Optimization Approach to Force Identification of Prestressed Pin-jointed Structures

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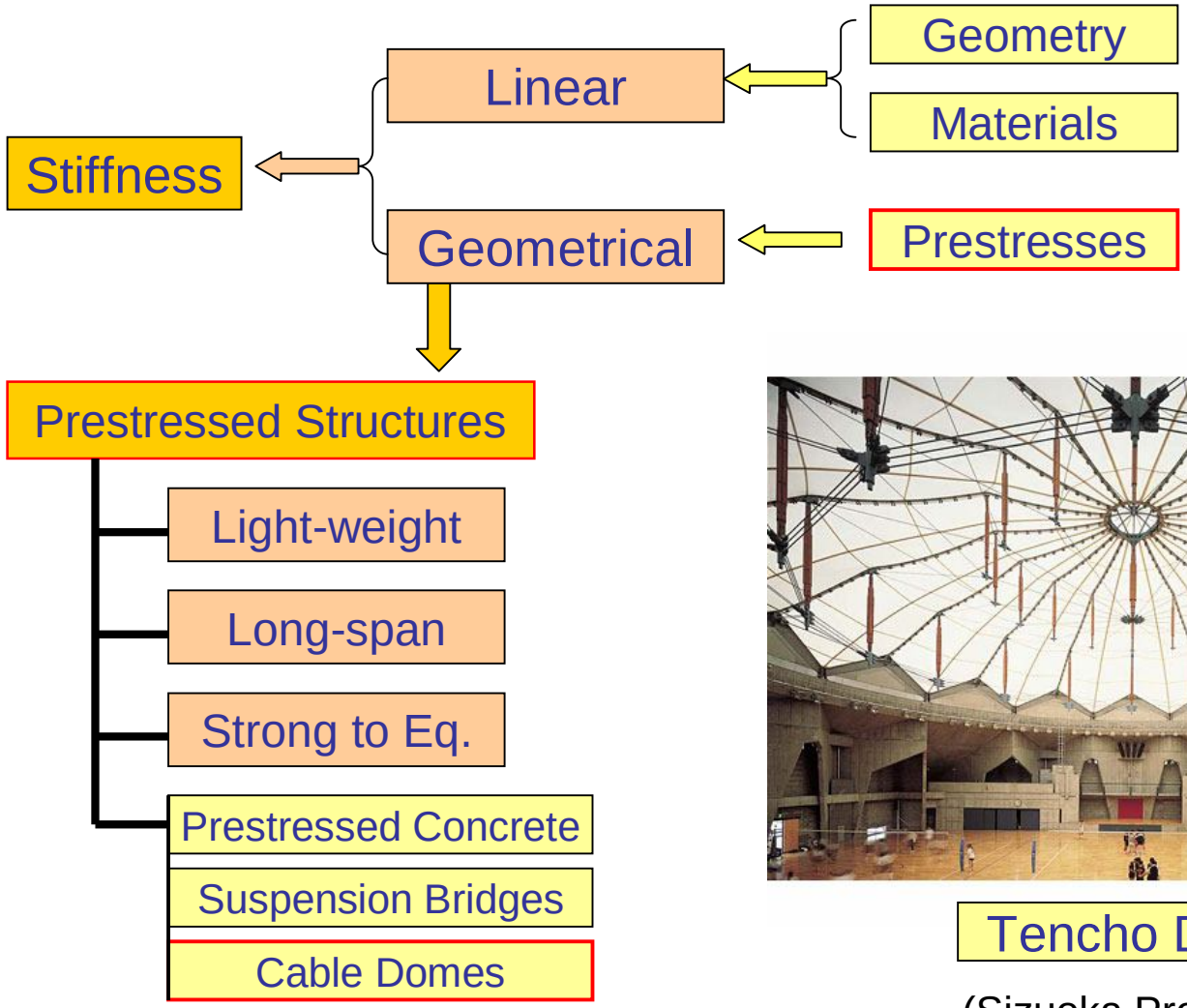
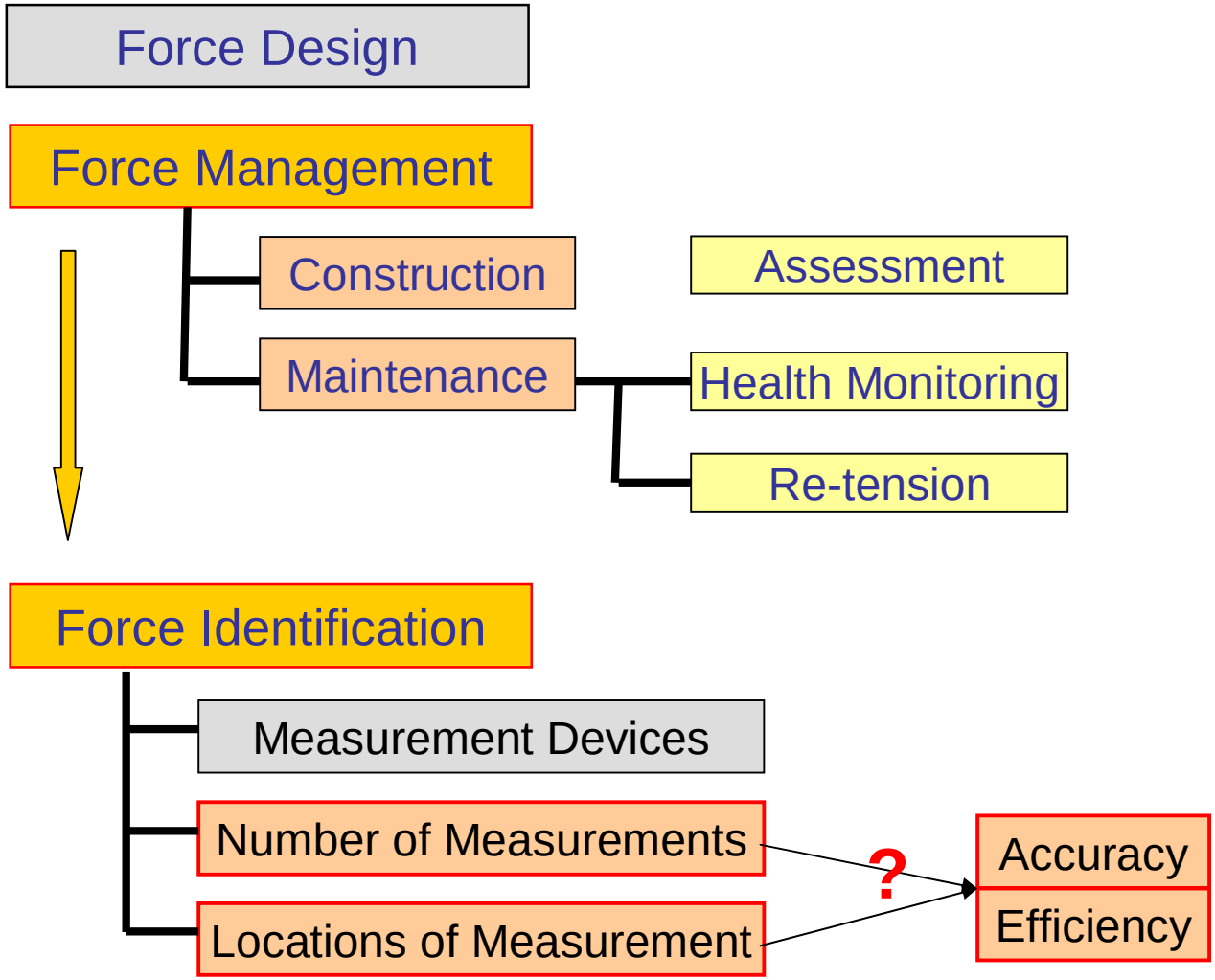
Background



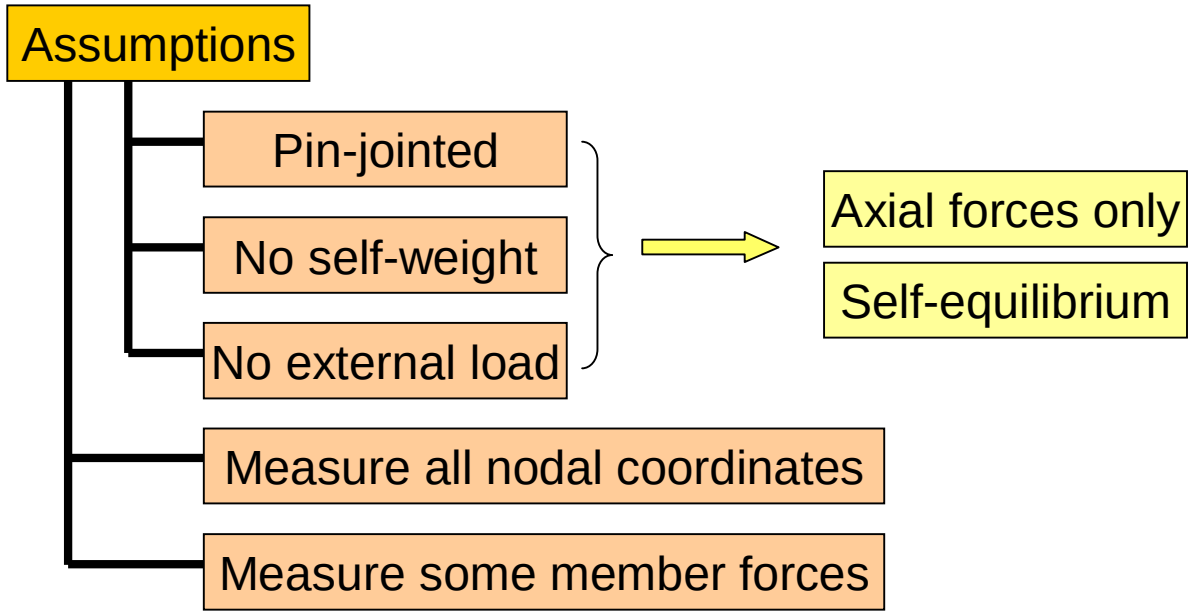
Tencho Dome

(Sizuoka Pro., Japan)

Motivation


Force Design
Force Management
Construction
Assessment
Maintenance
Health Monitoring
Re-tension
Force Identification
Measurement Devices
Number of Measurements
Locations of Measurement
?
Accuracy
Efficiency

Basics



Self-equilibrium $\mathbf{Ds} = \mathbf{0}$

$\mathbf{D}^m\mathbf{s}^m + \mathbf{D}^e\mathbf{s}^e = \mathbf{0}$

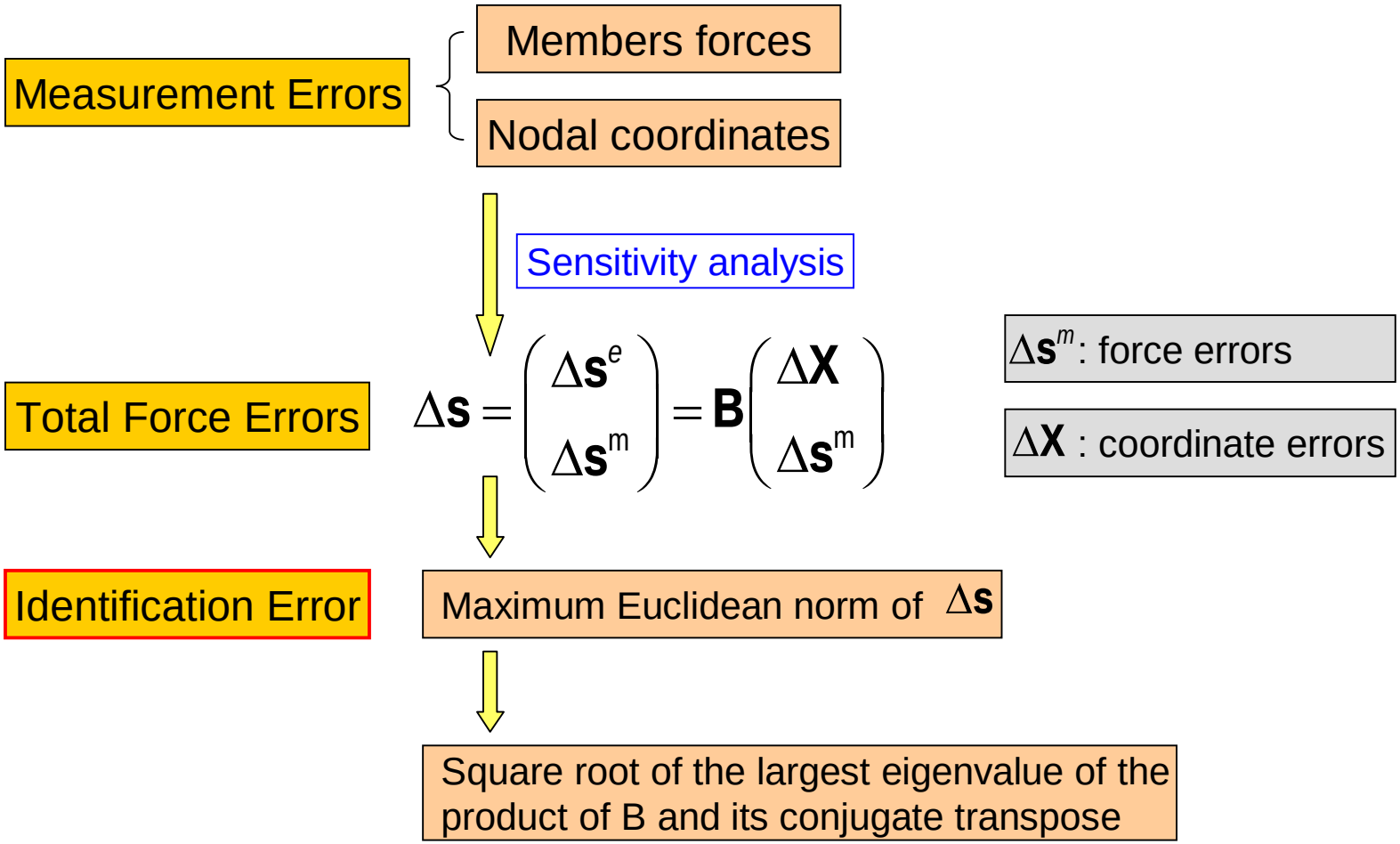
Estimated Forces $\mathbf{s}^e = -(\mathbf{D}^e)^{-}\mathbf{D}^m\mathbf{s}^m$

$\mathbf{D}$: equilibrium matrix

$\mathbf{s}^m$: measured forces

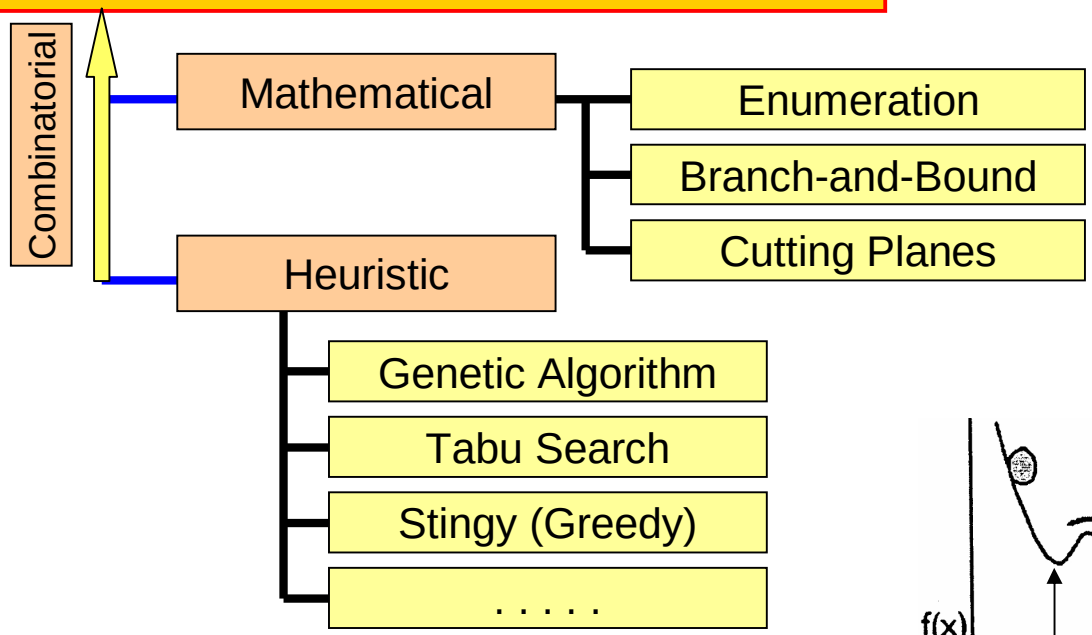
$\mathbf{s}^e$: estimated forces

Identification Error



Optimization Problem

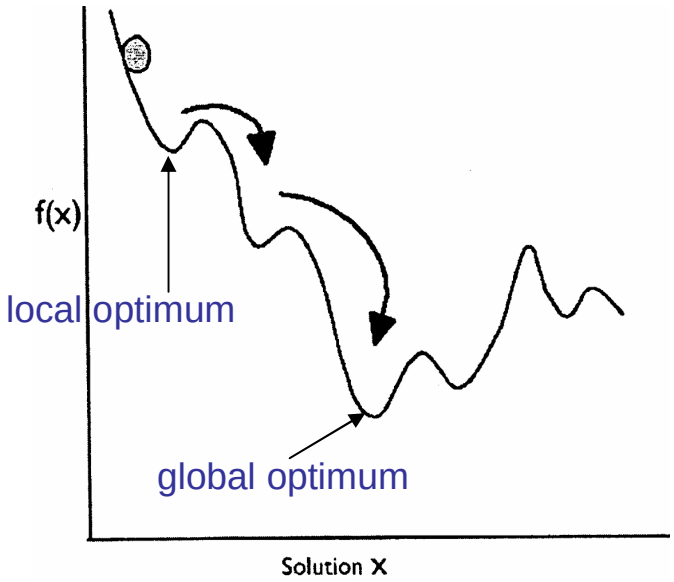
Find the optimal measurement members with specific number of measurements



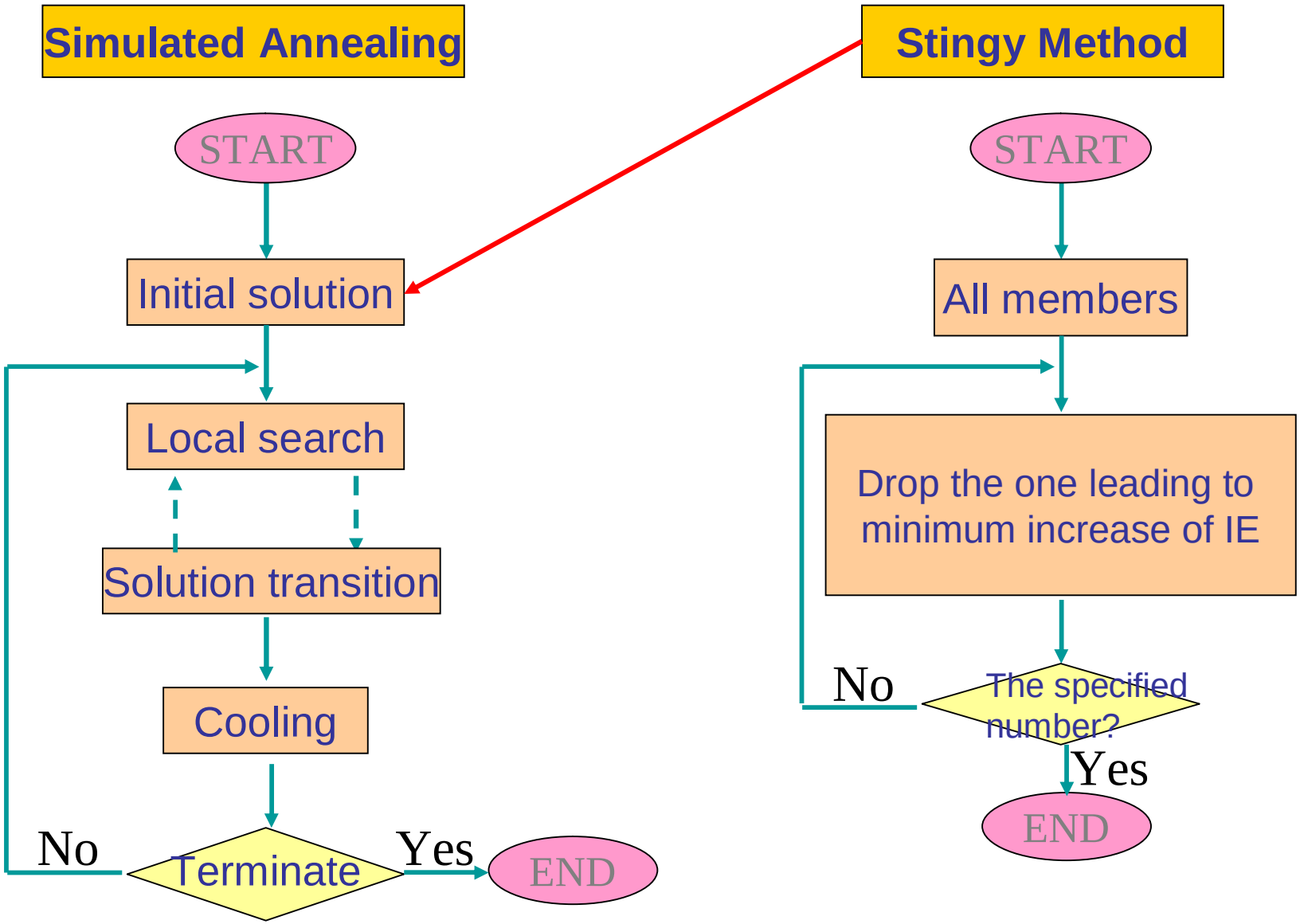
Simulated Annealing (SA)

Analogy between metal annealing and optimal solution searching

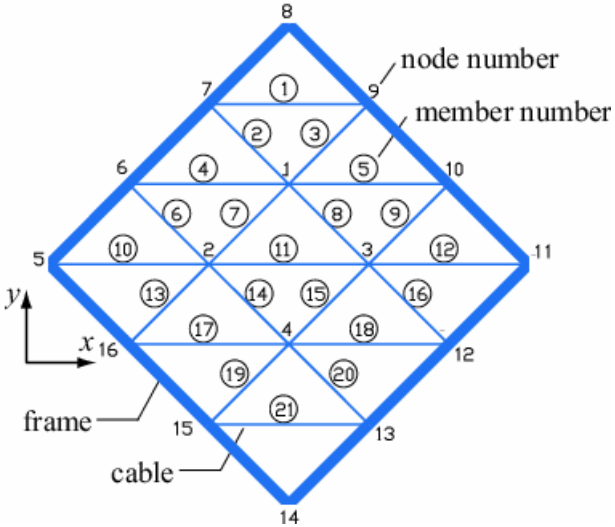
Able to escape from local optima



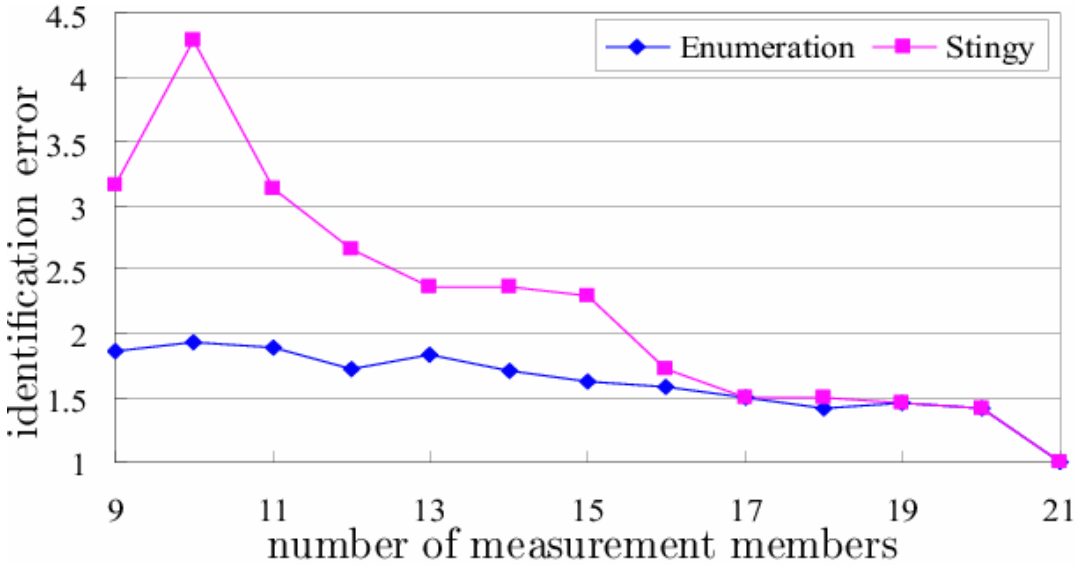
Solutions


Simulated Annealing
START
Initial solution
Local search
Solution transition
Cooling
No
Terminate
Yes
END
Stingy Method
START
All members
Drop the one leading to minimum increase of IE
No
The specified number?
Yes
END

Example ? Cable net 1



4 free nodes
21 members
9 force modes



Example ? Cable net 2

Determine 12 Measurement Members

Conventional SA

No. of Trials	1	2	3	4	5	6	Mean
Identification Error	1.9219	1.7302	1.7302	1.8252	1.8252	1.9219	1.8258
Computational Cost	24378	19941	16626	18768	16422	27795	20655

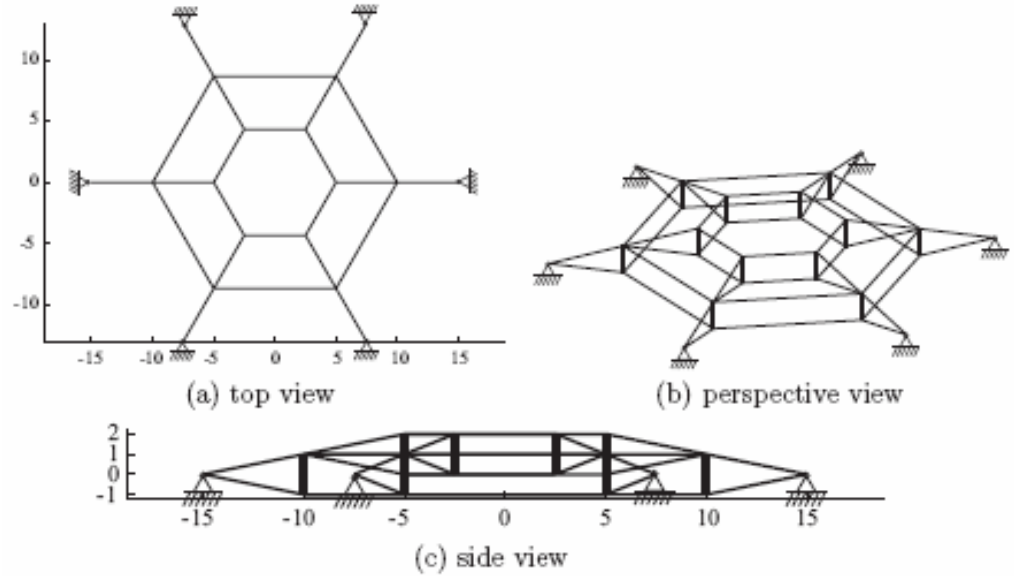
ISA (SA with Stingy)

No. of Trials	1	2	3	4	5	6	Mean
Identification Error	1.7302	1.7302	1.8252	1.7302	1.8252	1.7302	1.7619
Computational Cost	18666	18513	17085	17901	15198	18411	17629

Comparison

	Enumeration	Stingy	SA	ISA
Identification Error	1.7302	2.6607	1.8258	1.7619
Relative Error [a]	0%	53.78%	5.53%	1.83%
Computation Cost	293930	165	20655	17629
Relative Cost [b]	100%	0.056%	7.03%	6.0%

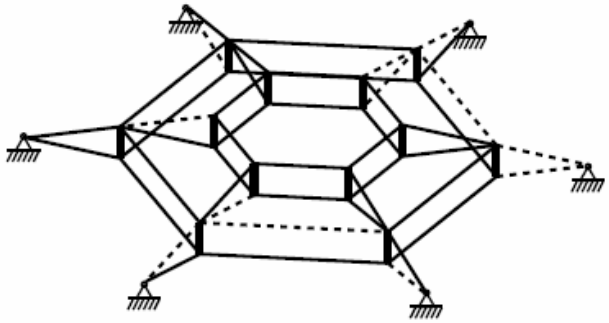
Example ? Cable Dome



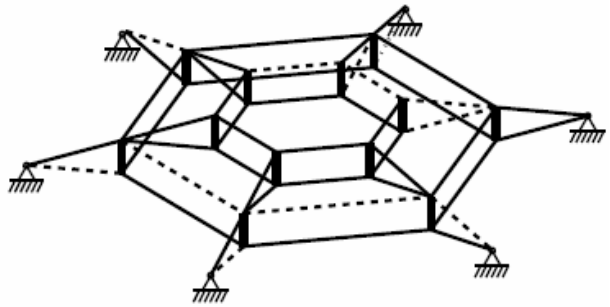
30 nodes
60 members
2 force modes

12 Measurements

Measure only cables



(a) measurement members by Stingy



(b) measurement members by ISA

IE = 1.1988

IE = 1.0418

Summary

Identification error

- Measurement errors of nodal coordinates
- Measurement errors of member forces

Optimization

Minimize Identification error

S.T. Specified number of measurements

Solutions

- Simulated Annealing
- Stingy Method
- SA + Stingy