



# **Research overview in SCCS**

SCIENTIFIC COMPUTING &  
CARDIOVASCULAR SIMULATION LABORATORY

# Introduction



## SCCS stands for Scientific Computing and Cardiovascular Simulation (<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

國立臺灣大學 工程科學與海洋工程學系  
計算力學與科學視覺研究室  
Computational Mechanics and Scientific Visualization laboratory 指導教授: 許文翰教授

目的:

- 執行科學計算 (Scientific Computing) 以探討複雜的非線性問題
- 發展各種數值計算方法
- 執行高階數值及大規模的平行計算

研究領域:

- 高階研究
  - 發展 Convection-Diffusion-Reaction (CDR) 問題之數值方法
  - 發展高階數值方法與非線性問題之數值方法 (IBM)
  - 發展高階數值方法與非線性問題之數值方法 (IBM)
  - 發展高階數值方法與非線性問題之數值方法 (IBM)
  - 發展高階數值方法與非線性問題之數值方法 (IBM)
- 流體運動的模擬與設計
  - 2D lid-driven cavity flow
  - 3D natural convection in a cavity
  - 3D backward-facing step flow
  - 3D 90-bend duct flow structure
  - 3D jet in cross flow structure
  - 3D expanded flow structure
- 應用研究
  - 自由101大樓的風場研究
  - 汽車的空氣動力學研究
  - 水下潛艇/風扇的空氣動力學研究
  - 中樞神經系統與神經元研究
  - 血液流動與血管疾病研究
  - 心臟傳導系統與心臟節律研究

計算資源:

- 硬體
  - 1) 專業工作站與伺服器
  - 2) 高性能 (MPI+GPU)
  - 3) Nvidia, Kepler GPU
- 軟體
  - 1) Intel/PGI 編譯器
  - 2) Tecplot, Paraview
  - 3) OpenFOAM, FreeFEM++

研究成果:  
[http://homepage.ntu.edu.tw/~twhsheu/member/member\\_tony\\_scs\\_pn.htm](http://homepage.ntu.edu.tw/~twhsheu/member/member_tony_scs_pn.htm)

高量算 Level Set/VOF 數值方法 | 直接動力滾動邊界法 | 水下潛艇/風扇的空氣動力學研究 | 中樞神經系統與神經元研究

台北101建築的風場研究 | 汽車的空氣動力學研究 | Vortex flow simulation | Wake flow | Velocity vector

心血管手術前模擬 | 高階流體動力學應用 | CPU/GPU 平行計算加速複雜三維不可壓縮流體流動 | Lid-driven cavity flow | Natural convection flow

ASO, TPCP, Cerebellum, HPU

2017 計算力學與科學視覺研究室

國立臺灣大學 工程科學及海洋工程學系  
科學計算及心血管模擬實驗室  
Scientific Computing and Cardiovascular Simulation Laboratory (SCCS) 指導教授: 許文翰教授

研究目的: 透過科學計算方法, 高準確度以及高效率  
完成: 程、科學等領域問題。

科學計算: 理論、實驗、實證三強合一

計算光電: 手機電腦輔助之計算

計算光電: Iso-surface of SAR = 0.05

程式開發

- 三維熱流有限元法 (Finite Element Method)
- 三維熱流有限差分法 (Finite Difference Method)
- 三維熱流高階波數法 (Lattice Boltzmann Method)
- 三維熱流混合拉格朗日-歐拉法 (Mixed Lagrangian-Eulerian)
- 三維熱流時間有限差分法 (Finite Difference Time-Domain)
- 流固耦合計算方法 (Immersed Boundary Method)
- 多相流計算方法 (Level Set Method)
- 高維線性代數直接解法 (Multiple Frontal Method)

影像處理: 血管切片重建模型

Acquisition | Pre-processing | Segmentation | Reconstruction | Regional Interest

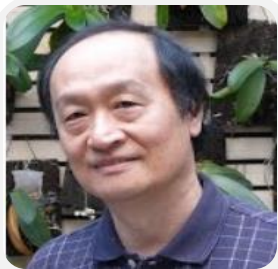
計算光電: 三維式數射問題 | 流固耦合: MLE & IBM

多相流: FDM & LS

流固耦合: FEM

數台: 2017/11/10

# SCCS current members



Tony Wen-Hann Sheu  
Director



Maxim A. Solovchuk  
Post-Doctoral



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

## ◦ Congenital heart diseases

- **TCPC** (Total **C**avo**P**ulmonary **C**onnection)
- **ASO** (Arterial **S**witch **O**peration)

## ◦ Adult heart disease

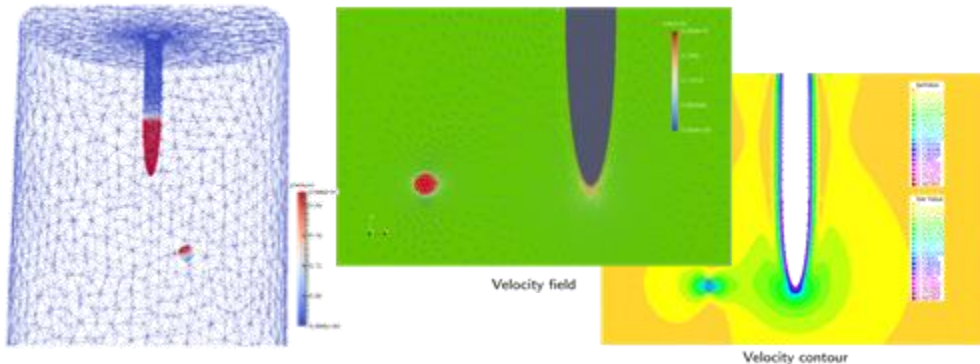
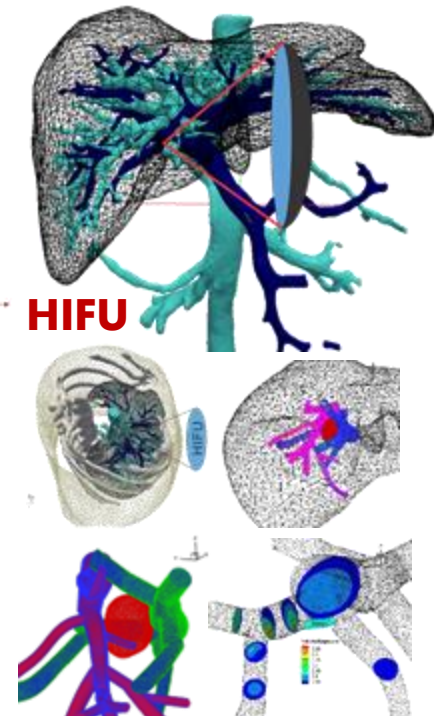
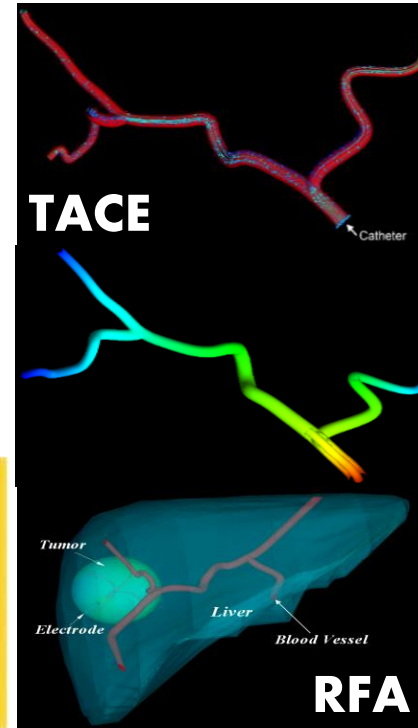
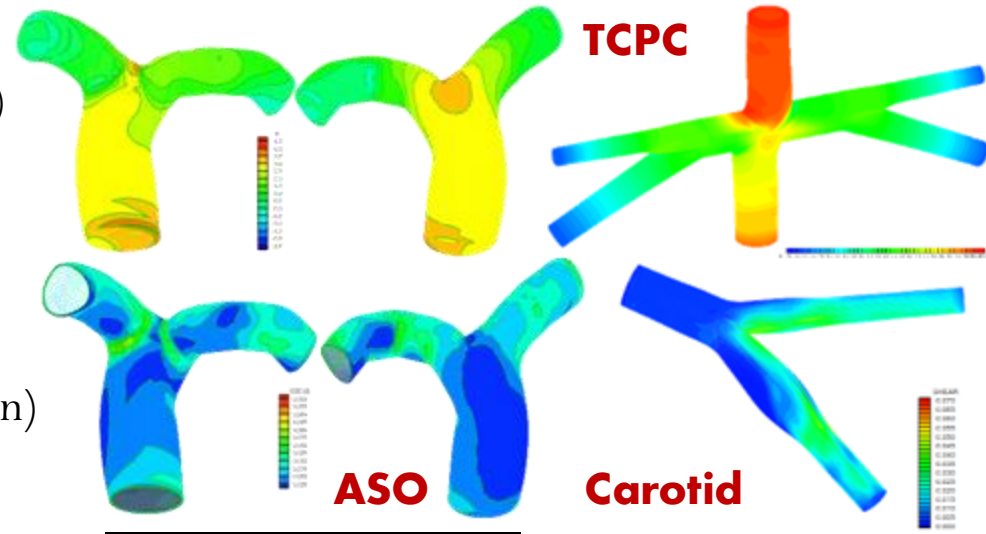
- Coronary artery by-pass surgery

## ◦ Liver tumor surgical planning

- **TACE** (Trans **A**rterial **C**hemo-**E**mbolization)
- **RFA** (Radio **F**requency **A**blation)
- **HIFU** (High **I**ntensity **F**ocal **U**ltrasound)
- Liver transplant surgery

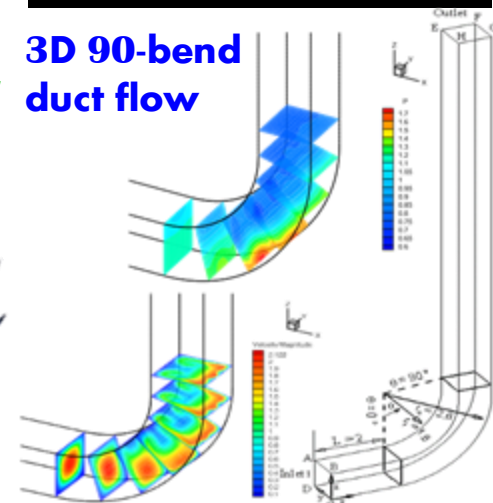
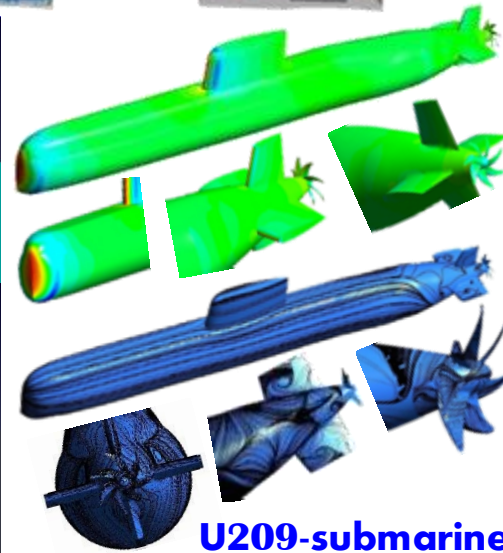
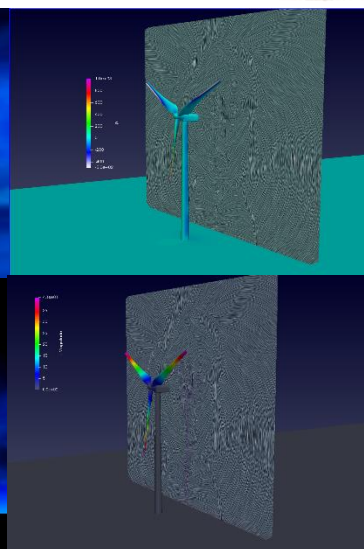
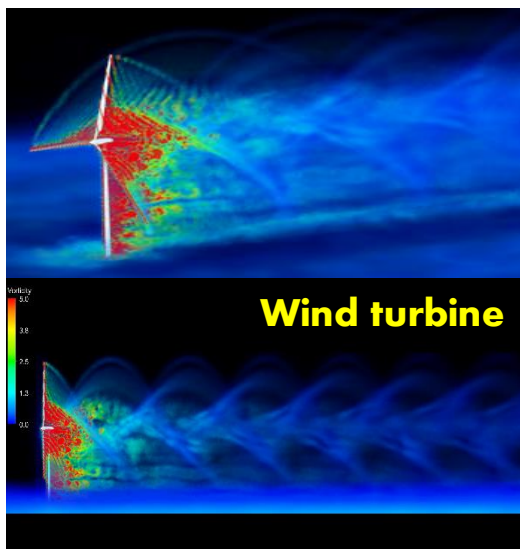
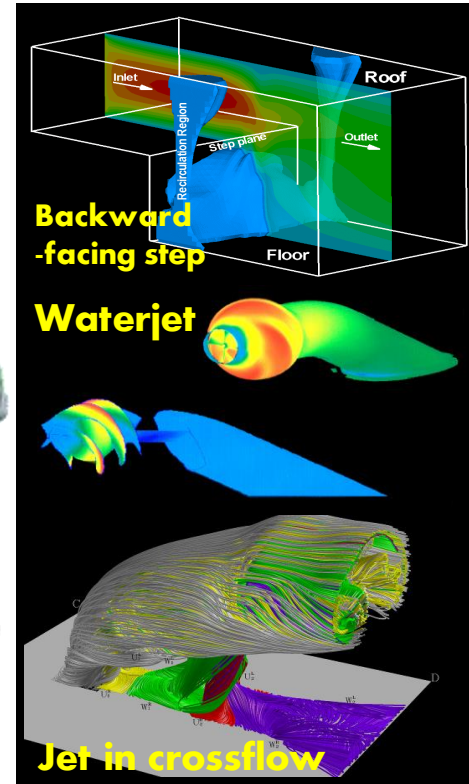
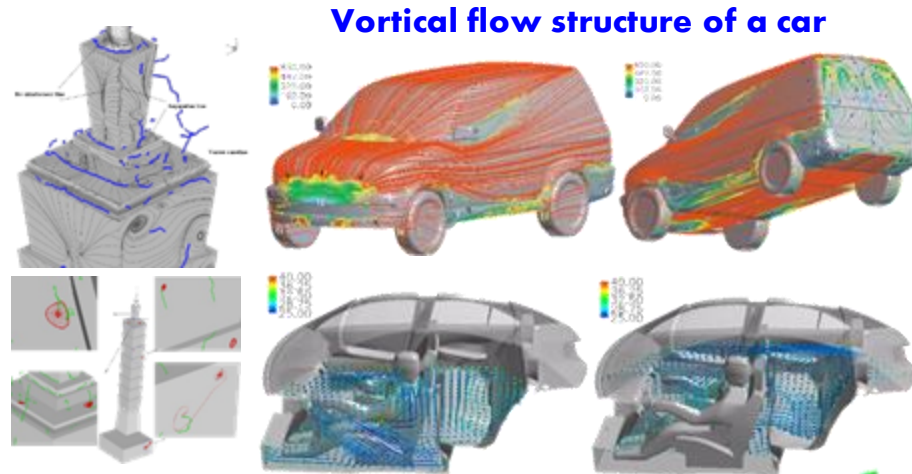
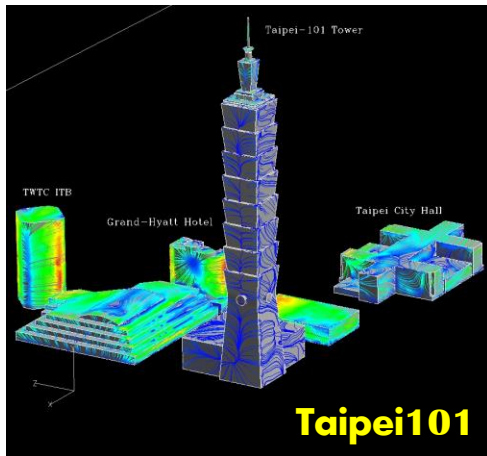
## ◦ Traditional Chinese medicine

- Electro Osmotic Fluid (EOF) model for studying chi-blood interaction
- **Acupuncture** modeling and simulation (針)
- **Moxibustion** modeling and simulation (灸)



# 2. Computational physics

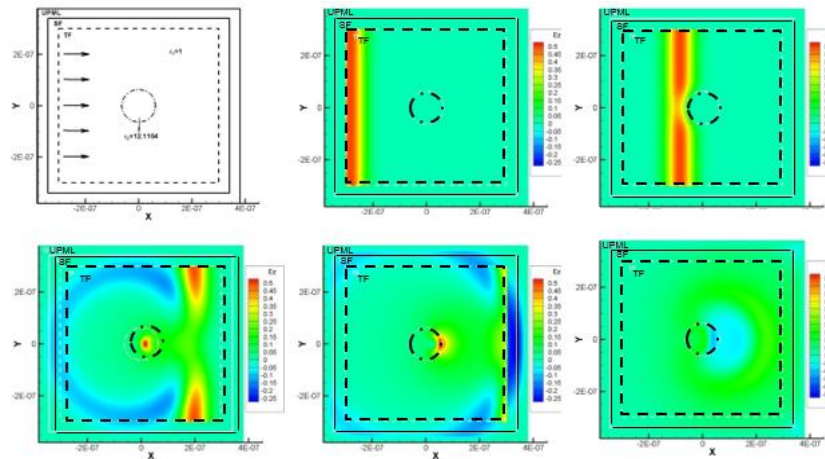
- Nonlinear dynamics around a high rising building
- Nonlinear dynamics in moving cars
- Nonlinear dynamics in waterjet
- Nonlinear dynamics of a propelling submerged body flow
- Nonlinear dynamics of wind turbine



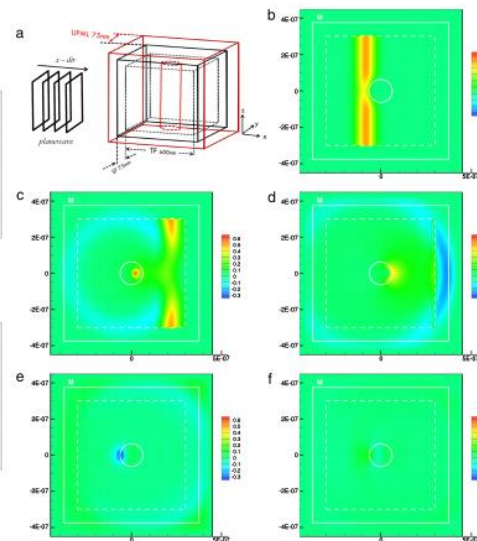
# 3. Computational EM wave

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

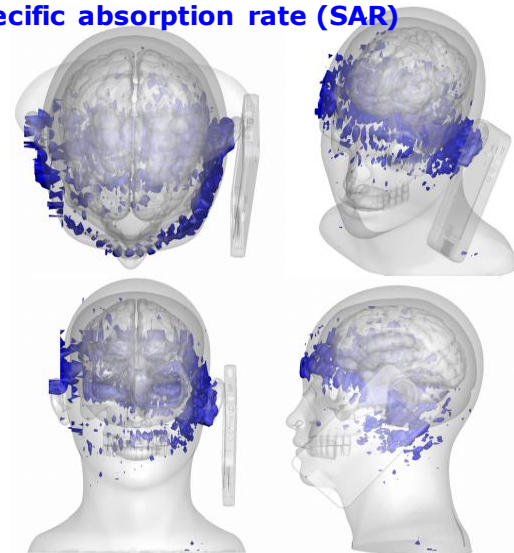
### 2D Mia-Scatter problem



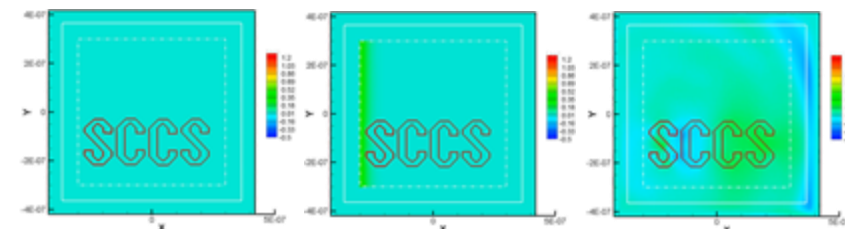
### 3D Mia-Scatter problem



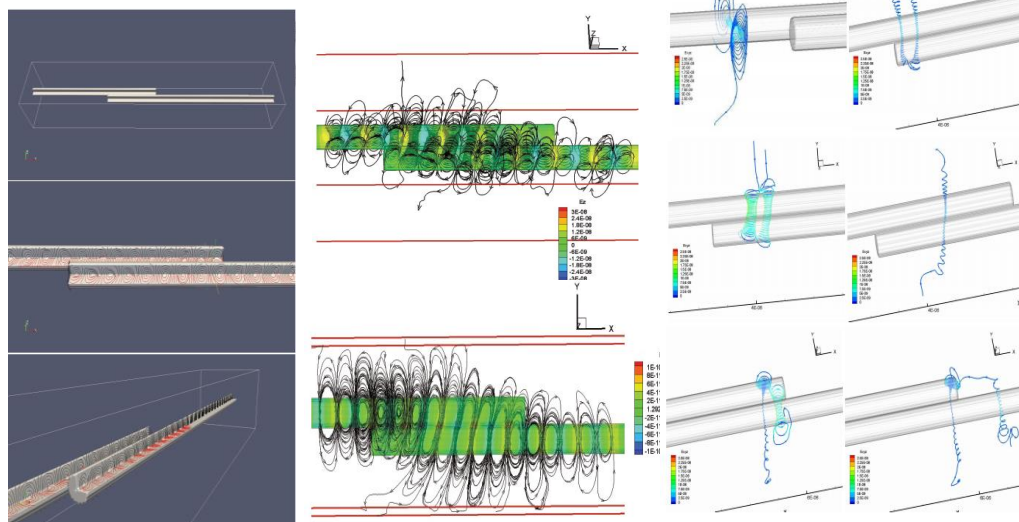
### Prediction of mobile phone induced specific absorption rate (SAR)



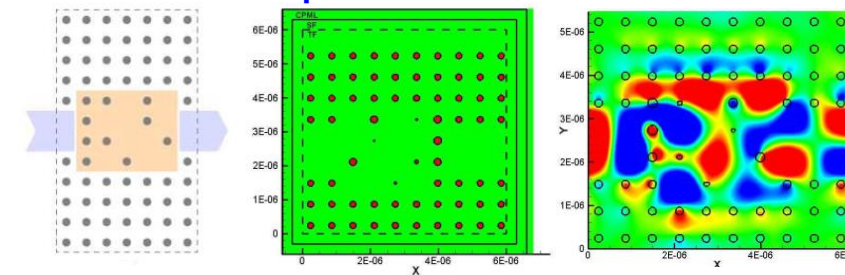
### 2D Mia-Scatter problem over "SCCS" mark



### 3D Two parallel silica nanowires



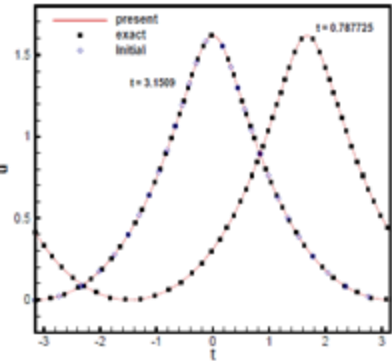
### 3D simulation of a photonic crystal waveguide spatial mode converter



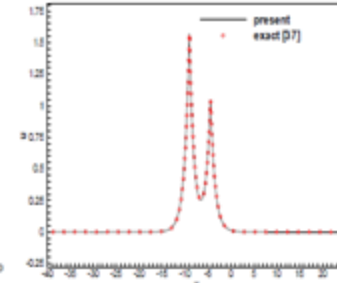
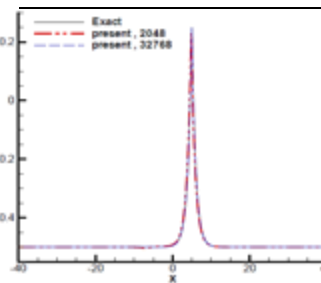
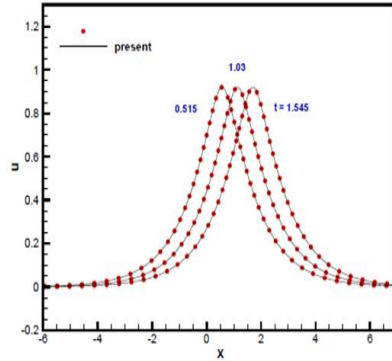
# 4. Computational integrable systems

- CH (Camassa-Holm) equation
- DP (Degasperis-Procesi) equation
- KS (Keller-Segel) equation
- 2-CH (Two-component CH) equation
- 2-HS (Two-component Hunter Saxon) equation

Smooth travelling wave problem (CH)

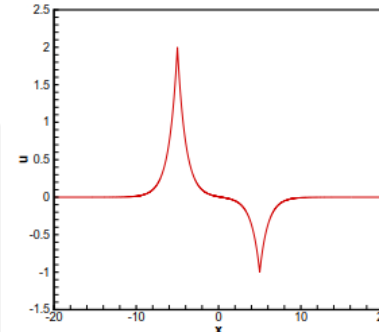


One-soliton problem (CH)

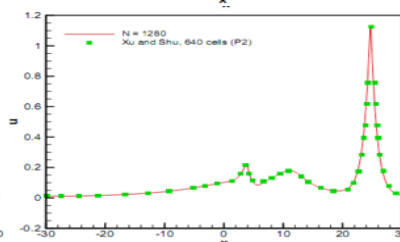
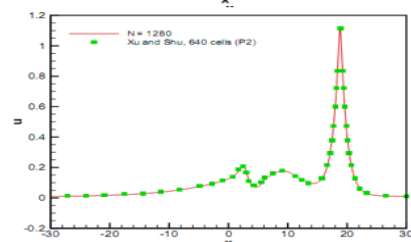
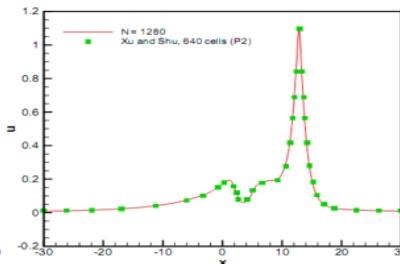
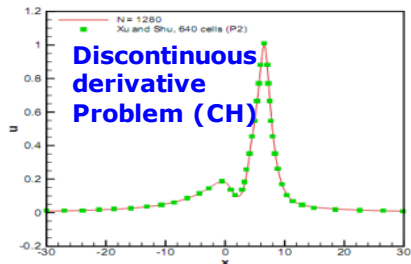


One-peakon problem Two-peakon problem

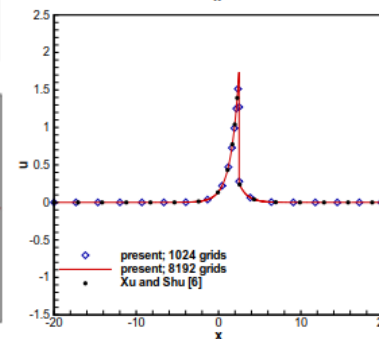
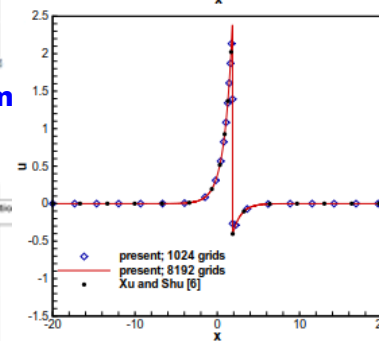
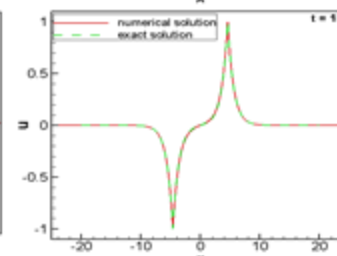
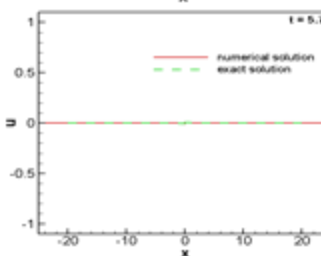
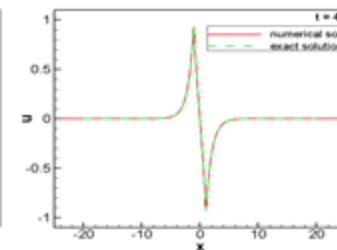
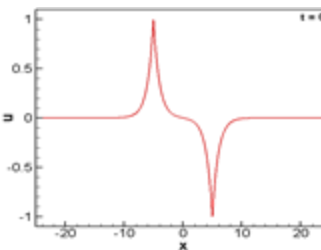
Peakon-antipeakon problem (DP)



Discontinuous derivative Problem (CH)



Peakon-antipeakon collision problem (CH)

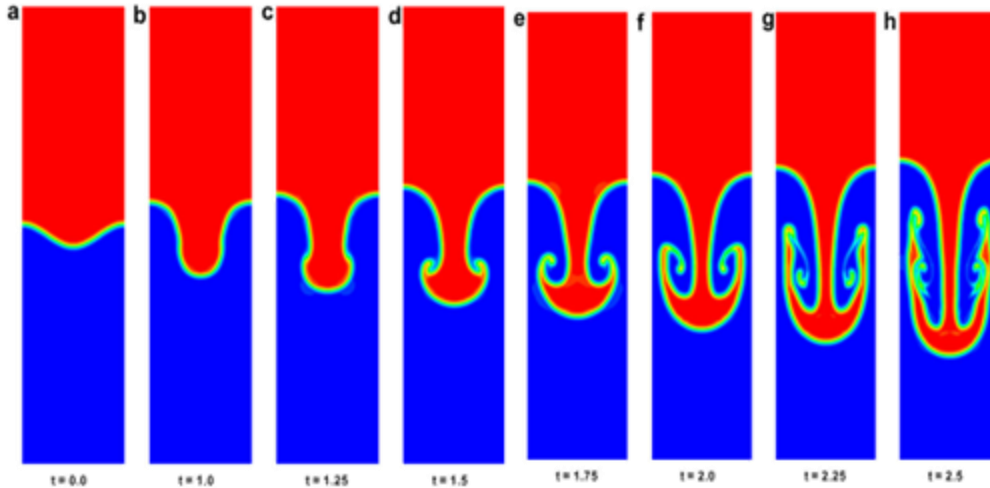




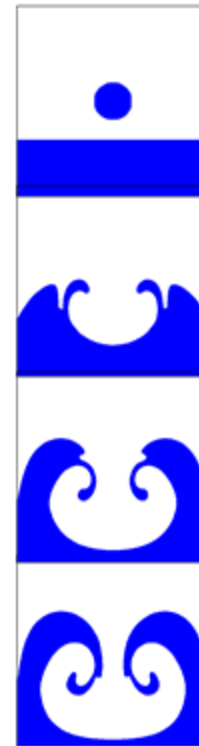
# 5. Complex flow simulation

- 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

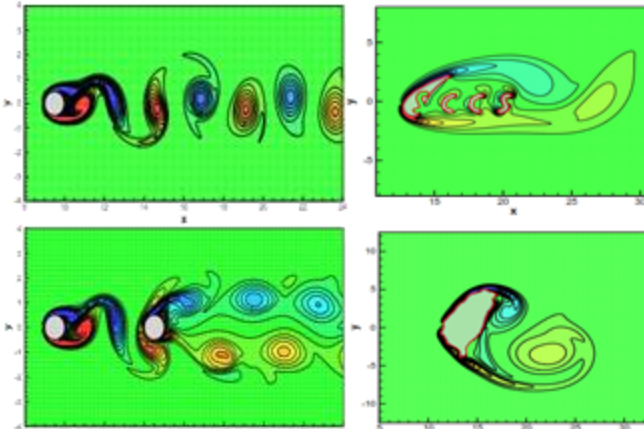
### 2D Rayleigh-Taylor problem (level-set)



### 2D bubble droplet problem (level-set)

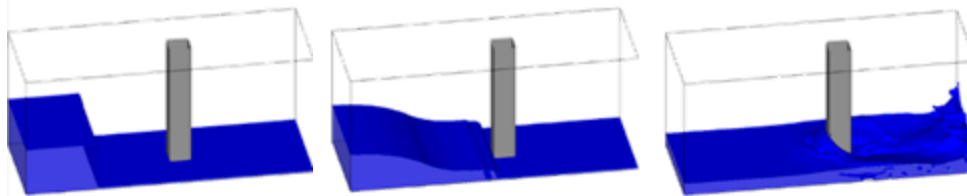


### Immersed boundary method

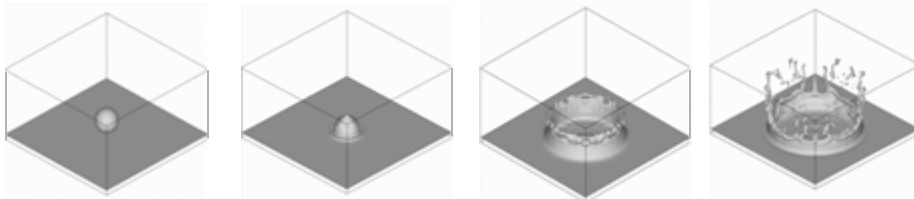


### Fluid-Structure Interaction

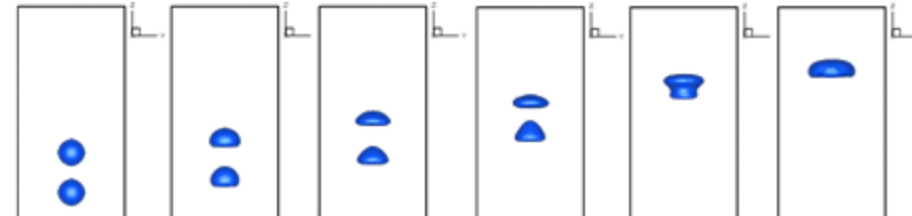
### 3D Dam-break problem over an obstacle (level-set)



### 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](http://homepage.ntu.edu.tw/~twhsheu/member/member_tony_pub_rp.htm)

Nonlinear Wave Phenomena, Part B, 67, 1–21, 2013  
Copyright © Taylor & Francis Group, LLC  
DOI: 10.1080/10717544.2013.786724

 Taylor & Francis

### ON A WAVELENGTH OPTIMIZED STREAMLINE UPWINDING METHOD FOR SOLVING STEADY INCOMPRESSIBLE NAVIER-STOKES EQUATIONS

Neo S. C. Kao<sup>a</sup>, Tony W. H. Sheu<sup>b,c,d</sup>, and S. F. Tsai<sup>e</sup>

<sup>a</sup>Department of Engineering Science and Ocean Engineering, National Taiwan University, Taipei, Taiwan, Republic of China  
<sup>b</sup>Center for Advanced Study in Theoretical Science (CASTS), National Taiwan University, Taipei, Taiwan, Republic of China  
<sup>c</sup>Department of Applied Mathematics, National Taiwan University, Taipei, Taiwan, Republic of China  
<sup>d</sup>Department of Marine Engineering, National Taiwan Ocean University, Taipei, Taiwan, Republic of China  
<sup>e</sup>Department of Mechanical Engineering, National Taiwan Ocean University, Taipei, Taiwan, Republic of China

A modified spatial finite-volume model is developed to solve the three-dimensional incompressible steady Navier-Stokes equations. The test function is constructed as linear velocity profiles on the streamlines. This has been achieved by taking a modified form of the shape function so as to optimize the numerical accuracy for convective terms. To avoid numerical instability brought about by taking the modified velocity profile as the basis function, matrix operations involving the basis function are not modified by pseudospectrality with a frequency filter. The resulting numerical accuracy is compared with the pseudospectral method. The numerical results show that the proposed streamline upwinding method can get an essentially equivalent solution accuracy to the pseudospectral method in the entire domain for the same number of grid points. To fully exploit the vector computation nature of the computer parallel hardware, an efficient block-matrix strategy is adopted to parallelize the operations of the computer program based on the numerical condition number by reorganizing the grid-function matrix. The resulting computational accuracy is compared with the pseudospectral method. The results show that the proposed upwinding method can achieve the same accuracy as the pseudospectral method in the entire domain for the same number of grid points in solving the three-dimensional Stokes equations.

Received 16 April 2014; accepted 27 May 2014.  
<sup>a</sup>Corresponding author. Email: skao@ntu.edu.tw  
<sup>b</sup>Department of Engineering Science and Ocean Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan 10611, Republic of China. E-mail: twhsheu@ntu.edu.tw  
<sup>c</sup>Center for advanced study of one of the figures in the article can be found online at [www.tandfonline.com](http://www.tandfonline.com/doi/abs/10.1080/10717544.2013.786724)

Computers and Mathematics with Applications  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### Development of a 3D staggered FEM solver for solving Maxwell's equations in dielectric medium

Sheng-Hui Wang<sup>a,b</sup>, Tzeng-Hong Jeng<sup>b</sup>

<sup>a</sup>Department of Applied Mathematics, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Mechanical Engineering, National Cheng Kung University, Tainan, Taiwan, Republic of China

Received 20 May 2014; accepted (in revised form) 8 August 2014

**Abstract** In this study, we employ the Finite Difference Method (FDM) based on the staggered grid to solve the three-dimensional (3D) Maxwell's equations in dielectric medium. The staggered grid is used to discretize the spatial domain. The staggered grid is used to discretize the spatial domain. The staggered grid is used to discretize the spatial domain. The staggered grid is used to discretize the spatial domain.

Applied Thermal Engineering  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### Computational study of acoustic streaming and heating during acoustic hemolysis

Maoxi A. Sobushchik<sup>a</sup>, Marc Thibaut<sup>b</sup>, Tony W.H. Sheu<sup>c</sup>

<sup>a</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>c</sup>Department of Applied Mathematics, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 16 April 2014; accepted 27 May 2014

**Abstract** High intensity acoustic streaming (HIAS) has been extensively studied for the treatment of various diseases. However, the acoustic streaming velocity is highly dependent on the acoustic intensity. In this study, the acoustic streaming velocity is investigated numerically. The results show that the acoustic streaming velocity is highly dependent on the acoustic intensity.

International Journal of Heat and Mass Transfer  
Volume 57, Issue 10, October 2014, Pages 3167–3180

### Study of cellular flow structure and pickoff information at a laminar heated tube

Yuan-Hong Chen<sup>a</sup>, Wen-Hsun Chen<sup>b</sup>

<sup>a</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 16 April 2014; accepted 27 May 2014

**Abstract** The flow structure and pickoff information at a laminar heated tube are studied numerically. The results show that the flow structure is highly dependent on the acoustic intensity.

Journal of Computational Physics  
Volume 275, Issue 10, October 2014, Pages 3167–3180

### Dispersion relation equation preserving FDTD method for nonlinear cubic Schrödinger equation

Yuan-Hong Chen<sup>a</sup>, Wen-Hsun Chen<sup>b</sup>

<sup>a</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 16 April 2014; accepted 27 May 2014

**Abstract** The dispersion relation equation preserving FDTD method is used to solve the nonlinear cubic Schrödinger equation. The results show that the method is highly accurate and stable.

Journal of Computational Physics  
Volume 275, Issue 10, October 2014, Pages 3167–3180

### On the Development of a Nonphysical Navier-Stokes Formulation Subject to Hieroglyphic Implementation of a New Variable Entropy Condition

Yuan-Hong Chen<sup>a</sup>, Wen-Hsun Chen<sup>b</sup>

<sup>a</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 16 April 2014; accepted 27 May 2014

**Abstract** A new variable entropy condition is proposed for the Navier-Stokes equations. The results show that the method is highly accurate and stable.

Journal of High-resolution Numerical Analysis  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### High-order particle method for solving incompressible Navier-Stokes equations within a mixed Lagrangian-Eulerian framework

Kuan-Shou Liu<sup>a</sup>, Tony Wen-Hsun Sheu<sup>b,c</sup>, Yao-Hsin Hwang<sup>d</sup>, Khai-Chen Ng<sup>e</sup>

<sup>a</sup>Department of Engineering Science and Ocean Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Applied Mathematics, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>c</sup>Department of Marine Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>d</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>e</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 17 February 2013; revised 15 July 2013; accepted 1 July 2013  
Available online 13 July 2013

**Highlights**  
• The method is applied to solve the incompressible Navier-Stokes equations.  
• The method is applied to solve the incompressible Navier-Stokes equations.  
• The method is applied to solve the incompressible Navier-Stokes equations.

Computational Physics Communications  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### Development of a coupled level set and immersed boundary method for predicting dam break flows

Chih-Yu<sup>a</sup>, Tony W.H. Sheu<sup>b</sup>

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Received 16 April 2014; accepted 27 May 2014

**Abstract** A coupled level set and immersed boundary method is used to predict dam break flows. The results show that the method is highly accurate and stable.

Computational Physics Communications  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### Development of a finite element flow solver for solving three-dimensional incompressible Navier-Stokes solutions on multiple GPU cards

Neo S. C. Kao<sup>a</sup>, Tony W.H. Sheu<sup>b,c</sup>

<sup>a</sup>Department of Engineering Science and Ocean Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Applied Mathematics, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>c</sup>Department of Marine Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 16 April 2014; accepted 27 May 2014

**Abstract** A finite element flow solver is developed for solving three-dimensional incompressible Navier-Stokes solutions on multiple GPU cards. The results show that the method is highly accurate and stable.

Journal of Computational Physics  
Volume 275, Issue 10, October 2014, Pages 3167–3180

### Simulation of nonlinear Westervelt equation for the investigation of acoustic streaming and nonlinear propagation effects

Yuan-Hong Chen<sup>a</sup>, Wen-Hsun Chen<sup>b</sup>

<sup>a</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 16 April 2014; accepted 27 May 2014

**Abstract** The simulation of nonlinear Westervelt equation is used to investigate acoustic streaming and nonlinear propagation effects. The results show that the method is highly accurate and stable.

Journal of High-resolution Numerical Analysis  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### Image-based computational model for focused ultrasound ablation of liver tumor

Yuan-Hong Chen<sup>a</sup>, Wen-Hsun Chen<sup>b</sup>

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<sup>b</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 16 April 2014; accepted 27 May 2014

**Abstract** An image-based computational model is used for focused ultrasound ablation of liver tumor. The results show that the method is highly accurate and stable.

Computers and Fluids  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### Computers and Fluids

Volume 67, Issue 10, October 2014, Pages 3167–3180

Received 16 April 2014; accepted 27 May 2014

**Abstract** Computers and Fluids is a journal that publishes research in the field of computational fluid dynamics. The results show that the method is highly accurate and stable.

ScienceDirect  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### High-order particle method for solving incompressible Navier-Stokes equations within a mixed Lagrangian-Eulerian framework

Kuan-Shou Liu<sup>a</sup>, Tony Wen-Hsun Sheu<sup>b,c</sup>, Yao-Hsin Hwang<sup>d</sup>, Khai-Chen Ng<sup>e</sup>

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<sup>b</sup>Department of Applied Mathematics, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>c</sup>Department of Marine Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>d</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>e</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 17 February 2013; revised 15 July 2013; accepted 1 July 2013  
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**Highlights**  
• The method is applied to solve the incompressible Navier-Stokes equations.  
• The method is applied to solve the incompressible Navier-Stokes equations.  
• The method is applied to solve the incompressible Navier-Stokes equations.

Computers and Mathematics with Applications  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### Development of a 3D staggered FEM solver for solving Maxwell's equations in dielectric medium

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<sup>a</sup>Department of Applied Mathematics, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Mechanical Engineering, National Cheng Kung University, Tainan, Taiwan, Republic of China

Received 20 May 2014; accepted (in revised form) 8 August 2014

**Abstract** In this study, we employ the Finite Difference Method (FDM) based on the staggered grid to solve the three-dimensional (3D) Maxwell's equations in dielectric medium. The staggered grid is used to discretize the spatial domain. The staggered grid is used to discretize the spatial domain. The staggered grid is used to discretize the spatial domain.

Applied Thermal Engineering  
Volume 67, Issue 10, October 2014, Pages 3167–3180

### Computational study of acoustic streaming and heating during acoustic hemolysis

Maoxi A. Sobushchik<sup>a</sup>, Marc Thibaut<sup>b</sup>, Tony W.H. Sheu<sup>c</sup>

<sup>a</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>b</sup>Department of Mechanical Engineering, National Taiwan Ocean University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China  
<sup>c</sup>Department of Applied Mathematics, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China

Received 16 April 2014; accepted 27 May 2014

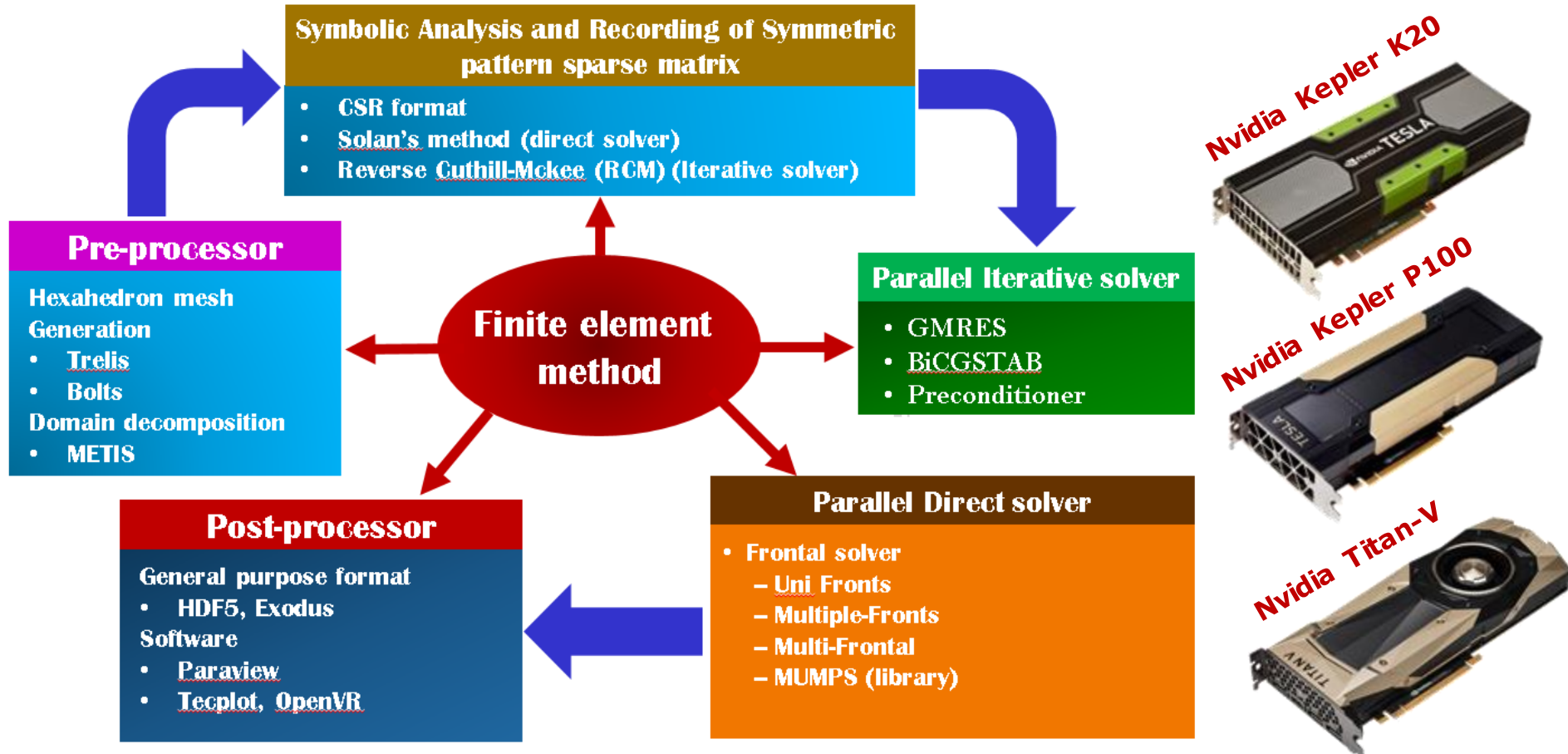
**Abstract** High intensity acoustic streaming (HIAS) has been extensively studied for the treatment of various diseases. However, the acoustic streaming velocity is highly dependent on the acoustic intensity. In this study, the acoustic streaming velocity is investigated numerically. The results show that the acoustic streaming velocity is highly dependent on the acoustic intensity.

# 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  
( $10^{-1} \sim 10^2$  m)

— **Meso**-scale : particle codes  
( $10^{-5} \sim 10^{-1}$  m)

MPS (Moving Particle Semi-Implicit)

DPD (Dissipative Particle Dynamics)

SPH (Smoothed Particle Hydrodynamics)

— **Micro**-scale : LBM (in progress)  
( $10^{-6} \sim 10^{-5}$  m)

— **Nano**-scale : GPAW (First Principles for solving  
Kohn-Sham equation ; in progress)  
( $10^{-10} \sim 10^{-6}$  m)

# **(II) SCCS on-going research**

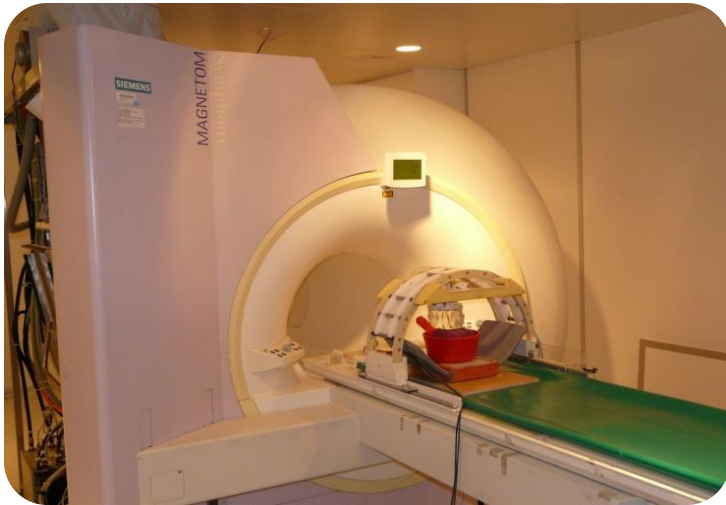
# (II) SCCS on-going research

## 1. Biomedical simulation

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

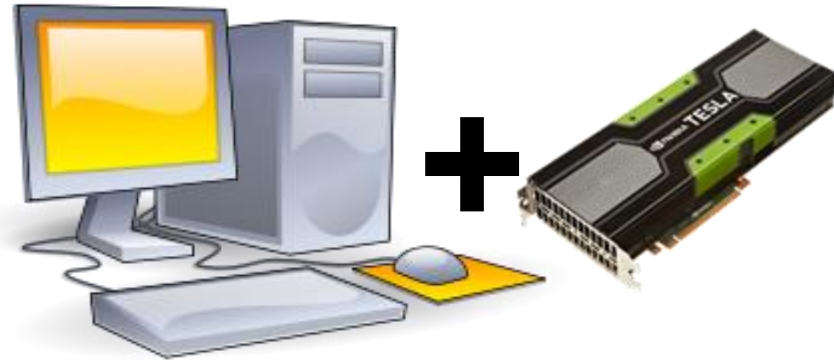
- Creation of a **surgical platform** containing two major components

(1) Medical equipment (HIFU machine) for measurements



**measurement**

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



**simulation**

**GPU cards**

# 2. Biomedical simulation

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

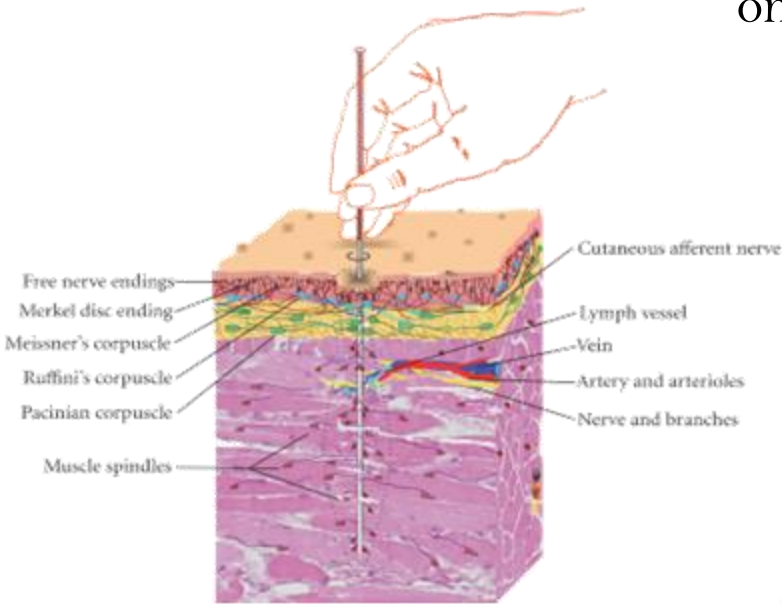


Figure: Needle in the hypodermis  
[Source: Zhang & al., 2012]

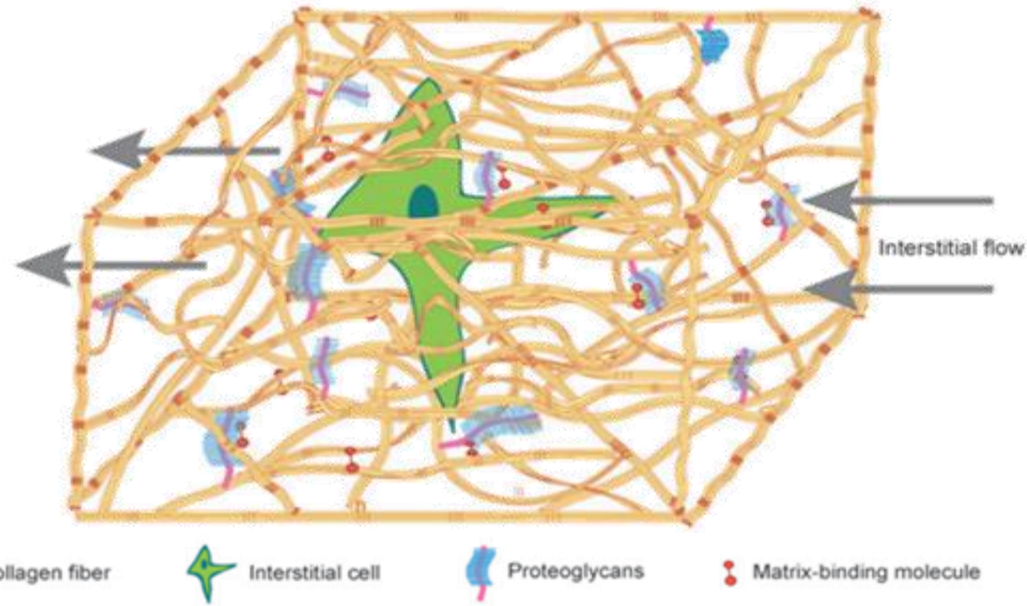
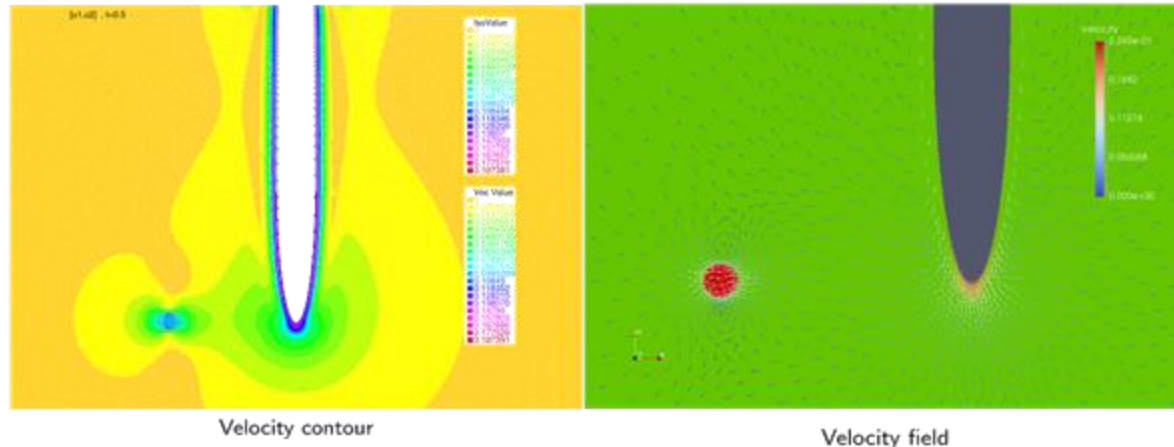
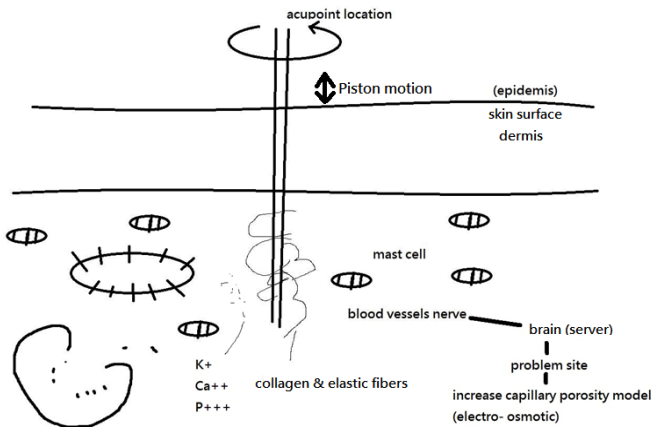
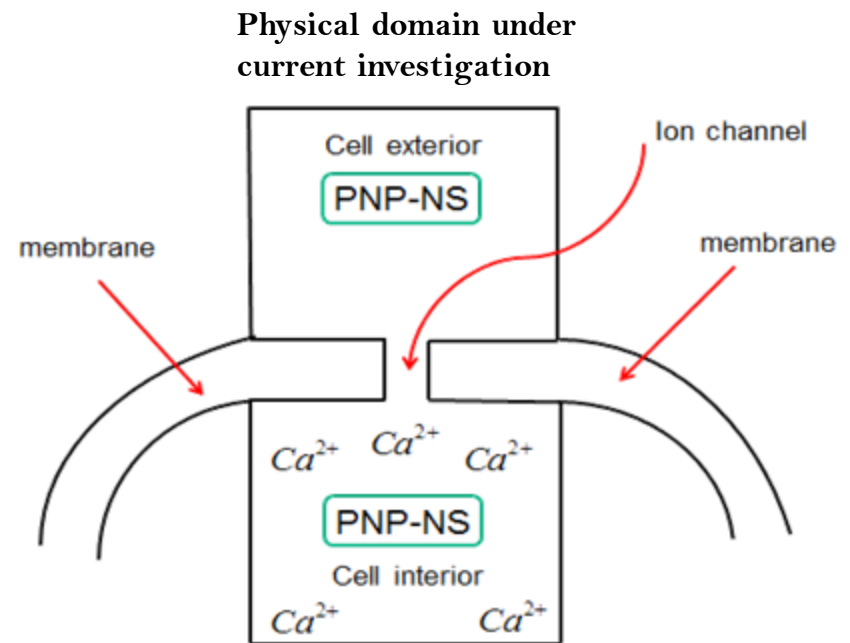
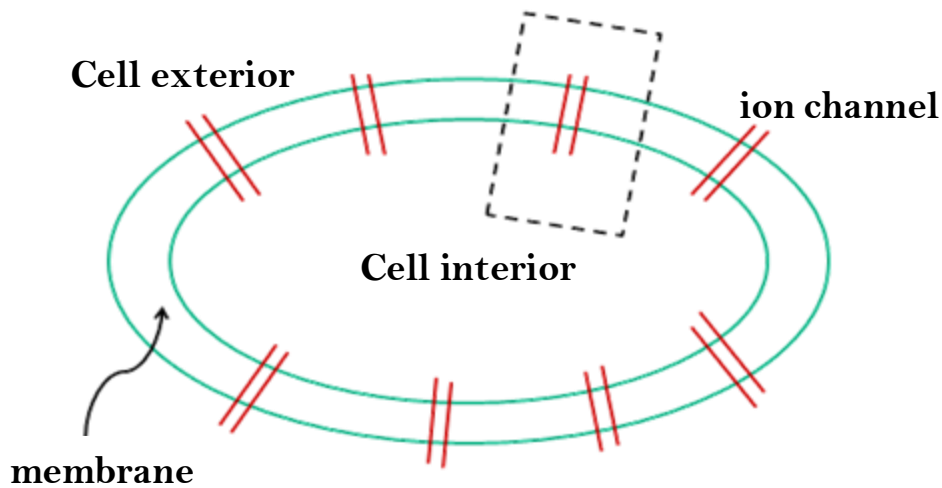


Figure: Cell embedded in the extracellular matrix (ECM) composed of collagen and elastic fibers, ground substance, and proteoglycans [Source: Alberts, 2007]



### 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-CPU
- 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<sup>rd</sup> 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<sup>th</sup> 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<sup>th</sup> TWSIAM) **最佳碩士生海報論文獎**



### 第三屆台灣工業與應用數學年會 (海報論文：博士生組)

#### GPU-based finite element solver for solving the three-dimensional incompressible Navier-Stokes equations

New Shih-Chao Kao (高仕超), Department of Engineering Science and Ocean Engineering, National Taiwan University, Taipei, Taiwan (s9732002@ntu.edu.tw)  
Advisor: Prof. Tony Wen-Huan Shue (許文勳)  
Acknowledgment: Computer and Information Networking Center, National Taiwan University.

**Abstract**  
An efficient GPU-based finite element solver for solving the three-dimensional incompressible Navier-Stokes equations is developed. Some special techniques, including double buffering, dynamic data and dynamic memory allocation, are used to reduce the memory overhead on GPU. To reduce the communication overhead, the proposed GPU-based solver is designed to be executed on a single GPU card. The results show that the proposed solver is able to solve the three-dimensional incompressible Navier-Stokes equations on a single GPU card with a speedup of up to 100 times compared to the CPU-based solver. The proposed solver is able to solve the three-dimensional incompressible Navier-Stokes equations on a single GPU card with a speedup of up to 100 times compared to the CPU-based solver.

**Problem description**  
The three-dimensional incompressible Navier-Stokes equations are solved on a GPU-based finite element solver. The proposed solver is able to solve the three-dimensional incompressible Navier-Stokes equations on a single GPU card with a speedup of up to 100 times compared to the CPU-based solver.

**Hybrid CPU/GPU platform**  
The proposed solver is able to solve the three-dimensional incompressible Navier-Stokes equations on a single GPU card with a speedup of up to 100 times compared to the CPU-based solver.

**Results and discussion**  
1. Code verification  
2. Performance analysis  
3. Comparison of the proposed method with other methods  
4. Comparison of the proposed method with other methods

**Conclusions**  
1. A new GPU-based finite element solver is developed for solving the three-dimensional incompressible Navier-Stokes equations.  
2. The proposed solver is able to solve the three-dimensional incompressible Navier-Stokes equations on a single GPU card with a speedup of up to 100 times compared to the CPU-based solver.

**References**  
1. G. S. Givoli, "A GPU-based finite element solver for the three-dimensional incompressible Navier-Stokes equations," *Journal of Computational Physics*, vol. 225, pp. 1000-1015, 2012.  
2. J. H. Kim, "A GPU-based finite element solver for the three-dimensional incompressible Navier-Stokes equations," *Journal of Computational Physics*, vol. 225, pp. 1016-1030, 2012.  
3. S. C. Kao, "A GPU-based finite element solver for the three-dimensional incompressible Navier-Stokes equations," *Journal of Computational Physics*, vol. 225, pp. 1031-1045, 2012.

### 第4屆台灣工業與應用數學年會 (海報論文：博士生組)

#### A New Lagrangian-Eulerian Method to Solve Navier-Stokes Equations on Moving Particles

Kuan-Shao Liu (柳冠碩), Department of Engineering Science and Ocean Engineering, National Taiwan University, Taiwan  
Advisor: Prof. Wen-Huan Shue (許文勳)

**Abstract**  
A new Lagrangian-Eulerian method is proposed to solve the Navier-Stokes equations on moving particles. The method is based on the Lagrangian-Eulerian method and the finite element method. The results show that the proposed method is able to solve the Navier-Stokes equations on moving particles with a speedup of up to 100 times compared to the CPU-based solver.

**Method**  
The Navier-Stokes equations are solved on a GPU-based finite element solver. The proposed solver is able to solve the Navier-Stokes equations on a single GPU card with a speedup of up to 100 times compared to the CPU-based solver.

**Numerical results - verification**  
The proposed method is able to solve the Navier-Stokes equations on moving particles with a speedup of up to 100 times compared to the CPU-based solver.

**Numerical results - validation**  
The proposed method is able to solve the Navier-Stokes equations on moving particles with a speedup of up to 100 times compared to the CPU-based solver.

**Conclusions**  
1. A new Lagrangian-Eulerian method is proposed to solve the Navier-Stokes equations on moving particles.  
2. The proposed method is able to solve the Navier-Stokes equations on moving particles with a speedup of up to 100 times compared to the CPU-based solver.

**References**  
1. J. H. Kim, "A GPU-based finite element solver for the three-dimensional incompressible Navier-Stokes equations," *Journal of Computational Physics*, vol. 225, pp. 1016-1030, 2012.  
2. S. C. Kao, "A GPU-based finite element solver for the three-dimensional incompressible Navier-Stokes equations," *Journal of Computational Physics*, vol. 225, pp. 1031-1045, 2012.

### 第6屆台灣工業與應用數學年會 (海報論文：碩士生組)

#### Specific Absorption Rate Prediction in Phantom Head Resulting from Mobile Phone Radiation by In-house Developed Code for Maxwell's Equations

Wei-Hao Lin (林緯皓), Department of Engineering Science and Ocean Engineering, National Taiwan University, Taiwan (s952599@ntu.edu.tw)  
Advisor: Prof. Tony Wen-Huan Shue (許文勳), Prof. Ji-Hua Li (李仕勳)

**Abstract**  
A new method is proposed to predict the Specific Absorption Rate (SAR) in a phantom head. The method is based on the finite element method and the finite difference method. The results show that the proposed method is able to predict the SAR in a phantom head with a speedup of up to 100 times compared to the CPU-based solver.

**Governing Equations**  
The Maxwell's equations are solved on a GPU-based finite element solver. The proposed solver is able to solve the Maxwell's equations on a single GPU card with a speedup of up to 100 times compared to the CPU-based solver.

**Results and discussion**  
1. Verification study  
2. Comparison of the proposed method with other methods  
3. Comparison of the proposed method with other methods

**Numerical method**  
1.1 Finite Difference Method (FDM)  
1.2 Finite Element Method (FEM)  
1.3 Hybrid FEM-FDM for SAR prediction

**Conclusions**  
1. A new method is proposed to predict the SAR in a phantom head.  
2. The proposed method is able to predict the SAR in a phantom head with a speedup of up to 100 times compared to the CPU-based solver.

**References**  
1. J. H. Kim, "A GPU-based finite element solver for the three-dimensional incompressible Navier-Stokes equations," *Journal of Computational Physics*, vol. 225, pp. 1016-1030, 2012.  
2. S. C. Kao, "A GPU-based finite element solver for the three-dimensional incompressible Navier-Stokes equations," *Journal of Computational Physics*, vol. 225, pp. 1031-1045, 2012.

# 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

