Understanding Synergy and Variations in Human vs Machine Cognition in Problem Solving

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What is Problem Solving?

- Problem solving consists of using generic or ad hoc methods in an orderly manner to find solutions to problems. (*Wikipedia*)

- Problem solving is the process of constructing and applying mental representations of problems to finding solutions to those problems that are encountered in nearly every context. (*David H. Jonassen,Woei Hung*)

Introduction

Why Problem Solving? 

As we know in Machine Learning, we aim to emulate cognitive processes through the data, cognition plays an important role in case of both machines and humans.

Problem Solving inherently involves cognition and well-made complex problems can give a better insight into the similarities and differences in how a machine solves a problem contrary to how a human does it.

Problem Solving - Human vs Machine

> *Cognitive science is the study of intelligent systems, whether natural or artificial, and treats both organisms and computers as types of information-processing systems. Clearly, humans and typical current computers have rather different functional or cognitive architectures. Thus, insights into the role of cognitive architecture in performance may be gained by comparing typical human problem solving with efficient machine problem solving over a range of tasks.* (Human and Machine Problem Solving, 1989, Gilhooly, K.J. (Ed.))

Introduction

Why Puzzles ? 

As per the Polya-Problem Solving Process[1], there are 4 steps in problem-solving, viz. understanding the problem, compiling a plan (dividing a plan), carrying out a plan (carrying out the plan) and checking back (looking back). Jigsaw Puzzles are a great example of this.

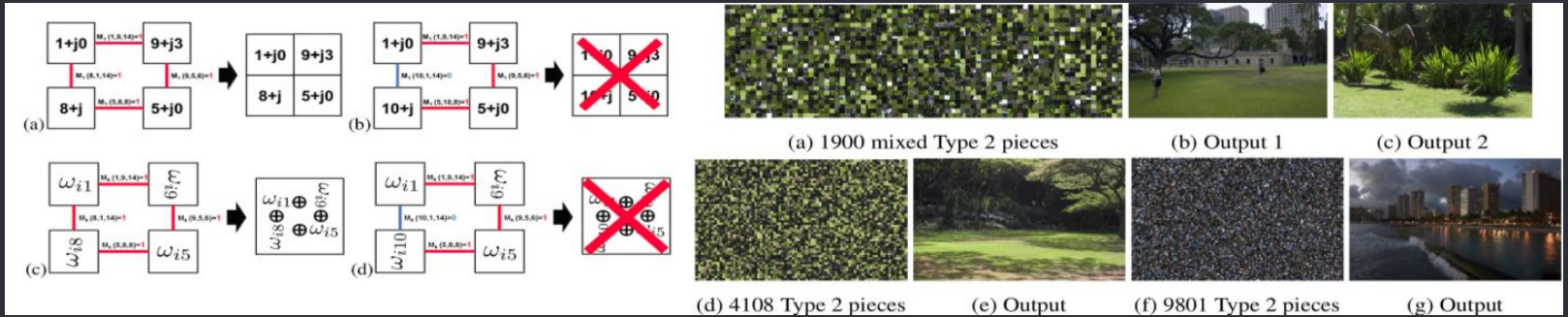
Jigsaw Puzzle use motor cognition as well as the previous intelligence and structure.

Apart from looking at a local orientation the human/machine also needs to take care of the global structure. Puzzles which use images are a good example.

Related Works (Regular Shaped Jigsaw Puzzles)

Solving Square Jigsaw Puzzles with Loop Constraints[2] (2014 ECCV)

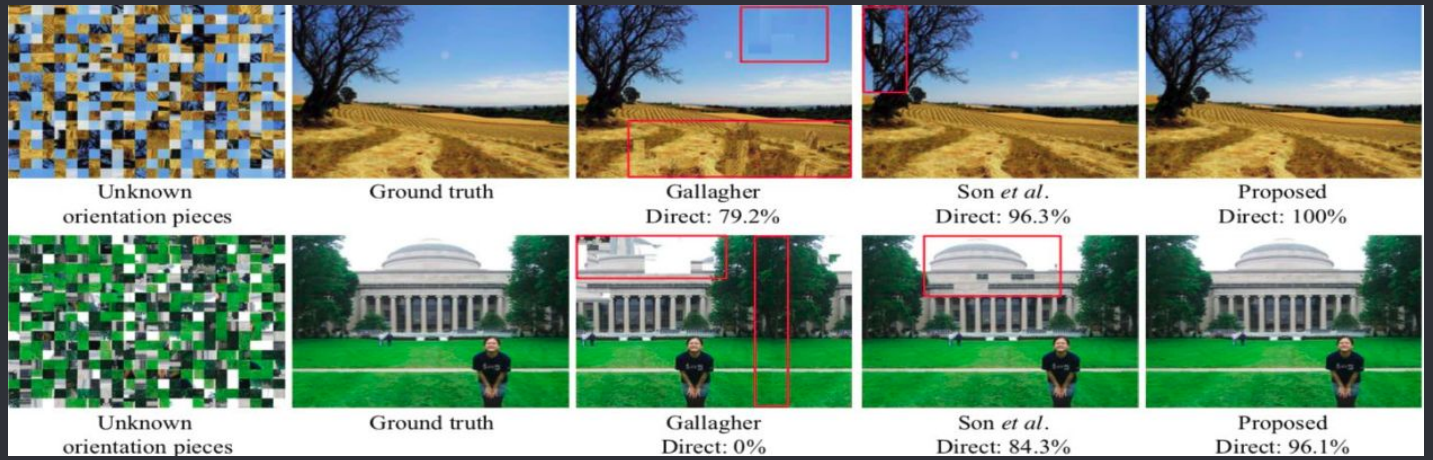
- ➔ First try to do the local composition of the jigsaw puzzle and then gradually move to solve the global composition.
- ➔ Using this idea they introduced Hierarchical Loop constraints (small to big loop)
- ➔ Uses Mahalanobis Gradient Compatibility (MGC), which takes in care of rotation of fragments.



Related Works (Regular Shaped Jigsaw Puzzles)

Solving small-pieces by Growing Consensus[3] (2016 CVPR)

- ➔ Merging, Trimming & Filling
- ➔ Consensus, Conflict & Acceptance



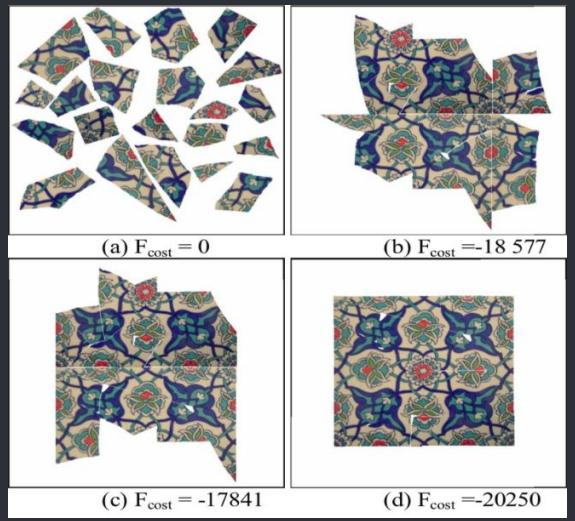
Related Works (Irregular Shaped Jigsaw Puzzles)

Texture Based Match for Puzzle Assembly[4] (2006 ICPR)

Tries to find out Longest Common Color Subsequence (LCCS) of boundary pixels of one fragment that matches with the other.

LCCS indicates that the boundaries of the two fragments are the most compatible to be merged with.

Combine pieces and align using FFT-based registration algorithm.



Related Works (Irregular Shaped Jigsaw Puzzles)

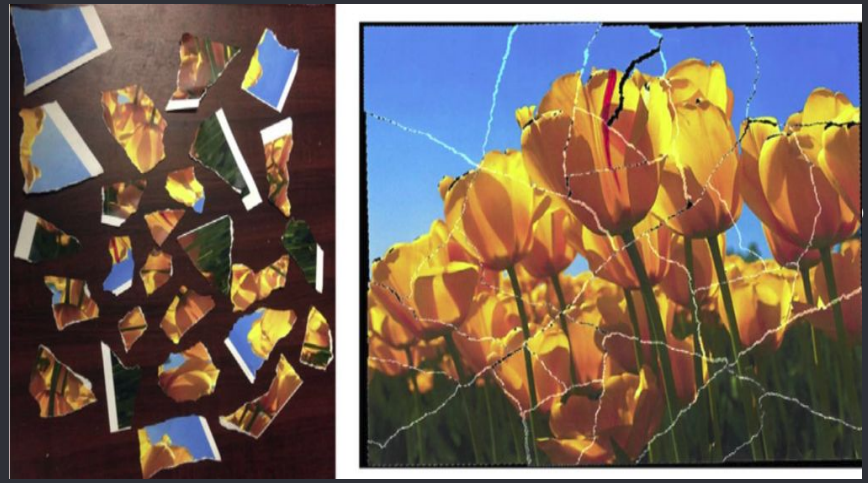
Graph-based optimization algorithm for fragmented image reassembly[5] (2014 Graph Models)

In Pairwise matching they modified ICP (Iterative Closest Point), curve contour borders, segment contour alignment.

Introduced group-wise matching which is used eliminate false alignments.

Refined the composition by graph optimisation.

Works well only in case of small number of fragments.



Related Works (In ML/DL Era)

Jigsaw Puzzle Solving Using Local Feature Co-Occurrences in Deep Neural Network[6] (2018 ICIP)

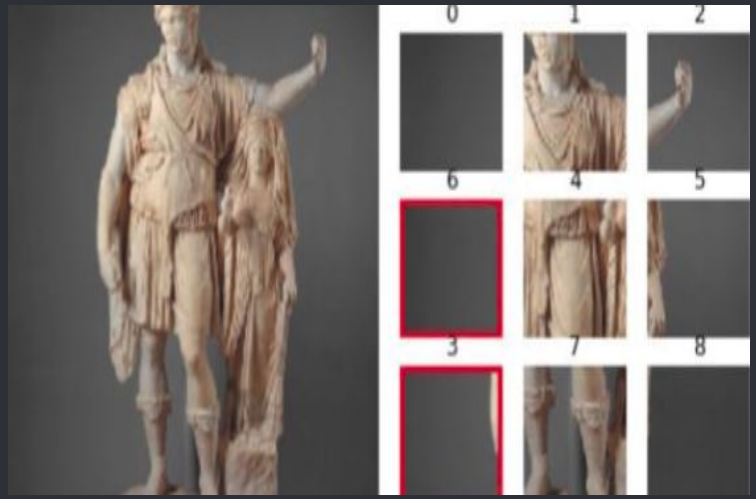
Uses CNN for feature extraction

Batch Normalisation

ReLU is used as activation layer

For global composition greedy graph-cut method is used.

Only applicable to solve 3 X 3 puzzle solving



Related Works (In ML/DL Era)

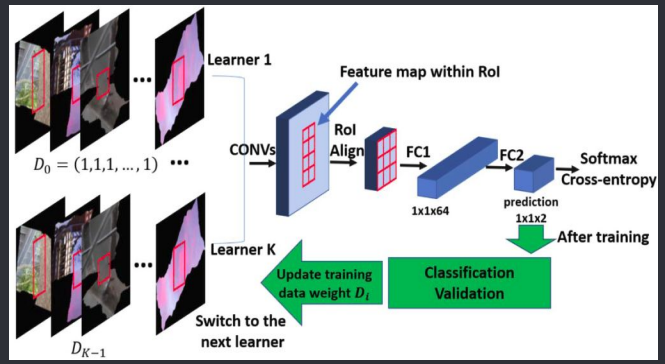
JigsawNet: Shredded Image Reassembly[7] (2019)

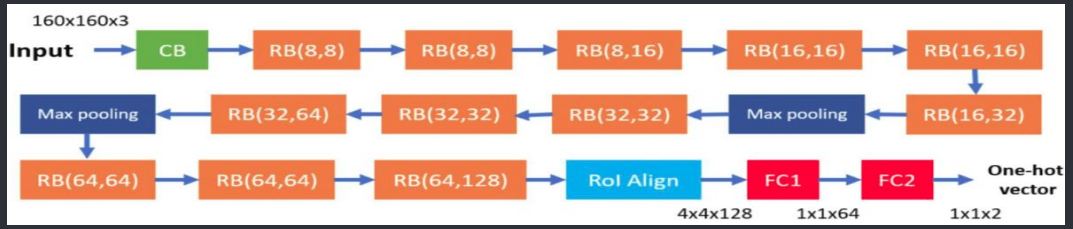
Local Matching

a) Pairwise Compatibility is obtained using CNN detector

b) Reliable Assembly using Piecewise Correlation

c) For solving Data Imbalance Problem boosting techniques are used (preferably AdaBoost). Two types :
- Between-class imbalance
- Within-class imbalance



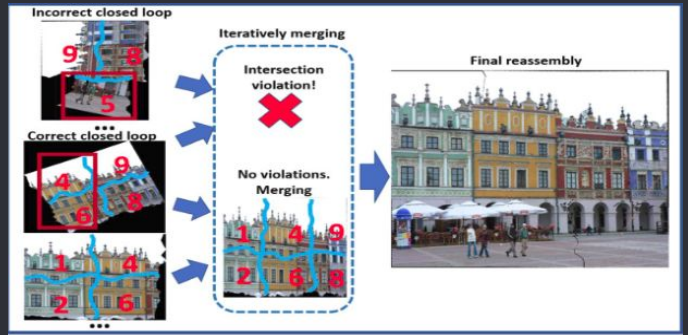


Related Works (In ML/DL Era)

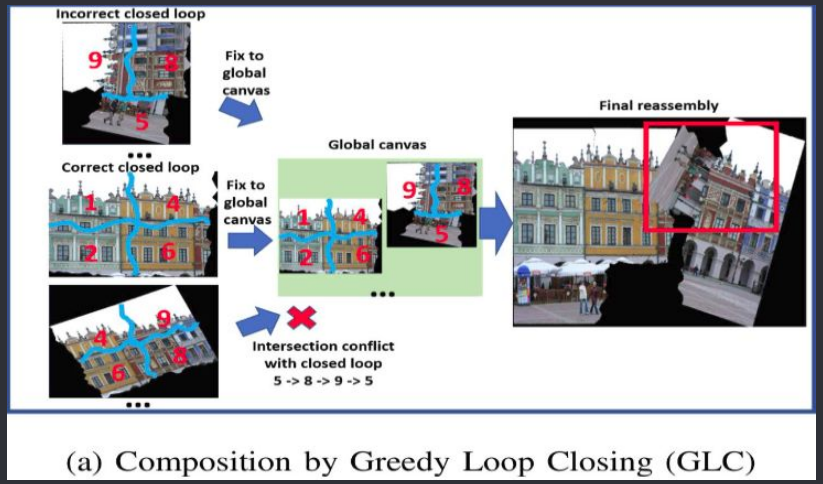
JigsawNet: Shredded Image Reassembly (2019)

Global Matching

a) Graph models and constraints
b) Loop closures (Induced and mergeable)
   - ➔ Greedy loop closing (GLC)
   - ➔ Hierarchical loop merging (HLM)



(b) Composition by Hierarchical Loop Merging (HLM)



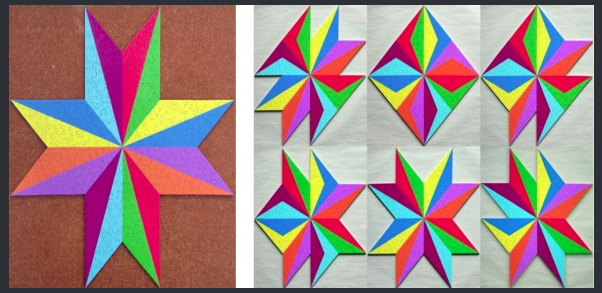
(a) Composition by Greedy Loop Closing (GLC)

Shortcomings

Open Problems in Jigsaw Puzzle

a) Multiple Solution Jigsaw Puzzles

b) Jigsaw Sudoku Puzzles



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

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

Problems with current Jigsaw Puzzle Solvers

a) Abstract images like pink sky, blue desert, or reflection of a scene in a very still lake,etc. which require deeper cognition and understanding must be modelled.

b) Only focuses on solving the puzzle but the broader picture of aiding to learning is not visible.

Areas I would like to work on

a) Comparing the approach of a human, a heuristic algorithm and a CNN learner to solve a sliding puzzle problem.

b) Building an interface to incorporate complicated Jigsaw Puzzles (to study human cognition in more depth).

c) Working on devising a better Global Composition method to increase efficiency of JigsawNet.

References

[1] D. Brijlall, — *Exploring The Stages of Polya's Problem Solving Model during Collaborative Learning: A Case of Fractions*,‖ Int. J. Educ. Sci., vol. 11, no. 3, pp. 291– 299, 2015.

[2] Kilho Son, James Hays and David B. Cooper : *Solving Square Jigsaw Puzzles with Loop Constraints, Brown University,* ECCV 2014.

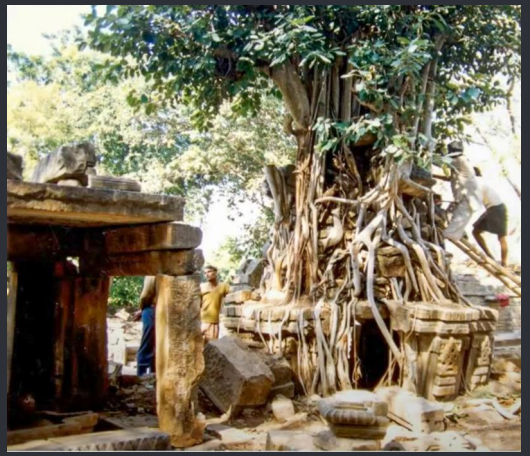
[3] Kilho Son, Daniel Moreno, James Hays and David B. Cooper : *Solving Small-Piece Jigsaw Puzzles by Growing Consensus,* CVPR 2016.

[4] M.S. Sagiroglu and A. Ercil : *A Texture Based Matching Approach for Automated Assembly of Puzzles,* ICPR 2006.

[5] Kang Zhang and Xin Li : *A graph-based optimization algorithm for fragmented image reassembly, School of Electrical Engineering and Computer Science, Louisiana State University, USA* , 2014

[6] Marie-Morgane Paumard, David Picard and Hedi Tabia : *Jigsaw Puzzle solving using Local feature co-occurrences in Deep neural networks,* ICIP, 2018

[7] Canyu Le and Xin Li : *JigsawNet: Shredded Image Reassembly using Convolutional Neural Network and Loop-based Composition, IEEE Transactions on Image Processing (Volume: 28, Issue: 8, Aug. 2019)*



Source : Kevin Standage - The Rebirth of Bateshwar

THANK YOU