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Living Grant for International Graduate Students

Artificial Intelligence System Using Novel Metaheuristic Optimization and Predictive Techniques for Civil Engineering and Management

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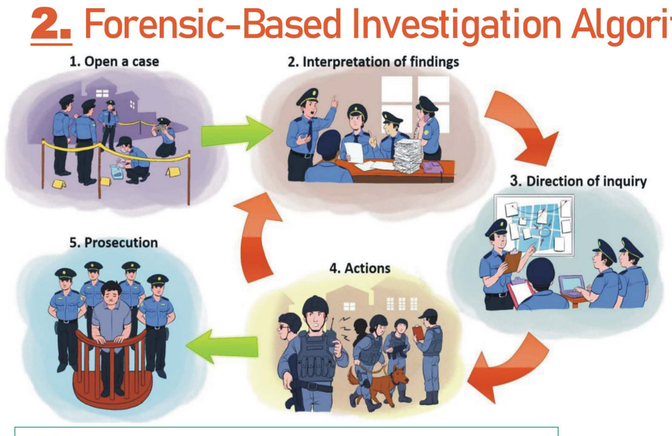
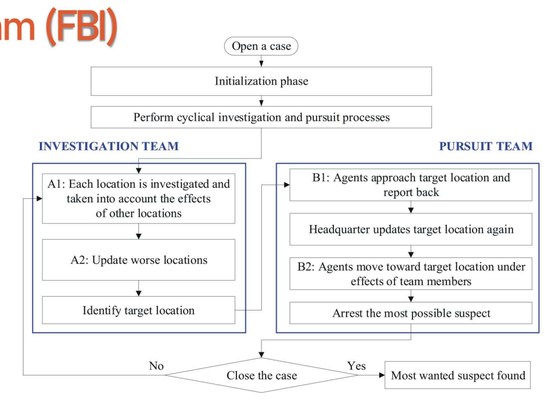
1. Introduction

The contributions of this research include: (1) developing a new optimization algorithm, called forensic-based investigation algorithm (FBI) to solve various optimization problems with low computational effort and high accuracy; ; (2) developing a metaheuristic optimization platform to provide performance indicators clearly, logically, and graphically; and (3) establishing a novel type of AI-inference technique, presented in two independent systems: metaheuristic-optimized ensemble system (MOES) and metaheuristic-optimized stacking system (MOSS), with remarkably greater accuracy than all current AI techniques. Those powerful tools were successfully applied in solving project scheduling problem, estimating mechanical strength of reinforced concrete materials, and predicting scour depth at bridge piers. The newly developed tools are highly expected to be applicable in a wide range of industries and help analysts to obtain proper decision-makings.

2. Forensic-Based Investigation Algorithm (FBI)



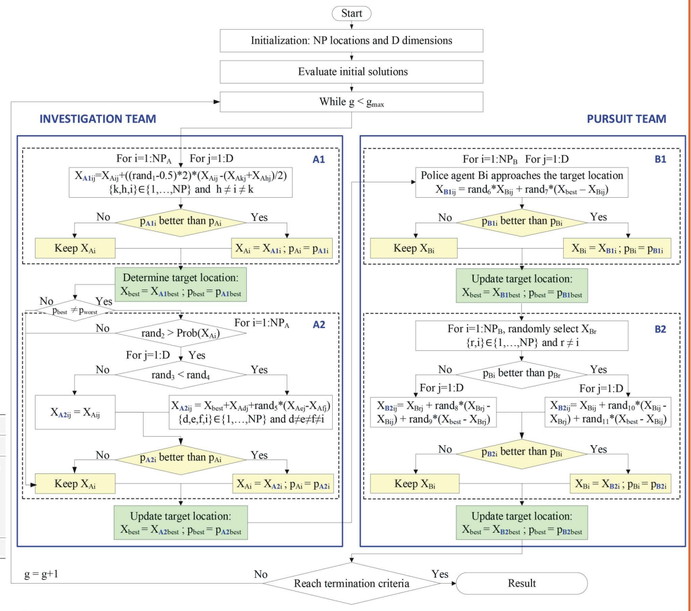


FBI has two teams:

Investigation team: analyze the probable hiding locations of the suspect within the search space.

Pursuit team: head toward the designated location, together with team members to arrest the suspect.

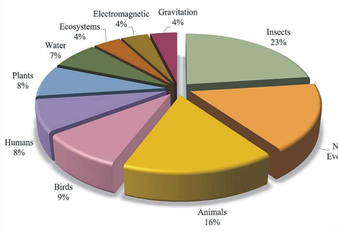
Throughout the investigation–finding–approaching process, the investigation and pursuit teams closely coordinate with each other.



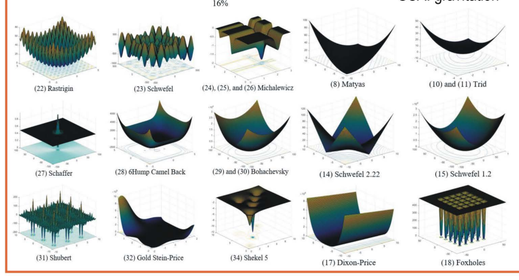
FBI was compared with 12 representations of top metaphors in performing 50 most renowned benchmark functions:

Function (F)	F1 to F5		F6 to F17		F18 to F26		F27 to F50		Total		
Quantity	5		12		9		24		50		
Benchmark function characteristic	Unimodal & Separable		Unimodal & Non-separable		Multimodal & Separable		Multimodal & Non-separable		Unimodal, Multimodal, Separable, Non-separable & Multidimensional		
Algorithm	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(3)
GA	1	1	3	3	5	5	6	6	15	15	170.1
PSO	4	4	9	9	4	4	7	7	24	24	150.7
DE	4	4	8	8	5	5	15	15	32	32	156.1
ABC	4	4	8	8	**9**	**9**	16	16	37	37	192.3
FA	1	1	6	6	5	5	11	11	23	23	714.9
WOA	4	4	8	8	4	4	11	11	27	27	101.8
FPA	2	2	9	9	4	4	13	13	28	28	201.6
TLBO	4	4	10	9	5	5	14	14	33	32	326.4
WCA	2	2	5	5	5	5	8	8	20	20	329.3
SOS	4	4	**10**	**10**	7	7	18	18	39	39	96.8
EFO	4	4	8	8	5	5	7	7	24	24	53.3
GSA	4	4	6	6	4	4	9	9	23	23	758.8
FBI	**5**	**4**	**10**	**10**	**9**	**9**	**24**	**22**	**48**	**45**	**65.2**

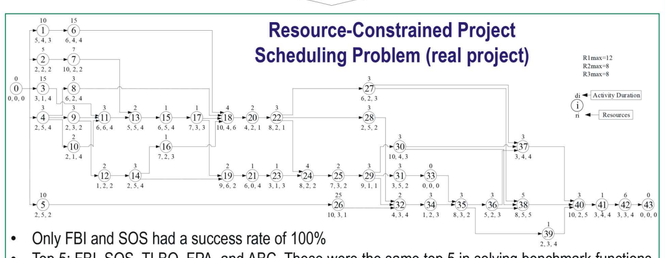
Note: (1) - Count of best performance; (2) - Count of found global minimum; (3) - Computation time (seconds); Bold blue values represent the best results.



- ABC and FA: insect
- GA and DE: natural evolution
- WOA: animals
- PSO: birds
- TLBO: humans
- FPA: plants
- WCA: water
- SOS: ecosystem
- EFO: electromagnetic force
- GSA: gravitation



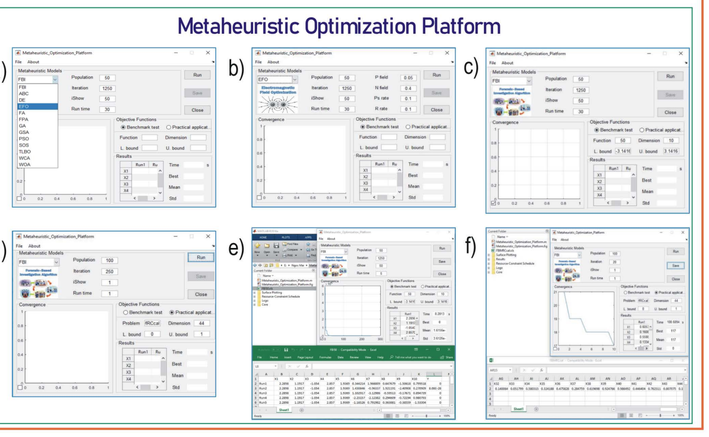
Resource-Constrained Project Scheduling Problem (real project)



- Only FBI and SOS had a success rate of 100%
- Top 5: FBI, SOS, TLBO, FPA, and ABC. These were the same top 5 in solving benchmark functions
- FBI found the optimal solution in fewer evaluations than the other algorithms

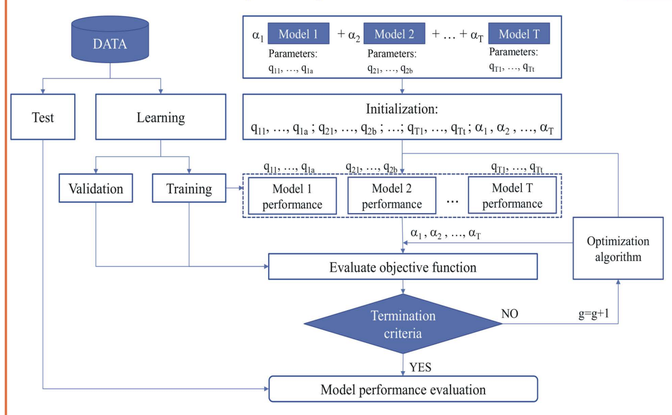
➔ **FBI is the most efficient optimizer when applied to this RCPSP case.**

Metaheuristic Optimization Platform

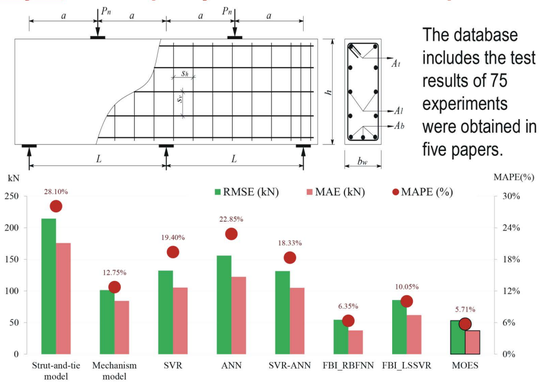


3. Metaheuristic-Optimized Ensemble System (MOES)

General concept and process of MOES

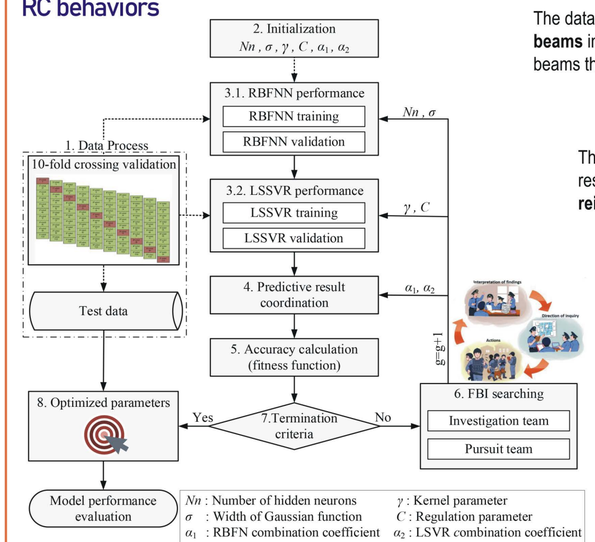


Case study 1: Load capacity of RC continuous deep beams



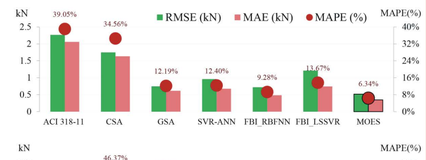
The database includes the test results of 75 experiments were obtained in five papers.

Structure of MOES applied to predict RC behaviors

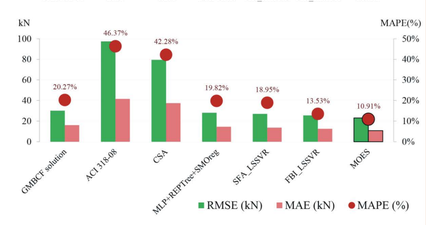


Case study 2: Shear strength of RC deep beams & RC beams with FRP reinforcement

The dataset of shear strength of **RC deep beams** includes test results for 214 deep beams that were obtained in eight papers.

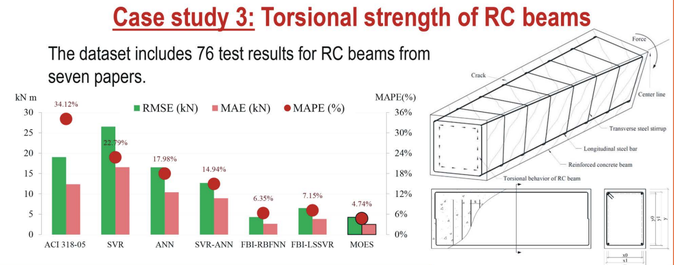


The dataset of shear strength results for 209 **RC beams with FRP reinforcement** taken from literature.

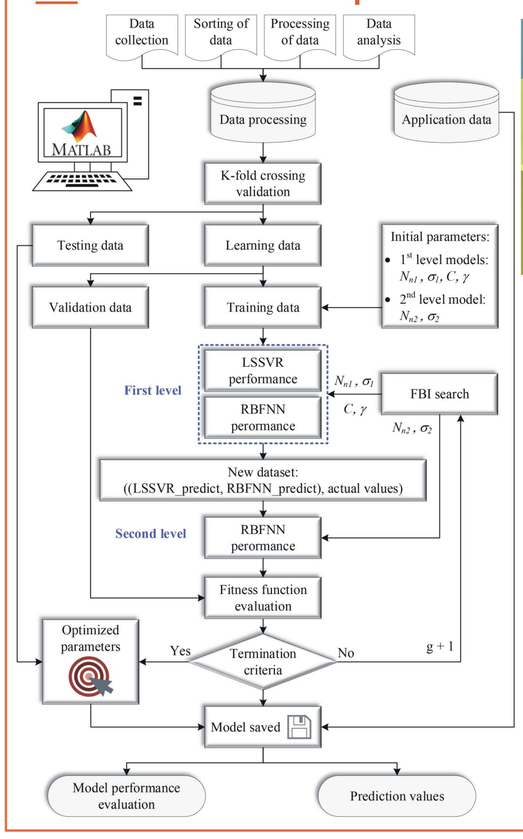


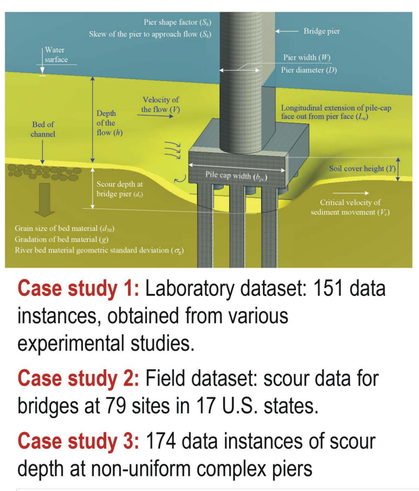
Case study 3: Torsional strength of RC beams

The dataset includes 76 test results for RC beams from seven papers.



4. Metaheuristic-Optimized Stacking System (MOSS)

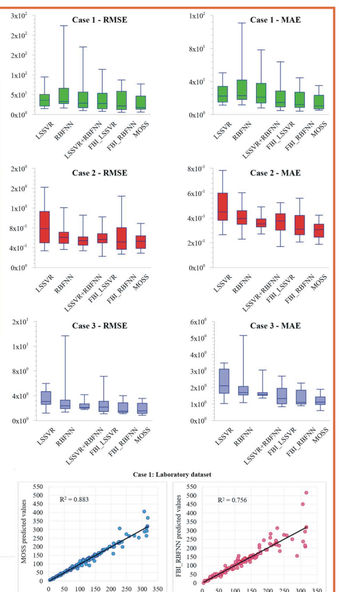




Case study 1: Laboratory dataset: 151 data instances, obtained from various experimental studies.

Case study 2: Field dataset: scour data for bridges at 79 sites in 17 U.S. states.

Case study 3: 174 data instances of scour depth at non-uniform complex piers



5. Conclusions

The products of this research are expected to be applicable in a wide range of industries, such as retail, heath care, manufacturing, finance, transportation, construction, *etc.* to help analysts to predict or identify in a timely fashion significant facts, relationships, trends, patterns and anomalies which might otherwise go unnoticed. This research involves establishing cooperation with the industry, to close the gap between industry and academia.

Reference: Jui-Sheng Chou, Ngoc-Mai Nguyen (2020), FBI inspired meta-optimization, Applied Soft Computing, Volume 93, August 2020, 106339.

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