP



Blackbox

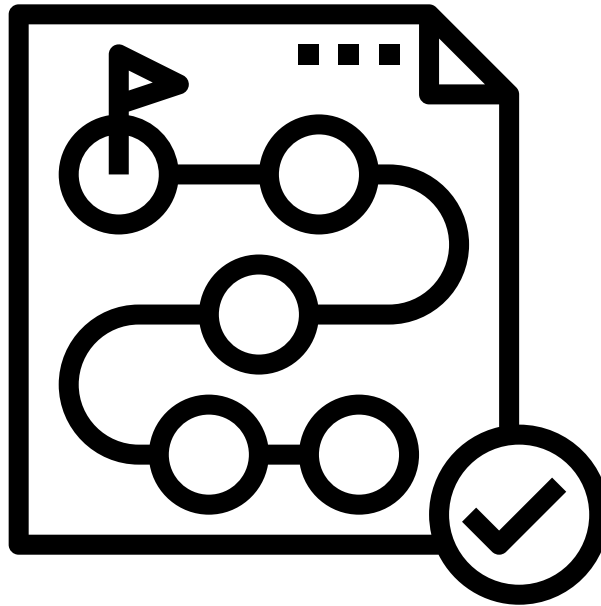


Set of Rules

Choosing the right model

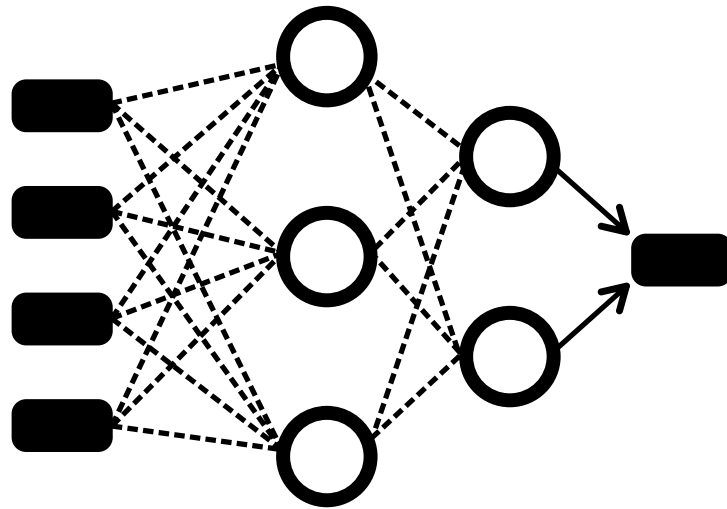


Choosing the right method



Evaluation

Neural Networks



Autoencoded Puzzle

97.84% Accuracy

T	T	E	F	T	I	R	O	T	K	E	T	O	R	P
T		A		R	U			D	E	H	E	U	R	F
R	R	L		U	F	U	R	H	C	A	N			K
O		A		F	P	O	K	L	A	K	O	L	R	A
B		O	F	F	L	O	N	R	O	T	S	I	H	N
B		K	G	A			E	B			L	E		E
E	R	A		U	L		T	L		L	G			G
N		A	R	T	Z	G	E	A	M	E	R	A	N	A
				D	E	W	N	A	H	N	O	R	A	N
A	R	E	S	I	M	U	R	R	F	A	R	M	E	R
A	P	E	R	C	U	O	S	E	L	T	S	A	M	A
	E	K	C	A	M	M	G	T	F		M	A	R	C

Original

S	T	E	F	T	I	S	P	T	L	E	T	O	R	O
T		A		R	U			C	F	I	E	U	S	E
R	S	M		U	F	U	R	G	C	A	O			K
O		A		F	P	P	M	M	A	L	P	M	R	A
B		P	H	G	M	P	O	R	P	T	S	J	I	O
B		L	F	B			D	B			M	E		E
F	R	A		U	M		T	M		M	G			G
O		A	R	T	Y	G	F	A	M	E	S	A	N	A
				E	F	V	O	A	I	O	P	R	A	N
A	R	E	S	J	N	V	S	R	G	A	S	N	E	O
A	O	F	S	D	U	P	S	F	L	T	T	A	N	A
	F	L	C	A	M	N	G	T	G		M	A	R	D

Autoencoded

Color represents word

Autoencoded Puzzle

99.88% Accuracy

T	T	E	F	T	I	R	O	T	K	E	T	O	R	P
T		A		R	U			D	E	H	E	U	R	F
R	R	L		U	F	U	R	H	C	A	N			K
O		A		F	P	O	K	L	A	K	O	L	R	A
B		O	F	F	L	O	N	R	O	T	S	I	H	N
B		K	G	A			E	B			L	E		E
E	R	A		U	L		T	L		L	G			G
N		A	R	T	Z	G	E	A	M	E	R	A	N	A
				D	E	W	N	A	H	N	O	R	A	N
A	R	E	S	I	M	U	R	R	F	A	R	M	E	R
A	P	E	R	C	U	O	S	E	L	T	S	A	M	A
	E	K	C	A	M	M	G	T	F			M	A	R

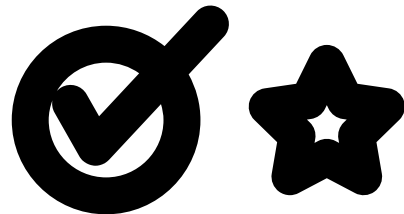
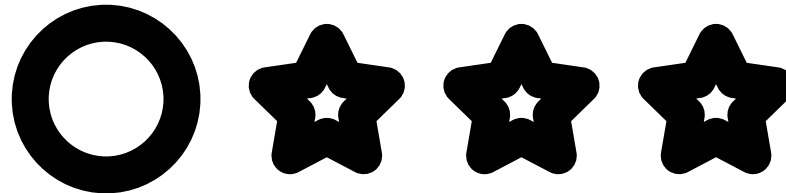
Original

T	T	E	F	T	I	R	O	T	K	E	T	O	R	P
T		A		R	U			D	E	H	E	U	R	F
R	R	L		U	F	U	R	H	C	A	N			K
O		A		F	P	O	K	L	A	K	O	L	R	A
B		O	F	F	L	O	N	R	O	T	S	I	H	N
B		K	G	A			E	B			L	E		E
E	R	A		U	L		T	L		L	G			G
N		A	R	T	Z	G	E	A	M	E	R	A	N	A
				D	E	W	N	A	H	N	O	R	A	N
A	R	E	S	I	M	U	R	R	F	A	R	M	E	R
A	P	E	R	C	U	O	S	E	L	T	S	A	M	A
	E	K	C	A	M	M	G	T	F			M	A	R

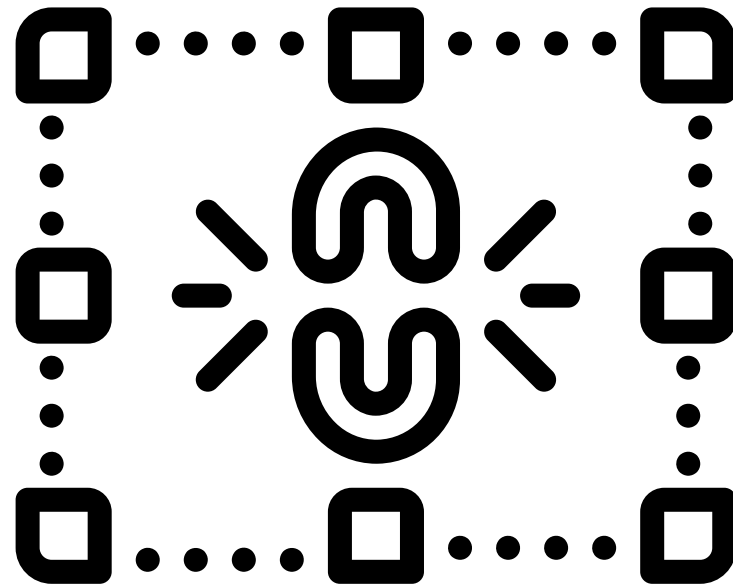
Autoencoded

Color represents word

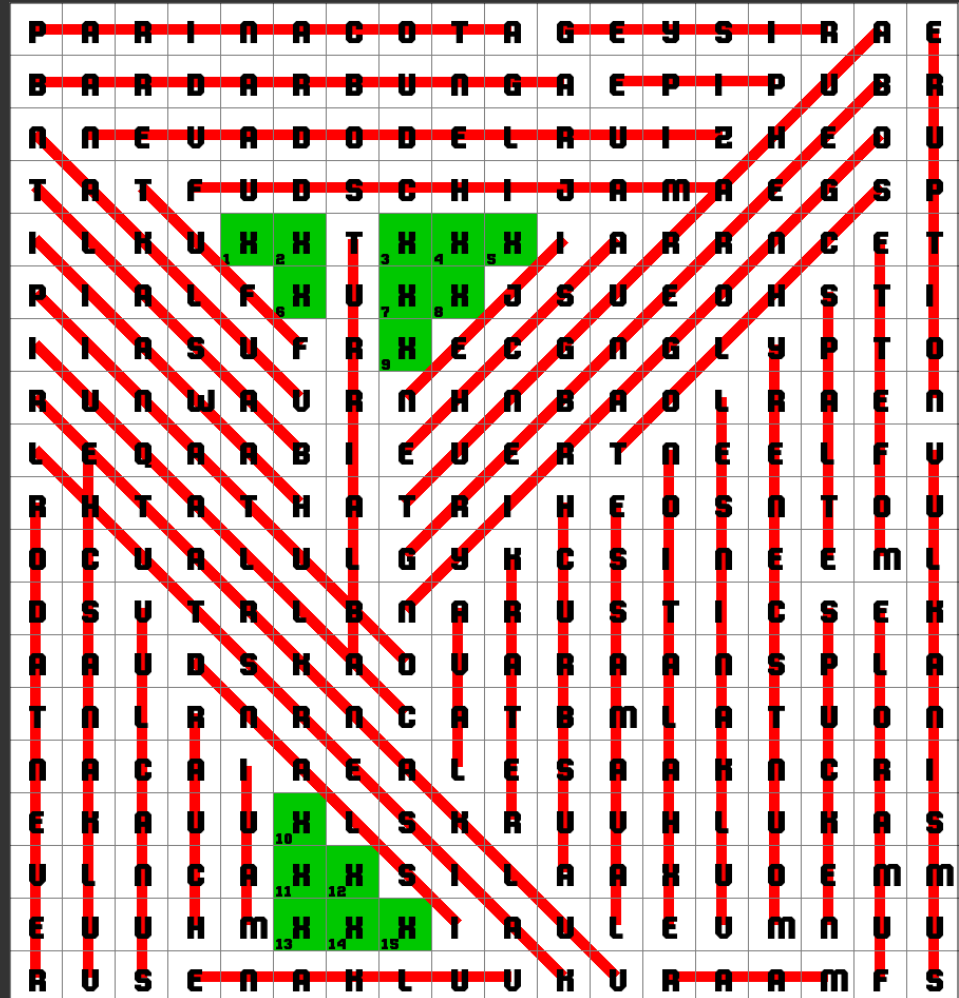
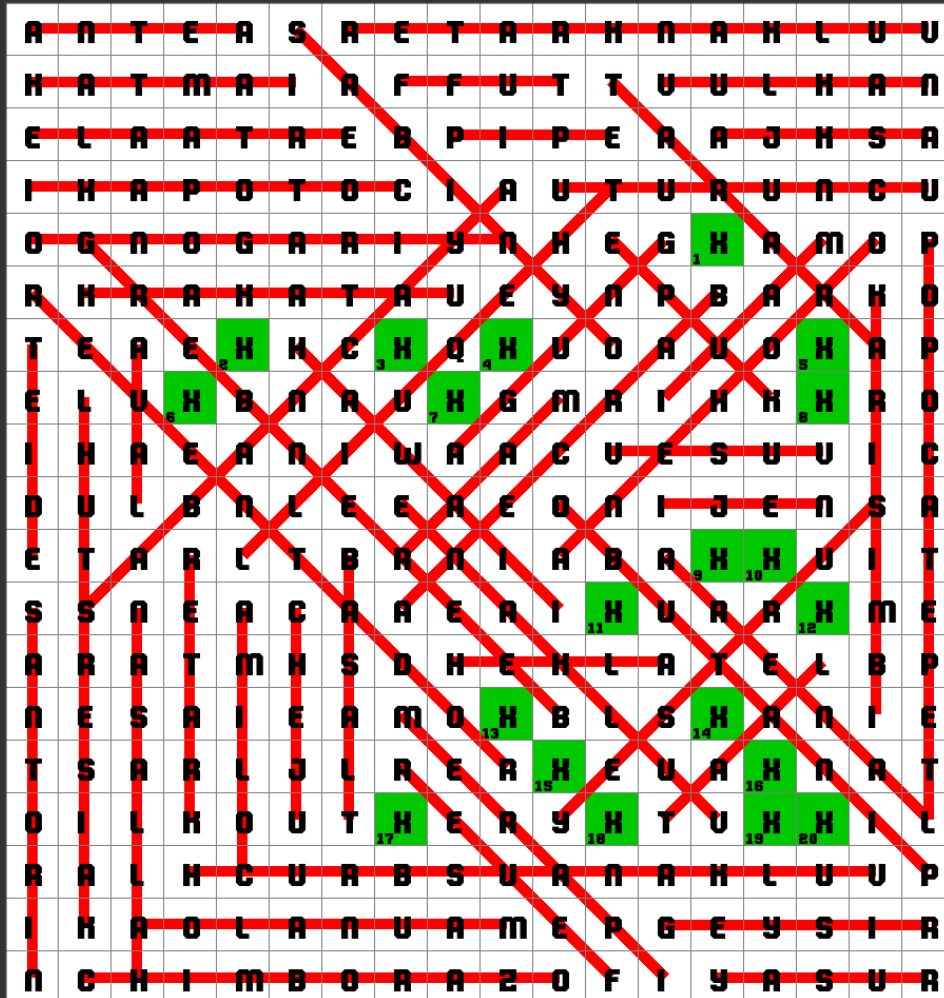
No Autoencoded Vocabulary



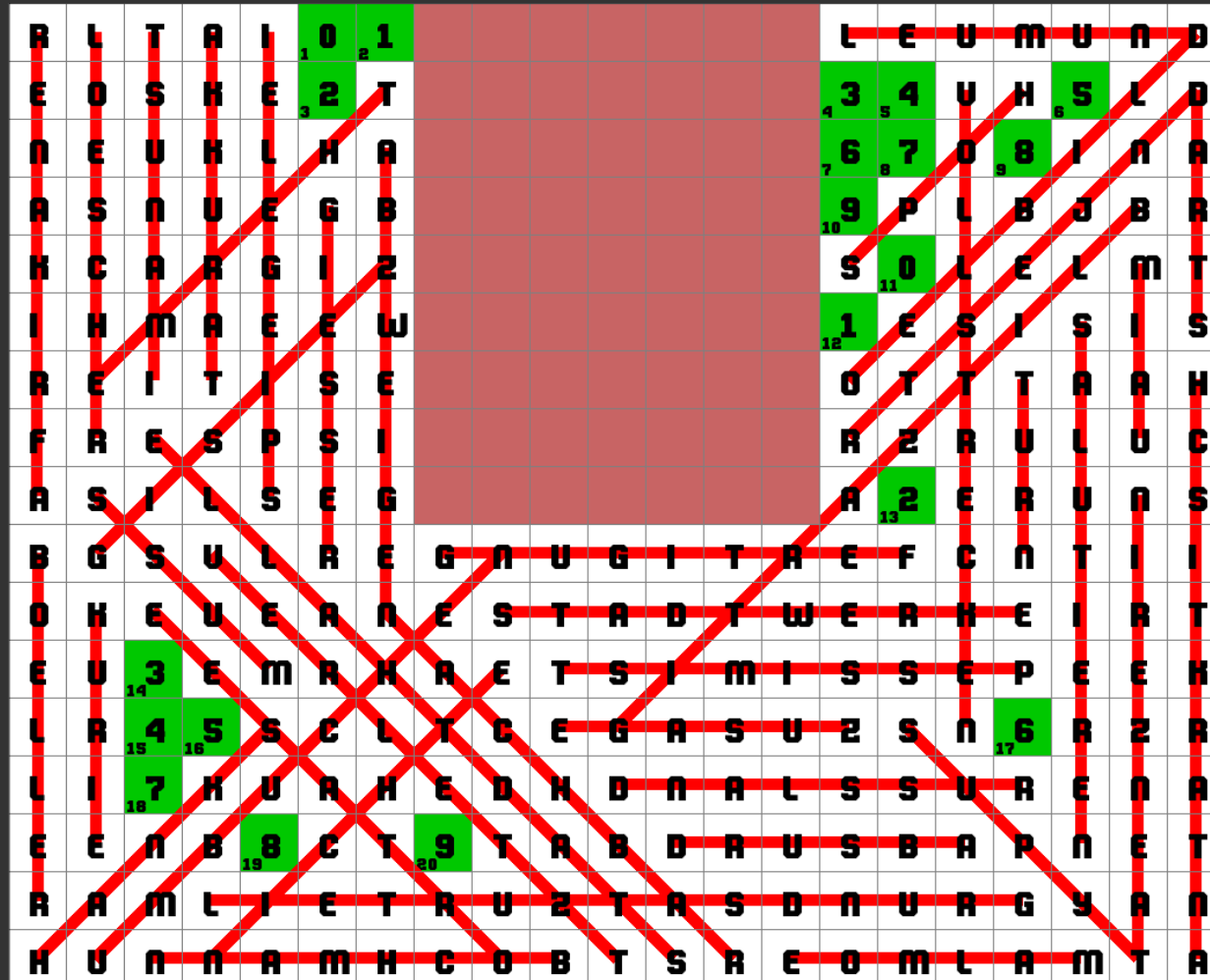
Constraint Satisfaction Programming



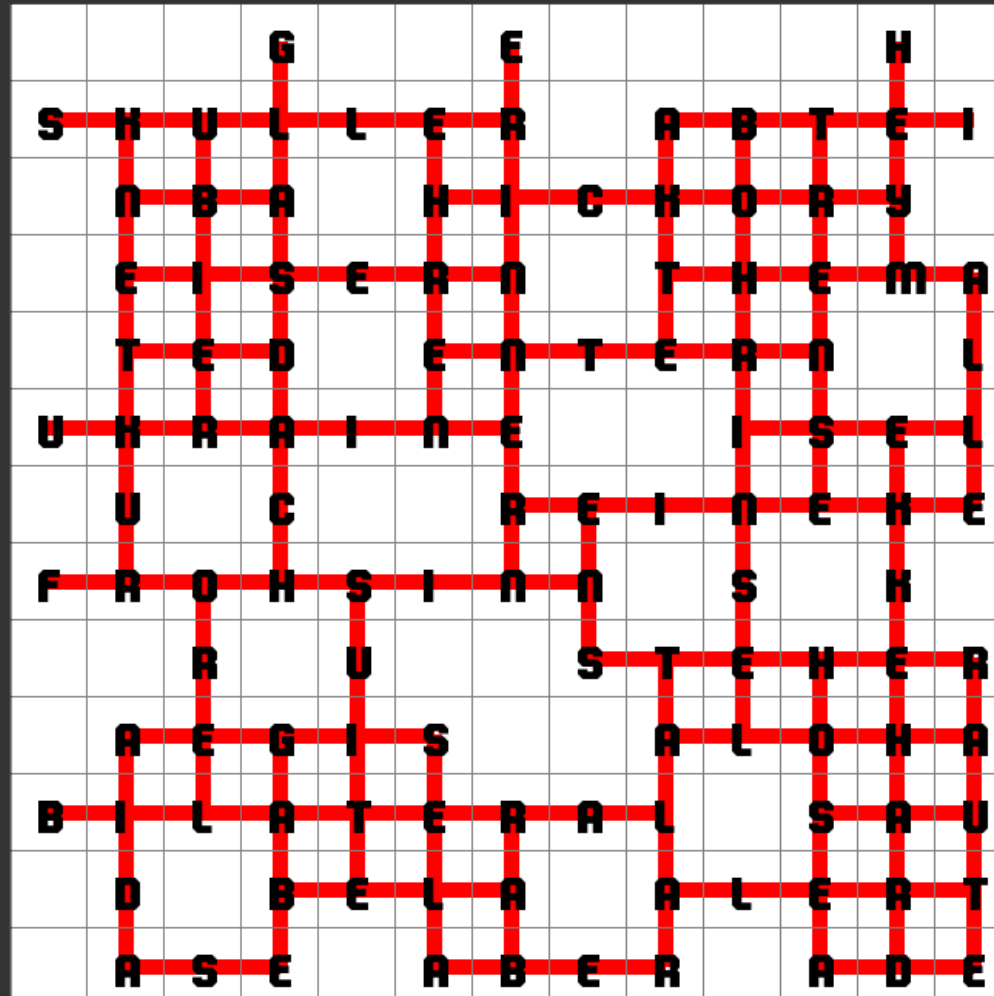
WordSearchAlgorithm Results



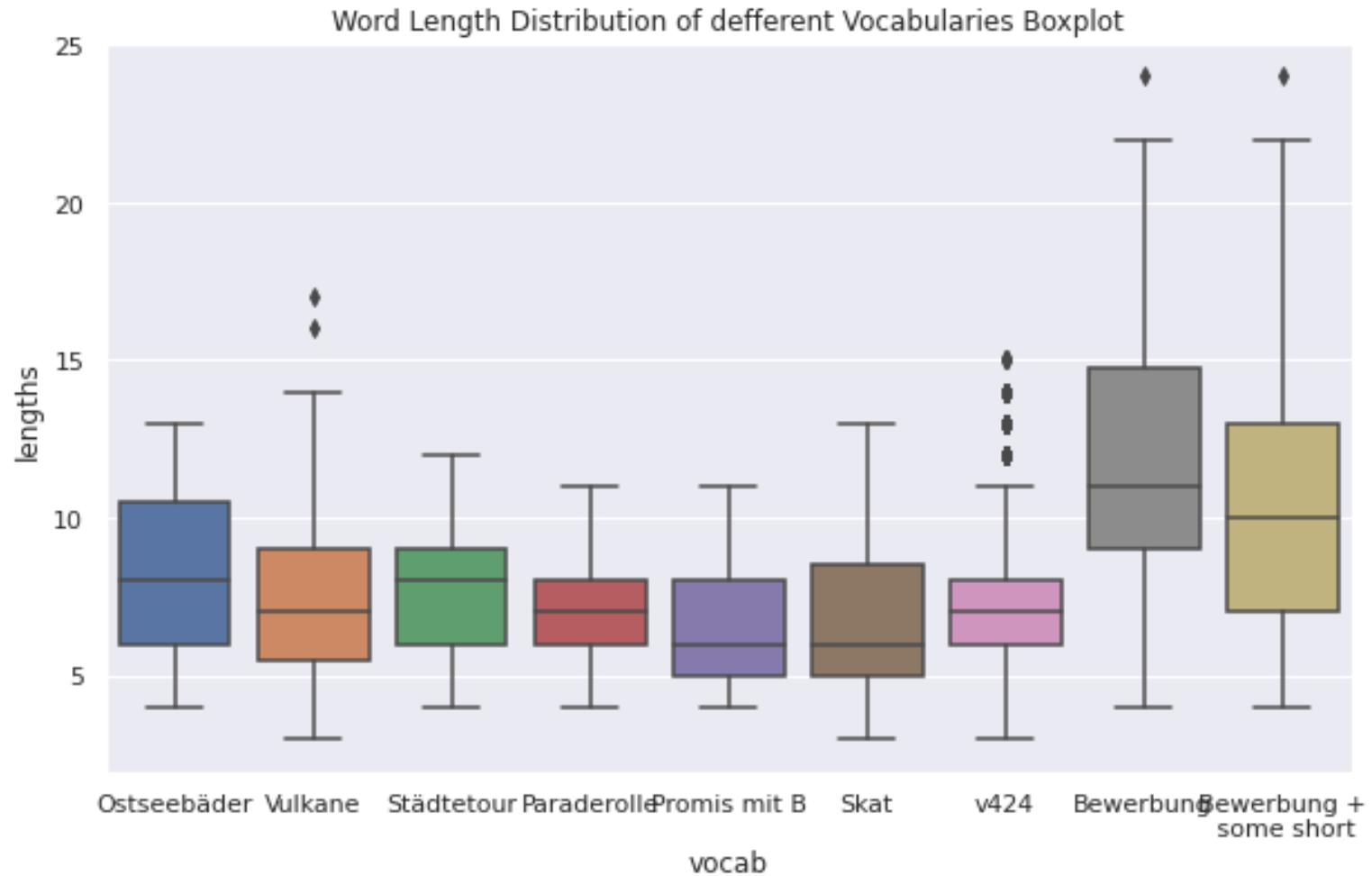
WordSearchAlgorithm Results



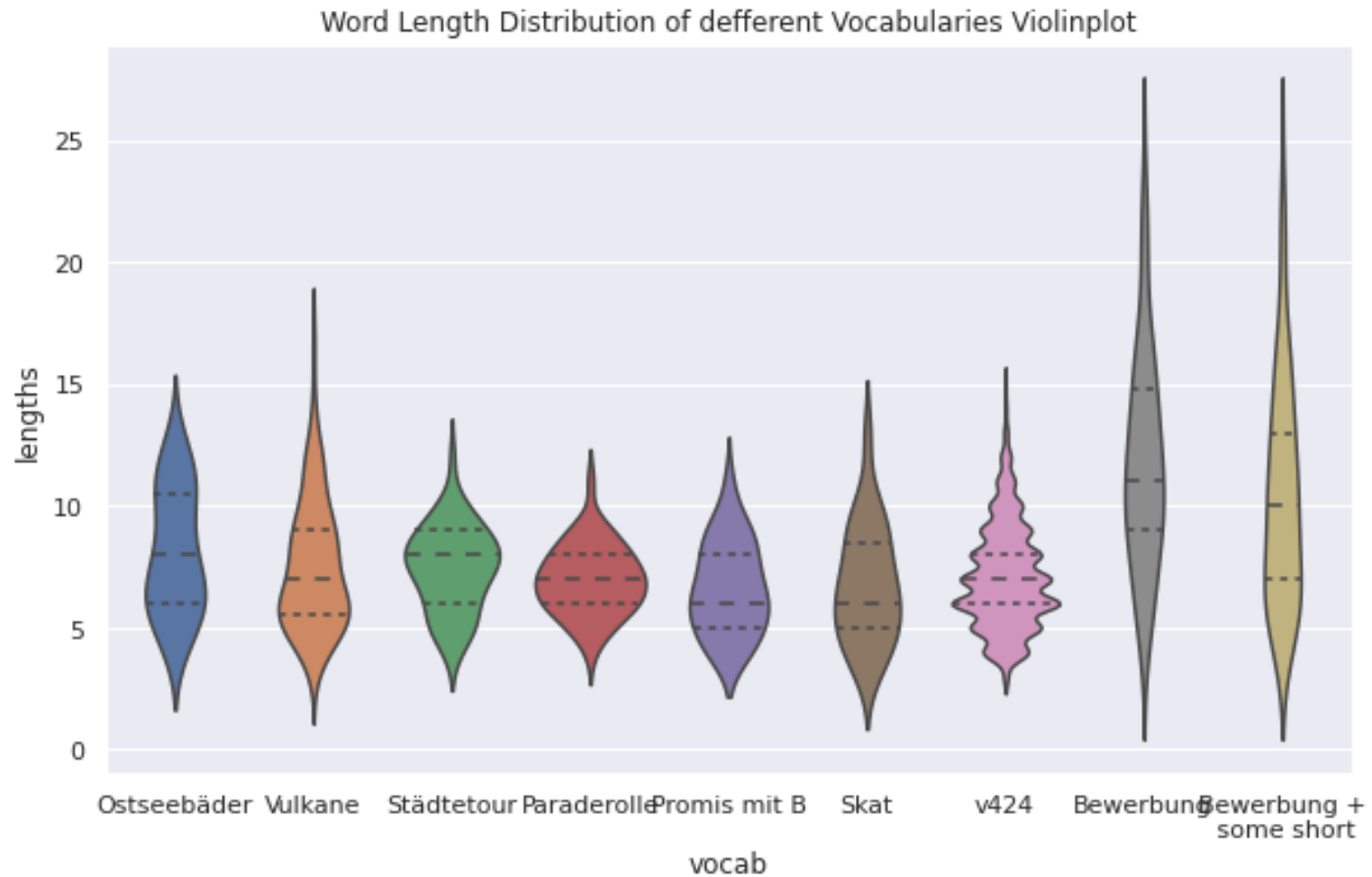
GridFiller for Swedish Results



Vocabulary Evaluation

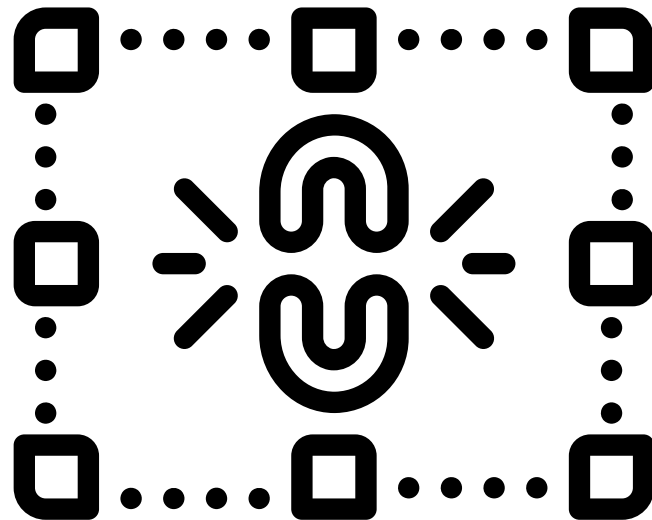


Vocabulary Evaluation

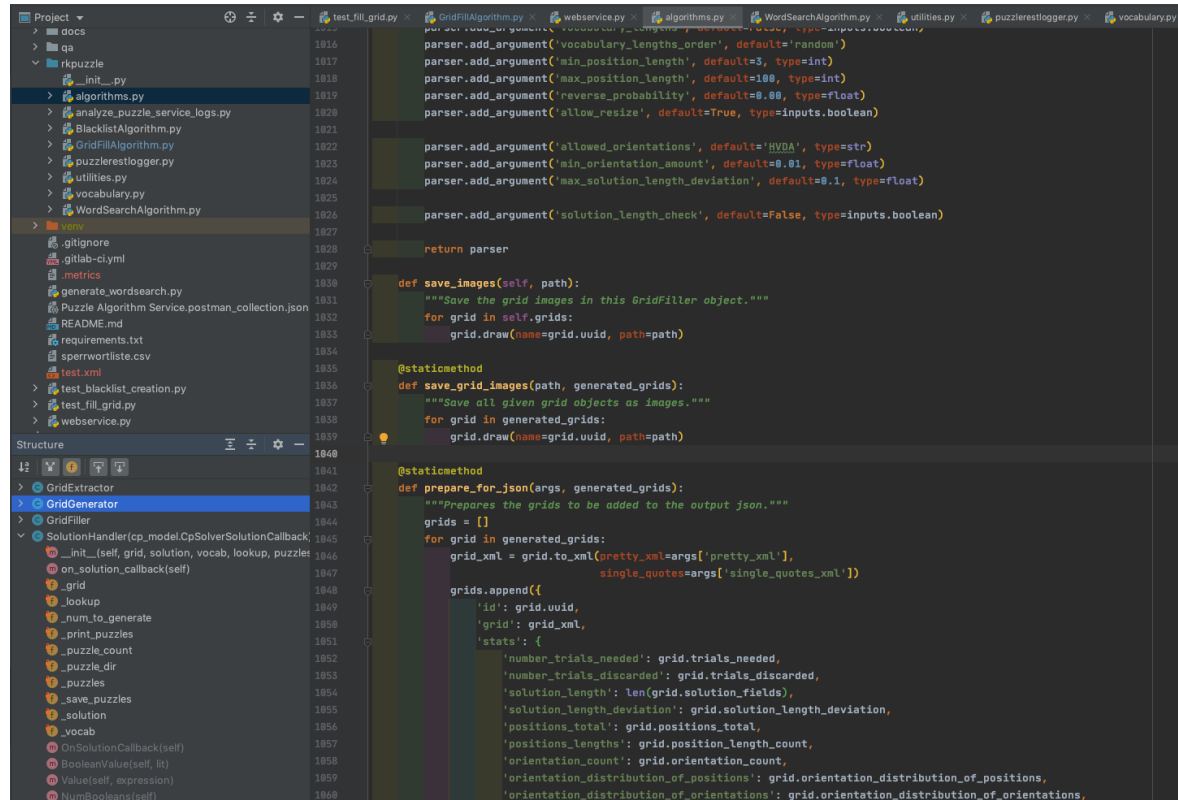


Method

Constraint Satisfaction Programming



Code



The screenshot shows an IDE with a project structure on the left and code in the main editor. The project structure includes a 'puzzle' directory with files like 'analyze_puzzle_service_logs.py', 'GridFillAlgorithm.py', 'puzzlerestlogger.py', 'utilities.py', 'vocabulary.py', and 'WordSearchAlgorithm.py'. The main editor displays the code for 'GridFillAlgorithm.py', which includes a parser for command-line arguments, methods for saving images and JSON, and a static method for preparing JSON output.

```
1016 parser.add_argument('vocabulary_lengths_order', default='random')
1017 parser.add_argument('min_position_length', default=3, type=int)
1018 parser.add_argument('max_position_length', default=100, type=int)
1019 parser.add_argument('reverse_probability', default=0.00, type=float)
1020 parser.add_argument('allow_resize', default=True, type=inputs.boolean)
1021
1022 parser.add_argument('allowed_orientations', default='HVDA', type=str)
1023 parser.add_argument('min_orientation_amount', default=0.01, type=float)
1024 parser.add_argument('max_solution_length_deviation', default=0.1, type=float)
1025
1026 parser.add_argument('solution_length_check', default=False, type=inputs.boolean)
1027
1028 return parser
1029
1030 def save_images(self, path):
1031     """Save the grid images in this GridFiller object."""
1032     for grid in self.grids:
1033         grid.draw(name=grid.uuid, path=path)
1034
1035 @staticmethod
1036 def save_grid_images(path, generated_grids):
1037     """Save all given grid objects as images."""
1038     for grid in generated_grids:
1039         grid.draw(name=grid.uuid, path=path)
1040
1041 @staticmethod
1042 def prepare_for_json(args, generated_grids):
1043     """Prepares the grids to be added to the output json."""
1044     grids = []
1045     for grid in generated_grids:
1046         grid_xml = grid.to_xml(pretty_xml=args['pretty_xml'],
1047                               single_quotes=args['single_quotes_xml'])
1048         grids.append({
1049             'id': grid.uuid,
1050             'grid': grid_xml,
1051             'stats': {
1052                 'number_trials_needed': grid.trials_needed,
1053                 'number_trials_discarded': grid.trials_discarded,
1054                 'solution_length': len(grid.solution_fields),
1055                 'solution_length_deviation': grid.solution_length_deviation,
1056                 'positions_total': grid.positions_total,
1057                 'positions_lengths': grid.position_length_count,
1058                 'orientation_count': grid.orientation_count,
1059                 'orientation_distribution_of_positions': grid.orientation_distribution_of_positions,
1060                 'orientation_distribution_of_orientations': grid.orientation_distribution_of_orientations,
```

2855
SLOC

1645
CLOC

615
McCabe

258 Blocks
low CC

Maintainab.
of A

Initial Intuition

O	S	K	A	R	O
O	S	K	A	R	S
O	S	K	A	R	K
O	S	K	A	R	A
O	S	K	A	R	R
O	S	K	A	R	

Oskar
Manuel
Stefan
Roman

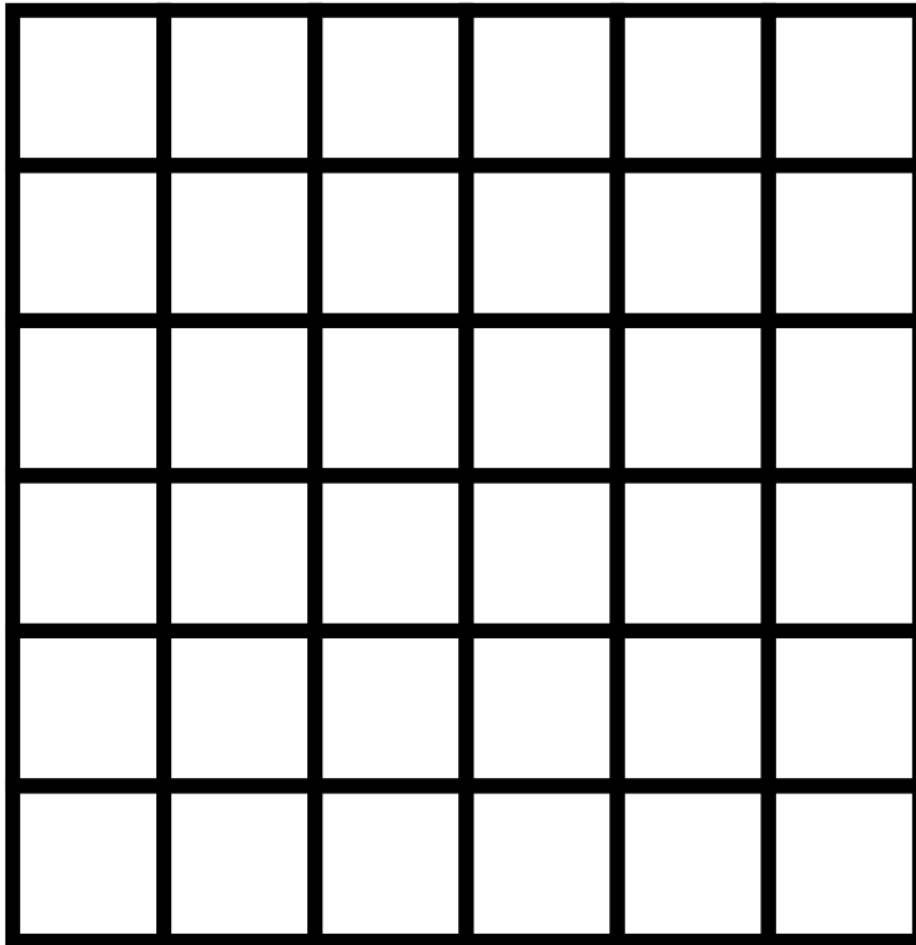
Initial Intuition

			M		
O	S	K	A	R	
			N		
			U		
			E		
			L		

Oskar
Manuel
Stefan
Roman

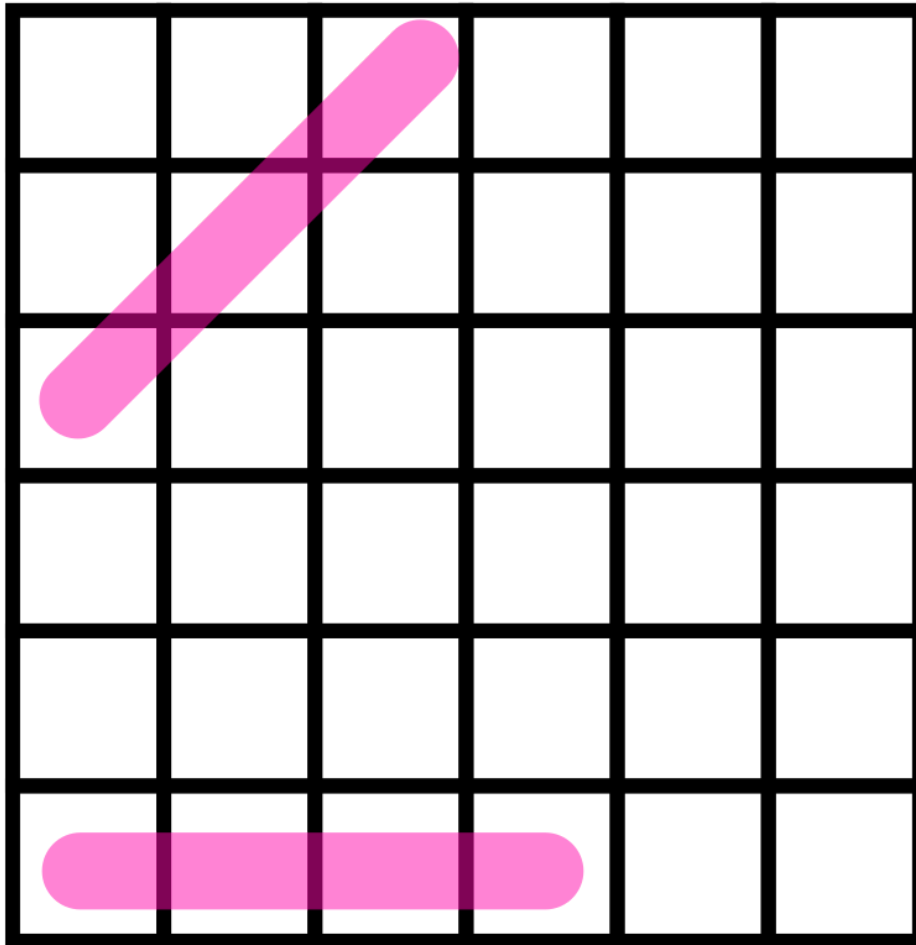
GridGenerator and GridFiller

GridGenerator



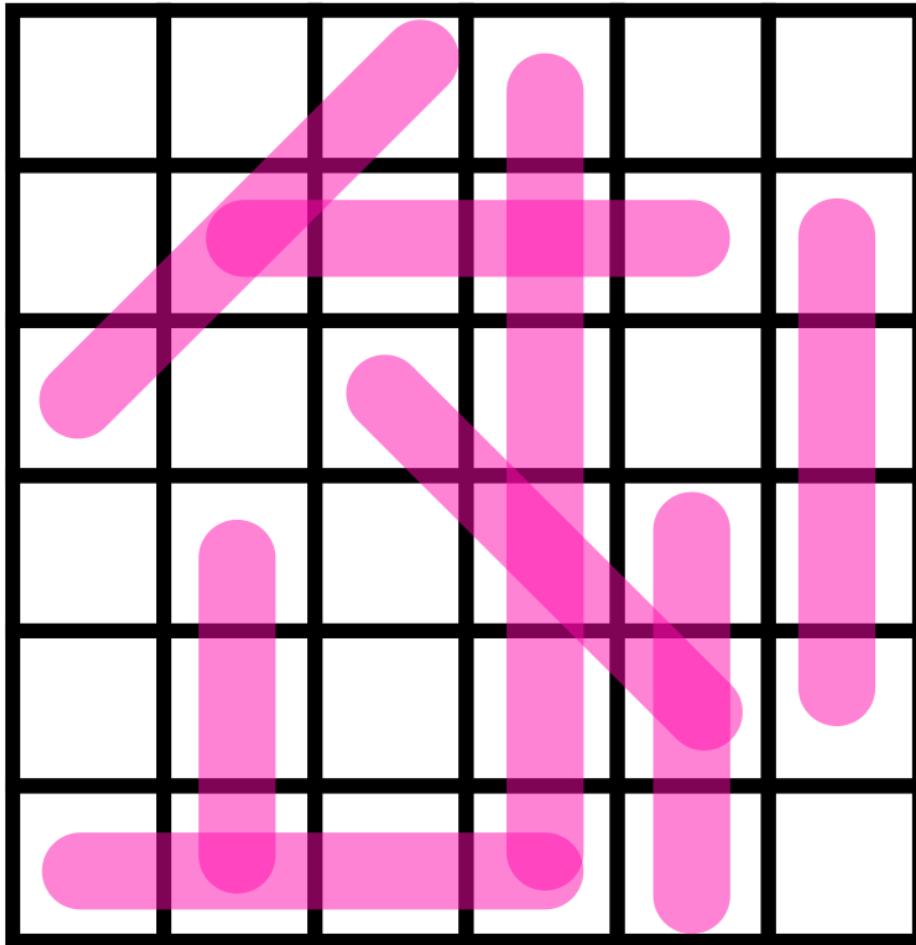
Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

GridGenerator



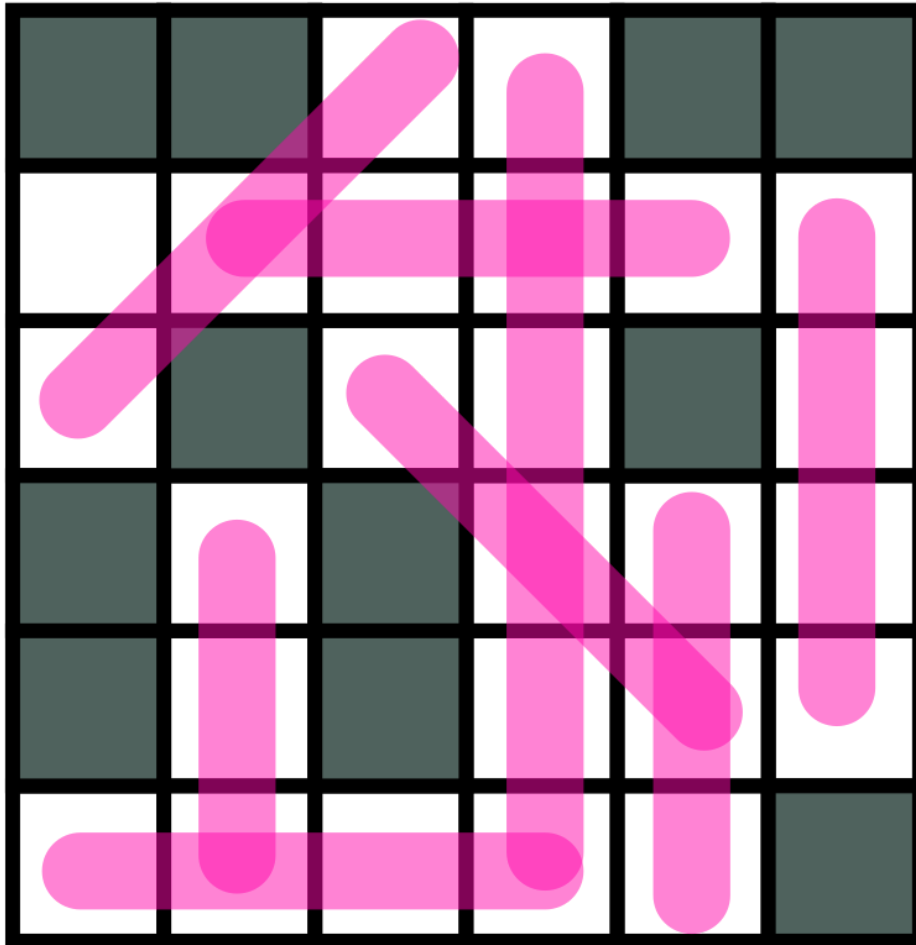
Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

GridGenerator



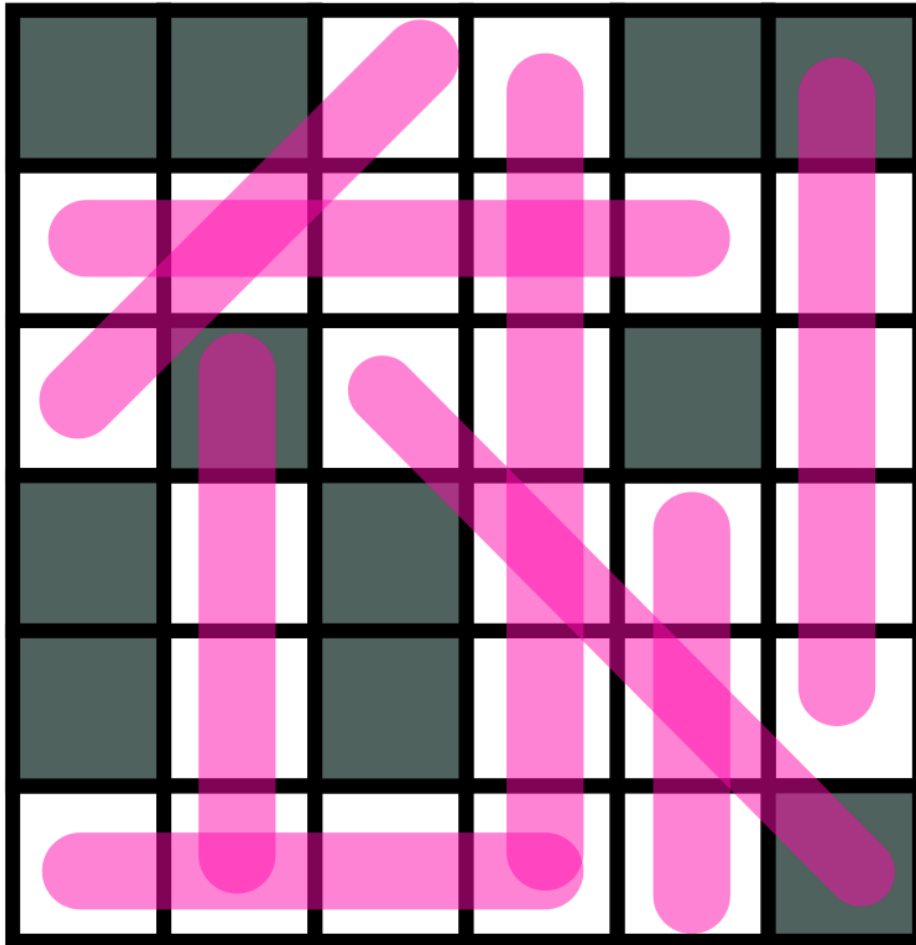
Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

GridGenerator



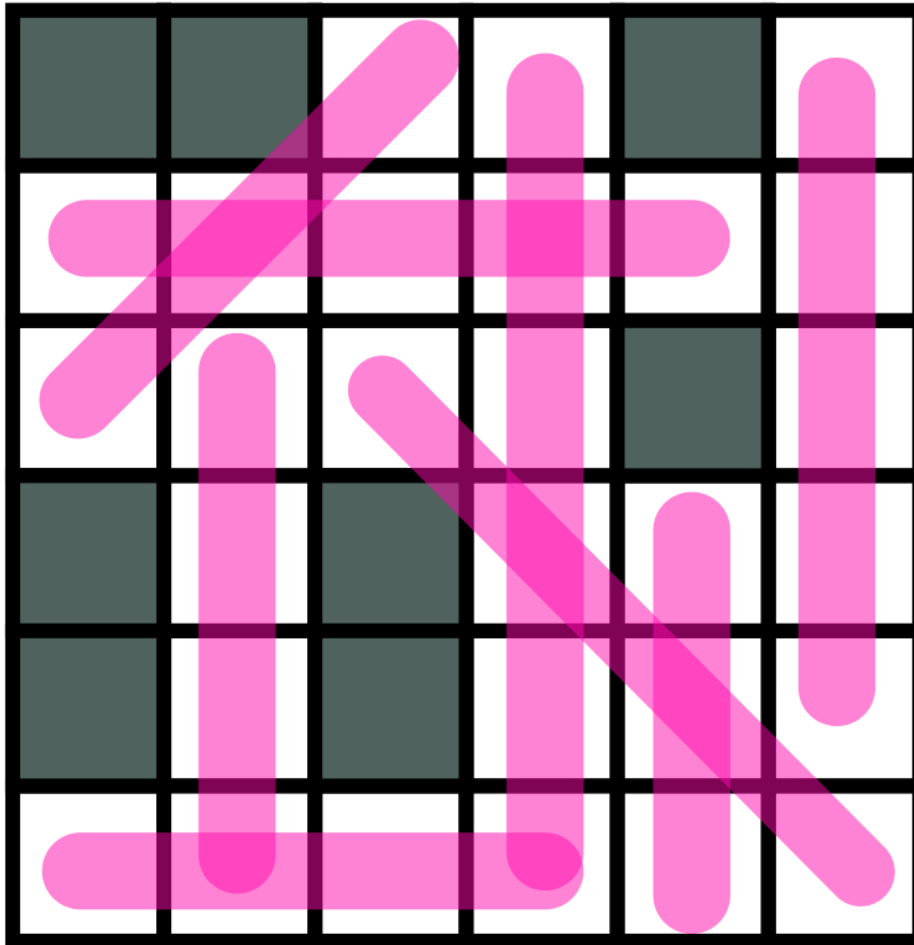
Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

GridGenerator



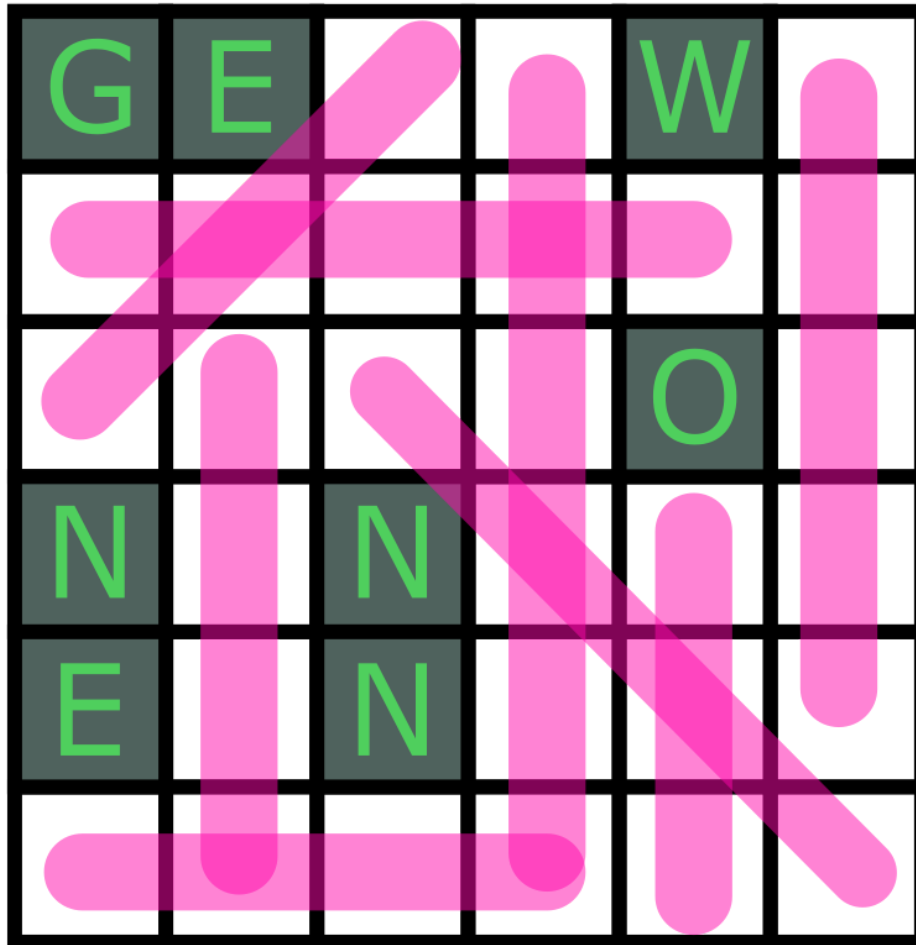
Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

GridGenerator



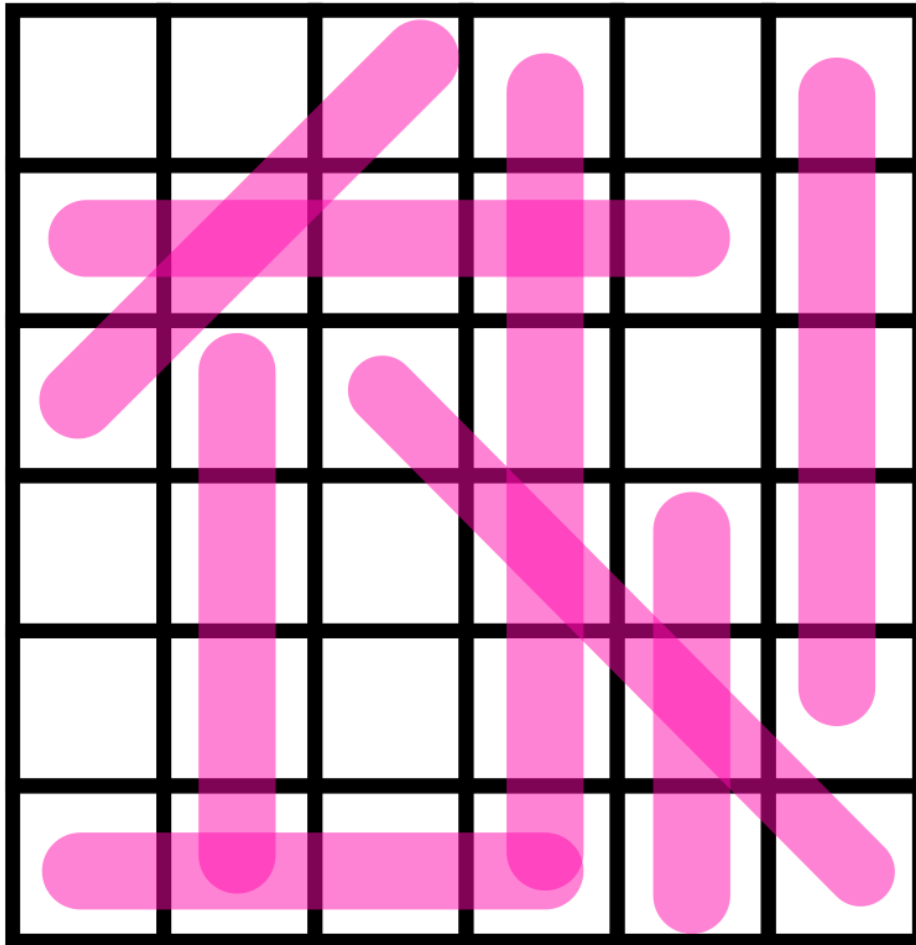
Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

GridGenerator



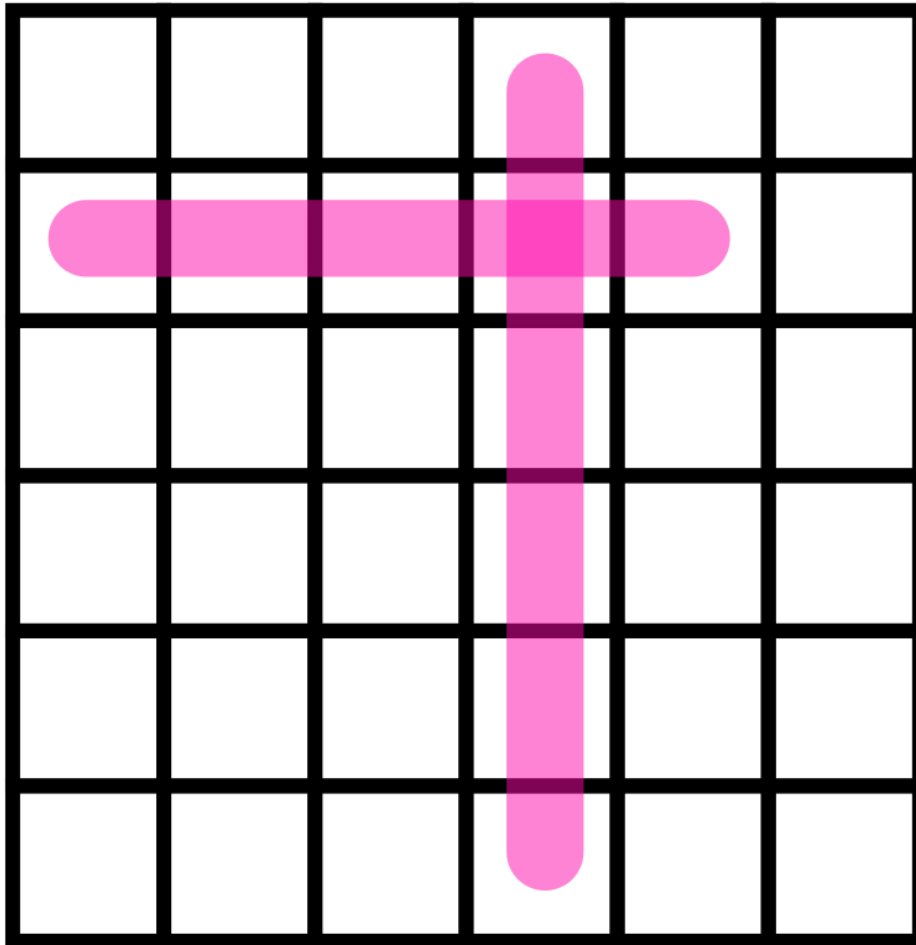
Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

GridFiller



Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

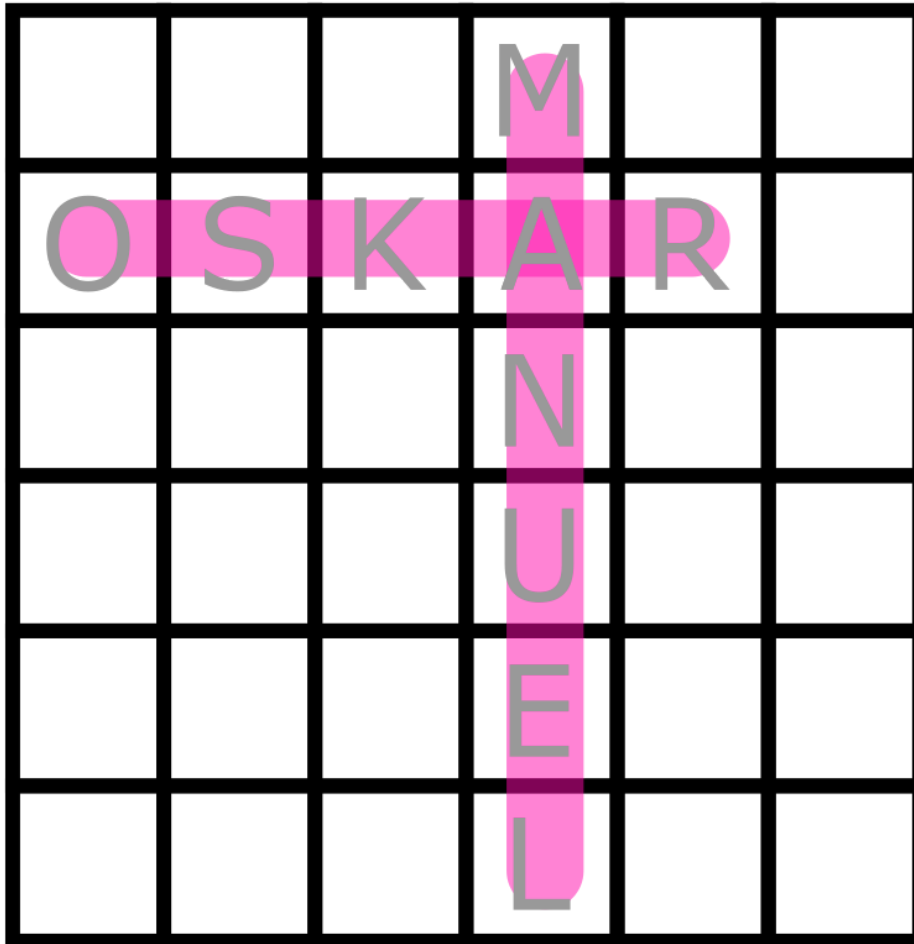
GridFiller



Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan

...
(A,B)

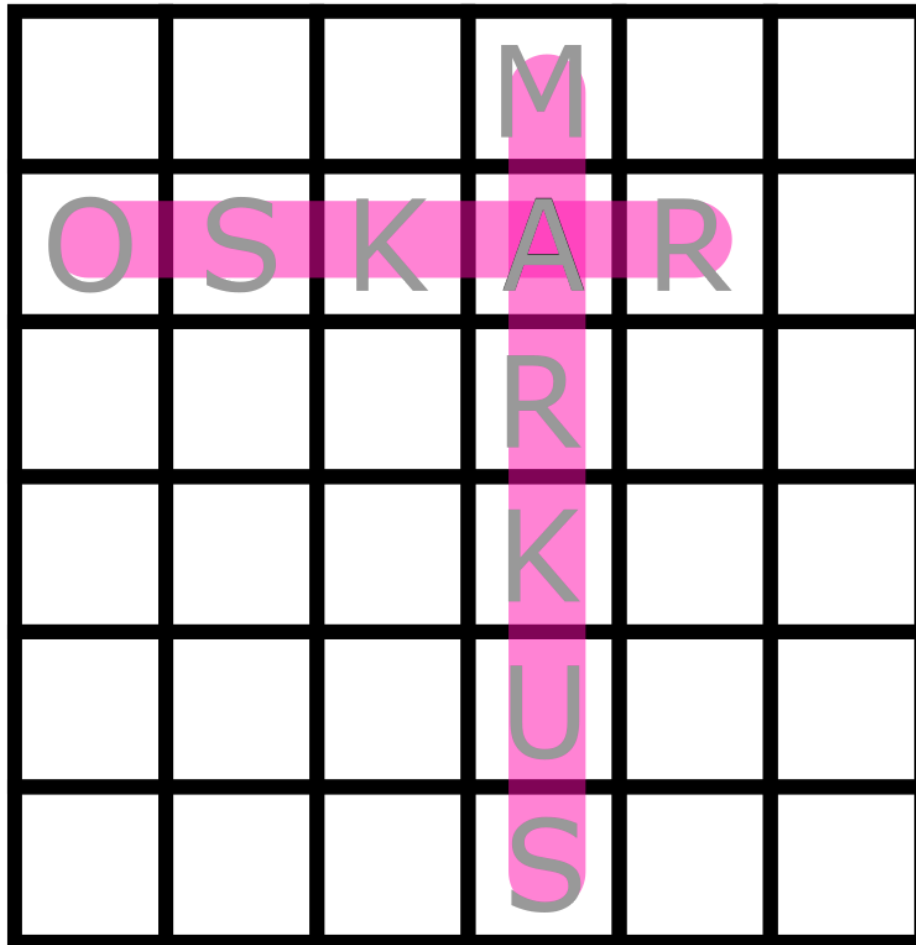
GridFiller



Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan

...
(A,B)
(O,M)

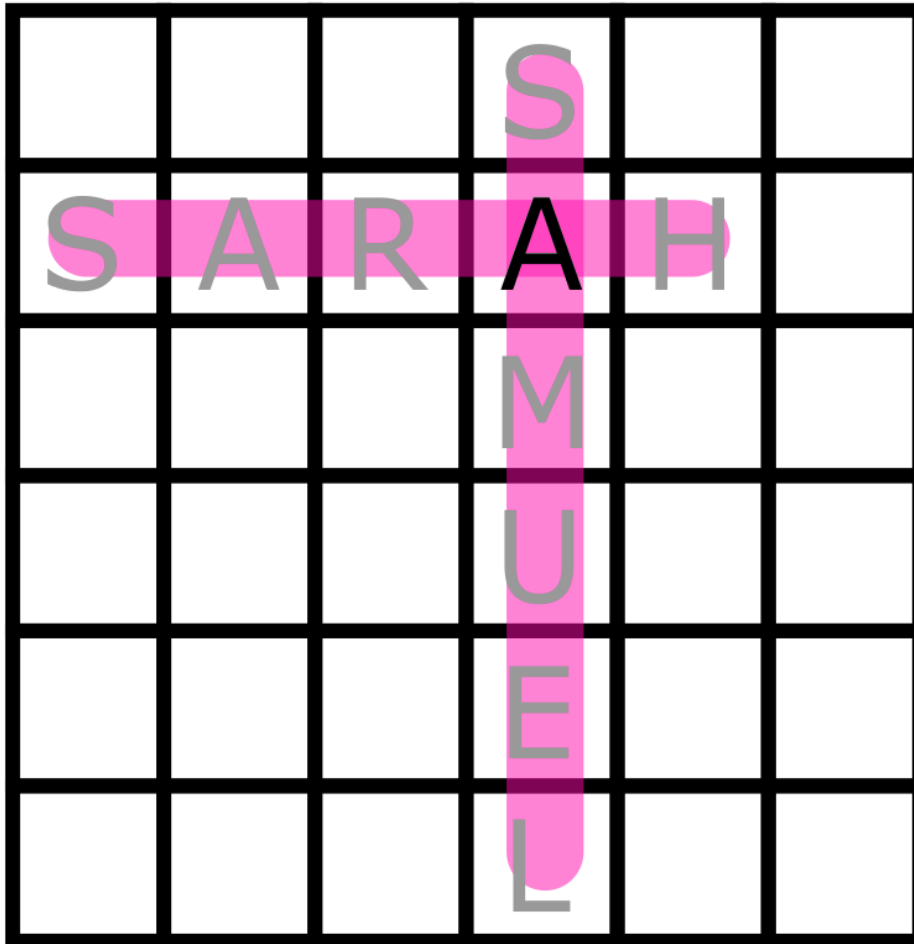
GridFiller



Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan

...
(Ä,B)
(O,M) (**O,M2**)

GridFiller



Jill

Manuel

Markus

Oskar

Roman

Paul

Samuel

Sarah

Stefan

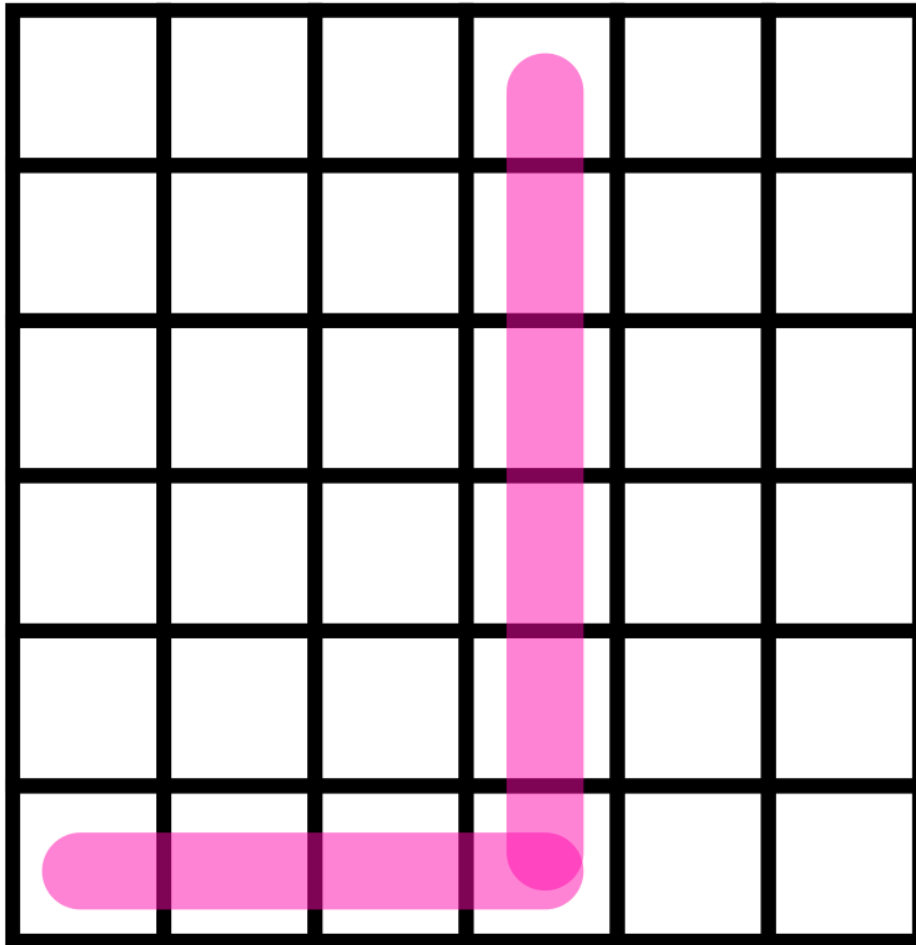
...

(A,B)

(O,M) (O,M2)

(S1,S2) ...

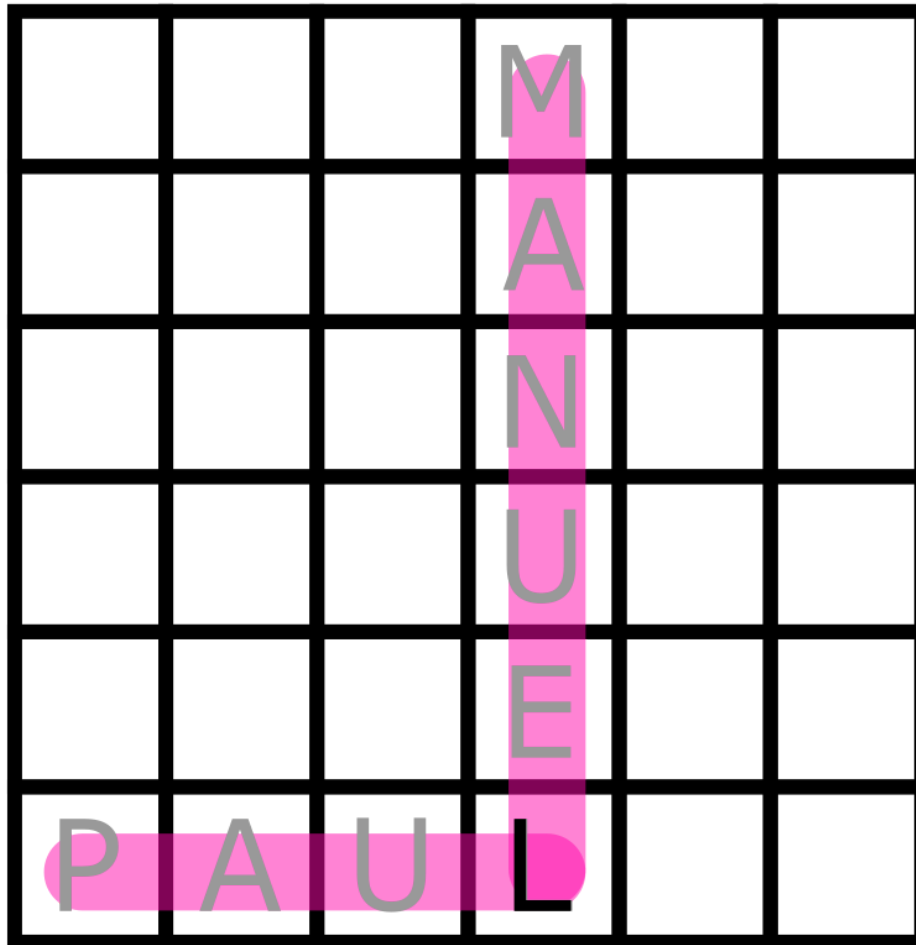
GridFiller



Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

(C,B)

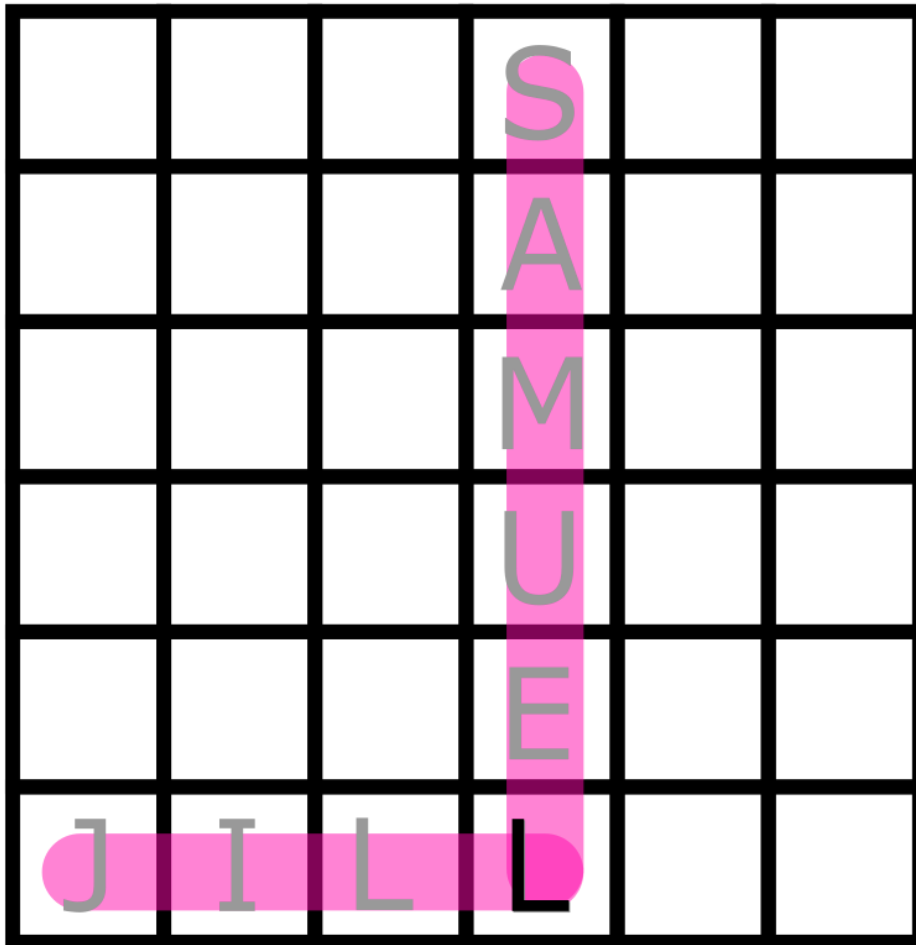
GridFiller



Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

(C,B)
(P,M)

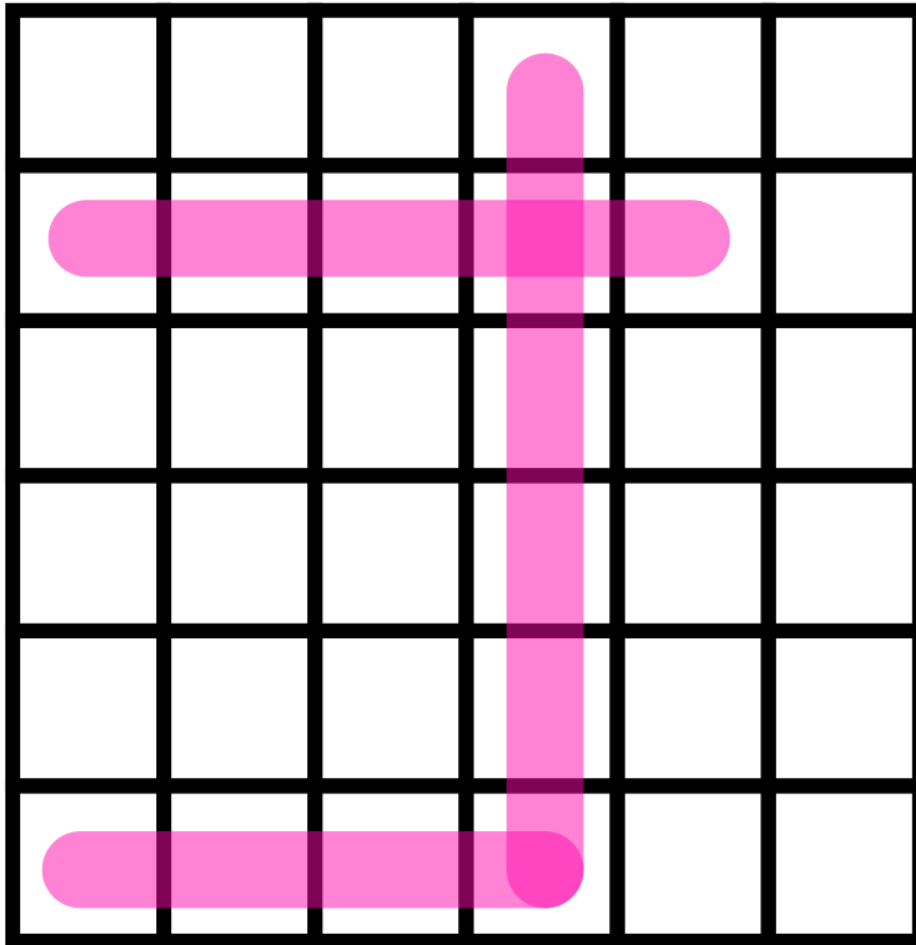
GridFiller



Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan
...

(C,B)
(P,M) (**J,S2**).

GridFiller



Jill

Manuel

Markus

Oskar

Roman

Paul

Samuel

Sarah

Stefan

...

(A,B)

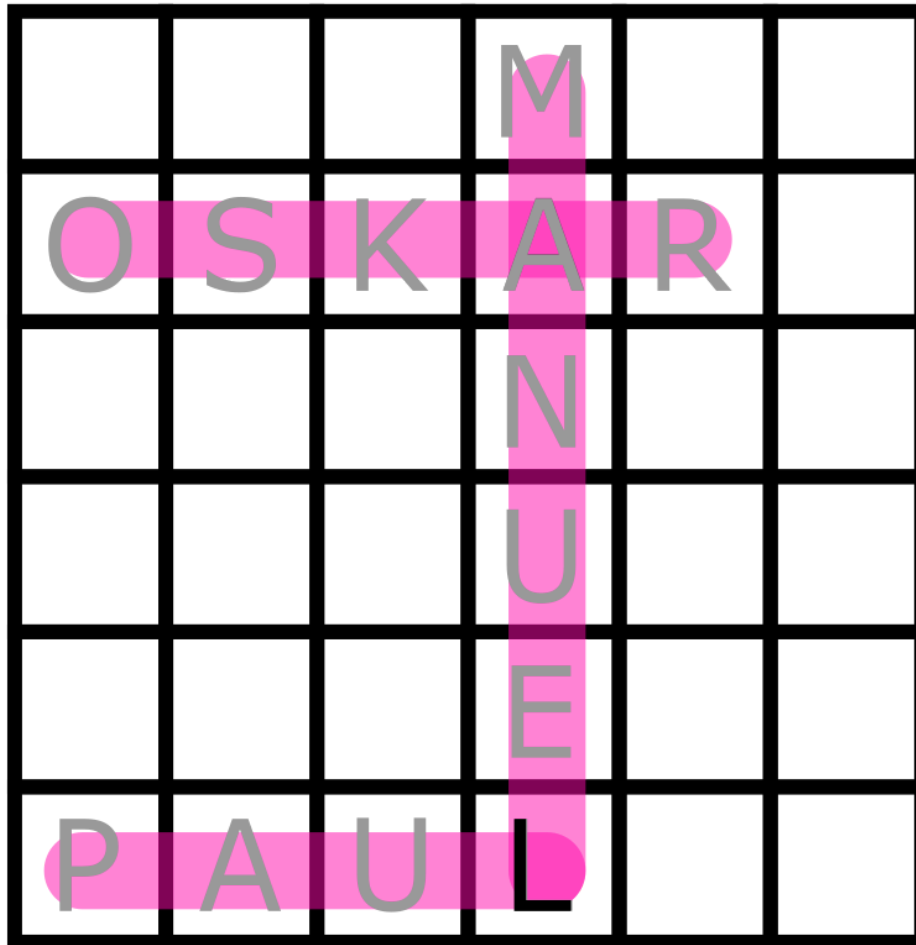
(O,M) (O,M2)

(S1,S2) ...

(C,B)

(P,M) (J,S2)..

GridFiller

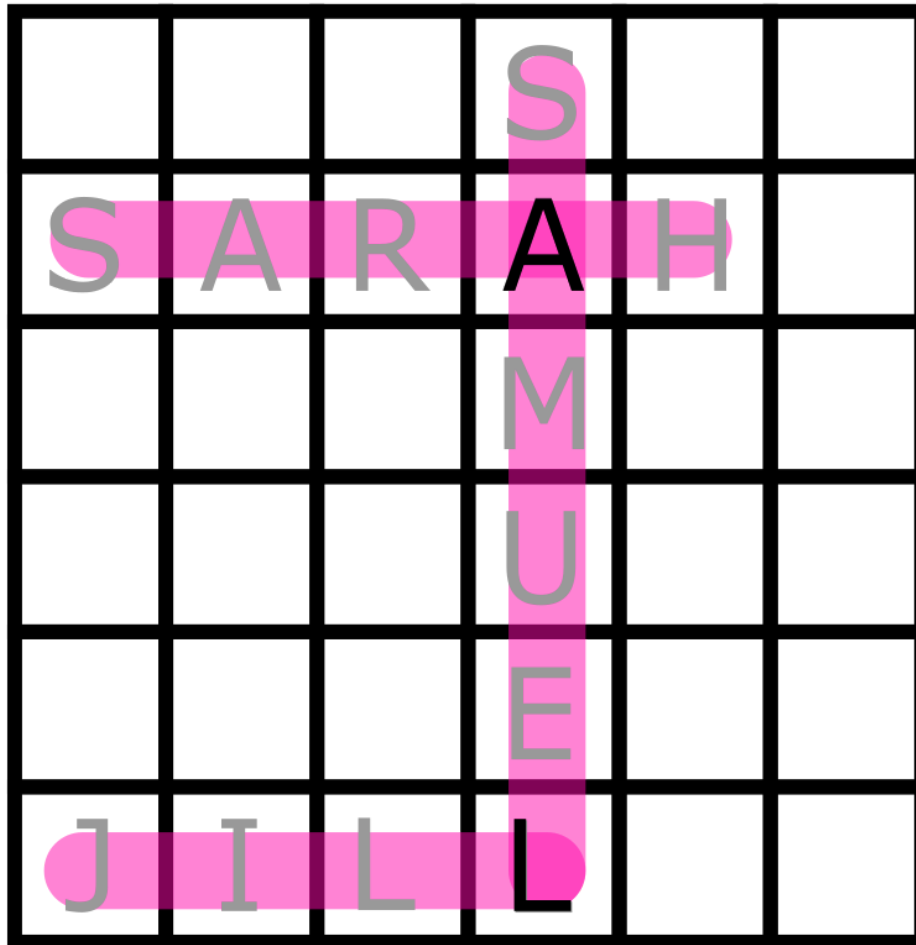


Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan

...
(A,B)
(O,M) (O,M2)
(S1,S2) ...

(C,B)
(P,M) (J,S2).

GridFiller



Jill
Manuel
Markus
Oskar
Roman
Paul
Samuel
Sarah
Stefan

...
(A,B)
(O,M) (O,M2)

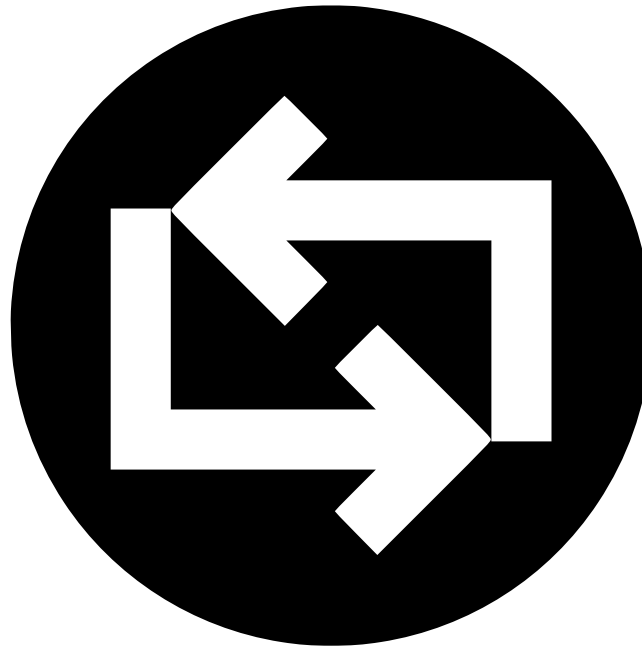
(S1,S2) ...

(C,B)
(P,M) **(J,S2)**.

WordSearchAlgorithm

Analyse Vocabulary

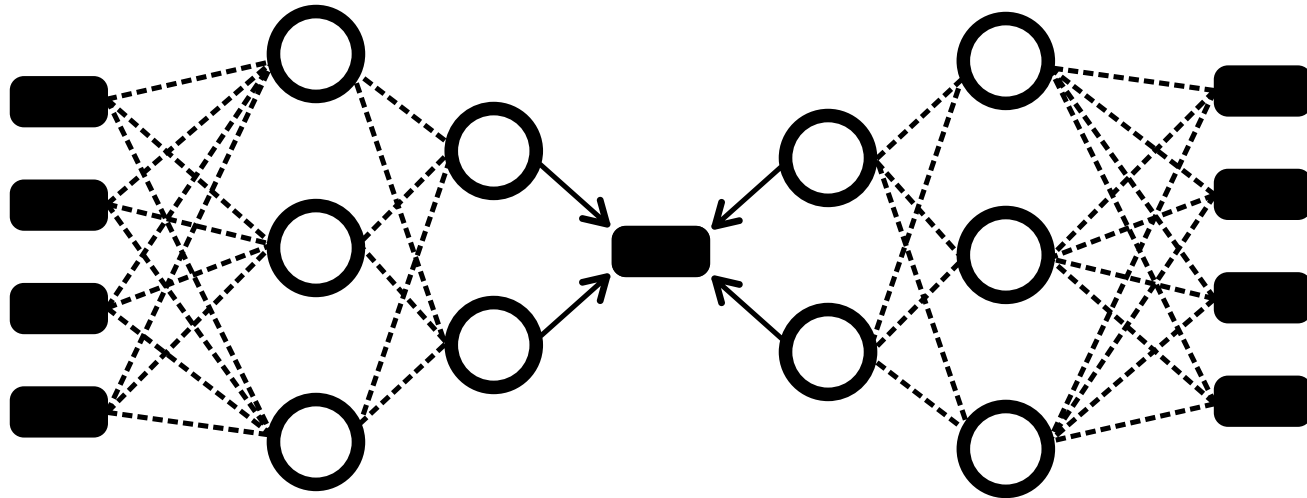
GridGenerator



GridFiller

Neural Networks

Autoencoders

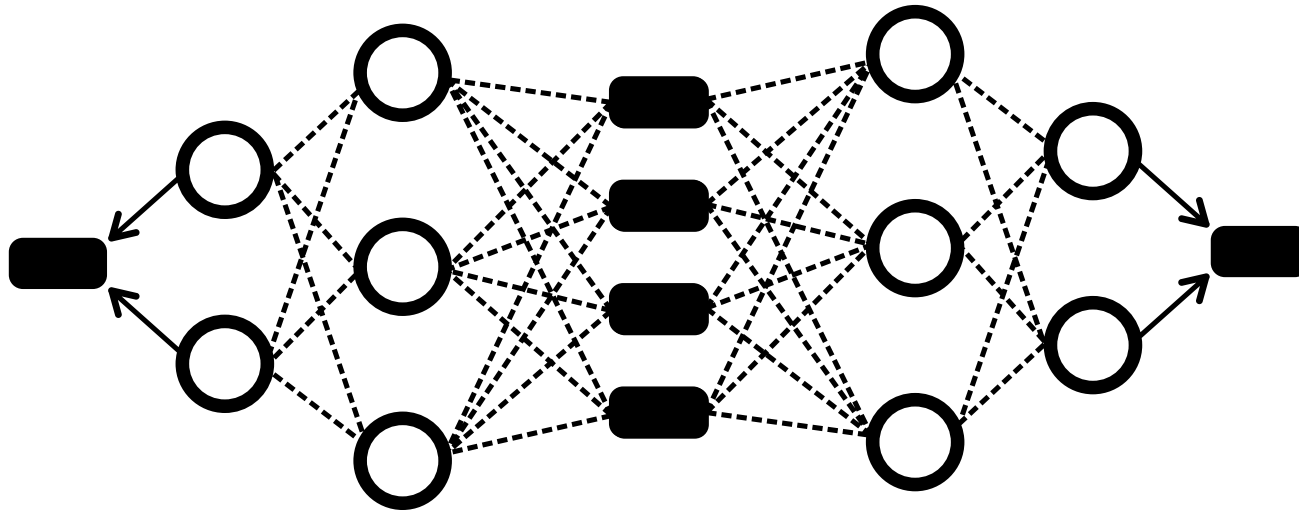


T	T	E	F	T	I	R	O	T	K	E	T	O	R	P	
T		A		R	U				D	E	H	E	U	R	F
R	R	L		U	F	U	R	H	C	A	N			K	
O		A		F	P	O	K	L	A	K	O	L	R	A	
B			O	F	F	L	O	N	R	O	T	S	I	H	N
B		K	G	A			E	B			L	E		E	
E	R	A		U	L		T	L		L	G			G	
N			A	R	T	Z	G	E	A	M	E	R	A	N	A
				D	E	W	N	A	H	N	O	R	A	N	T
A	R	E	S	I	M	U	R	R	F	A	R	M	E	R	
A	P	E	R	C	U	O	S	E	L	T	S	A	M	A	
	E	K	C	A	M	M	G	T	F		M	A	R	C	

T	T	E	F	T	I	R	O	T	K	E	T	O	R	P	
T		A		R	U				D	E	H	E	U	R	F
R	R	L		U	F	U	R	H	C	A	N			K	
O		A		F	P	O	K	L	A	K	O	L	R	A	
B			O	F	F	L	O	N	R	O	T	S	I	H	N
B		K	G	A			E	B			L	E		E	
E	R	A		U	L		T	L		L	G			G	
N			A	R	T	Z	G	E	A	M	E	R	A	N	A
				D	E	W	N	A	H	N	O	R	A	N	T
A	R	E	S	I	M	U	R	R	F	A	R	M	E	R	
A	P	E	R	C	U	O	S	E	L	T	S	A	M	A	
	E	K	C	A	M	M	G	T	F		M	A	R	C	

Neural Networks

Sparse Autoencoders



T	T	E	F	T	I	R	O	T	K	E	T	O	R	P	
T		A		R	U				D	E	H	E	U	R	F
R	R	L		U	F	U	R	H	C	A	N			K	
O		A		F	P	O	K	L	A	K	O	L	R	A	
B			O	F	F	L	O	N	R	O	T	S	I	H	N
B		K	G	A			E	B			L	E		E	
E	R	A		U	L		T	L		L	G			G	
N			A	R	T	Z	G	E	A	M	E	R	A	N	A
				D	E	W	N	A	H	N	O	R	A	N	T
A	R	E	S	I	M	U	R	R	F	A	R	M	E	R	
A	P	E	R	C	U	O	S	E	L	T	S	A	M	A	
	E	K	C	A	M	M	G	T	F		M	A	R	C	

T	T	E	F	T	I	R	O	T	K	E	T	O	R	P	
T		A		R	U				D	E	H	E	U	R	F
R	R	L		U	F	U	R	H	C	A	N			K	
O		A		F	P	O	K	L	A	K	O	L	R	A	
B			O	F	F	L	O	N	R	O	T	S	I	H	N
B		K	G	A			E	B			L	E		E	
E	R	A		U	L		T	L		L	G			G	
N			A	R	T	Z	G	E	A	M	E	R	A	N	A
				D	E	W	N	A	H	N	O	R	A	N	T
A	R	E	S	I	M	U	R	R	F	A	R	M	E	R	
A	P	E	R	C	U	O	S	E	L	T	S	A	M	A	
	E	K	C	A	M	M	G	T	F		M	A	R	C	

Data Representation

R G B	R G B	R G B			

Word 1 Word 2 Letter	Word 1 Word 2 Letter	Word 1 Word 2 Letter			

Data Representation

R G B	R G B	R G B			
			0 0 0		
		0 0 0		0 0 0	
	0 0 0				0 0 0
	0 0 0		0 0 0		0 0 0
	0 0 0		0 0 0		0 0 0

Word 1 Word 2 Letter	Word 1 Word 2 Letter	Word 1 Word 2 Letter			

Data Representation

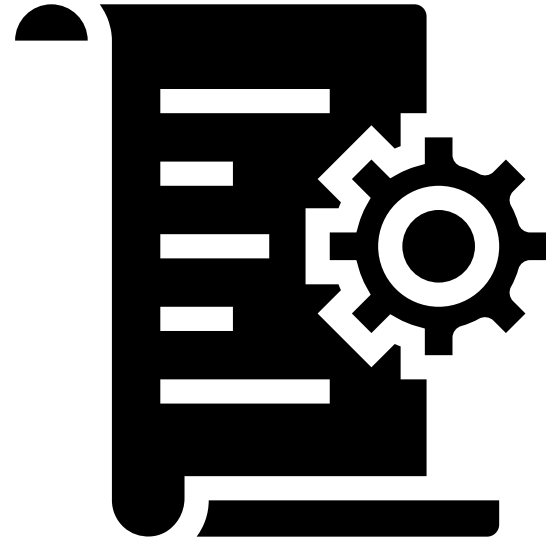
R G B	R G B	R G B			
			0 0 0		
		0 0 0		0 0 0	
	0 0 0				0 0 0
	0 0 0		0 0 0		0 0 0
	0 0 0		0 0 0		0 0 0

Word 1 Word 2 Letter	Word 1 Word 2 Letter	Word 1 Word 2 Letter	2 0 19		
1 0 15	1 0 19	1 0 B	1 2 1	1 0 18	
			2 0 13		
			2 0 21		
			2 0 5		
			2 0 12		

Training Data



424 Handmade



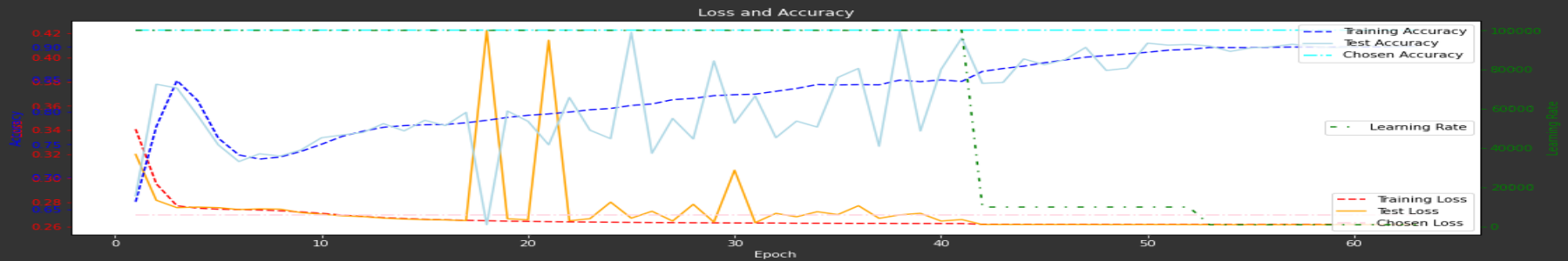
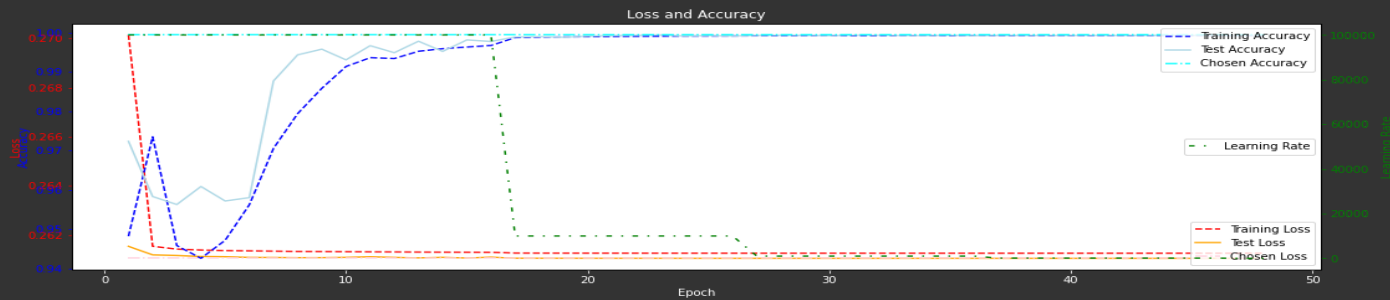
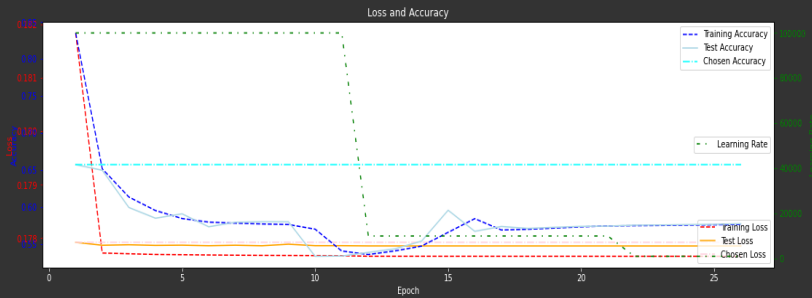
40.000 CSP Generated

Experiments

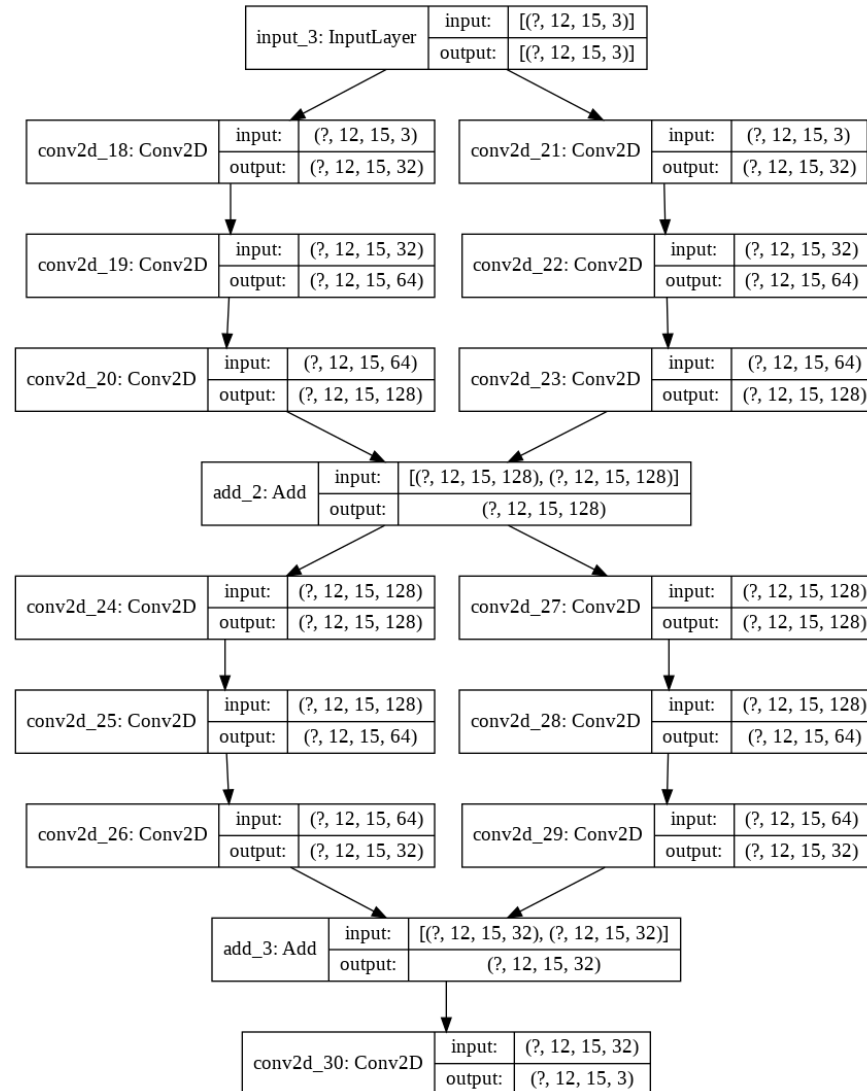
```
model, history = do_it(  
    train_data=config['data'],  
    model=config['model'],  
    restore_best_weights=config['restore_best_weights'],  
    optimizer=config['optimizer'],  
    loss=config['loss'],  
    epochs=300,  
    batch_size=config['batch_size'],  
    metrics=config['metrics'],  
    es_patience=config['es_patience']  
)  
models.append(model)  
histories.append(history)  
  
bot.send_message(chat_id=CHAT_ID, text=message)
```

- Automated
- Hyperparameter Search
- > 21 Architectures
- > 9 Optimizers
- > 17 Loss Functions

Experiments



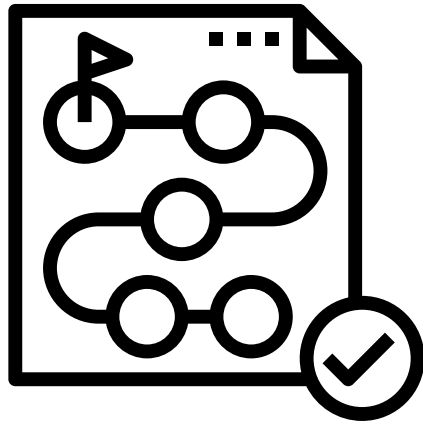
Network Architecture



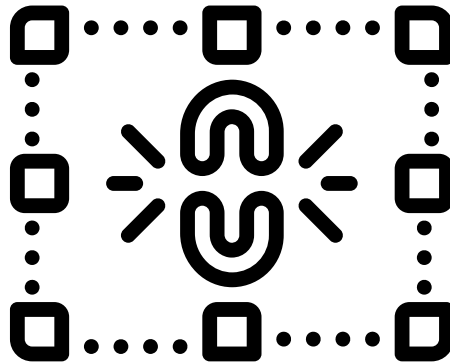
Take Home Message



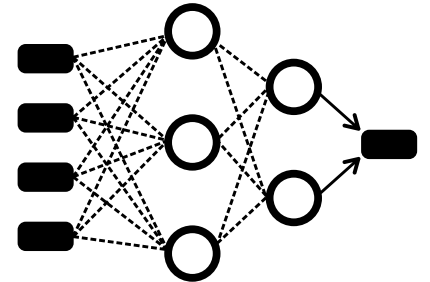
Modeling
important



Method
important



CSP
Works



NN
Unsuitable

What next?

- Blacklists
- Clue Assignment
- Syllable Puzzles

