Bio-numerical Simulation with Grid Applied for the Oral Region


*CMC, Osaka University, Japan
**Faculty of Dentistry, Osaka University, Japan

Today’s contents

- Introduction
- The aim of a bio-numeric simulation
- Why should Grid be required?
- About my simulation for the oral region
- How to mount the simulation on the Grid environment
  - Acoustical analysis with Grid
  - Computational Fluid Dynamic analysis with GRID
- DentGrid proposal
Introduction

- The aim of our research
  - To realize the evidence base dentistry by deploying the grid environment

- About me
  - Eccentric dentist
    - Speciality of the treatment of speech disorders related with teeth.
  - Engineering officer of Super computer, SX5, NEC Corp.

Example of a bio-numeric simulation

- **GEMSS** (Grid-Enabled Medical Simulation Services), Simbio
  - [http://www.gemss.de/](http://www.gemss.de/)
  - Surgical planning for the maxillofacial region
  - Blood flow simulation of an artery

- **Biogrid**
  - CMC, Osaka University

- **Virtual Heart**
  - K.Nakazawa, CMC-CAVE, 2004
The advantage of Bio-numeric simulations with Grid (1/2)

- Low cost and high power
  - Plenty of the computational power
  - Data sharing
  - The visualization of over 2GB data

Bio-numeric simulation might teach me how to treat this disease.

The advantage of Bio-numeric simulations with Grid (2/2)

- Accumulation and utilization of the simulation results combined with clinical data
  - Security
    - PKI based
  - Search facility
  - Semantic Grid
Bio-numeric simulation with non-grid applied for the oral region

- **The aim of our simulation**
  - To know how to fix the dental prostheses of the patients who complain about speech disorders
  - To examine which part of the oral tract feature make the difference of the sounds such as the sibilant /s/

**In my experience for this case, ... Where should be fixed?**
**You'll get used to it.**

Bio-numeric simulation (1/14): for a Dental prosthesis

This patient has the complain about the speech disorders with her denture. Especially, The speech disorders were found about the pronunciation of /s/.
Bio-numeric simulation (2/14): Conventional way to treat the speech disorders of dentures

Paratogram:
- One of the clinical technique for examination of the speech disorders
  - The paratogram enables dentists to assess the area contacted by the tongue
  - It is only indirect method to examine the speech disorders with dentures

The area contacted by the tongue

Bio-numeric simulation (3/14): New approach for the speech disorders

- How to modify the feature of the dentures?
- Examination
  - Change of the anterior teeth angular (+30, normal, -30)
    - Acoustical analysis
    - Computational Fluid Dynamic analysis (CFD analysis)
Bio-numeric simulation (4/14):
Results (Acoustical analysis)

- Acoustical analysis
  - Around high frequency area, pink square, the signal intensity is different.

Bio-numeric simulation (5/14):
Results (CFD analysis)
Bio-numeric simulation (6/14): Discussion for semantic database

- It is important for the clinical treatment to combine the results of the acoustical analysis and CFD analysis related with the anterior teeth features
  - It will achieve the semantic database by storing those clinical data with metadata.

Bio-numeric simulation (7/14): Discussion for 3 dimension (3D)

- The change of sibilant sounds depend on the anterior teeth area.
- It will be better to examine that area by 3D simulation than to do whole area by 2D.
  - Oral region has a complicated 3D feature such as teeth.
Bio-numeric simulation (8/14): Taking an impression (3D)

- Taking impression of 3D oral tract while pronouncing the sibilant /s/
  - Dental silicon impression paste
  - Hardened silicon could reflect the relationship between the tongue and teeth

Bio-numeric simulation (9/14): Model construction

- 3D oral tract model for CFD analysis
  - Laser scan of dental plaster-models
  - Converting 3d points data to polygon data on CAD software, SURFACER
Bio-numeric simulation (10/14):
Results of the 3D simulation

- CFD analysis was performed by using
  **STREAM** (CRADLE Co. Ltd.)

![Transparent model](image1)

Bio-numeric simulation (11/14):
Results of the 3D simulation

- Helicity
  - In front of anterior teeth
  - Time round change distribution of the distributed area of helicity

\[ h = \omega \cdot v = \text{curl}(v) \cdot v \]
Bio-numeric simulation (12/14):
Results of the 3D simulation

- Powel sound source
  - Around the anterior teeth

\[ \text{div}(\omega \times v) \]

Bio-numeric simulation (13/14):
Results of the 3D simulation

- Zoom up around anterior teeth
  - Left: vertical slice image
  - Right: 3D powel sound source
Bio-numeric simulation (14/14):
Discussion

- The area of the sound source could be found by this methods.
- This bio-numeric simulation needed;
  - A lot of computational resources
    - 40GFlops, 36 hours
  - Large amount of storage areas
    - More than 2Gbyte for only 10 time steps of tensor data such as the velocity (x,y,z), pressure in condition of 6,500,000 mesh
    - We needs 15,000 steps!
  - Large amount of memories
    - Working memory was restricted to be less than 1Gbyte because 32bit visualization software can only visualize less than 2Gbyte data.
- Future plan
  - Computational Aero-Acoustics (CAA) will be mounted, however CAA will need much more those resources.

Grid testbed (Acoustical Analysis)

- Globus2.4 + GridPort2.3.1 + SRBv2 + FFT
Grid testbed (1/5) (CFD analysis)

- Some difficulty come from Grid
  - Computation of CFD by using MPI
    - Piled up a communication **latency**
  - Connectivity among clusters
    - Occasionally cluster has the **private IP**.
      - *Grid enabled MPI solutions for Clusters, Matthias M. et al, 2002*

![Diagram of computation latency time](image)

Grid testbed (2/5) (CFD analysis)

- MPICH-G2 was used as parallel processing for the bio-numeric simulations
- It has been often said, “GRID is not good at CFD”.
  - Hypothesis: The volume of “computation/1node” might be the key to brake such as a **latency** problem.

![Graph showing the ratio of communication in total simulation time](image)
Grid testbed (3/5) (CFD analysis)

- MPICH-G2 can’t realize the use of several clusters simultaneously.

RSL file (hoge.rsl)

```plaintext
- Grid port 2.3.2
- SimpleCA
- Globus 2.4
- MPICH-G2

mpirun -globusrsl hoge.rsl
```

Machines

- grid.port2.3.2
- SimpleCA
- Globus 2.4
- MPICH-G2

Grid testbed (3/5) (CFD analysis): How to solve this problem?

- Iptunnel
  - VPN
- jojo (AIST)
- IPv6
  - All nodes have their own IP.
    - GT3.2 + Kernel 2.6!

To be continued....
Grid testbed (3/5) (CFD analysis) :
Developing CFD analysis system

- GT 3.2
- MPICH-G2
- NaSt3DGP
  - A Parallel 3D Navier-Stokes Solver
- VRML 1.0 importer
  - Rhinoceros 3.0J
    - SURFLASER (3d laser scanner)
- VTK4.2 exporter, etc.

Testbed map of CFD with GRID
(under construction)
Summary of this talk

- There is an optimal relationship between network communication time and data size to perform the bio-numeric simulation.
- Future medical treatment should be required the Evidence why the treatment should be needed and selected.

Thank you!

- I really appreciate to the audience and especially, Mr. Seventeen Chen who invite me here.
- Special contribution by T. Kaishima and T. Akiyama, who help me to mount the globus software kindly.

Kazunori Nozaki
nozaki@cmc.osaka-u.ac.jp