Research overview in SCCS

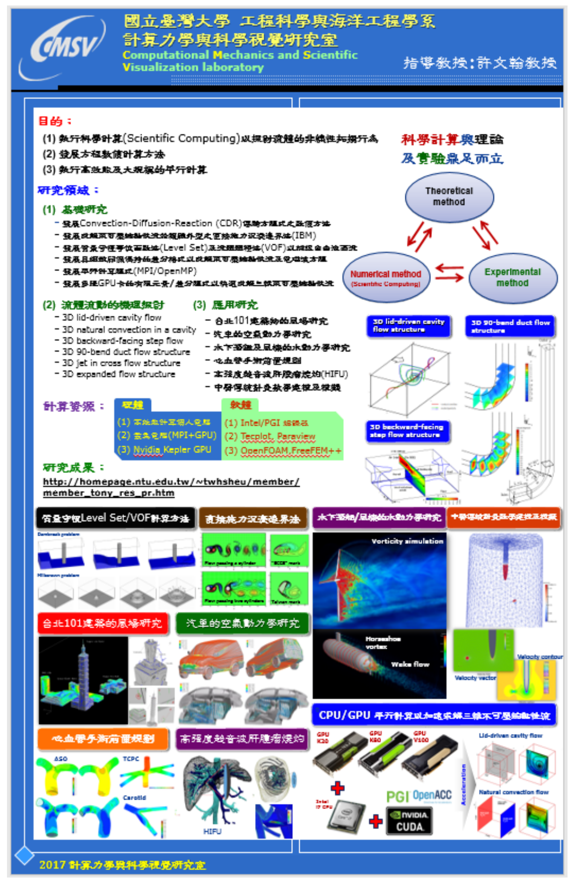
Introduction

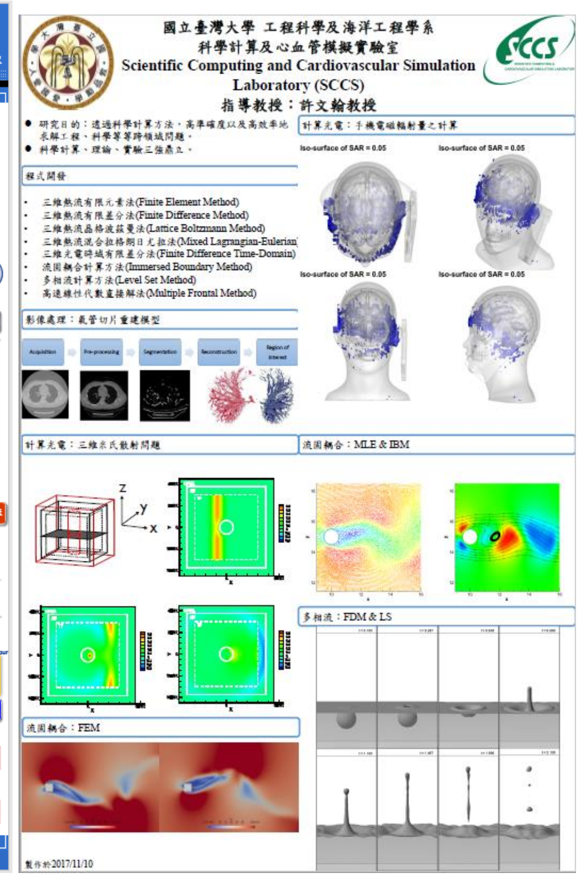
SCCS stands for

Scientific **C**omputing and **C**ardiovascular **S**imulation

(http://homepage.ntu.edu.tw/~twhsheu/index.htm)

- Established in **2001**
- Director – Prof. Tony Wen-Hann Sheu
- Current students
  - 2 post-doctoral
  - 7 PhD students
  - 6 Master students





SCCS current members


Tony Wen-Hann Sheu
Director


Maxim A. Solovchuk
Post-Doctoral
Professor


Neo Shih-Chao Kao
Post-Doctoral


C. Symphony
Post-Doctoral


Rex Kuan-Shuo Liu
PhD student


Chen-Yu Chiang
PhD student


Yee-Yuon Ng
PhD student


Po-Yi Wu
PhD student


Zilonova Ekaterina
PhD student

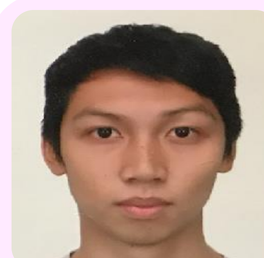

Filip Ivancic
PhD student

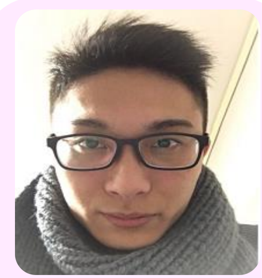

Kumar Saurabh
PhD student

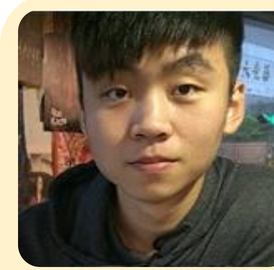

Shu-Sheng Chou
Master student


Cheng-Tao Wu
Master student


Ting-Jui Nieh
Master student


Chin-Ming Wang
Master student

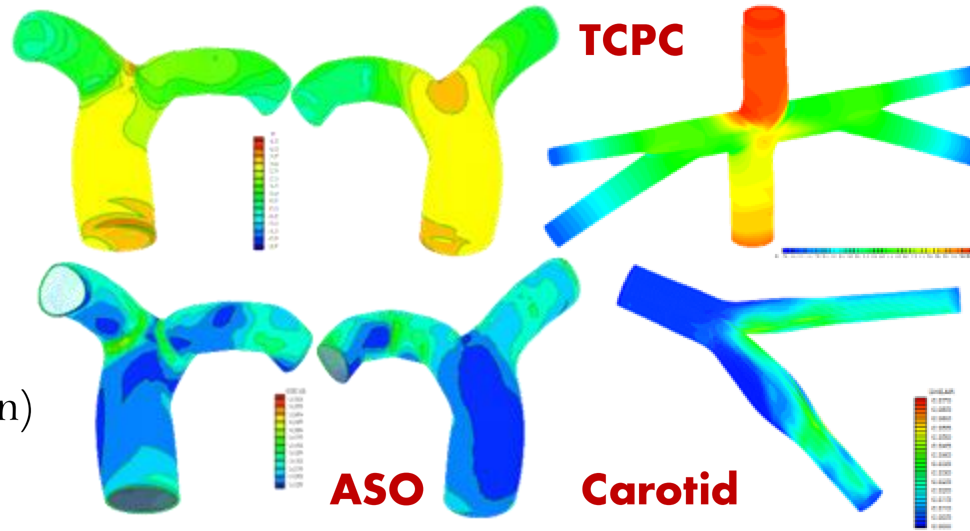

Yu-Chi Lo
Master student

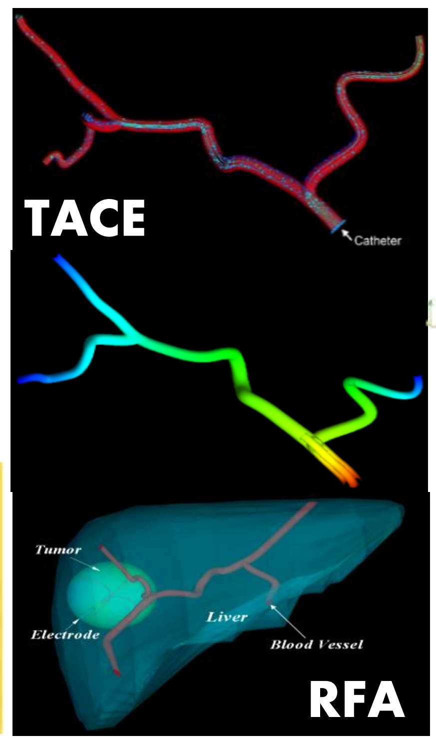

Hao-Liang Wen
Undergraduate student

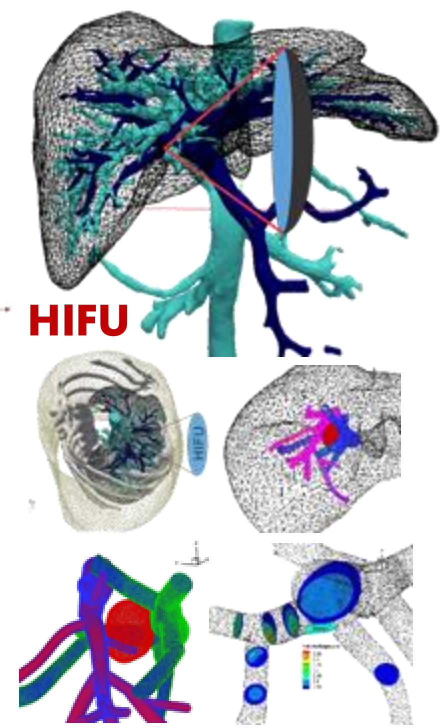
(I) Summary of SCCS previous works

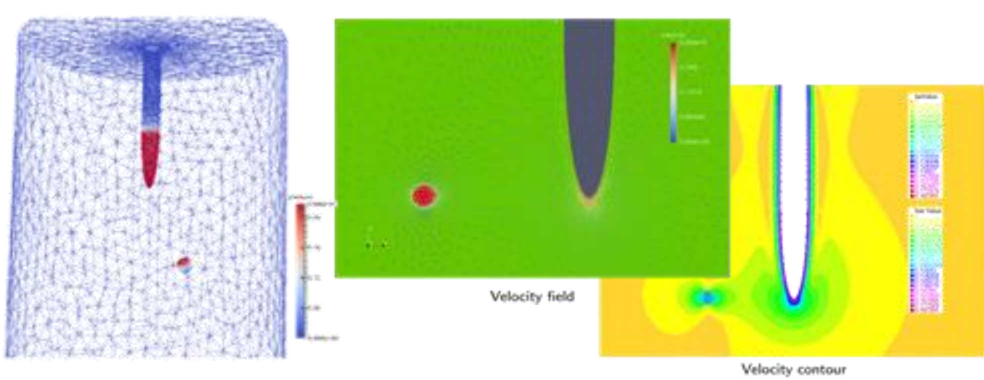
1. Computational surgery

- <u>Congenital heart diseases</u>
  - **TCPC** (**T**otal **C**avo**P**ulmonary **C**onnection)
  - **ASO** (**A**rterial **S**witch **O**peration)
- <u>Adult heart disease</u>
  - Coronary artery by-pass surgery
- <u>Liver tumor surgical planning</u>
  - **TACE** (**T**rans **A**rterial **C**hemo-**E**mbolization)
  - **RFA** (**R**adio **F**requency **A**blation)
  - **HIFU** (**H**igh **I**ntensity **F**ocal **U**ltrasound)
  - Liver transplant surgery
- <u>Traditional Chinese medicine</u>
  - Electro Osmotic Fluid (EOF) model for studying chi-blood interaction
  - Acupuncture modeling and simulation (針)
  - Moxibustion modeling and simulation (灸)



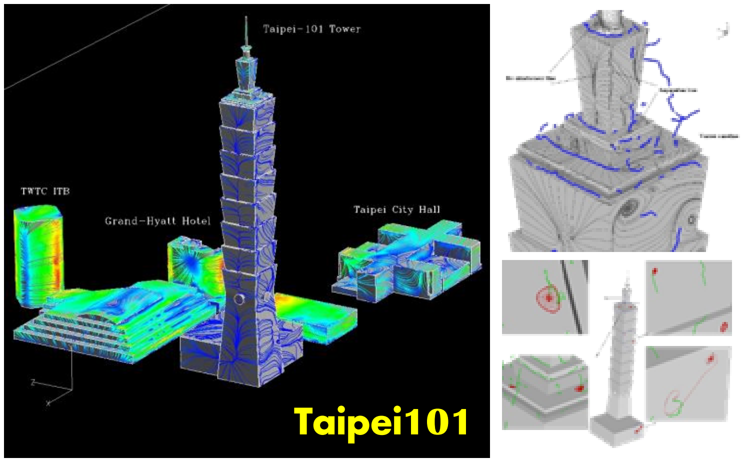




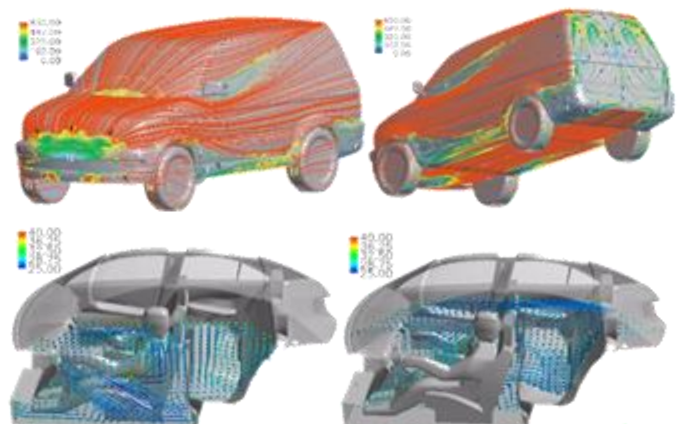


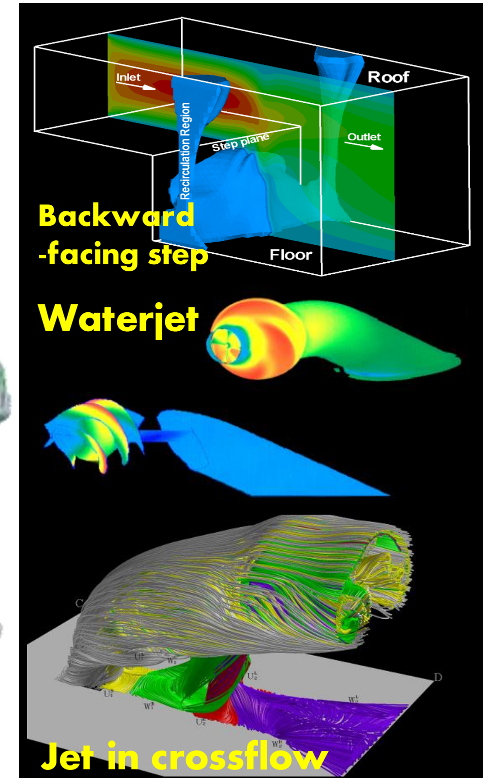
2. Computational physics

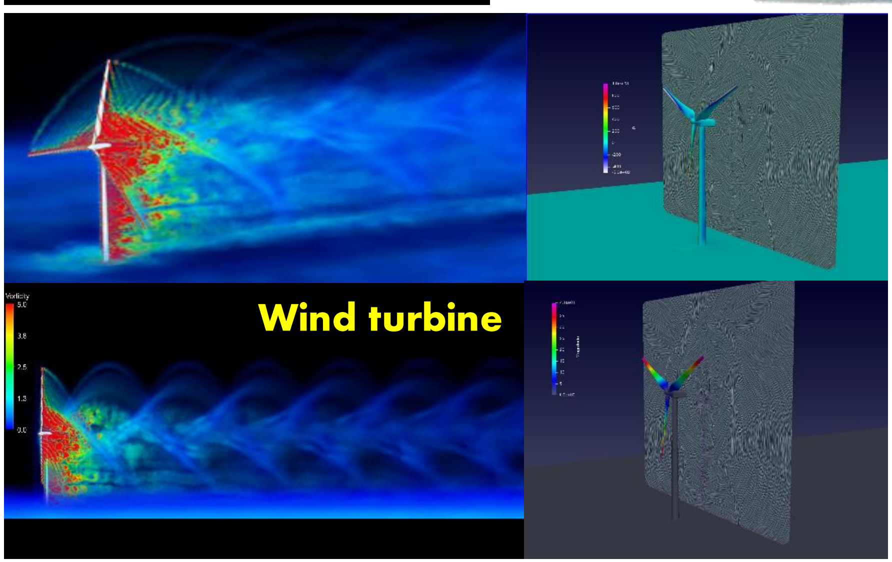
- Nonlinear dynamics around a high rising building
- Nonlinear dynamics in moving cars
- Nonlinear dynamics in waterjet
- Nonlinear dynamics of a propelling submerged body flow
- Nonlinear dynamics of wind turbine

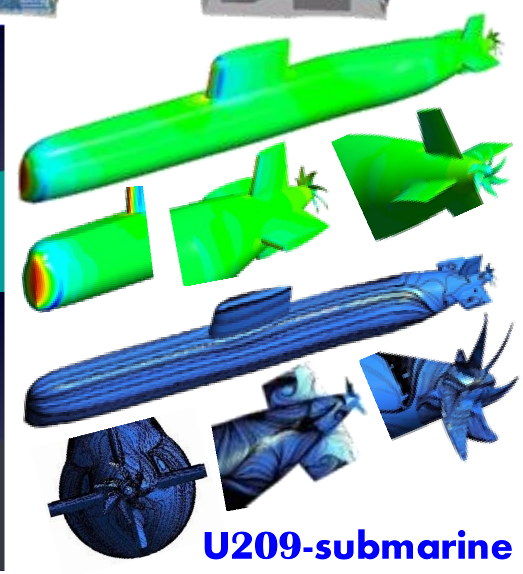


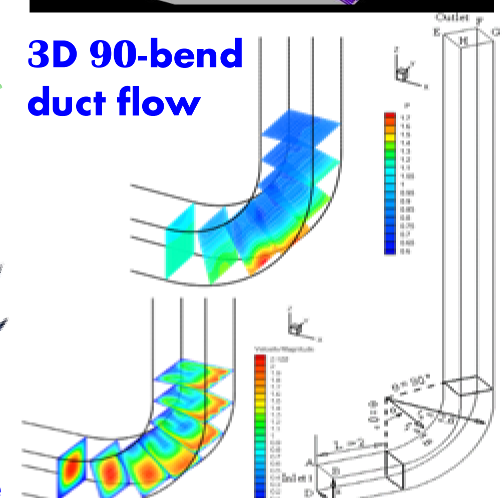
Vortical flow structure of a car







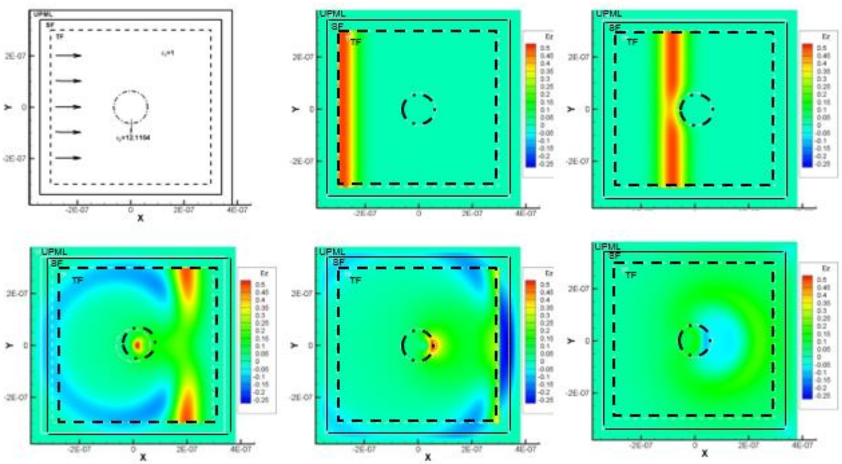




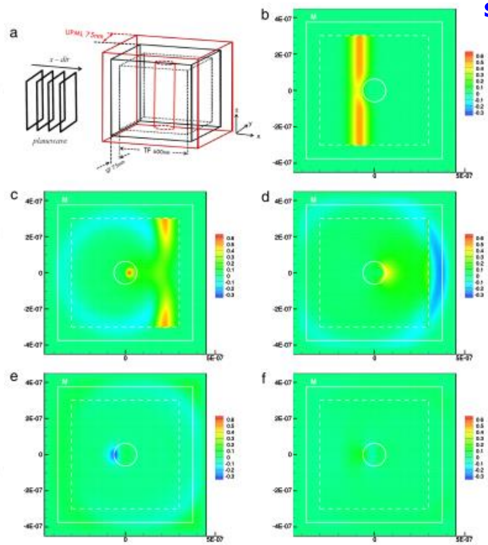
3. Computational EM wave

- Maxwell's equations in ideal medium and in media like plasma, dielectric and metals
- Schrödinger equation

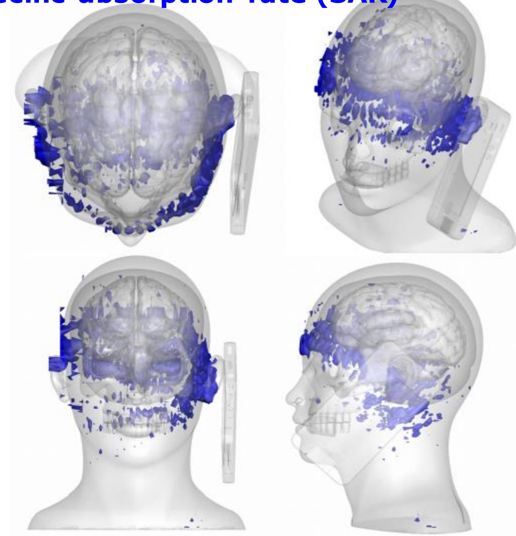
2D Mia-Scatter problem



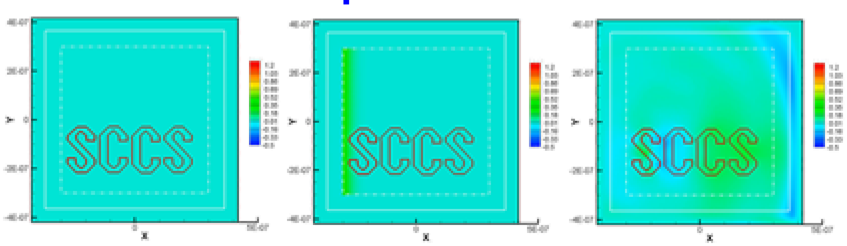
3D Mia-Scatter problem



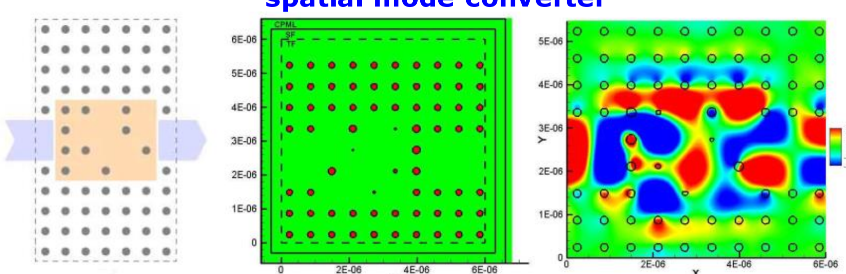
Prediction of mobile phone induced specific absorption rate (SAR)



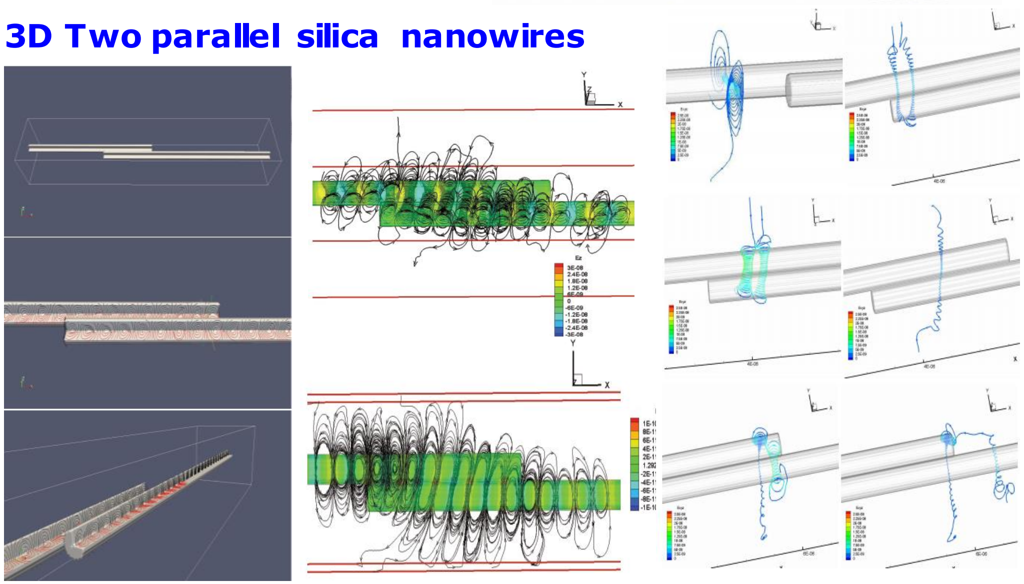
2D Mia-Scatter problem over "SCCS" mark



3D simulation of a photonic crystal waveguide spatial mode converter



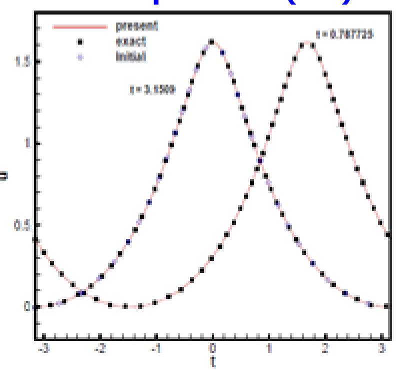
3D Two parallel silica nanowires



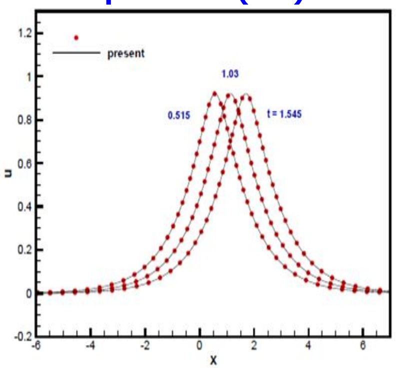
4. Computational integrable systems

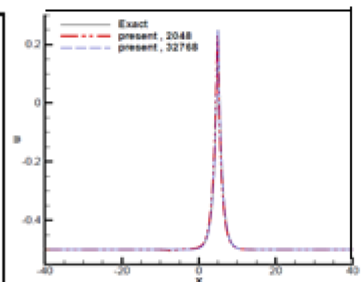
- CH (**C**amassa-**H**olm) equation
- DP (**D**egasperis-**P**rocesi) equation
- KS (**K**eller-**S**egel) equation
- 2-CH (Two-component CH) equation
- 2-HS (Two-component Hunter Saxon) equation

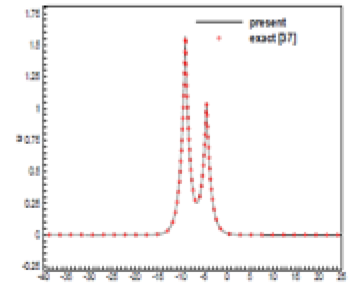
Smooth travelling wave problem (CH)



One-soliton problem (CH)

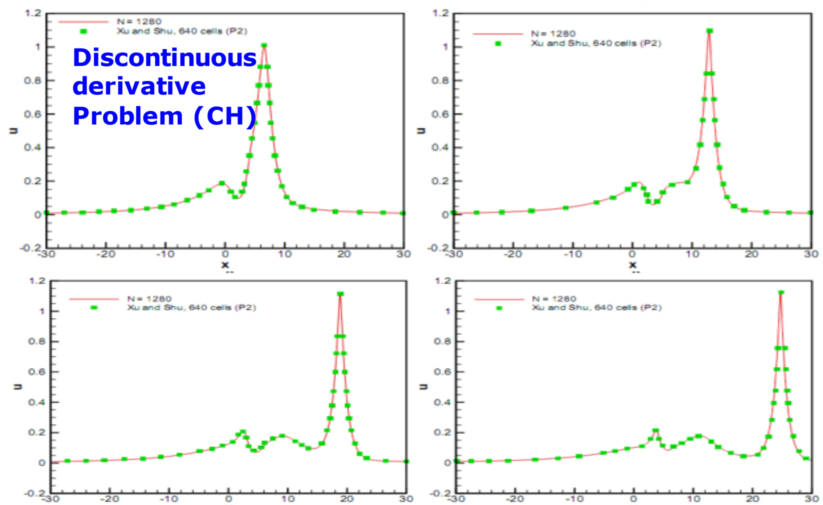




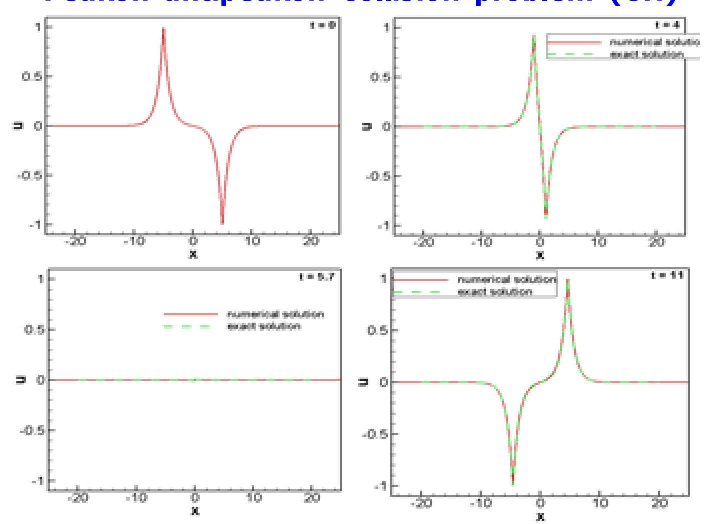


One–peakon problem **Two–peakon problem**

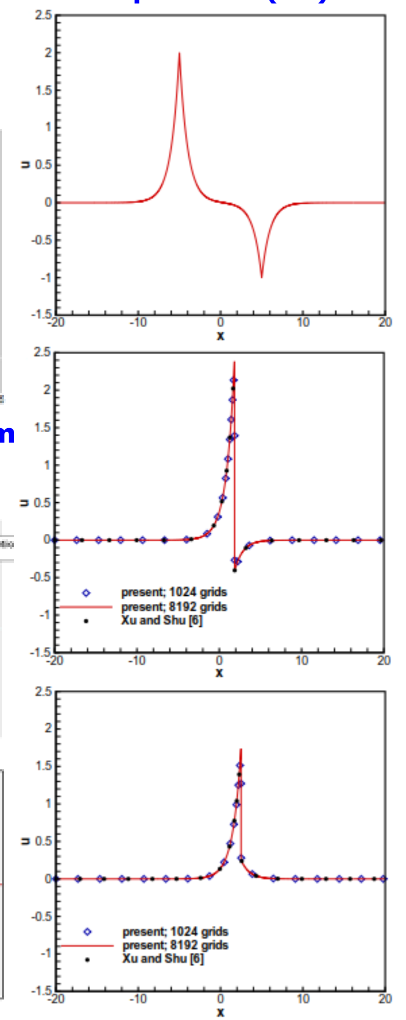
Discontinuous derivative Problem (CH)



Peakon-antipeakon collision problem (CH)



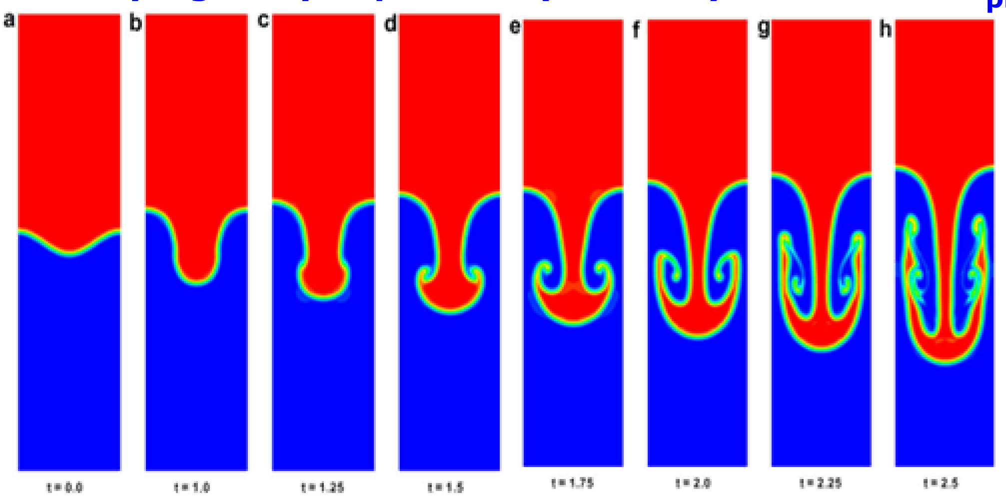
Peakon-antipeakon problem (DP)



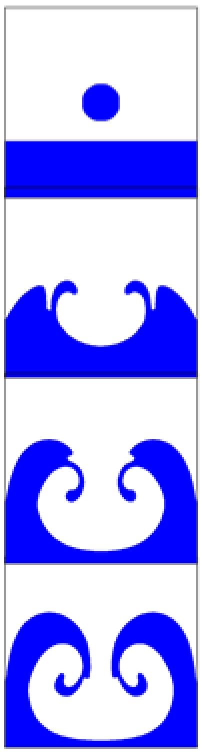
5. Complex flow simulation

- Level set method for 2D/3D multi-phase fluid flow
- Immersed boundary method for moving objects in flows with complex geometry
- Moving particle semi-implicit (MPS) method for modeling interfacial flow

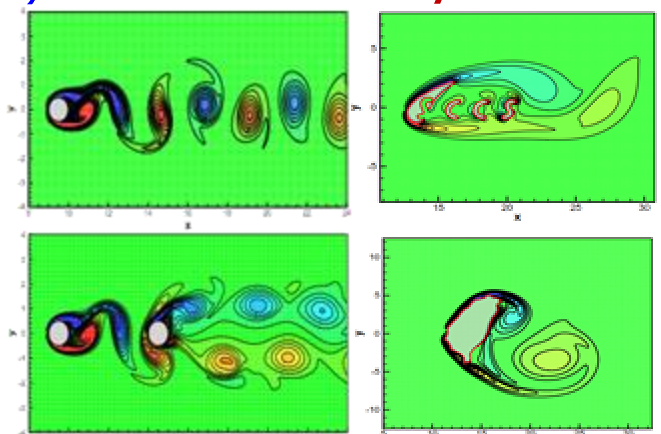
2D Rayleigh-Taylor problem (level-set)



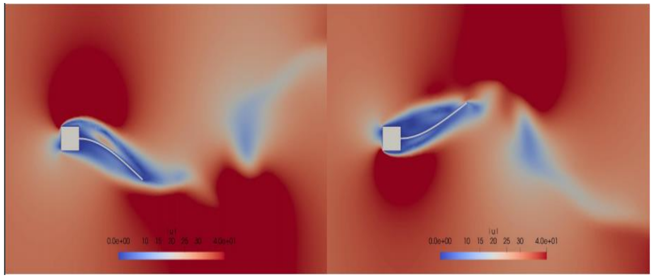
2D bubble droplet problem (level-set)



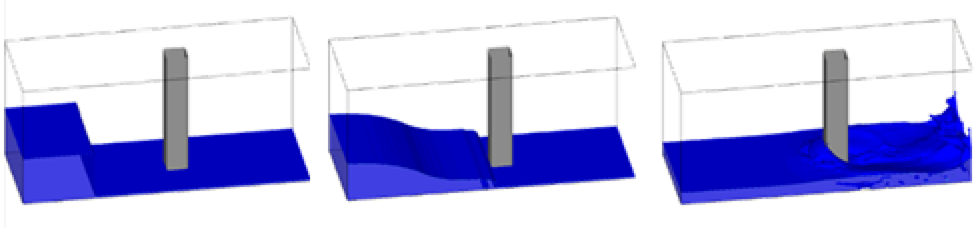
Immersed boundary method



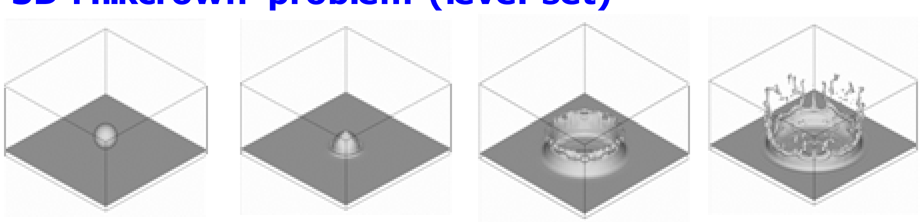
Fluid-Structure Interaction



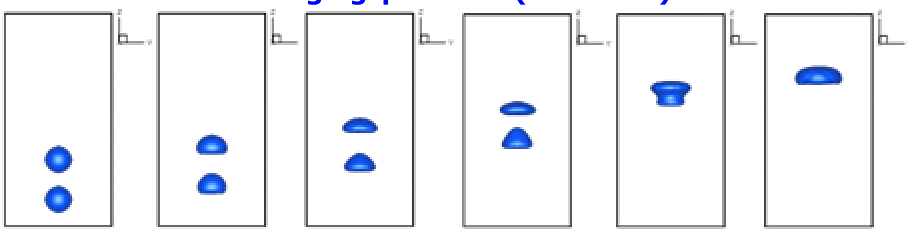
3D Dam-break problem over an obstacle (level-set)



3D Milkcrown problem (level-set)

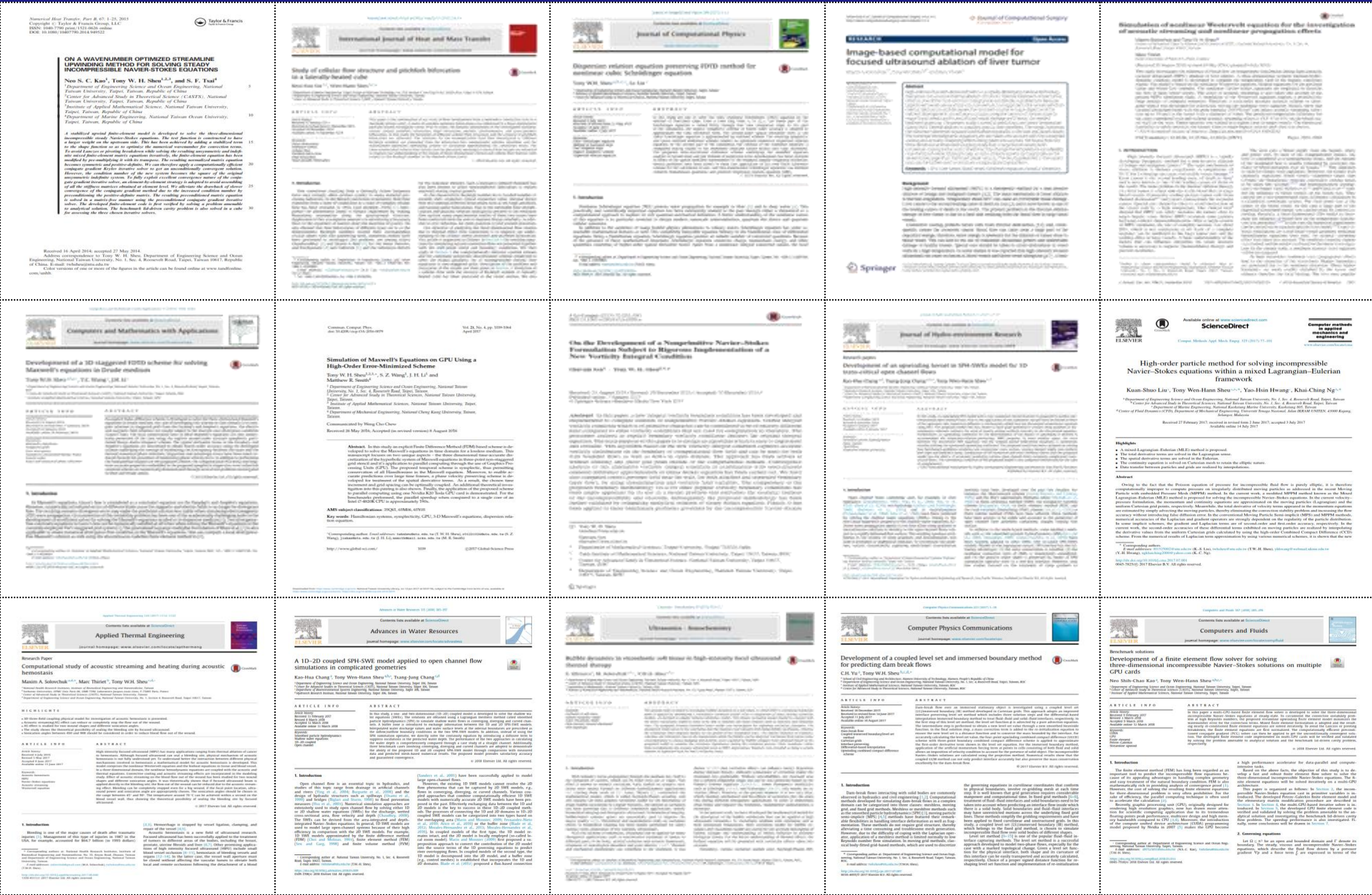


3D two bubbles merging problem (level-set)



Reference papers

http://homepage.ntu.edu.tw/~twhsheu/member/member_tony_pub_rp.htm

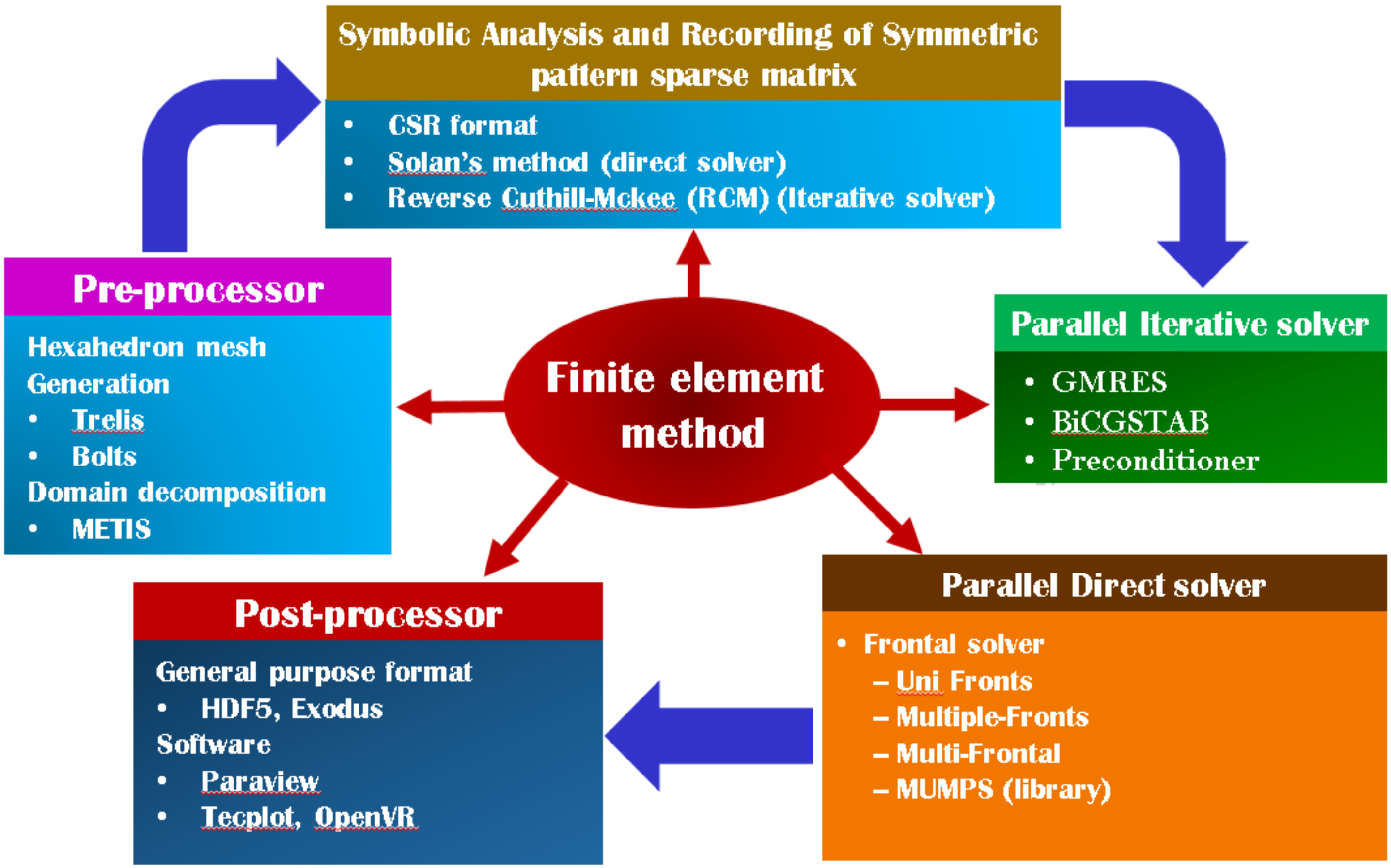


Code development in SCCS

A. 3D incompressible Navier-Stokes equations

Steady/unsteady wavenumber-preserving finite element code (implemented on multi-GPUs)

A.1 Paradigm of in-house computing software packages



A.2 Combined compact finite difference code for modeling 3D free surface flows

A.3 Moving particle semi-implicit 3D code (implemented on GPUs)

In-house developed computer programs for multi-scale (in space) flow modelling

- **Macro**-scale : 3D finite element/finite difference code
  (10^{-1}~10^{2} m)
- **Meso**-scale : particle codes
  (10^{-5}~10^{-1} m)
  - MPS (Moving Particle Semi-Implicit)
  - DPD (Dissipative Particle Dynamics)
  - SPH (Smoothed Particle Hydrodynamics)
- **Micro**-scale : LBM (in progress)
  (10^{-6}~10^{-5} m)
- **Nano**-scale : GPAW (First Principles for solving Kohn-Sham equation ; in progress)
  (10^{-10}~10^{-6} m)

(II) SCCS on-going research

(II) SCCS on-going research

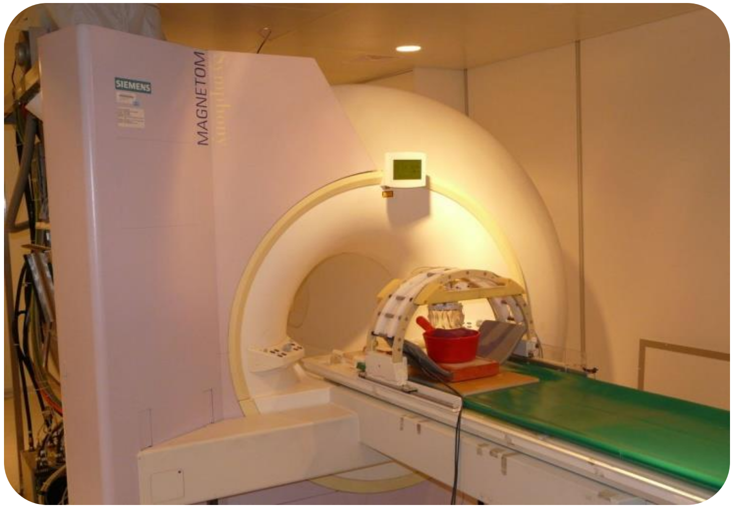
1. Biomedical simulation

(II.A) Surgical planning on liver ablation by HIFU (with Dr. Maxim Solovchuk (NHRI))

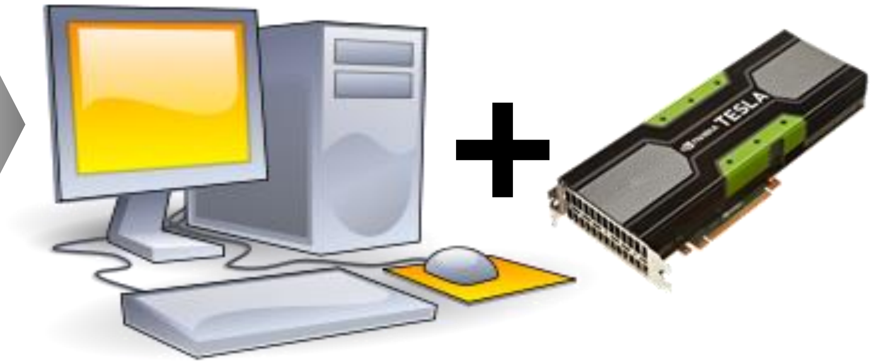
- Creation of a surgical platform containing two major components

(1) Medical equipment (HIFU machine) for measurements

(2) Simulation in a stand-alone computer with multiple GPU processors



measurement



simulation GPU cards

2. Biomedical simulation

- 2.1 Acupuncture modelling - Needle motion induced mechanical stress force on mast cell membrane (mechanotransduction)

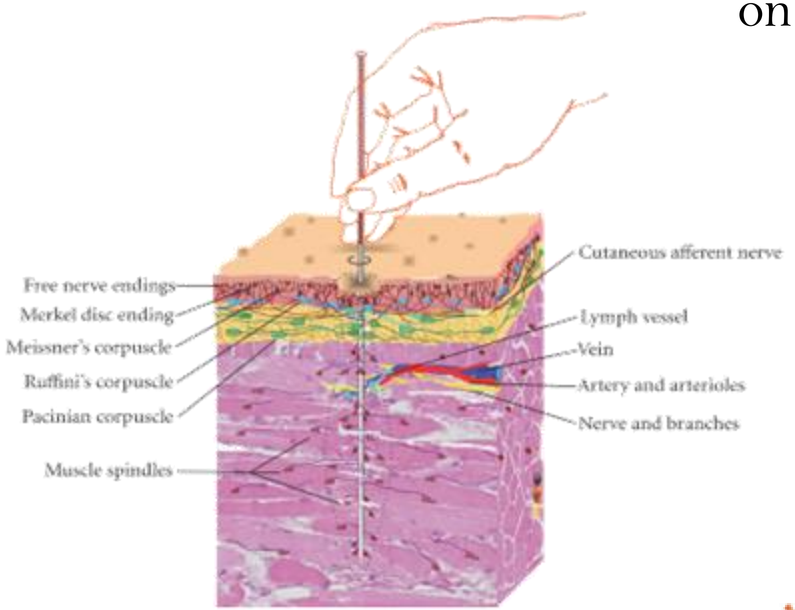


Figure: Needle in the hypodernis [Source: Zhang & al., 2012]

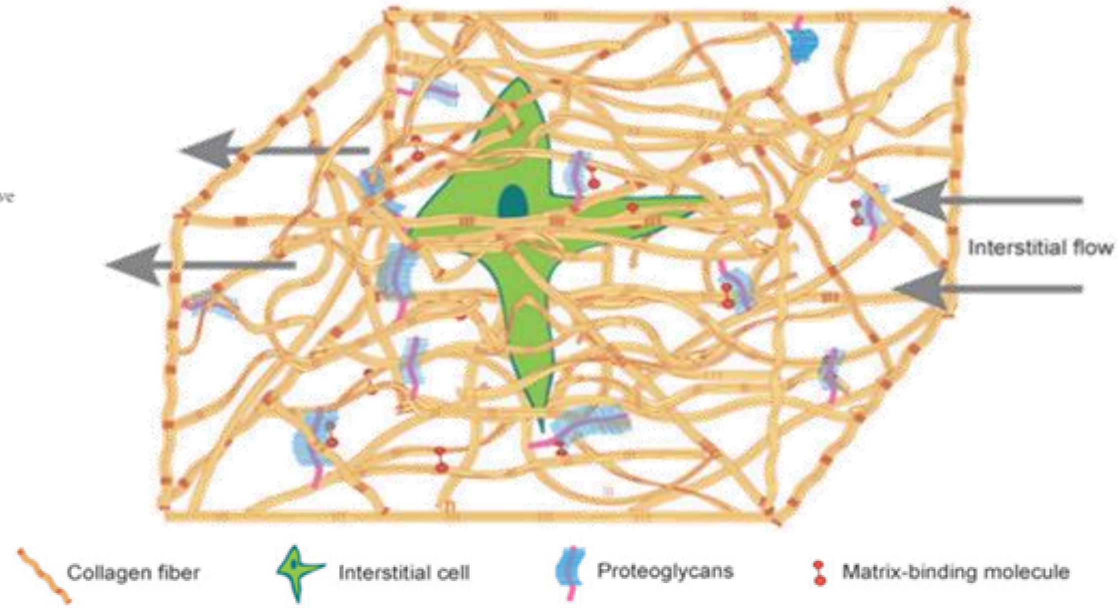
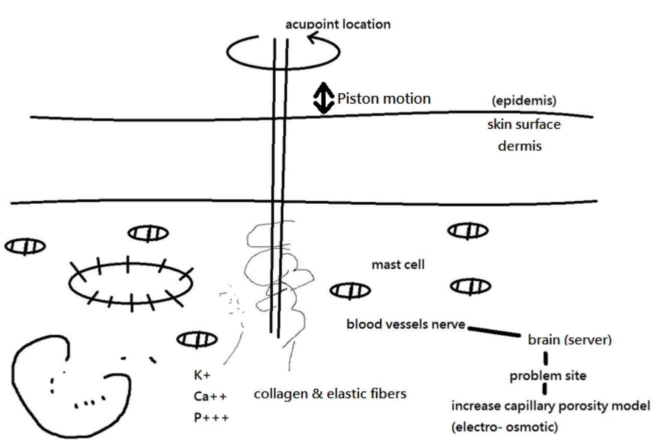
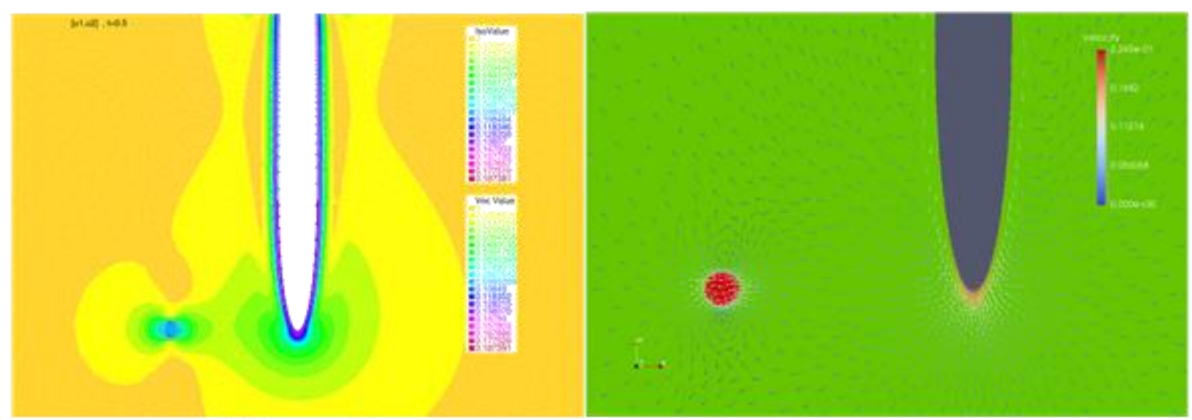


Figure: Cell embedded in the extracellular matrix (ECM) composed of collagen and elastic fibers, ground substance, and proteoglycans [Source: Alberts, 2007]



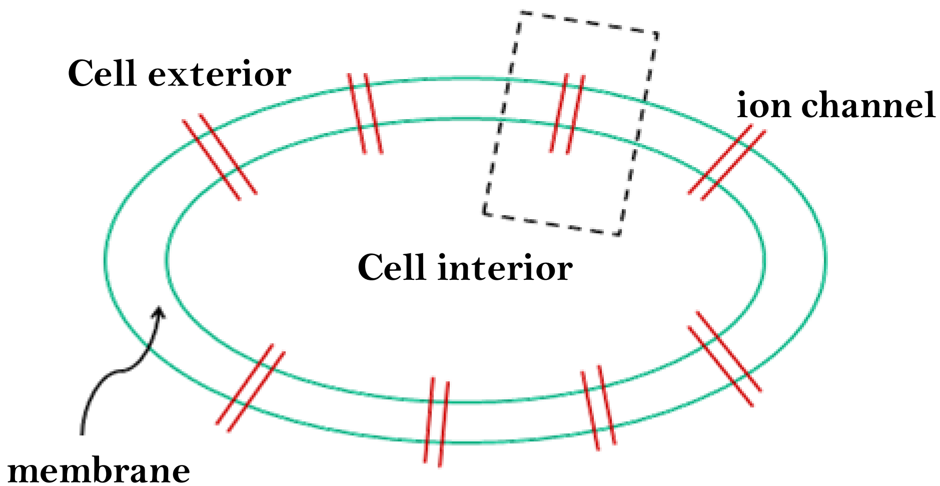


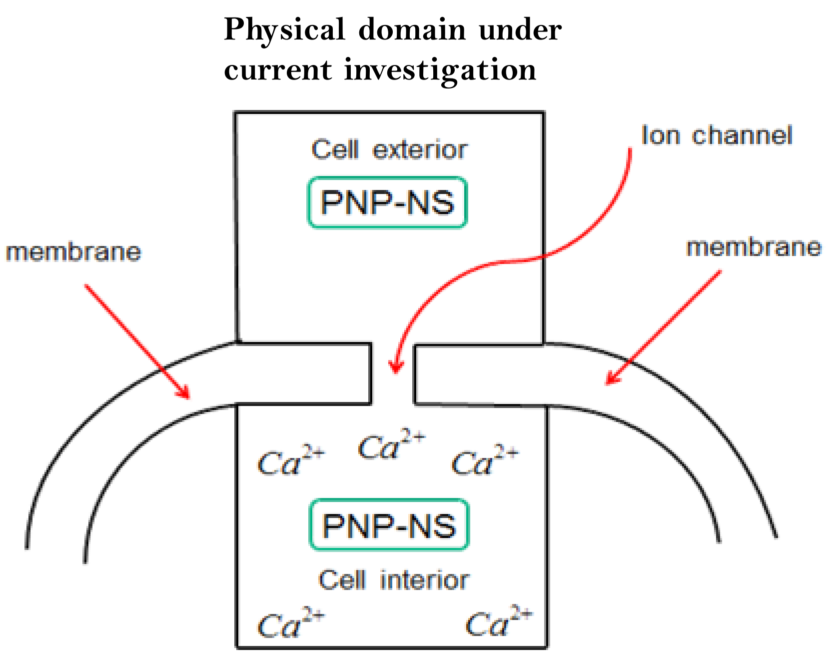
Velocity contour

Velocity field

3. Code development for ion channel flow

- High-order compact difference scheme for solving the coupled NS and PNP equations
- Lattice Boltzmann method for solving the coupled NS and PNP equations





4. Mathematical physics

- Scattering analysis on cubic Schrödinger equation
- Scattering analysis on Camassa-Holm (CH) equation

5. Computational mathematics

- Two-component Hunter-Saxton (HS) equation

6. CPU/GPU parallel computing

- 3D finite element/difference calculation of incompressible Navier-Stokes equations on GPUs and MPI-CPUs
- 3D finite difference calculation of Maxwell's equations on GPU

7. Direct/Iterative parallel solvers

- Multi-Frontal & multiple Fronts solvers for solving unsymmetric indefinite finite element matrix equation on GPUs for incompressible Navier-Stokes equations

8. Scientific computing methods

- 3D particle method for solving incompressible Navier-Stokes equations on GPU
- Particle method for solving fluid-structure interaction problems
- Immersed boundary method for solving fluid flow equations in moving (time-varying) domain
- Finite difference method for the simulation of debris fluid flow
- ALE calculation of incompressible Navier-Stokes equations on moving meshes
- Fractional derivative PDE simulation

9. Image segmentation and reconstruction

10. Machine learning on tumor detection

SCCS awards

許文翰教授與Marc Thiriet教授
榮獲2011年台法科技獎

SCCS awards

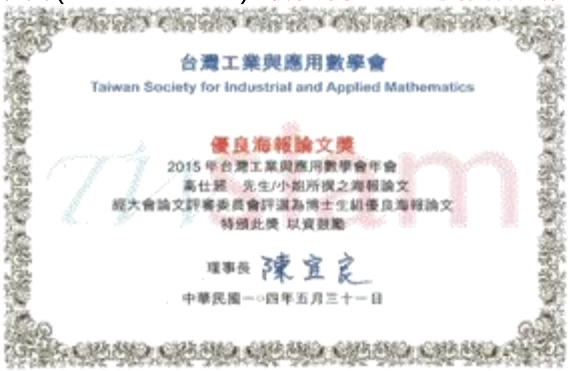
許文翰教授榮獲2015年
國立臺灣大學工學院宗倬章講座

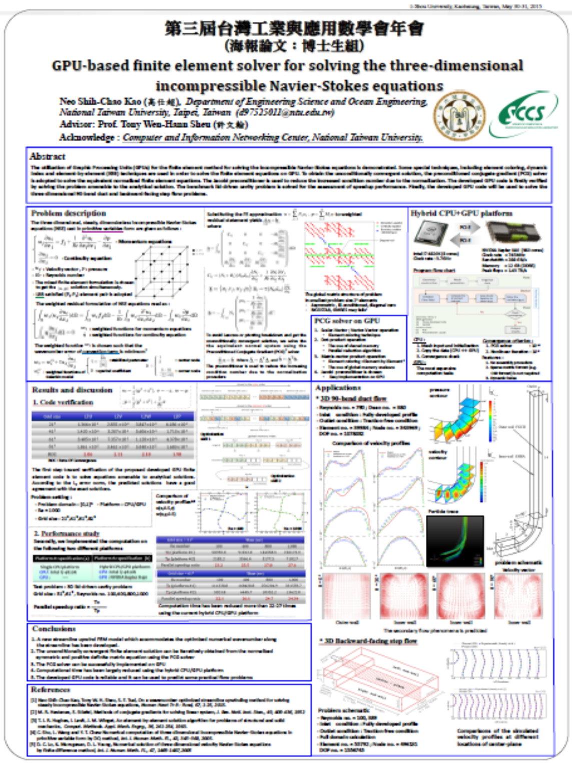
SCCS students awards-A

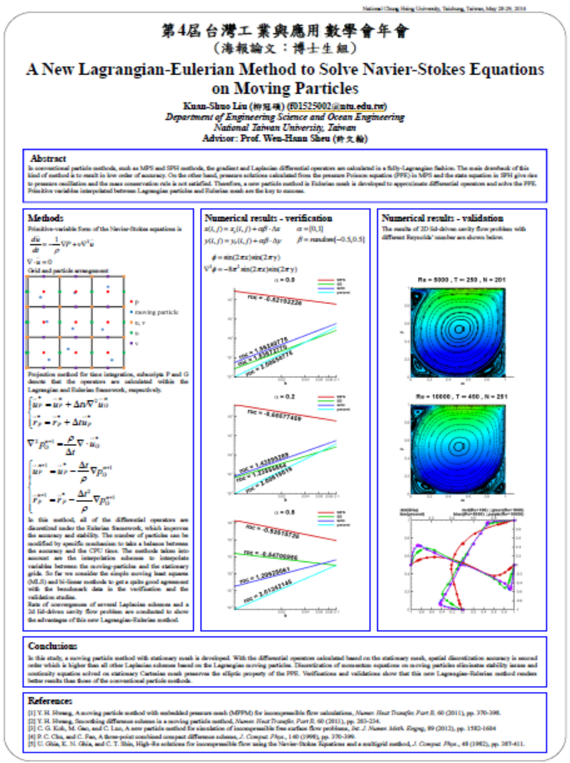
高仕超 2015年第三屆台灣工業與應用數學年會(3^{rd} TWSIAM) **最佳博士生海報論文獎**

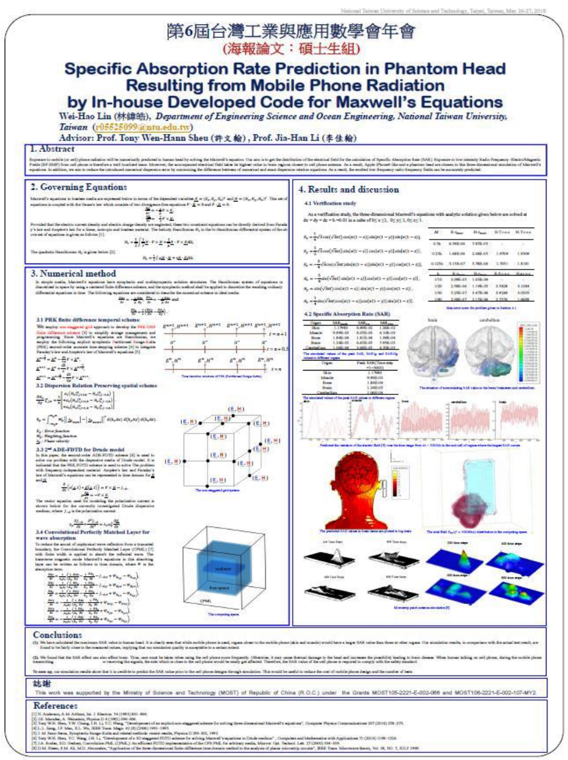
柳冠碩 2016年第四屆台灣工業與應用數學年會(4^{th} TWSIAM) **最佳博士生海報論文獎**

林緯皓 2018年第六屆台灣工業與應用數學年會(6^{th} TWSIAM) **最佳碩士生海報論文獎**









SCCS students awards-B

溫皓良 2018年第二屆國立臺灣大學學士班
學生論文獎獲得最高榮譽傅斯年獎

國立臺灣大學獎狀

學生 溫皓良 （學號 B04505050）就讀本校工學院工程科學及海洋工程學系榮獲 107 年學士班學生論文傅斯年獎

特頒此狀 以資鼓勵

論文題目：以高階緊緻差分格式的方法模擬曲線受到曲率觸發的相關運動

代理校長 郭大維

中華民國一百零七年六月

The 2018 Bachelor Degree Thesis Award

1st Place

This certificate is proudly presented to

Wen Haw Liang

for the thesis entitled

"On a high-order combined compact finite difference scheme for simulating the evolution of a mean curvature driven interface"

Tei-Wei Kuo

Acting President of National Taiwan University

June 2018