XVI ECSMGE 2015

Soft Computing Applied to Earthworks Optimization: A Survey and Application

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Overview

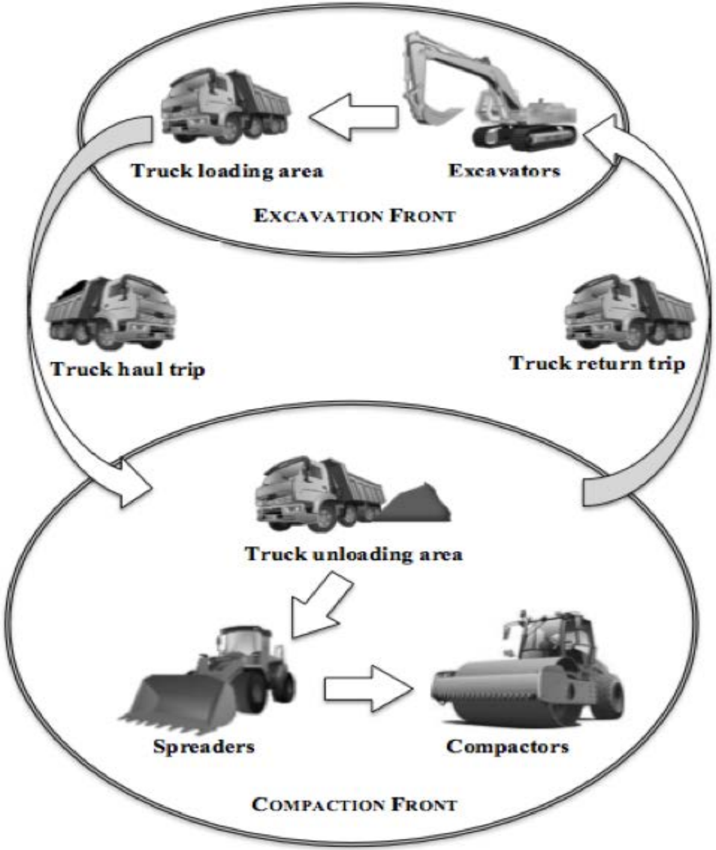
- Background
  - Earthworks as an optimization problem
  - Survey of earthwork optimization applications
- Soft Computing tools
  - Metaheuristics
  - Data Mining
- System architecture
  - Overview
  - Solution assessment
- Application results

Background Earthworks as an optimization problem

Ground levelling in Engineering precedes any type of structural construction. Earthworks achieve this by:

- Excavating geomaterials from areas above the target height
- Transporting them to areas below target height, where they are spread into layers and compacted

As an optimization problem, earthworks can be translated into several production lines that require different types of resources (mechanical equipment).



Background Earthworks as an optimization problem

An earthwork production line:

- Is associated with high construction costs and durations in transportation infrastructure projects;
- Involves repetitive sets of sequential and interdependent tasks, strongly based on mechanical equipment;
- Is highly susceptible to being optimized, even though few attempts have been carried out, due to their complex and dynamic nature.

Several production lines can be active simultaneously:
Where to start?
How to distribute the available equipment through construction site?

Background Survey of earthworks optimization applications

There have been few attempts at optimizing the earthworks process – mainly as a result of the above-mentioned difficulties (i.e. complex and dynamic nature of the problem).

Architecture of existent systems according to used technologies:

System/Technology	Metaheuristics			GIS	DM
	GA	PSO	Petri.net		
Marzouk & Moselhi (2000, 2002)	X				
T. Cheng et al. (2005)	X				
Moselhi & Alshibani (2007)	X			X	
Marques, Gomes Correia, & Cortez (2008)	X				X
Zhang (2008)		X			
F. Cheng, Wang, & Ling (2010)			X		
Hola & Schabowicz (2010)					X

Background Survey of earthworks optimization applications

Classification of existent systems according to application area:

System Type	Data acquisition & application	Planning & Design phase	Monitoring & Control phase
Data Mining systems	Marques et al. (2008)		
		Hola and Schabowicz (2010)	
Simulation optimization systems		Marzouk and Moselhi (2002)	
		T. Cheng et al. (2005)	
			Moselhi and Alshibani (2007)
		Zhang (2008)	
		F. Cheng et al. (2010)	

A system capable of integrating and optimizing all areas is necessary!

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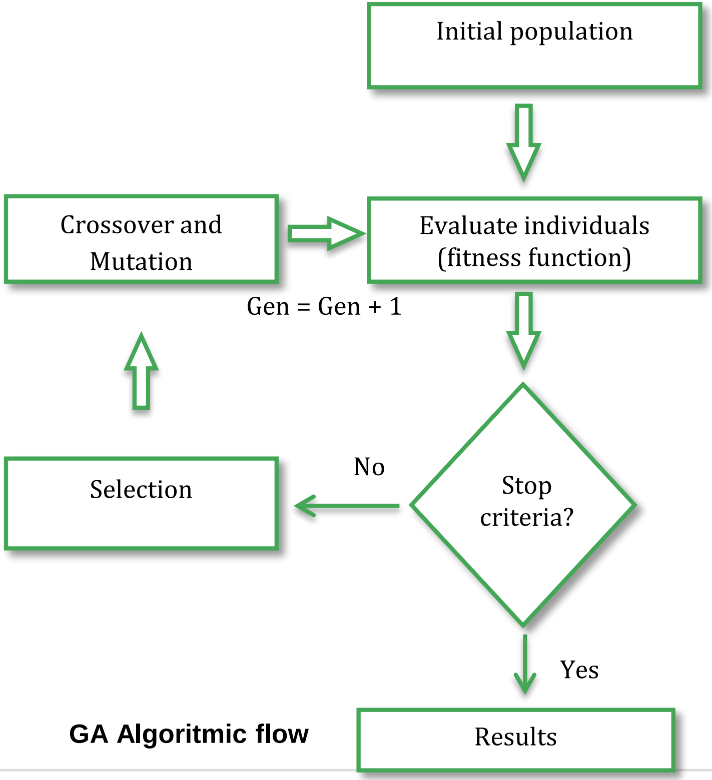
Soft Computing tools Metaheuristics



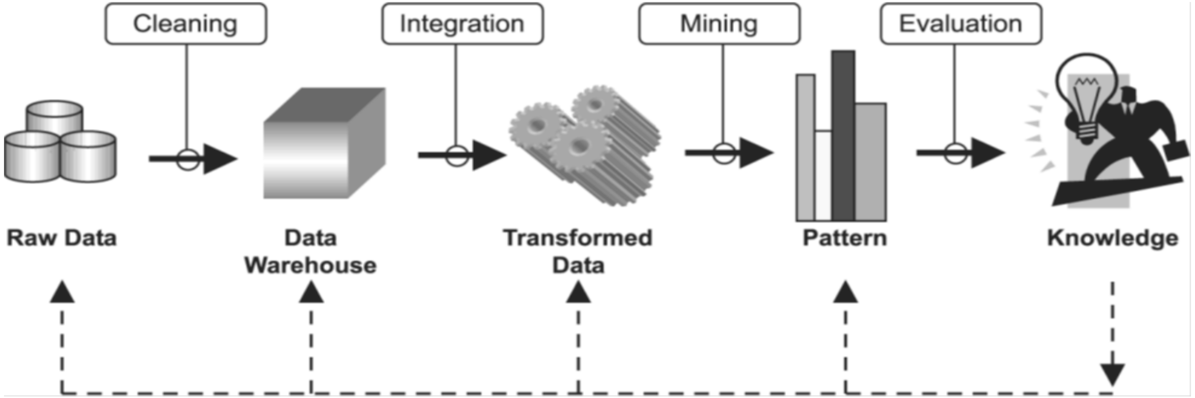
GA Algoritmic flow

Genetic algorithms (GA):

- Based on evolutionary ideas of natural selection and genetics
- Can deal with large search spaces within reasonable computational effort
- In each iteration, the GA improves on the best-found solutions of the previous one

Gradually tend towards an optimal solution for the problem

Soft Computing tools Data Mining



DM Process

Data Mining (DM):

- Applied to databases where results are known
- Can be used to predict the behaviour of new data in similar conditions/situations

Prediction of unknown earthworks parameters (e.g. equipment productivity)

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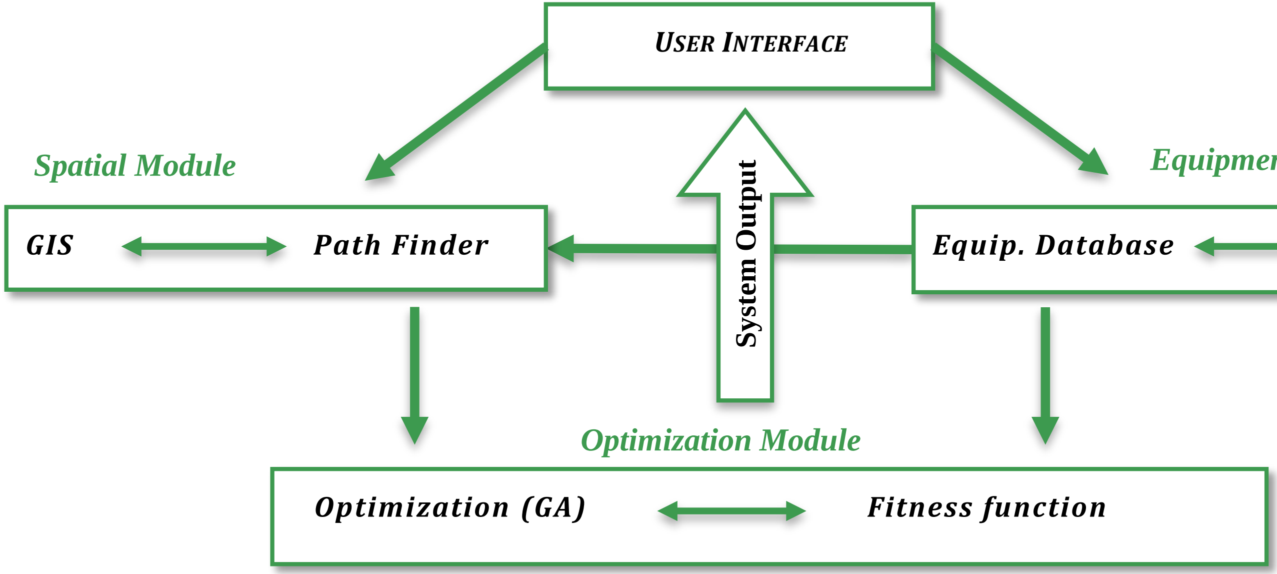
System architecture Overview

Intelligent earthwork optimization system:

- 3 modules
- 1 technology / module
- Integrated modules

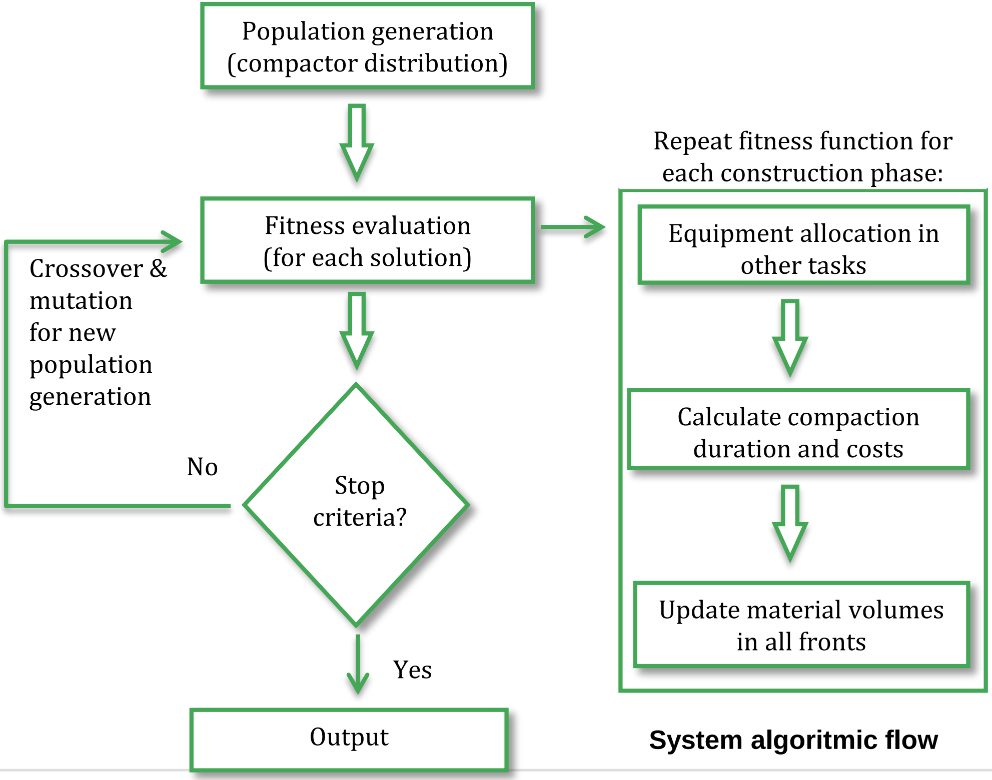
Module	Technology	Function
Equipment	Data Mining	• user inputs; • estimation of productivity & costs
Spatial	Geographic Information Systems	• modelling of construction site; • path finder
Optimization	Metaheuristics	• (near) optimal selection of equipment fleet depending on availability; • (near) optimal equipment fleet allocation throughout construction phase; • return output to user.

System architecture Overview



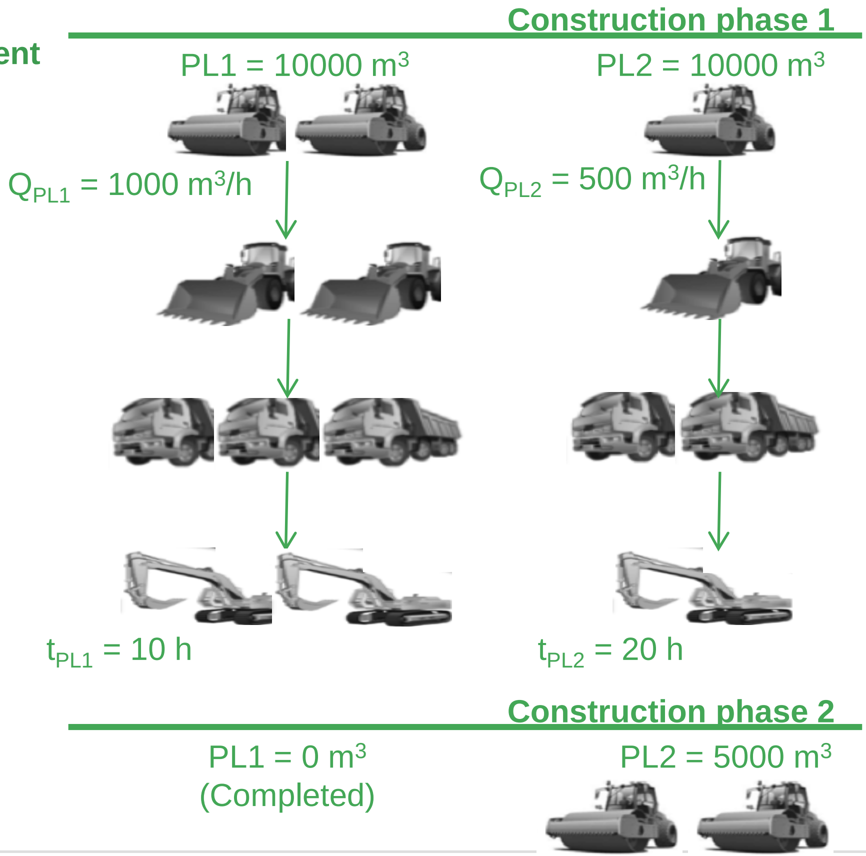
Module integration

System architecture



System algoritmic flow

Solution assessment



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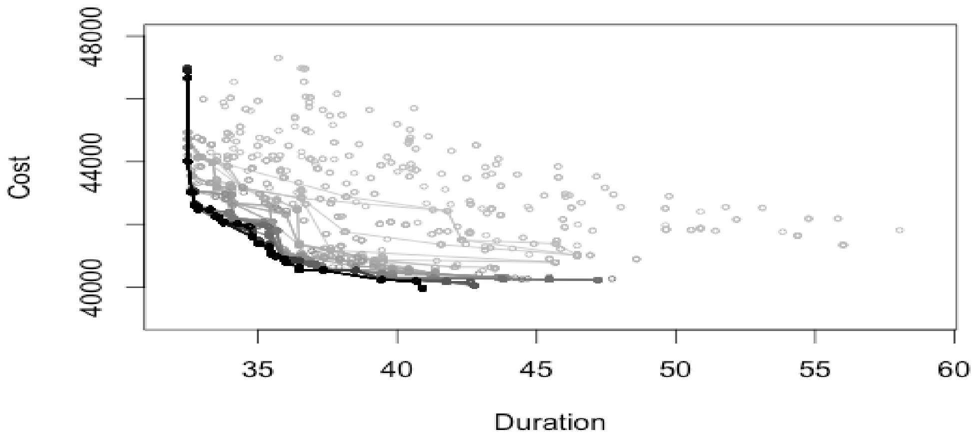
Application results

Implementation of the system has been successfully achieved, including validation with real construction data from a Portuguese construction site.

Assessment of optimization algorithm convergence towards Pareto-optimal front:



This type of solution representation increases the versatility of the system from the designer point of view

Algorithm convergence – Cost in euro; Duration in hours.

Application results

Parameter	Conventional allocation	Optimized allocation
Approximate distance to excavation front (m)	500	
Number of compactors	1	1
Compactor work rate (m^3/h)	683	683
Number of spreaders	1	1
Spreader work rate (m^3/h)	675	820
Number of dumper trucks	3	2
Dumper truck work rate (m^3/h)	1280	880
Number of excavators	1	2
Excavator work rate (m^3/h)	540	743

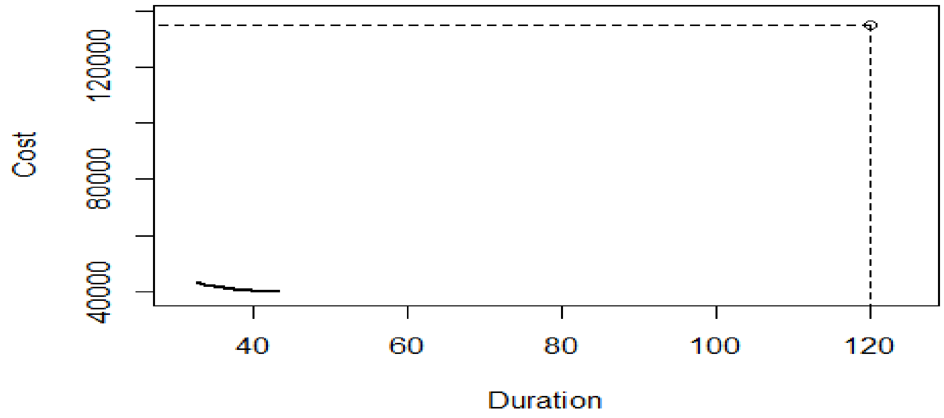
Example – comparison between the optimized solution and the conventional solution obtained by manual design:

- Conventional allocation:
  - Limited by the excavation team work rate
  - Over-allocation of dumper trucks
- The optimized allocation finds the most homogeneous allocation solution given the available resources

Resources are used at full efficiency (e.g. no idle time)

Application results

Overall comparison between the obtained Pareto-optimal solutions and the original manual solution adopted by the designer:



***Dot*: Original human solution**
***Line*: Obtained Pareto front of solutions**

Competitive results were achieved by the proposed system (reduction of 50-70% in project cost and duration when compared with human solution), stressing the advantages of intelligent optimization tools in the design of earthworks.

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Thank you

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