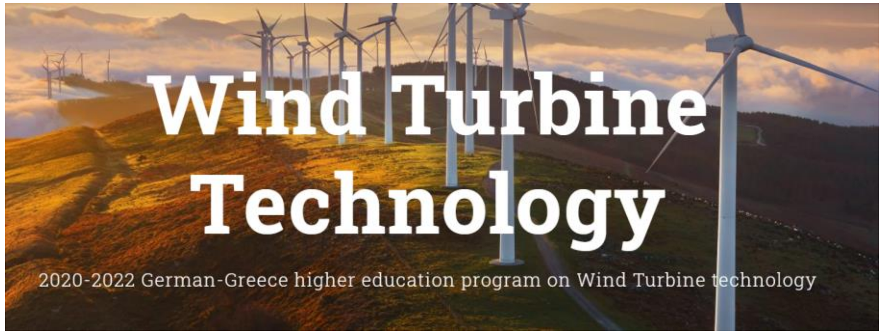


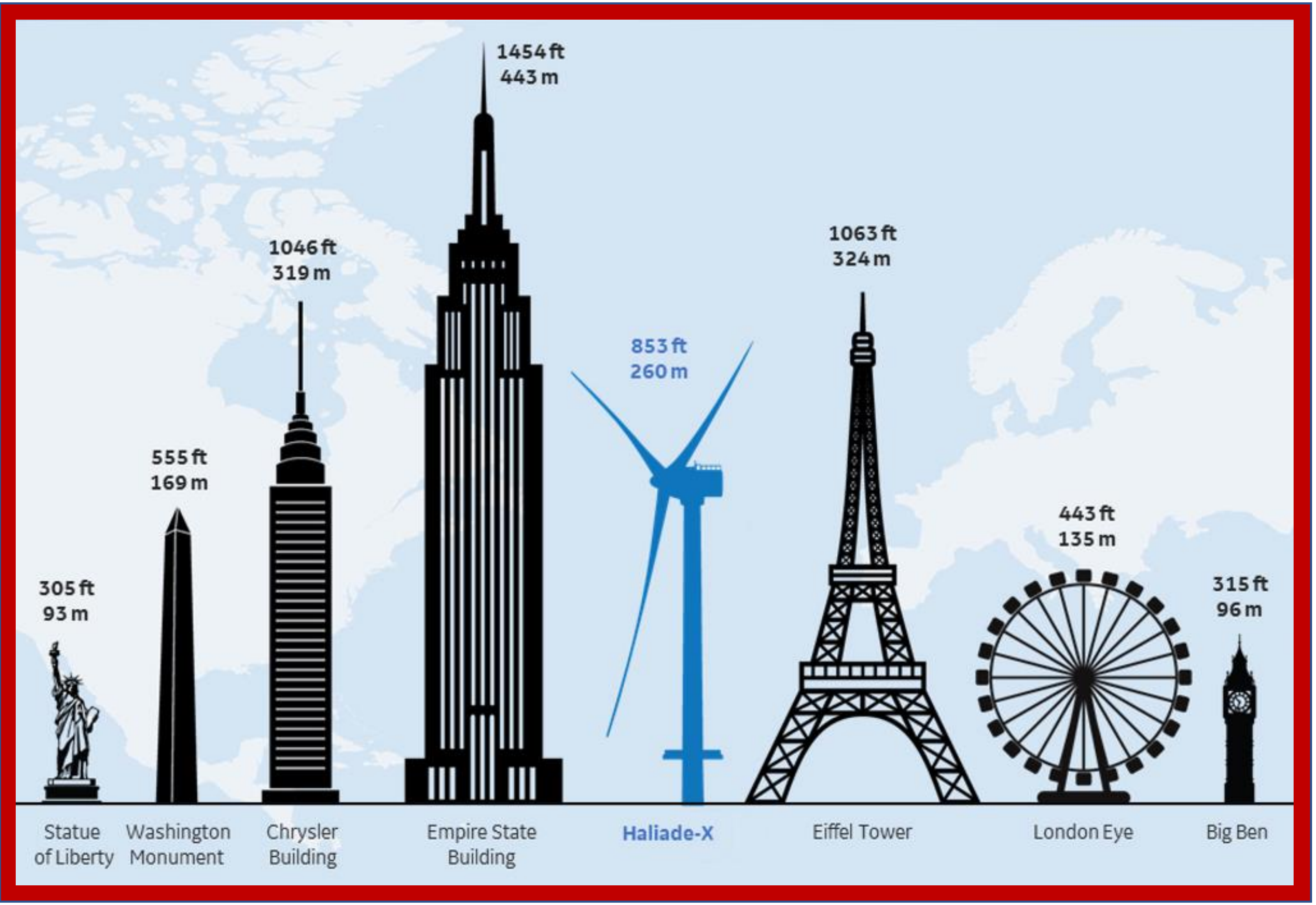
Simulations in Wind Turbine Technology

Prof. Demosthenes Polyzos

Department of Mechanical and Aeronautical Engineering,
University of Patras
Greece

Climate changes

Wind energy is a part of the solution playing a significant role in powering our future!



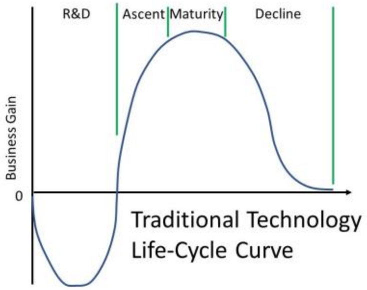
Nowadays Wind Turbines (WT) are very large structures with many engineering challenges.

The Haliade-X, for example, is a 14 MW, 13 MW or 12 MW capacity offshore Wind Turbine with, 220-meter rotor diameter, a 107-meter blade, and digital capabilities.

However, WT manufacturers and suppliers are facing many problems dealing with

A very competitive market

Expensive test procedures



Short development cycles

Regional regulations

High installation costs

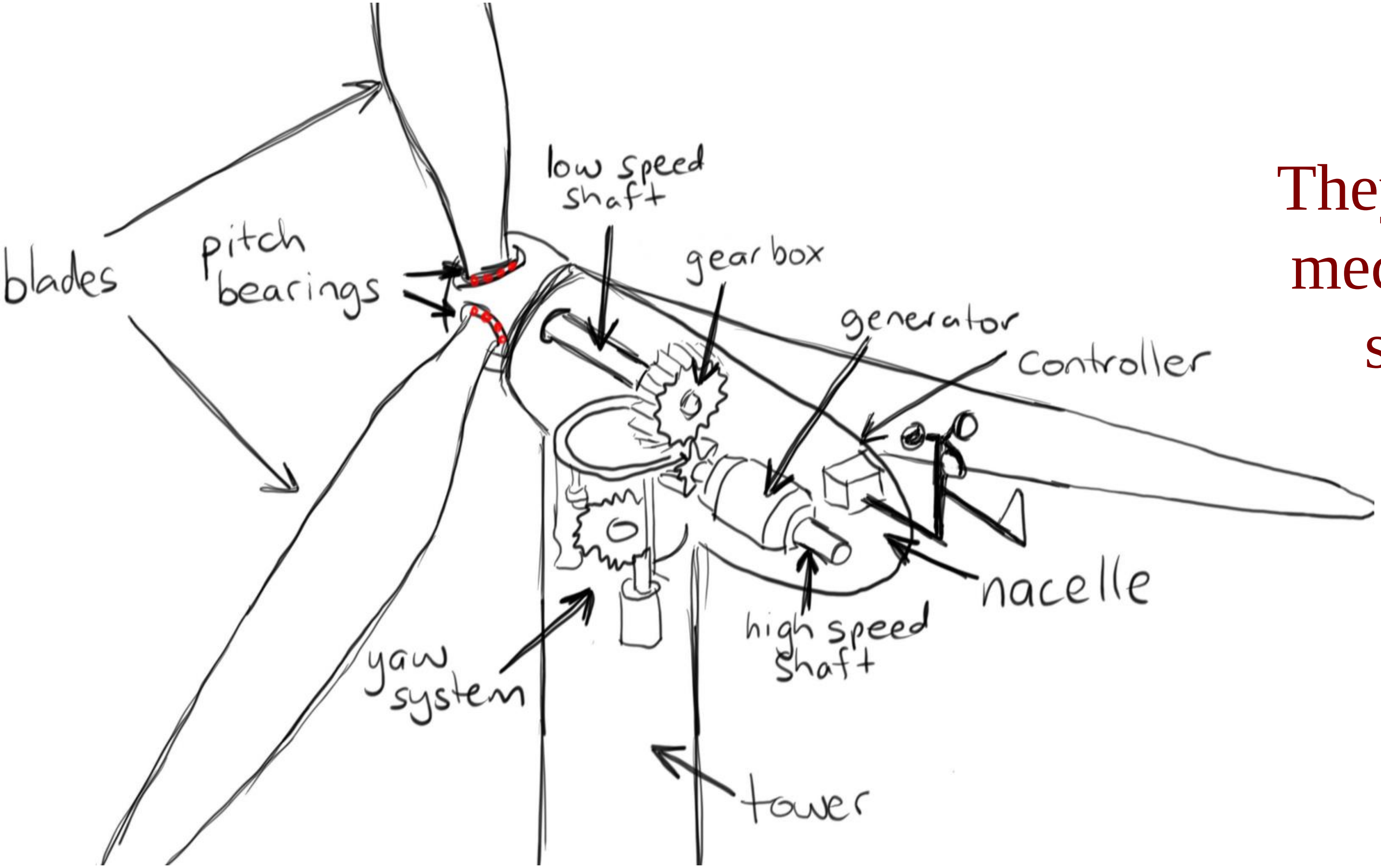
Energy storage

What manufacturers and suppliers want to know and what they want to avoid.

What they expect from engineers

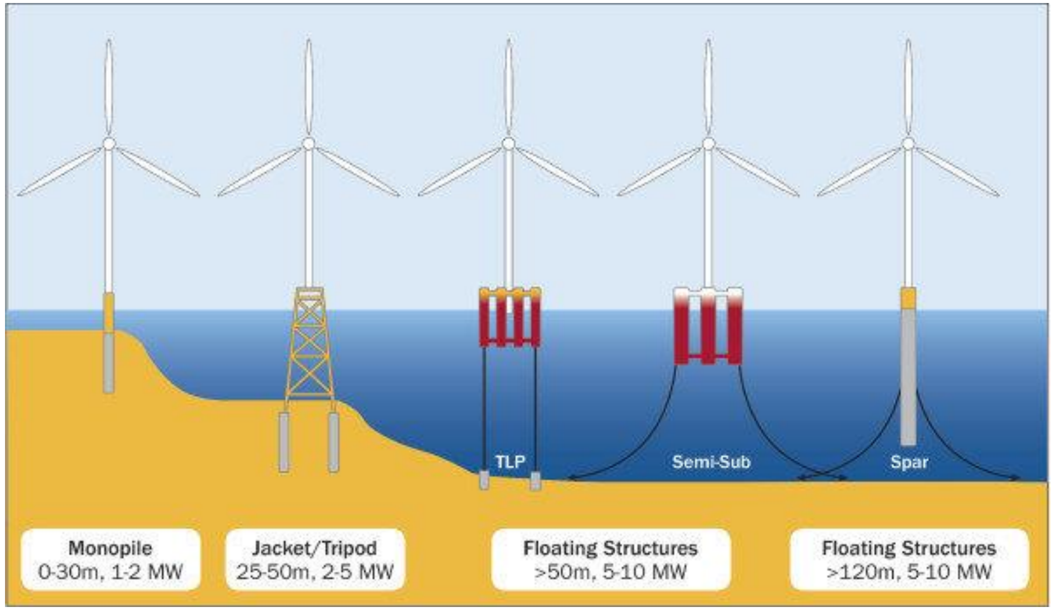
They want the optimum design for long and low weight blades avoiding a sequence of expensive mechanical tests

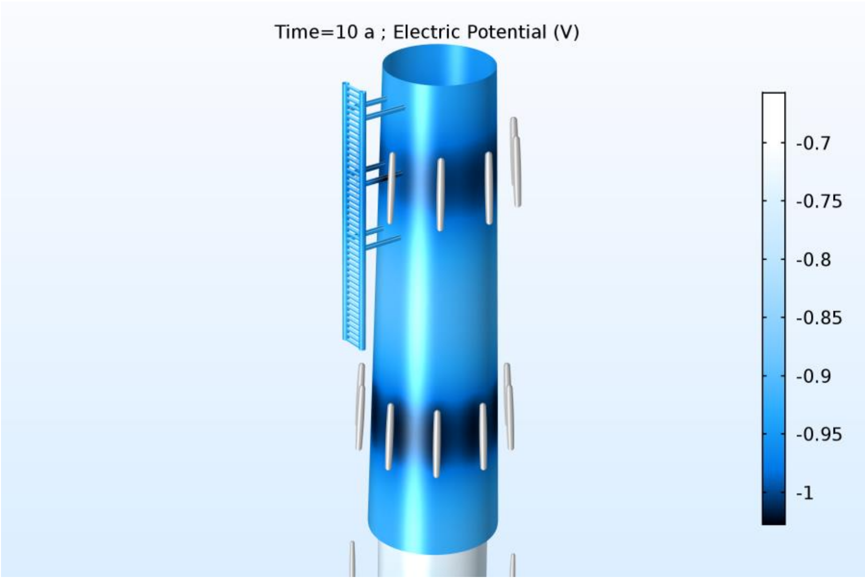
They want efficiency with respect to air flow conditions avoiding expensive field and/or tunnel tests.



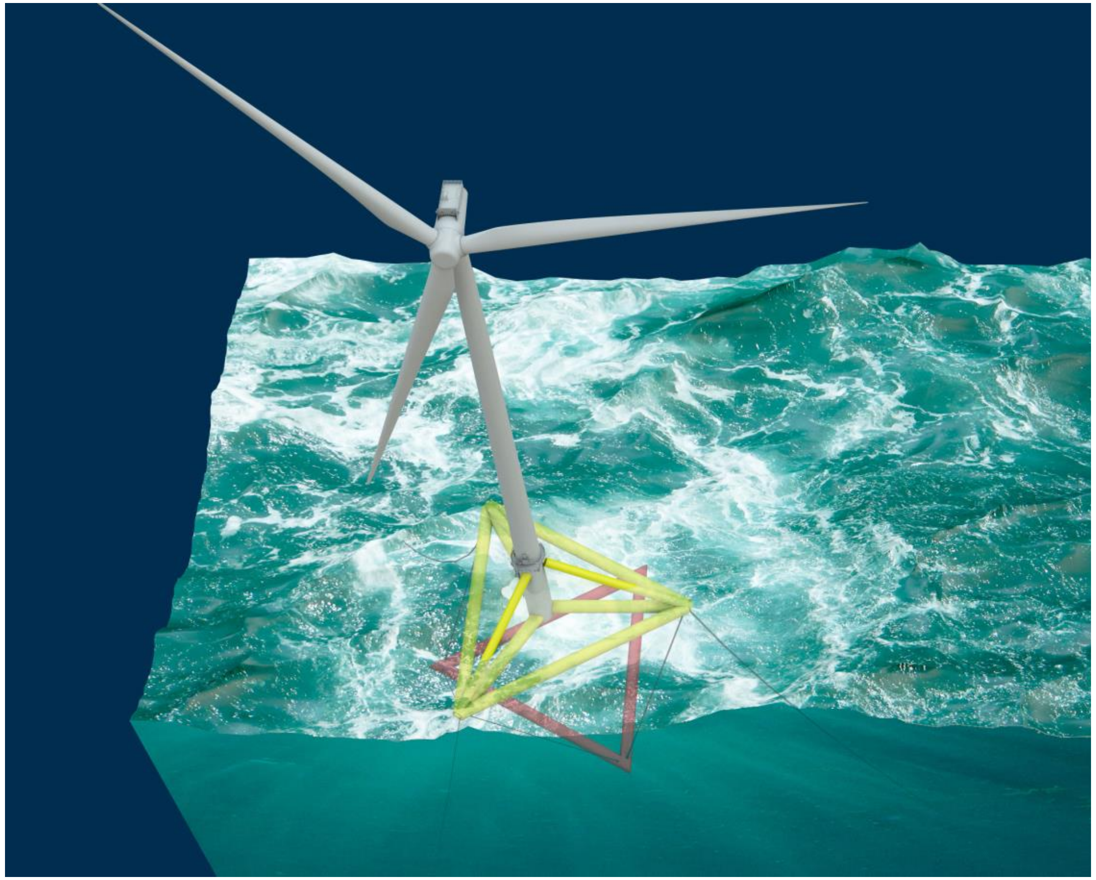
They need predictions for the mechanical behaviour of the structural components.

They want safe and low-cost foundations for offshore and onshore installations





They want to have a long term corrosion protection, especially for the offshore Wind Turbines

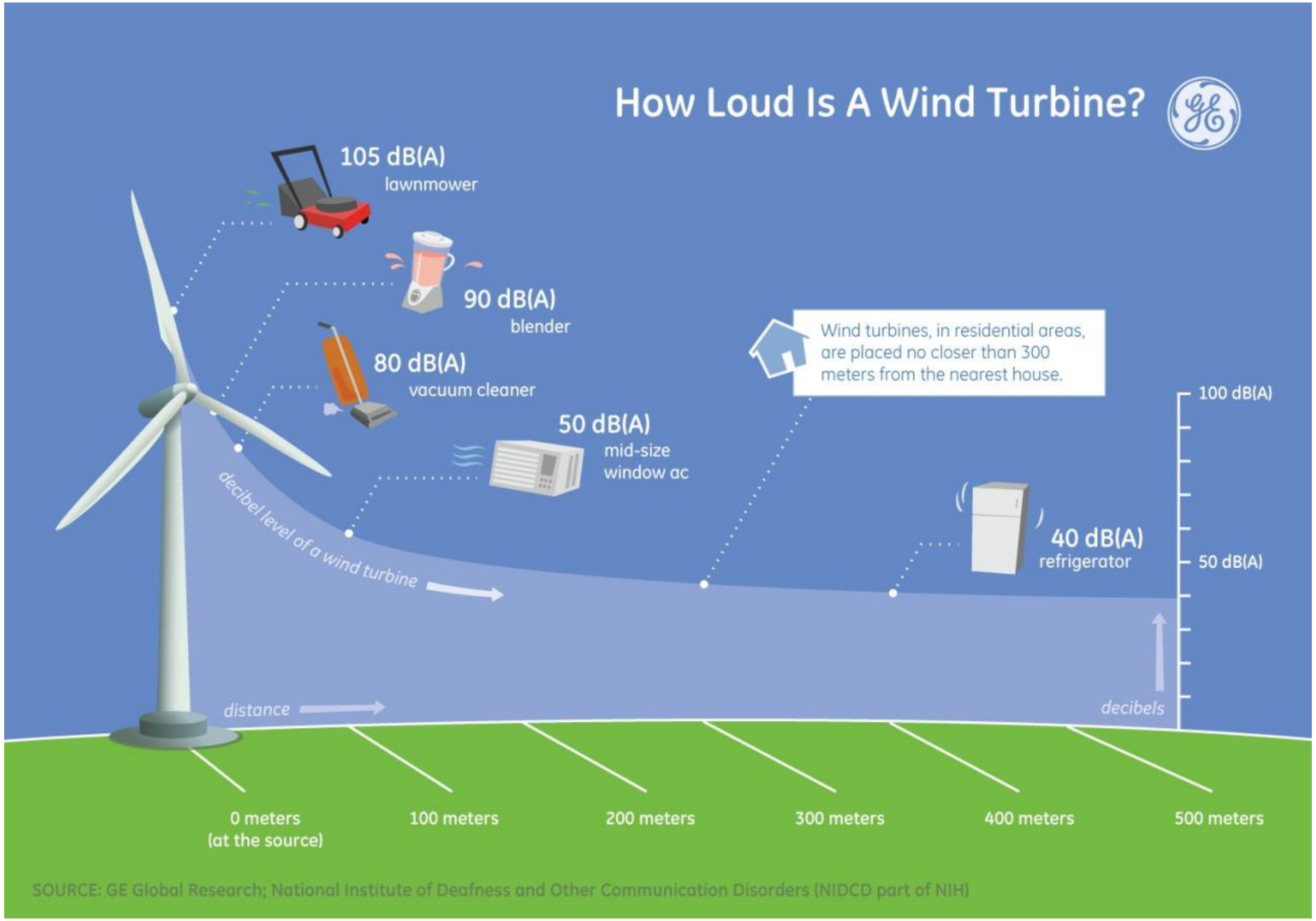


They want to know the WT performance in deep sea before installation

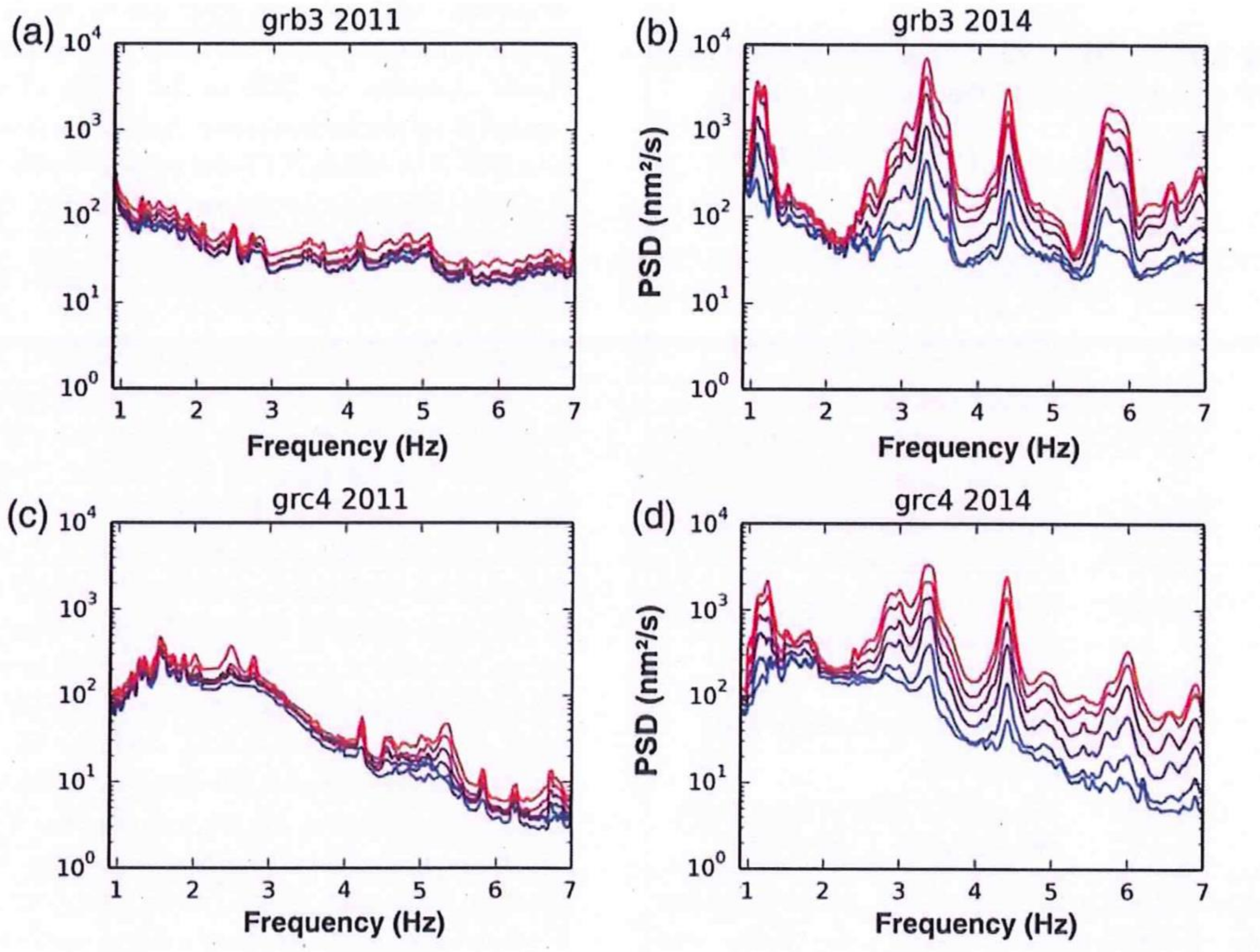

They want to know the WT performance in deep sea before installation

They want a quiet installation

They want to know problems appearing in wind farms and how they can be solved before the installation.

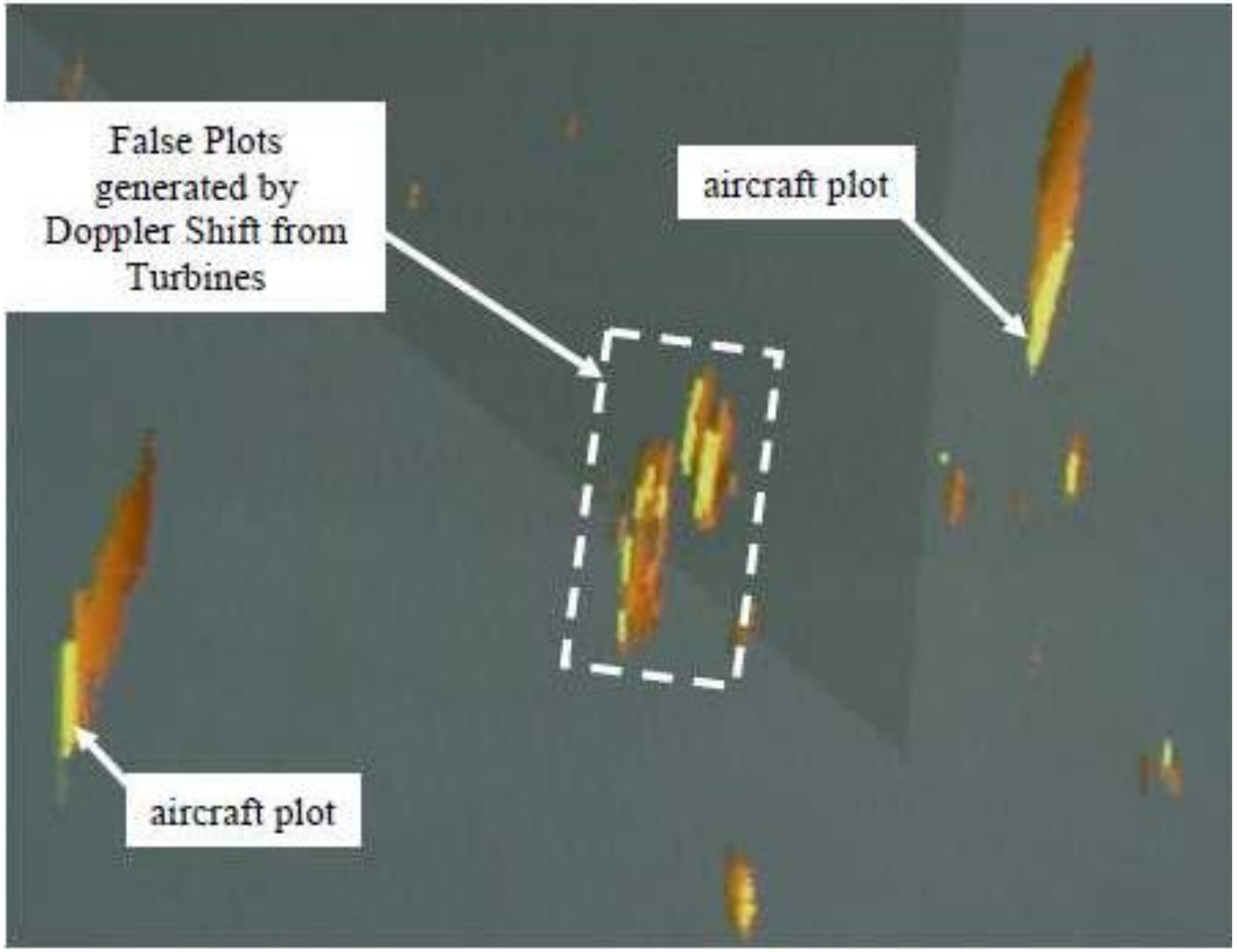


They want quiet WTs without experimental parametric studies



They want to know the radius and the size of the generated micro-seismicity

Stammler and Ceranna seismological center
Grafenberg, Germany



They want stealth WTs avoiding expensive tests in anechoic chambers

They want to know how to be protected by lightning damage

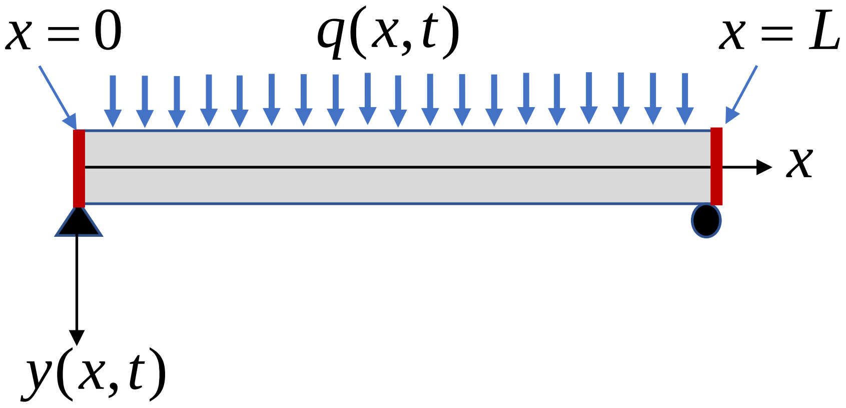
The solution to all those problems is the use of robust computational tools for efficient computer simulations

Digital twin WT

Digital WT models:

- *Continuously updated in real time by turbines and wind farm sensors, to reflect the real conditions experienced by the turbines on-site and helping engineers for performance optimization and maintenance scheduling.*
- *Enable engineers to determine overall energy levels, optimize turbine layout and assess farm behavior under specific wind conditions.*

Analytical solutions & Numerical simulations



Newton's Law

Mathematics

$$-\frac{\partial^4 y(x,t)}{\partial x^4} + q(x,t) = \frac{1}{\gamma^2}\frac{\partial^2 y(x,t)}{\partial t^2} + BC$$

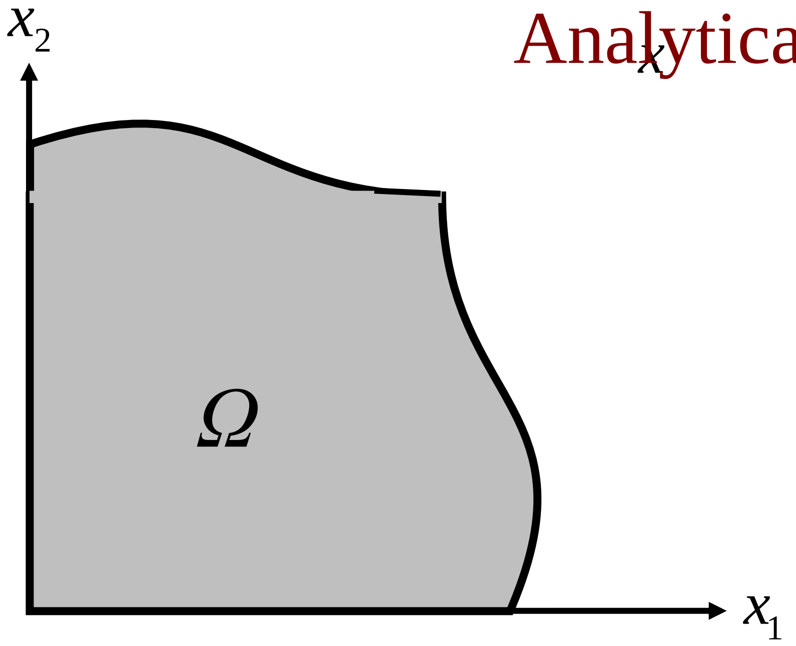
Algebra

$y(x,t)$

in

closed form

Analytical solutions & Numerical simulations



Newton's Law

Mathematics

$$\partial_j \sigma_{ij}(x_1, x_2, t) = \rho \frac{\partial^2 u(x_1, x_2, t)}{\partial t^2} + BC$$

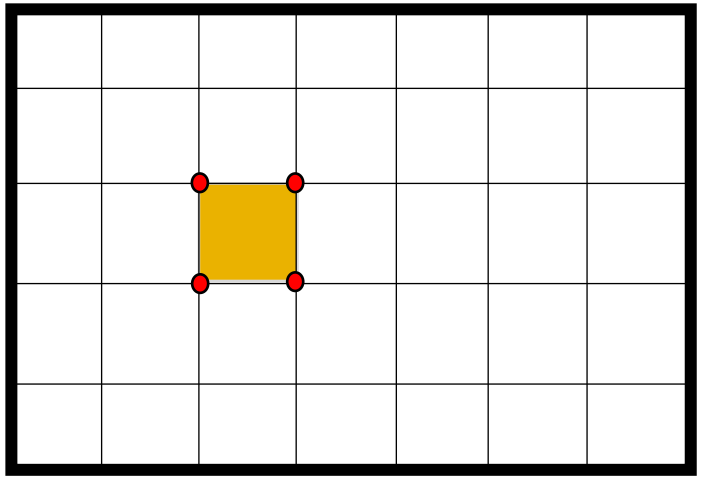
Numerical method

Software package

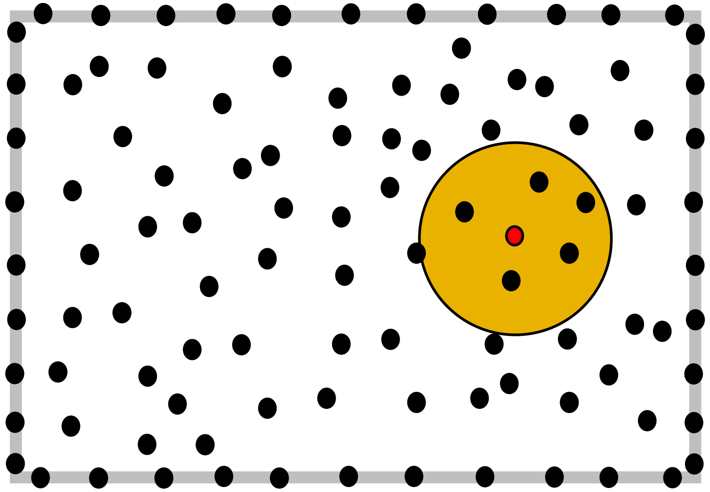
$u(x_1, x_2, t)$

pointwise

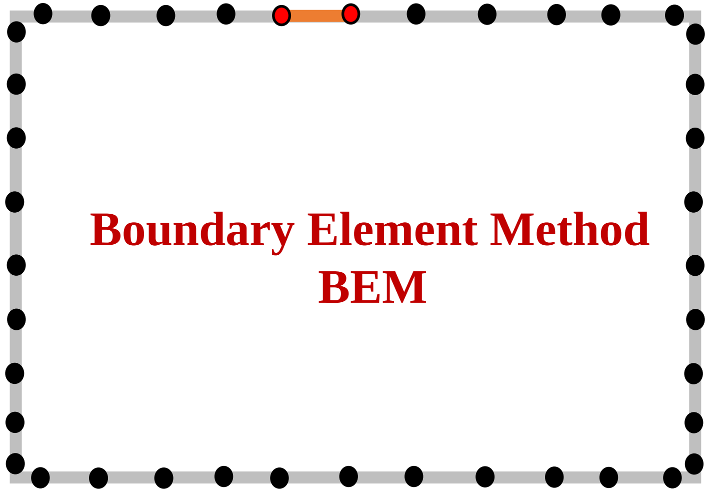
Finite Element Method
FEM



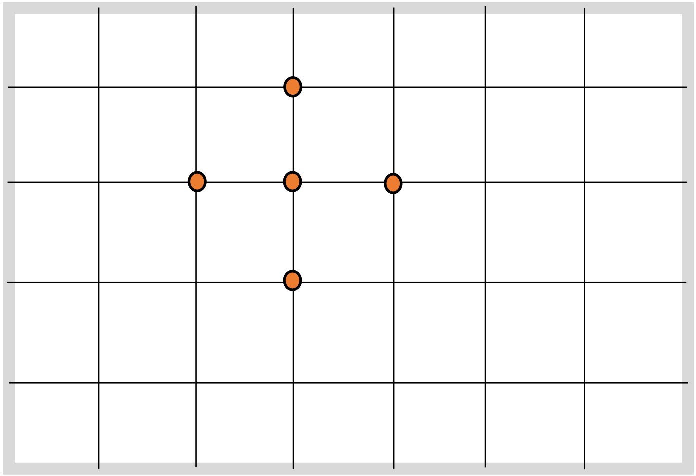
Meshless & Meshfree Methods



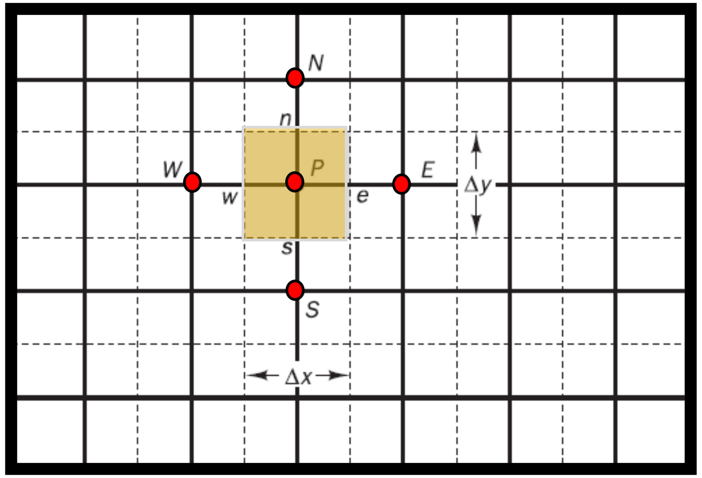
Boundary Element Method
BEM



Finite Differences Method FDM



Finite Volumes Method
FVM

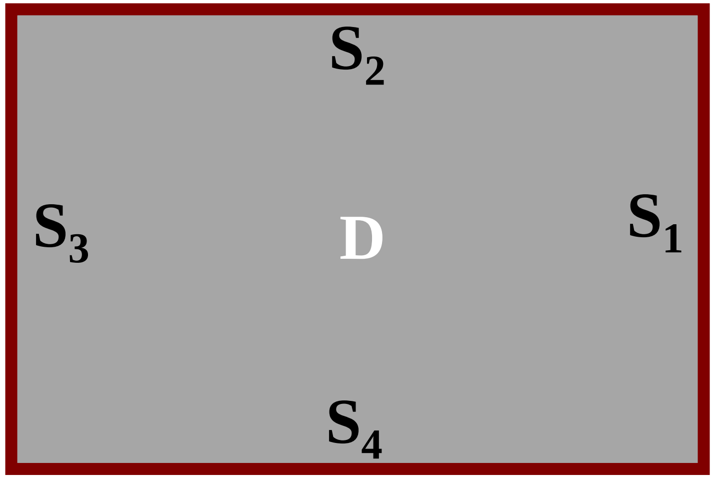


Strong and Weak Formulation

FDM, Meshless Methods ⇨ ***Solve the strong formulation of a Boundary Value Problem***

FEM, BEM, FVM, Meshless Methods ⇨ ***Solve the weak formulation of a Boundary Value Problem***

Strong Formulation of a Poisson Boundary Value Problem



$$\nabla^2 \varphi(\mathbf{x}) - f(\mathbf{x}) = 0, \quad \mathbf{x} \in D$$

Boundary Conditions

$$\partial_n \varphi(\mathbf{x}) = q_0, \quad \mathbf{x} \in S_1$$

$$\partial_n \varphi(\mathbf{x}) = 0, \quad \mathbf{x} \in S_2 \cup S_4$$

$$\varphi(\mathbf{x}) = \varphi_0, \quad \mathbf{x} \in S_3$$

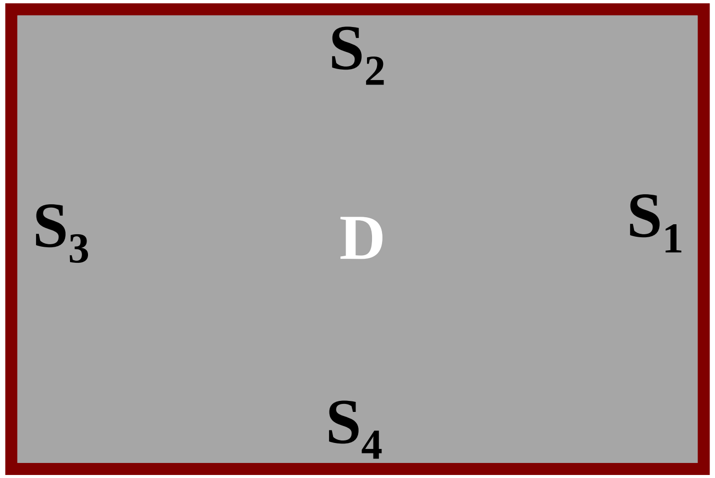
$$S = S_1 \cup S_2 \cup S_3 \cup S_4$$

Weak Formulation of a Poisson Boundary Value Problem

$$\int_D w(\mathbf{x})\left[\nabla^2\varphi(\mathbf{x}) - f(\mathbf{x})\right] dV(\mathbf{x}) = 0, \quad \mathbf{x}\in D$$

2nd Green Identity

$$\int_D \left[w(\mathbf{x}) f(\mathbf{x}) - \varphi\nabla^2 w\right] dV(\mathbf{x}) + \int_S w(\mathbf{x})\partial_n\varphi(\mathbf{x}) dS(\mathbf{x}) - \int_S \varphi(\mathbf{x})\partial_n w(\mathbf{x}) dS(\mathbf{x}) = 0$$



Boundary Conditions

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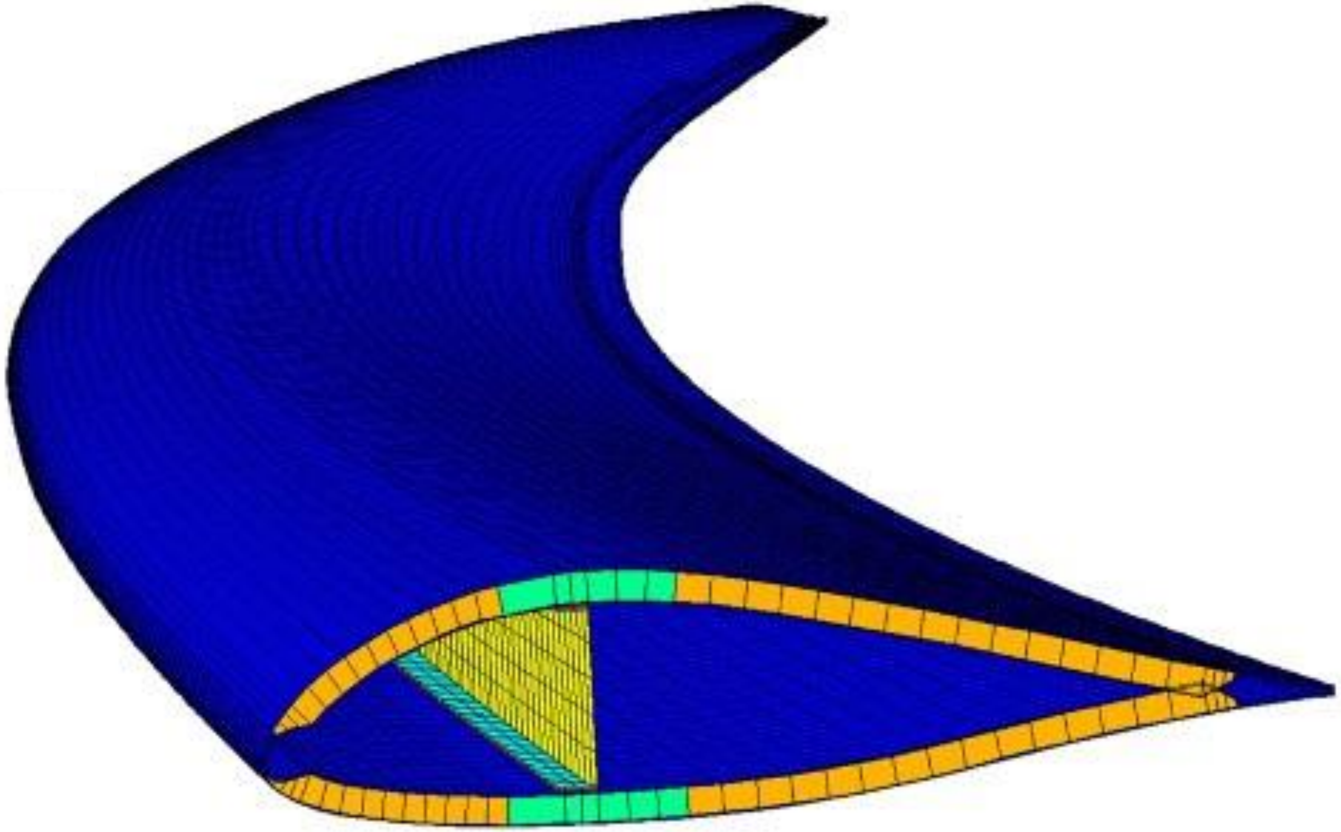
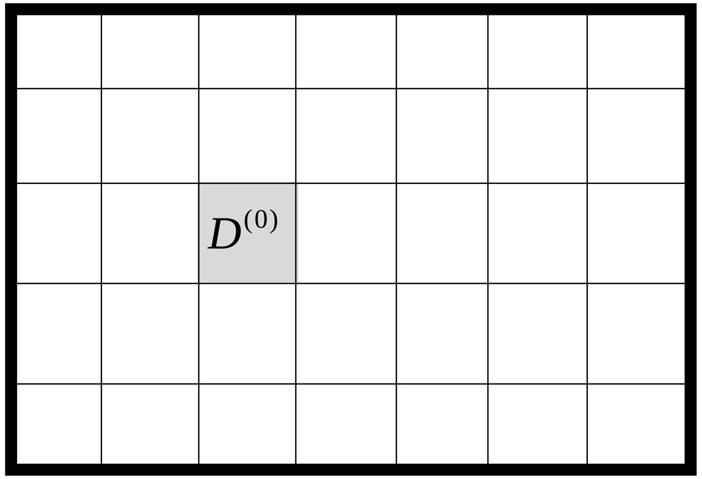
$$\varphi(\mathbf{x}) = \varphi_0, \quad \mathbf{x}\in S_3$$

$$S = S_1\cup S_2\cup S_3\cup S_4$$

The Finite Element Method



The Finite Element Method



Weak Formulation: $\int_{D^{(0)}} w(\mathbf{x})\left[\nabla^2\varphi(\mathbf{x}) - f(\mathbf{x})\right] dV(\mathbf{x}) = 0, \quad \mathbf{x} \in D$

1^st Green Identity

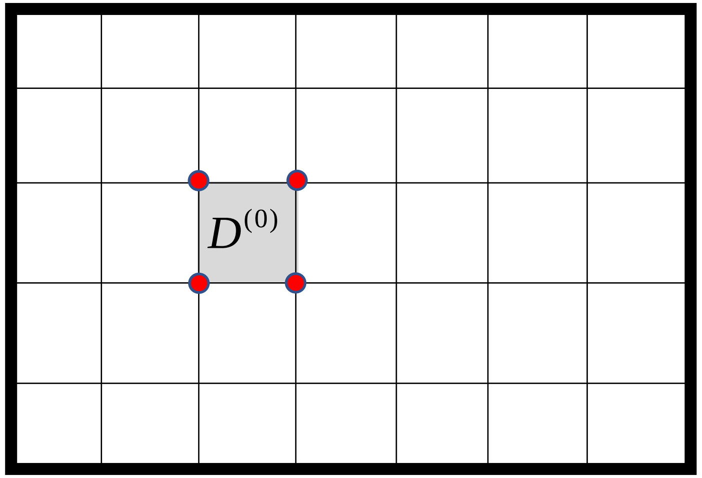
$$\int_{D^{(0)}} w(\mathbf{x}) f(\mathbf{x}) dV(\mathbf{x}) + \int_{D^{(0)}} \nabla w(\mathbf{x}) \cdot \nabla \varphi(\mathbf{x}) dV(\mathbf{x}) = \int_{S^{(0)}} w(\mathbf{x}) q_0(\mathbf{x}) dS(\mathbf{x})$$

For all the internal elements

$$\int_{D^{(0)}} w(\mathbf{x}) f(\mathbf{x}) dV(\mathbf{x}) + \int_{D^{(0)}} \nabla w(\mathbf{x}) \cdot \nabla \varphi(\mathbf{x}) dV(\mathbf{x}) = 0$$

$$\int_{D^{(0)}} \nabla w(\mathbf{x}) \cdot \nabla \varphi(\mathbf{x}) dV(\mathbf{x}) = -\int_{D^{(0)}} w(\mathbf{x}) f(\mathbf{x}) dV(\mathbf{x})$$

The Finite Element Method

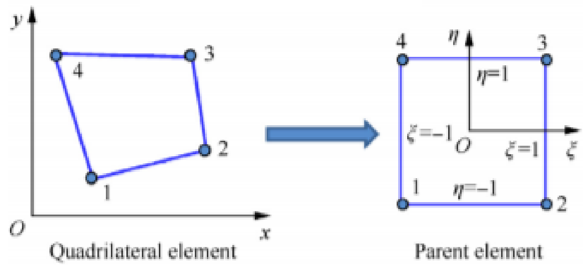


$$\int_{D^{(0)}} \nabla w(\mathbf{x}) \cdot \nabla \varphi(\mathbf{x}) dV(\mathbf{x}) = -\int_{D^{(0)}} w(\mathbf{x}) f(\mathbf{x}) dV(\mathbf{x})$$

$$w = \sum_{n=1}^{4} N^n \cdot w_n \qquad \varphi = \sum_{m=1}^{4} N^m \cdot \varphi_m$$

$$\nabla w = \sum_{n=1}^{4} \nabla N^n \cdot w_n \qquad \nabla \varphi = \sum_{m=1}^{4} \nabla N^m \cdot \varphi_m$$

$$N^n(\xi, \eta)$$



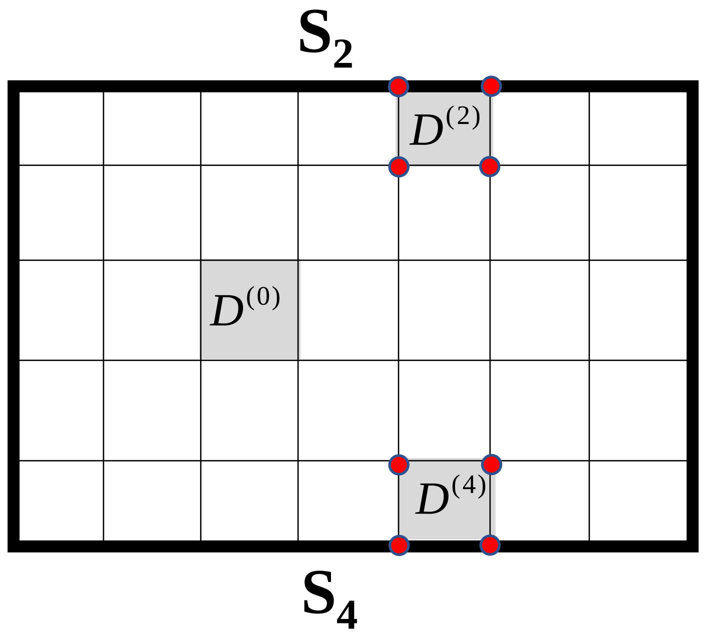
$vector\ 4\times1$ $\quad$ $vector\ 1\times4$

$$\mathbf{w}^{(0)} \cdot \left[\int_{D^{(0)}} \nabla N^n \nabla N^m dV(\mathbf{x}) \right] \cdot \boldsymbol{\varphi}^{(0)} = \mathbf{w}^{(0)} \cdot \left[-\int_{D^{(0)}} N^n f_n dV(\mathbf{x}) \right]$$

$\left[\mathbf{k}^{(0)}\right]$, $matrix\ 4\times4$ $\quad$ $\mathbf{f}^{(0)}$, $vector\ 1\times4$

$$\mathbf{w}^{(0)} \cdot \left[\mathbf{k}^{(0)}\right] \cdot \boldsymbol{\varphi}^{(0)} = \mathbf{w}^{(0)} \cdot \mathbf{f}^{(0)}$$

The Finite Element Method



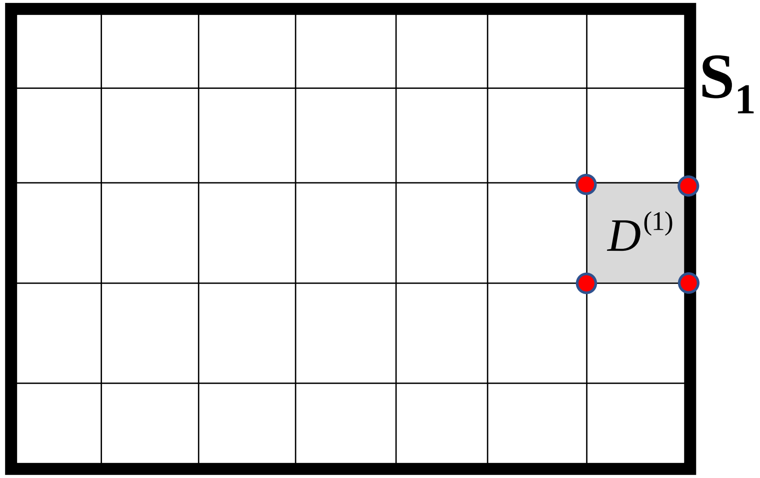
Since the fluxes at boundaries S_2 and S_4 are zero, similar equations for the domains $D^{(2)}$ and $D^{(4)}$ are valid, i.e.

$$\mathbf{w}^{(0)} \cdot \left[\mathbf{k}^{(0)}\right] \cdot \boldsymbol{\varphi}^{(0)} = \mathbf{w}^{(0)} \cdot \mathbf{f}^{(0)}$$

$$\mathbf{w}^{(2)} \cdot \left[\mathbf{k}^{(2)}\right] \cdot \boldsymbol{\varphi}^{(2)} = \mathbf{w}^{(2)} \cdot \mathbf{f}^{(2)}$$

$$\mathbf{w}^{(4)} \cdot \left[\mathbf{k}^{(4)}\right] \cdot \boldsymbol{\varphi}^{(4)} = \mathbf{w}^{(4)} \cdot \mathbf{f}^{(4)}$$

The Finite Element Method



Weak Formulation: $\int_{D^{(1)}} w(\mathbf{x})\left[\nabla^2\varphi(\mathbf{x}) - f(\mathbf{x})\right] dV(\mathbf{x}) = 0, \quad \mathbf{x} \in D$

1st Green Identity

$$\int_{D^{(1)}} w(\mathbf{x}) f(\mathbf{x}) dV(\mathbf{x}) + \int_{D^{(1)}} \nabla w(\mathbf{x}) \cdot \nabla\varphi(\mathbf{x}) dV(\mathbf{x}) = \int_{S_1^{(1)}} w(\mathbf{x}) q_0(\mathbf{x}) dS(\mathbf{x})$$

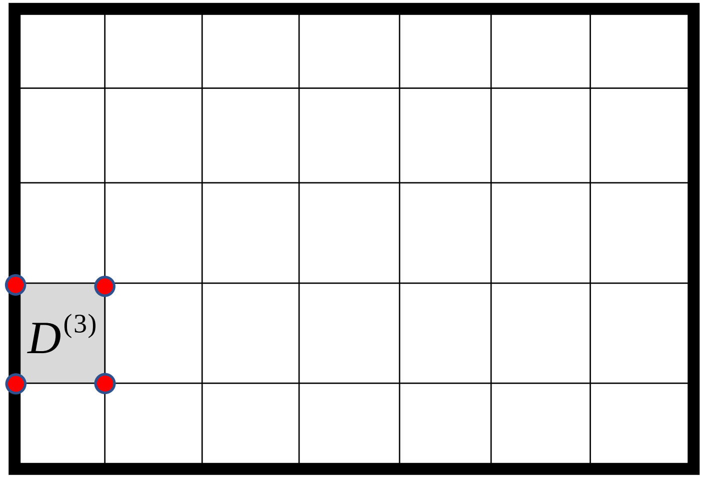
$$\int_{D^{(1)}} \nabla w(\mathbf{x}) \cdot \nabla\varphi(\mathbf{x}) dV(\mathbf{x}) = \int_{S_1^{(1)}} w(\mathbf{x}) q_0(\mathbf{x}) dS(\mathbf{x}) - \int_{D^{(1)}} w(\mathbf{x}) f(\mathbf{x}) dV(\mathbf{x})$$

$$\mathbf{w}^{(1)} \cdot \left[\mathbf{k}^{(1)}\right] \cdot \boldsymbol{\varphi}^{(1)} = \mathbf{w}^{(1)} \cdot \mathbf{f}^{(1)}$$

The Finite Element Method

Weak Formulation: $\int_{D^{(3)}} w(\mathbf{x})\left[\nabla^2\varphi(\mathbf{x}) - f(\mathbf{x})\right]dV(\mathbf{x}) = 0, \quad \mathbf{x}\in D$

S_3



1st Green Identity

$$\int_{D^{(3)}} w(\mathbf{x}) f(\mathbf{x}) dV(\mathbf{x}) + \int_{D^{(3)}} \nabla w(\mathbf{x})\cdot\nabla\varphi(\mathbf{x}) dV(\mathbf{x}) = \int_{S_3^{(3)}} w(\mathbf{x})\partial_n\varphi(\mathbf{x}) dS(\mathbf{x})$$

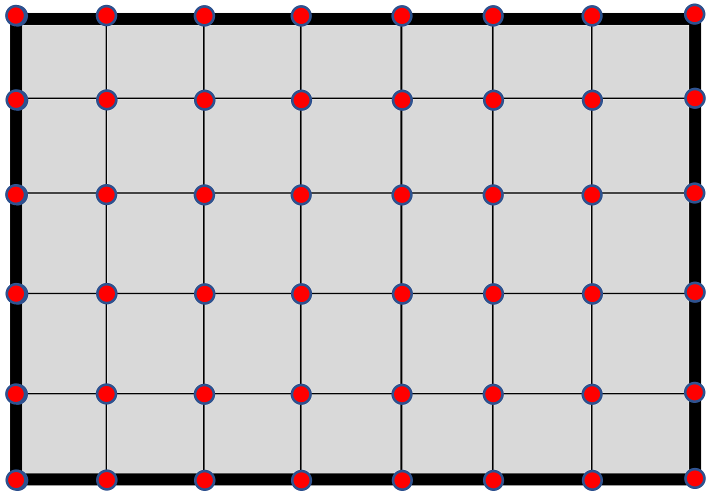
$$\int_{D^{(3)}} \nabla w(\mathbf{x})\cdot\nabla\varphi(\mathbf{x}) dV(\mathbf{x}) - \int_{S_3^{(3)}} w(\mathbf{x})\partial_n\varphi(\mathbf{x}) dS(\mathbf{x}) = -\int_{D^{(3)}} w(\mathbf{x}) f(\mathbf{x}) dV(\mathbf{x})$$

$$\partial_n\varphi = \hat{\mathbf{n}}\cdot\nabla\varphi$$

$$\hat{\mathbf{n}}\cdot\nabla\varphi = \sum_{m=1}^{4}\hat{\mathbf{n}}\cdot\nabla N^m\cdot\varphi_m$$

$$\mathbf{w}^{(3)}\cdot\left[\mathbf{k}^{(3)}\right]\cdot\boldsymbol{\varphi}^{(3)} = \mathbf{w}^{(3)}\cdot\mathbf{f}^{(3)}$$

The Finite Element Method



The vector **Φ** contains all the unknown nodal potentials of the problem

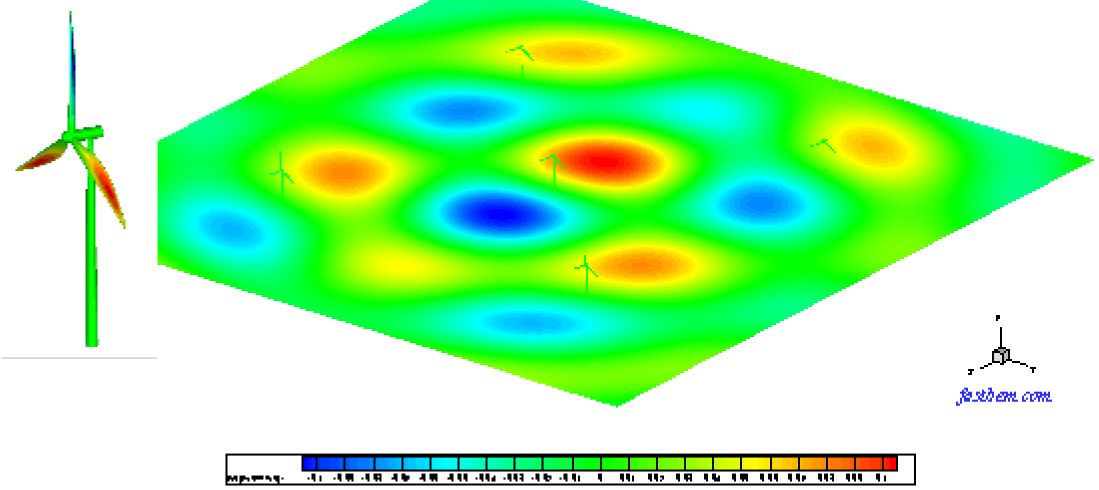
The assembly of all equations, produced for each element, provides the following equation valid for any arbitrary vector **W**:

$$\mathbf{W} \cdot [\mathbf{K}] \cdot \mathbf{\Phi} = \mathbf{W} \cdot \mathbf{F}$$

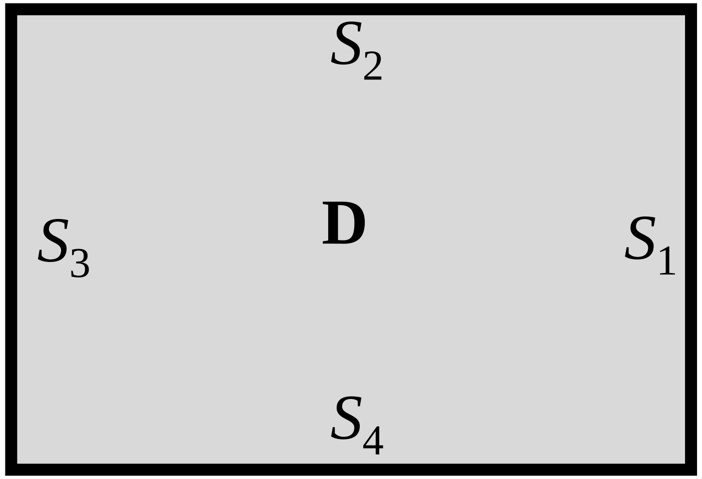
$$\Downarrow$$

$$[\mathbf{K}] \cdot \mathbf{\Phi} = \mathbf{F}$$

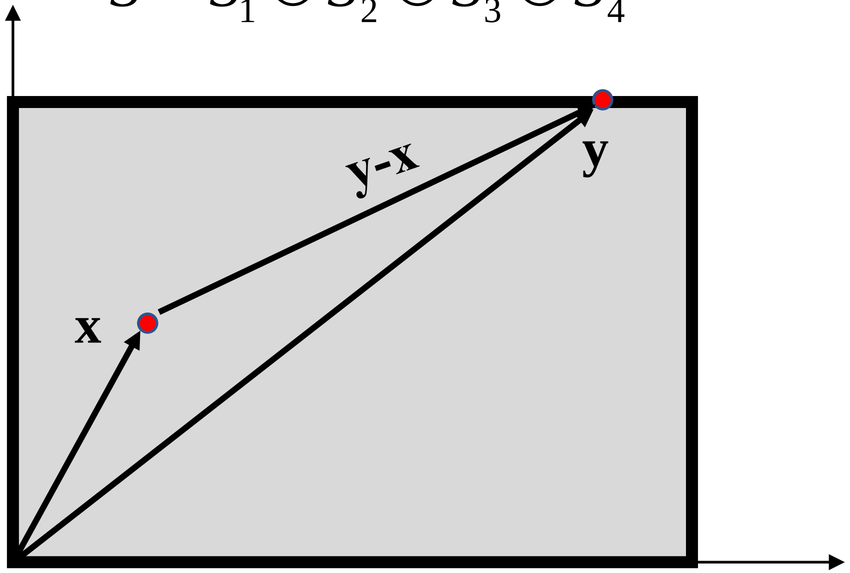
The Boundary Element Method



The Boundary Element Method



$$S = S_1 \cup S_2 \cup S_3 \cup S_4$$



Weak Formulation: $\int_D w(\mathbf{x})\left[\nabla^2\varphi(\mathbf{x}) - f(\mathbf{x})\right]dV(\mathbf{x}) = 0, \quad \mathbf{x} \in D$

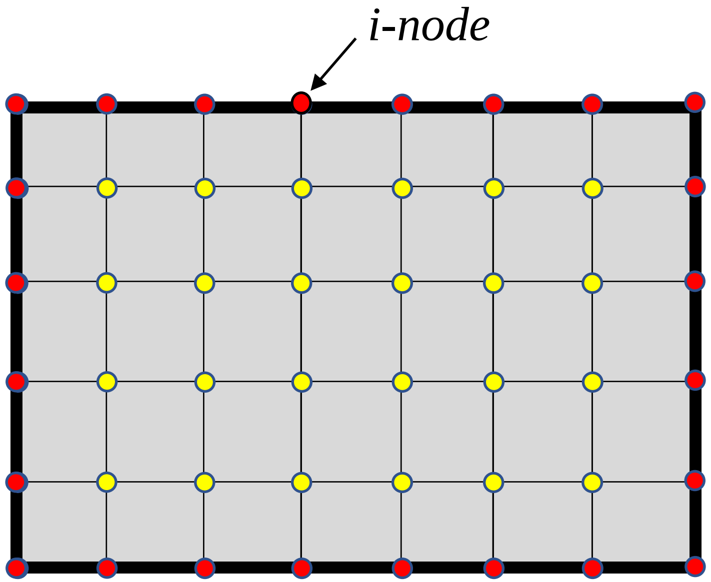
2nd Green Identity

$$\int_D \left[w(\mathbf{x})f(\mathbf{x}) - \varphi\nabla^2 w\right]dV(\mathbf{x}) + \int_S w(\mathbf{x})\partial_n\varphi(\mathbf{x})dS(\mathbf{x}) - \int_S \varphi(\mathbf{x})\partial_n w(\mathbf{x})dS(\mathbf{x}) = 0$$

$$w(\mathbf{x}) \equiv G(\mathbf{x},\mathbf{y}) = \frac{1}{2\pi}\ln|\mathbf{y}-\mathbf{x}| \qquad \nabla^2 G(\mathbf{x},\mathbf{y}) = \delta(\mathbf{x},\mathbf{y})$$

$$c\varphi(\mathbf{x}) + \int_S \varphi(\mathbf{y})\partial_n G(\mathbf{y},\mathbf{x})dS(\mathbf{y}) = \int_S G(\mathbf{y},\mathbf{x})\partial_n\varphi(\mathbf{y})dS(\mathbf{y}) + \int_D G(\mathbf{y},\mathbf{x})f(\mathbf{y})dV(\mathbf{y})$$

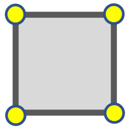
The Boundary Element Method



L boundary nodes
M internal nodes

$$c\varphi(\mathbf{x}) + \int_S \varphi(\mathbf{y})\partial_n G(\mathbf{y},\mathbf{x})dS(\mathbf{y}) = \int_S G(\mathbf{y},\mathbf{x})\partial_n \varphi(\mathbf{y})dS(\mathbf{y}) + \int_D G(\mathbf{y},\mathbf{x})\, f(\mathbf{y})dV(\mathbf{y})$$

$$\varphi = \sum_{n=1}^{2} \Phi^n \cdot \varphi_n$$

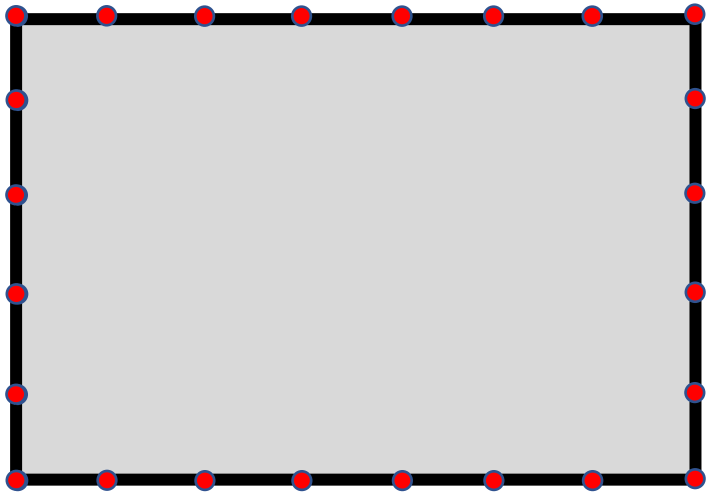


$$\varphi = \sum_{m=1}^{4} N^m \cdot \varphi_m$$

$$f = \sum_{m=1}^{4} N^m \cdot f_m$$

$$\frac{1}{2}\varphi_i + \underbrace{\left[\int_S \Phi(\mathbf{y})\partial_n G(\mathbf{y},\mathbf{x})dS(\mathbf{y})\right]_{ij}}_{[\mathbf{H}],\ matrix\ L\times L} \varphi_j = \underbrace{\left[\int_S G(\mathbf{y},\mathbf{x})\Phi(\mathbf{y})dS(\mathbf{y})\right]_{ij}}_{[\mathbf{G}],\ matrix\ L\times L} q_j + f_i$$

The Boundary Element Method



L boundary nodes

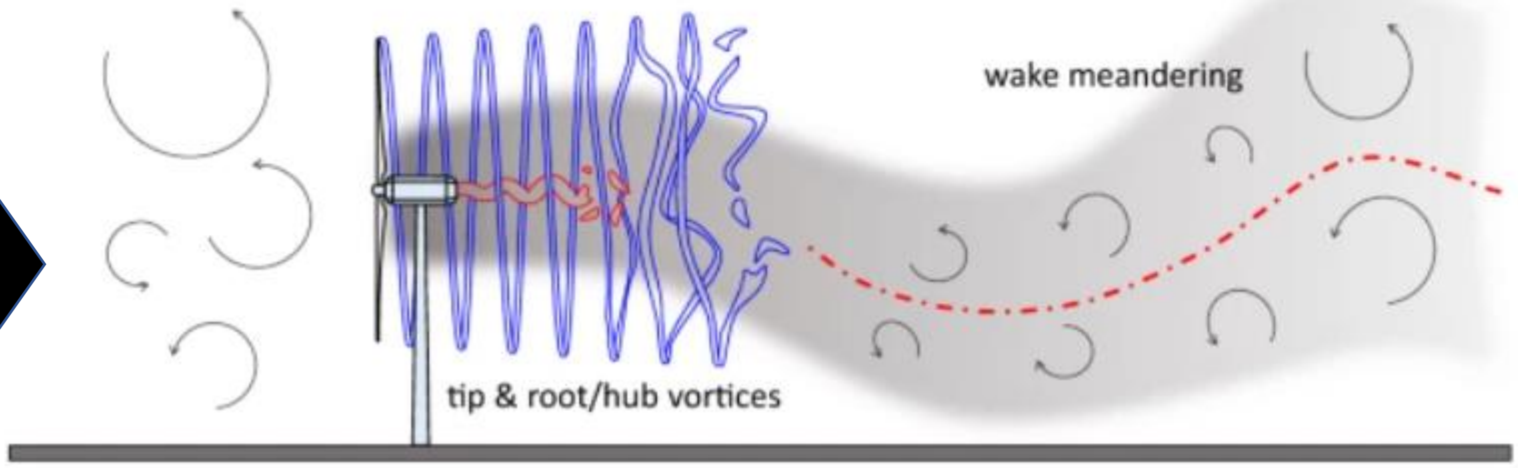
Vectors $1 \times L$

$$\underbrace{\left[\frac{1}{2}\mathbf{I} + \mathbf{H}\right]}_{Matrix\ L \times L} \cdot \boldsymbol{\varphi} = \underbrace{[\mathbf{G}]}_{Matrix\ L \times L} \cdot \mathbf{q} + \mathbf{f}$$

Inserting BCs

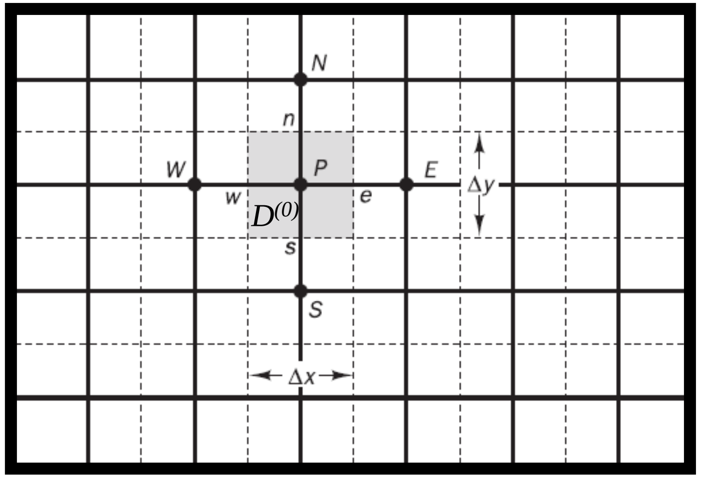
$$[\mathbf{A}] \cdot \mathbf{X} = \mathbf{B}$$

The Finite Volumes Method



Finite Volumes Method

Weak Formulation: $$\int_{D^{(0)}} w(\mathbf{x})\left[\nabla^2\varphi(\mathbf{x}) - f(\mathbf{x})\right]dV(\mathbf{x}) = 0, \quad \mathbf{x} \in D$$



$$w(\mathbf{x}) = 1$$

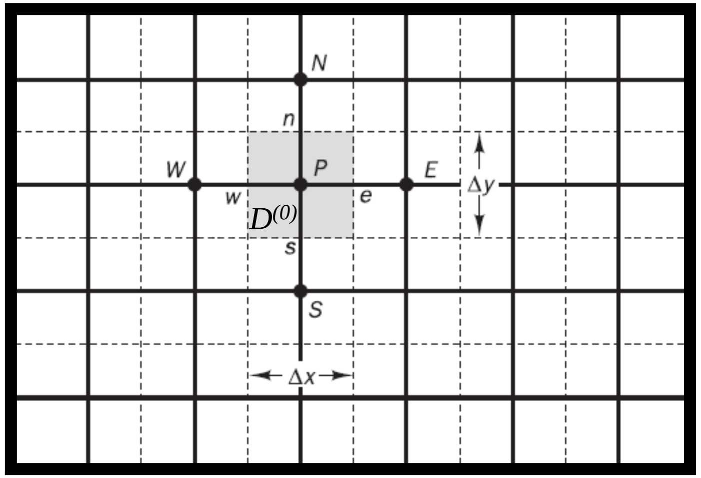
$$\int_{D^{(0)}} \left[\nabla^2\varphi(\mathbf{x}) - f(\mathbf{x})\right]dV(\mathbf{x}) = 0, \quad \mathbf{x} \in D$$

Divergence Theorem

$$\int_{S^{(0)}} \hat{\mathbf{n}} \cdot \nabla\varphi(\mathbf{x})dS(\mathbf{x}) - \int_{D^{(0)}} f(\mathbf{x})dV(\mathbf{x}) = 0, \quad \mathbf{x} \in D$$

Finite Volumes Method

$$\int_{S^{(0)}} \underbrace{\hat{\mathbf{n}} \cdot \nabla \varphi(\mathbf{x})}_{q(\mathbf{x})} dS(\mathbf{x}) - \int_{D^{(0)}} f(\mathbf{x}) dV(\mathbf{x}) = 0, \quad \mathbf{x} \in D$$

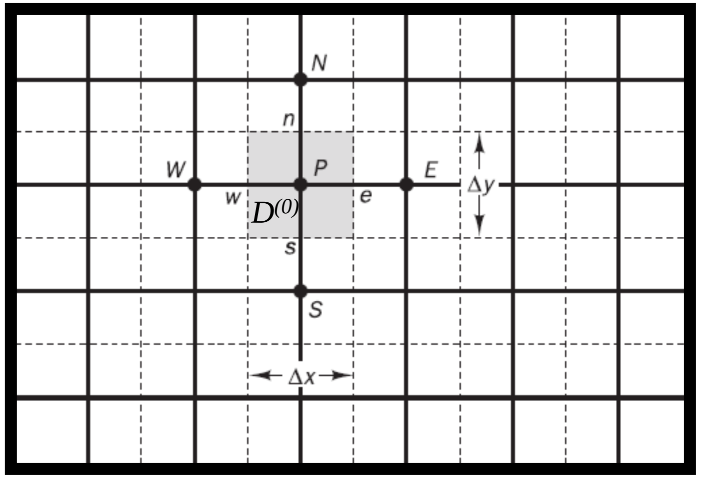


$$\left[S_e \cdot q_e - S_w \cdot q_w\right] + \left[S_n \cdot q_n - S_s \cdot q_s\right] + \bar{f} V_D = 0$$

$$\left[S_e \left(\frac{\partial \varphi}{\partial x}\right)_e - S_w \left(\frac{\partial \varphi}{\partial x}\right)_w\right] + \left[S_n \left(\frac{\partial \varphi}{\partial y}\right)_n - S_s \left(\frac{\partial \varphi}{\partial y}\right)_s\right] + \bar{f} V_D = 0$$

Finite Volumes Method

$$\left[S_e\left(\frac{\partial\varphi}{\partial x}\right)_e - S_w\left(\frac{\partial\varphi}{\partial x}\right)_w\right] + \left[S_n\left(\frac{\partial\varphi}{\partial y}\right)_n - S_s\left(\frac{\partial\varphi}{\partial y}\right)_s\right] + \bar{f}V_D = 0$$



$$q_w = \left(\frac{\partial\varphi}{\partial x}\right)_w = \frac{\varphi_P - \varphi_W}{\delta x_{WP}}$$

$$q_e = \left(\frac{\partial\varphi}{\partial x}\right)_e = \frac{\varphi_E - \varphi_P}{\delta x_{PE}}$$

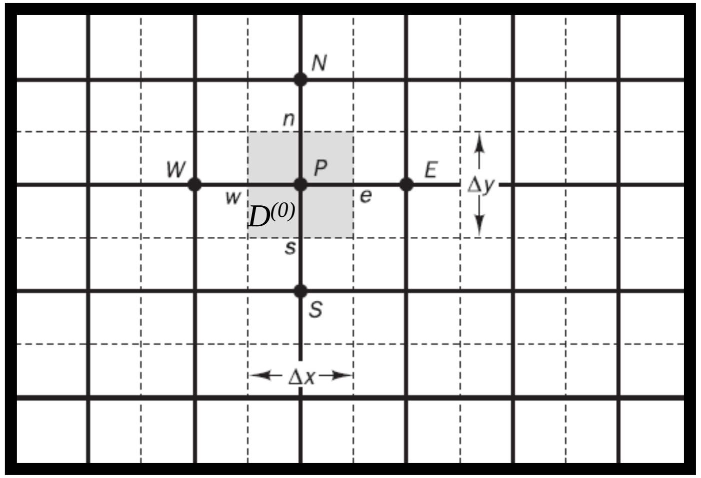
$$q_s = \left(\frac{\partial\varphi}{\partial y}\right)_s = \frac{\varphi_P - \varphi_S}{\delta x_{SP}}$$

$$q_n = \left(\frac{\partial\varphi}{\partial y}\right)_n = \frac{\varphi_N - \varphi_P}{\delta x_{PN}}$$

$$S_e\frac{\varphi_E - \varphi_P}{\delta x_{PE}} - S_w\frac{\varphi_P - \varphi_W}{\delta x_{WP}} + S_n\frac{\varphi_N - \varphi_P}{\delta x_{PN}} - S_s\frac{\varphi_P - \varphi_S}{\delta x_{SP}} + \bar{f}V_D = 0$$

Finite Volumes Method

$$S_e \frac{\varphi_E - \varphi_P}{\delta x_{PE}} - S_w \frac{\varphi_P - \varphi_W}{\delta x_{WP}} + S_n \frac{\varphi_N - \varphi_P}{\delta x_{PN}} - S_s \frac{\varphi_P - \varphi_S}{\delta x_{SP}} + \bar{f} V_D = 0$$



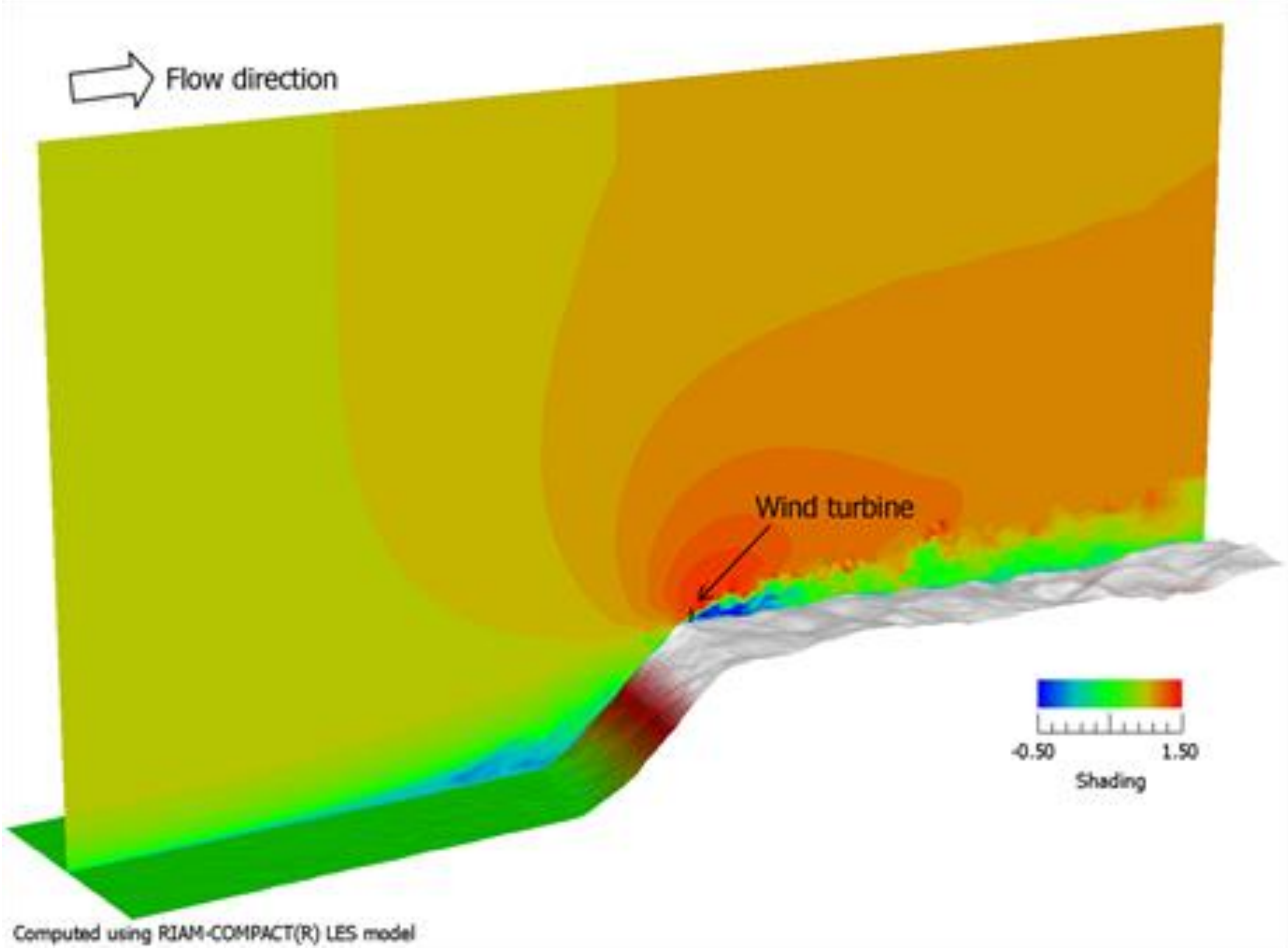
$$a_P \varphi_P = a_P \varphi_P + a_E \varphi_E + a_S \varphi_S + a_N \varphi_N + F_P = 0$$

Treating BCs

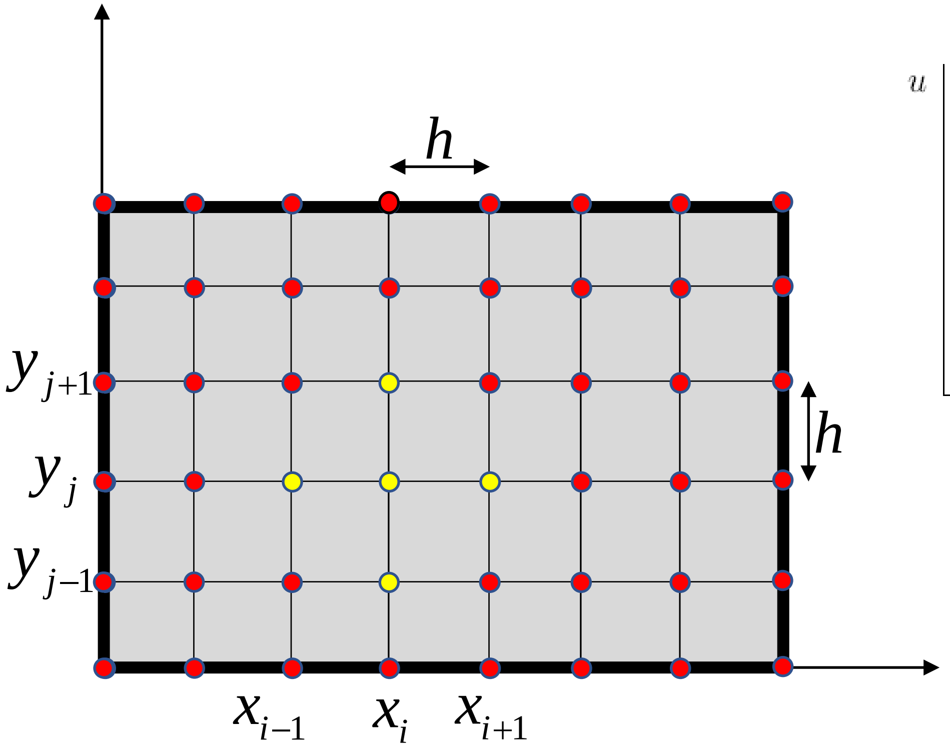
Collocating at all internal points

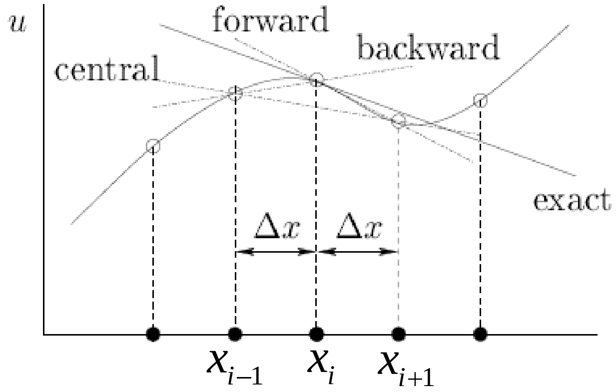
$$[\mathbf{A}] \cdot \mathbf{\Phi} = \mathbf{B}$$

The Finite Differences Method



The Finite Differences Method





$$\left(\frac{\partial u}{\partial x}\right)_i \approx \frac{u_{i+1}-u_i}{\Delta x}$$ forward difference

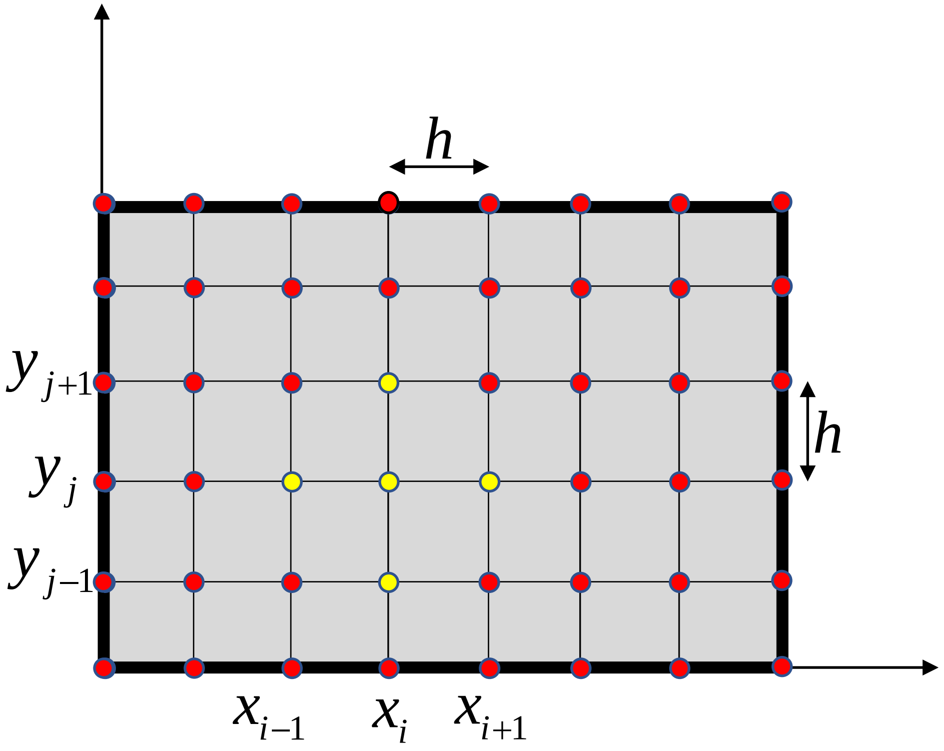
$$\left(\frac{\partial u}{\partial x}\right)_i \approx \frac{u_i-u_{i-1}}{\Delta x}$$ backward difference

$$\left(\frac{\partial u}{\partial x}\right)_i \approx \frac{u_{i+1}-u_{i-1}}{2\Delta x}$$ central difference

$$u_{i+1} = u_i + \Delta x\left(\frac{\partial u}{\partial x}\right)_i + \frac{(\Delta x)^2}{2}\left(\frac{\partial^2 u}{\partial x^2}\right)_i + \frac{(\Delta x)^3}{6}\left(\frac{\partial^3 u}{\partial x^3}\right)_i + \ldots$$

$$u_{i-1} = u_i - \Delta x\left(\frac{\partial u}{\partial x}\right)_i + \frac{(\Delta x)^2}{2}\left(\frac{\partial^2 u}{\partial x^2}\right)_i - \frac{(\Delta x)^3}{6}\left(\frac{\partial^3 u}{\partial x^3}\right)_i + \ldots$$

The Finite Differences Method



$$\nabla^2\varphi(x,y) - f(x,y) = 0$$

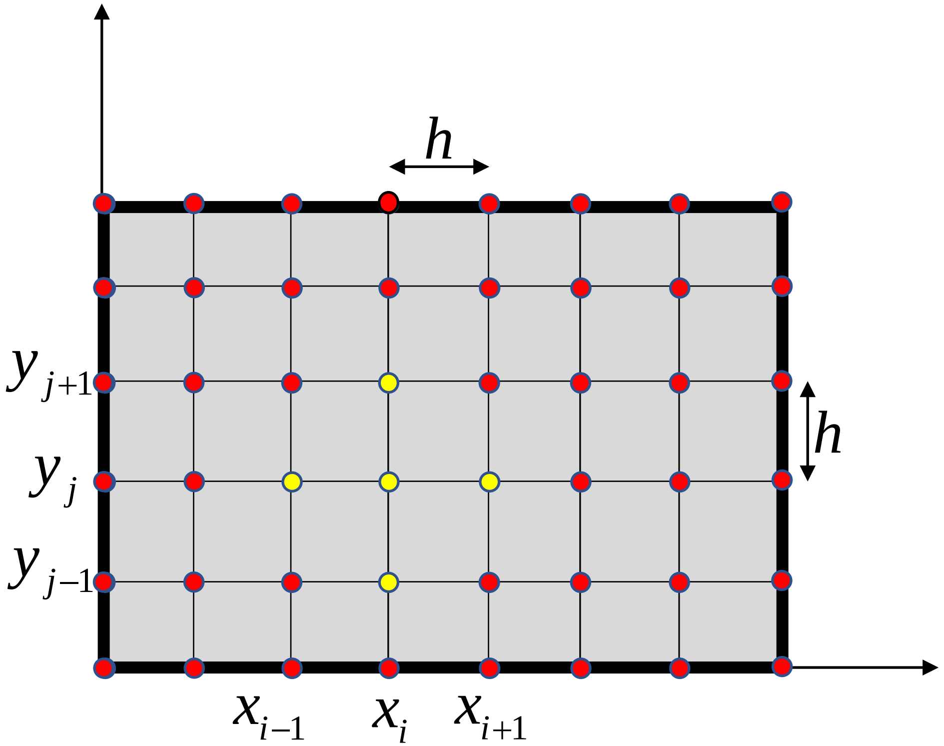
$$\varphi(x_i, y_j) \equiv \varphi_i^j$$

$$f(x_i, y_j) \equiv f_i^j$$

$$(x_i, y_j) = (ih, jh), \quad \Delta x = \Delta y = h$$

$$\nabla^2\varphi(x,y) = \frac{\varphi_{i-1}^j + \varphi_i^{j-1} - 4\varphi_i^j + \varphi_{i+1}^j + \varphi_i^{j+1}}{h^2}$$

The Finite Differences Method



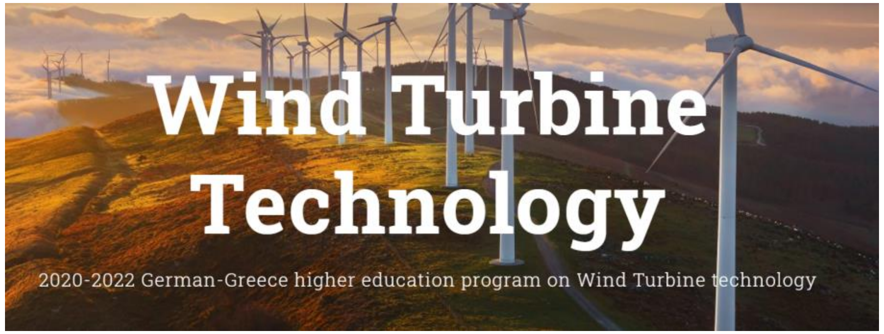
$$\nabla^2 \varphi(x,y) - f(x,y) = 0$$

$$\frac{\varphi_{i-1}^{j} + \varphi_{i}^{j-1} - 4\varphi_{i}^{j} + \varphi_{i+1}^{j} + \varphi_{i}^{j+1}}{h^2} = f_i^{\,j}$$

Treating BCs

Collocating at all stencils

$$[\mathbf{A}]\cdot \mathbf{\Phi} = \mathbf{F}$$



Workshop 1

Numerical Simulations for Wind Turbine Engineering Problems

28/06/2021-03/07/2021

1st Day: Teaching

9:00-9:30	Registration and welcome
9:30-10:00	**Workshop opening by Prof. T. Triantafyllidis and Prof. D. Polyzos**
10:00-10:50	**Wind Energy in Greece: Current Status, Developments, Market and Technology Trends** Panagiotis Ladakakos, HWEA, President
11:00-11:50	**Simulations in Wind Turbine Technology** Prof. Demosthenes Polyzos
12:00-12:20	**Break**
BEM 12:30-13:30	**The Boundary Element Method for Acoustics and Fluid-Structure interaction problems** Dr. Theodore Gortsas and Prof. Demosthenes Polyzos

2nd Day: Teaching

9:15-10:00	BEM	**Cathodic Protection Design for offshore Wind Turbines, Part 1** Prof. Stephanos Tsinopoulos
10:15-11:00		**Cathodic Protection Design for offshore Wind Turbines, Part 2** Prof. Stephanos Tsinopoulos
11:00-11:30		**Break**
11:30-12:30	BEM/FEM	**Solving Selected Nonlinear Problems with the Finite and Boundary Element Methods** Prof. George Hatzigeorgiou
12:30-13:30		**How Wind Turbine Engineers Confront Structural Nonlinearities** Prof. George Hatzigeorgiou

3rd Day: Teaching

9:15-10:00	**Wind Turbine Structural Dynamics with the Finite Element Method, Part 1** Prof. Dimitrios Saravanos
FEM 10:15-11:00	**Wind Turbine Structural Dynamics with the Finite Element Method, Part 2** Prof. Dimitrios Saravanos
11:00-11:30	**Break**
11:30-12:30	**Wind Turbines and Digital Twin Technology, Part 1** Charis Kokkinos, FEAC Engineering
12:30-13:30	**Wind Turbines and Digital Twin Technology, Part 2** Charis Kokkinos, FEAC Engineering

4th Day: Teaching

FEM, FVM FDM

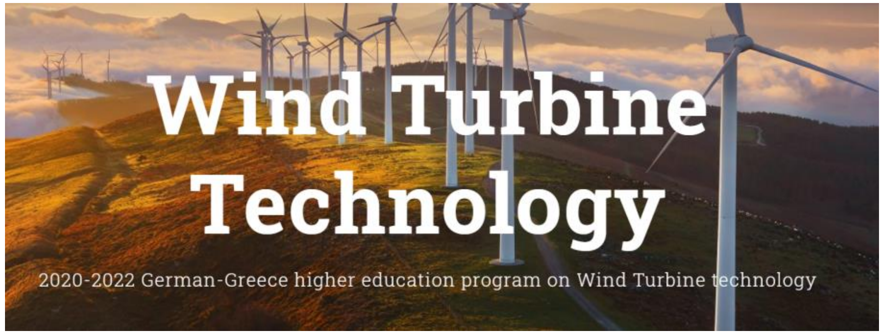
9:15-10:00	**Computer Fluid Dynamics for Wind Turbine Engineering Problems, Part 1** Prof. Thorsten Lutz
10:15-11:00	**Computer Fluid Dynamics for Wind Turbine Engineering Problems, Part 2** Prof. Thorsten Lutz
11:00-11:30	**Break**
11:30-12:30	**1D System Simulation for the Operation of Wind Turbines using SIEMENS Amesim, Part 1** Charis Kokkinos and Dionisis Pettas, FEAC Engineering
12:30-13:30	**1D System Simulation for the Operation of Wind Turbines using SIEMENS Amesim, Part 2** Charis Kokkinos and Dionisis Pettas, FEAC Engineering

5th Day: Simulations practice

BEM	9:15-10:00	**Boundary Element Method Laboratory: Solving a problem with BEM, Part 1** Prof. Stephanos Tsinopoulos and Dr. Theodore Gortsas
	10:15-11:00	**Boundary Element Method Laboratory: Solving a problem with BEM, Part 2** Prof. Stephanos Tsinopoulos and Dr. Theodore Gortsas
	11:00-11:30	**Break**
FEM	11:30-12:30	**Finite Element Method Laboratory: Solving structural dynamic problems with FEM, Part 1** Prof. Dimitrios Saravanos
	12:30-13:30	**Finite Element Method Laboratory: Solving structural dynamic problems with FEM, Part 2** Prof. Dimitrios Saravanos

6th Day: Simulations practice

9:15-10:00	**Vibro-acoustics Simulations using SIEMENS Simcenter 3D, Part 1** Dr. Theodore Gortsas and Charis Kokkinos
FEM	
10:15-11:00	**Vibro-acoustics Simulations using SIEMENS Simcenter 3D, Part 2** Dr. Theodore Gortsas and Charis Kokkinos
11:00-11:30	**Break**
11:30-12:30	**Fluid-Structure Interaction (FSI) Simulation using SIEMENS Star-CCM+ & Simcenter 3D, Part 1** Charis Kokkinos and Konstantinos Loukas, FEAC Engineering
FEM	
12:30-13:30	**Fluid-Structure Interaction (FSI) Simulation using SIEMENS Star-CCM+ & Simcenter 3D, Part 2** Charis Kokkinos and Konstantinos Loukas, FEAC Engineering



Thank you for your attention