Weight Optimisation of Warren Truss using Harmony Search Algorithm

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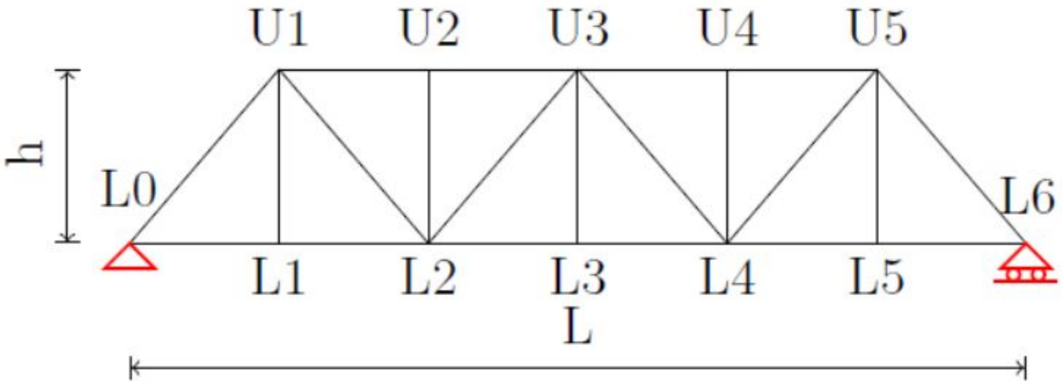
Optimization Problem

Consider a 21 bar Warren truss subjected to loads as shown in figure

The cost of material needed for making the truss needs to be minimised



Load=250KN

density=7850 kg/m^3

E=200 GPa

Objective Function

The minimum weight design problem for a truss structure can be formulated as:

$$W(x)=\Sigma xi*\rho i*Li$$

Where, W = weight of truss structure

Xi = cross section area of member i

ρi = density of member i

Li = length of member

Constraints

Stress Constraint: 120 MPa (both in Tension and Compression)

Deflection: span/600

Cross Section Area = 0.025 m^2 - 1m^2

Algorithm

Step 1: Initializing the harmony search parameters (HMS, HMCR, PAR)

Step 2: Initializing harmony memory

Step 3: Improvising a new harmony.

> HMCR and PAR parameters are introduced to allow the solution to escape from local optima and to improve the global optimum prediction of HS algorithm

Step 4. Updating the harmony memory

Input

Step 1: Initializing the harmony search parameters (HMS, HMCR, PAR)

- HMS=20
- HMCR=0.8
- PAR=0.3
- bw=0.01
- Max searches=30000

Step-2:

- Initializing Harmony Memory
- filled with randomly generated design vectors as the size of the harmony memory (HMS)

$$HM = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_{ng-1}^1 & x_{ng}^1 \\ x_1^2 & x_2^2 & \cdots & x_{ng-1}^2 & x_{ng}^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_1^{HMS-1} & x_2^{HMS-1} & \cdots & x_{ng-1}^{HMS-1} & x_{ng}^{HMS-1} \\ x_1^{HMS} & x_2^{HMS} & \cdots & x_{ng-1}^{HMS} & x_{ng}^{HMS} \end{bmatrix} \begin{matrix} \rightarrow & W(X^1) \\ \rightarrow & W(X^2) \\ \rightarrow & \vdots \\ \rightarrow & \vdots \\ \rightarrow & W(X^{HMS-1}) \\ \rightarrow & W(X^{HMS}) \end{matrix}$$

Harmonic Memory

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[0.31, 0.33, 0.84, 0.76, 0.33, 0.22, 0.48, 0.56, 0.14, 0.27, 0.81, 0.37, 0.85, 0.98, 0.9, 0.42, 0.92, 0.4, 0.21, 0.12, 0.98]
[0.74, 0.05, 0.13, 0.13, 0.92, 0.7, 0.56, 0.35, 0.38, 1.0, 0.31, 0.38, 0.14, 0.12, 0.74, 0.55, 0.23, 0.41, 0.51, 0.47, 0.5]
[0.29, 0.06, 0.44, 0.83, 0.17, 0.12, 0.18, 0.57, 0.62, 0.83, 0.99, 0.27, 0.99, 0.45, 0.16, 0.56, 0.13, 0.15, 0.13, 0.44, 0.45]
[0.79, 0.68, 0.99, 0.53, 0.5, 0.49, 0.11, 0.64, 0.23, 0.89, 0.89, 0.4, 0.78, 0.42, 0.46, 0.29, 0.03, 0.78, 0.31, 0.62, 0.44]
[0.3, 0.08, 0.03, 0.65, 0.43, 0.81, 0.21, 0.18, 0.58, 0.17, 0.54, 0.52, 0.51, 0.54, 0.47, 0.88, 0.55, 0.76, 0.56, 0.52, 0.3]
[0.03, 0.63, 0.03, 0.4, 0.47, 0.63, 0.72, 0.2, 0.6, 0.64, 0.72, 0.16, 0.19, 0.48, 0.9, 0.72, 0.66, 0.91, 0.69, 0.69, 0.79]
[0.17, 0.69, 0.92, 0.32, 0.88, 0.43, 0.93, 0.09, 0.73, 0.75, 0.42, 0.03, 0.25, 0.35, 0.75, 0.37, 0.12, 0.27, 0.5, 0.45, 0.94]
[0.53, 0.85, 0.63, 0.53, 0.88, 0.28, 0.92, 0.1, 0.24, 0.35, 0.44, 0.52, 0.37, 0.97, 0.31, 0.34, 0.19, 0.53, 0.26, 0.47, 0.19]
[0.42, 0.52, 0.43, 0.7, 0.21, 0.47, 0.54, 0.94, 0.69, 0.26, 0.79, 0.88, 0.1, 0.13, 0.66, 0.7, 0.49, 0.62, 0.46, 0.73, 0.61]
[0.96, 0.45, 0.23, 0.36, 0.26, 0.63, 0.22, 0.29, 0.96, 0.11, 0.39, 0.6, 0.19, 0.37, 0.99, 0.59, 0.09, 0.59, 0.14, 0.63, 0.19]
[0.7, 0.91, 0.72, 0.64, 0.7, 0.74, 0.16, 0.68, 0.73, 0.93, 0.5, 0.14, 0.13, 0.56, 0.16, 0.89, 0.29, 0.43, 0.67, 0.29, 0.49]
[0.41, 0.38, 0.67, 0.1, 0.06, 0.09, 0.07, 0.18, 0.7, 0.79, 0.18, 0.14, 1.0, 0.69, 0.31, 0.1, 0.87, 0.75, 0.38, 0.24, 0.35]
[0.84, 0.88, 0.43, 0.32, 0.45, 0.49, 0.6, 0.55, 0.11, 0.37, 0.46, 0.22, 0.15, 0.94, 0.73, 0.17, 0.12, 0.57, 0.72, 0.96, 0.82]
[0.62, 0.21, 0.85, 0.64, 0.8, 0.07, 0.68, 0.09, 0.46, 0.42, 0.33, 0.33, 0.08, 0.28, 0.64, 0.32, 0.49, 0.09, 0.5, 0.8, 0.38]
[0.93, 0.7, 0.74, 0.53, 0.18, 0.71, 0.41, 0.13, 0.42, 0.36, 0.1, 0.26, 0.16, 0.64, 0.31, 0.56, 0.85, 0.25, 0.41, 0.46, 0.22]
[0.52, 0.29, 0.85, 0.22, 0.29, 0.96, 0.21, 0.22, 0.4, 0.75, 0.15, 0.9, 0.2, 0.95, 0.69, 0.67, 0.03, 0.05, 0.32, 0.28, 0.56]
[0.09, 0.54, 0.63, 0.28, 0.84, 0.38, 0.74, 0.47, 0.35, 0.58, 0.04, 0.15, 0.29, 0.67, 0.94, 0.8, 0.84, 0.32, 0.95, 0.38, 0.17]
[0.83, 0.36, 0.36, 0.03, 0.11, 0.61, 0.11, 0.64, 0.48, 0.69, 0.7, 0.37, 0.9, 0.57, 0.75, 0.83, 0.12, 0.77, 0.51, 0.22, 0.41]
[0.84, 0.42, 0.17, 0.35, 0.34, 0.47, 0.95, 0.86, 0.48, 0.06, 0.21, 0.88, 0.17, 0.07, 0.08, 0.88, 0.38, 0.67, 0.94, 0.26, 0.82]
[0.29, 0.19, 0.56, 0.13, 0.5, 0.85, 0.7, 0.25, 0.5, 0.38, 0.81, 0.12, 0.89, 0.87, 0.65, 0.56, 0.04, 0.04, 0.89, 0.62, 0.79]
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Step-3: New harmony vector

➔ HM consideration:

$x^{new}_{ij} = x_{ij} \{x_{ij}, x_{2j}, \ldots\ldots\ldots, x_{hms,j}\}$ with probability of HMCR

$X_{inew} = l_{ij} + (U_{ij} - l_{ij}) * rand(0,1)$ with probability of 1-HCMR

➔ Pitch adjusting decision:

yes with probability PAR i.e $x^{new}_{ij} = x_{ij} + bw * rand(-1,1)$

no with probability 1- PAR

Weights at step-0

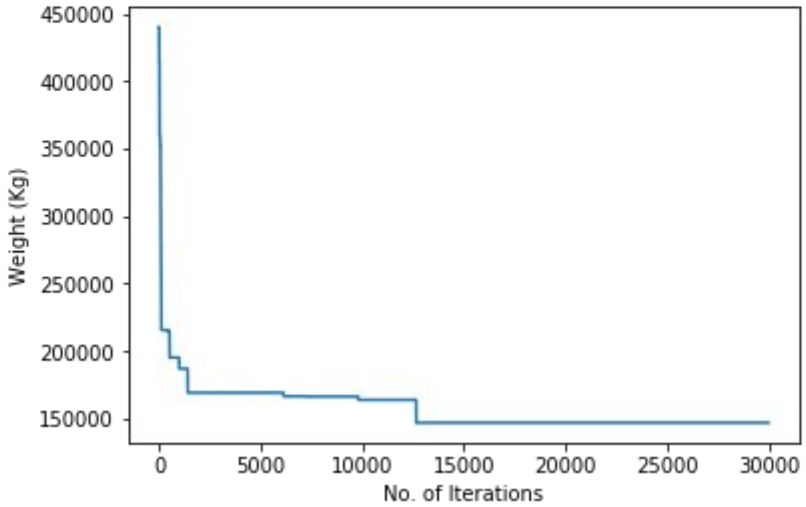
Odd Rows	Even Rows
603421	463598
462606	569242
516390	590875
504712	497093
583174	476268
550440	440219
551919	448149
458450	494944
533418	555208
517372	564279

Step-1000

Odd Rows	Even Rows
208235	214175
211403	214966
216802	187023
209853	200968
214993	200645
214409	215147
209086	195261
217986	212845
215591	196424
216202	207056

Output

Step-0	---->	440219Kg
Step-1000	---->	187023Kg
Step-2500	---->	170228 Kg
Step-5000	---->	167442Kg
Step-10000	---->	166654Kg
Step-20000	---->	150752Kg
Step-30000	---->	150752Kg



References

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