11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Human swallowing simulation by the Hamiltonian MPS method

Takahiro KIKUCHI[1]*, Yukihiro MICHIWAKI[1], Seiichi KOSHIZUKA[2], Tetsu KAMIYA[3], Yoshio TOYAMA[3], Takashi OSADA[3] and Nobuko JINNO[3]

[1] Oral Surgery Division, Japanese Red Cross Musashino Hospital
1-26-1, Kyonancho, Musashino, Tokyo 180-8610, Japan, oralsurg@musashino.jrc.or.jp

[2] Department of Systems Innovation, The University of Tokyo
7-3-1, Hongo, Bunkyo, Tokyo 113-8656, Japan, koshizuka@sys.t.u-tokyo.ac.jp

[3] Food Technology Research Laboratories, Meiji Co., Ltd.
540, Naruda, Odawara, Kanagawa 250-0862, Japan, tetsu.kamiya@meiji.com

Key Words: *Swallowing, Particle Methods, Hamiltonian MPS, Hyperelasticity, Soft Tissue.*

Swallowing is a complex motion which involves the oral cavity, the pharynx, the larynx and the esophagus and takes about one second. Because it is difficult to analyze the quick and complex motion by small organs during swallowing, the mechanism of swallowing has not been fully understood. In the numerical simulation, the finite element method has been applied in this field [1], however, the shape of organs was excessively simplified and the motion was not smooth.

In this study, we applied the particle method for swallowing simulation, which was expected to be useful to analyze large deformation without mesh generation.

The particles were arranged based from the CT (Computed Tomography) and the VF (Video Fluorography) images of head and neck of a normal volunteer (25-year old male) who provided an informed consent for this study. The particles were generated not in whole neck but in surface having some thickness because of less computational cost. The soft tissue organs were treated as a nonlinear elastic material of Hamiltonian MPS (HMPS) method [2]. For its stability, viscous forces based on the MPS method and auxiliary potential forces [3] were also employed. The contact forces between the wall surfaces were calculated using the penalty method. The movements of muscles were modeled as control points, which were some particle groups shifted with enforced displacements, placed in consideration of muscle arrangements and swallowing function so that this model reflected the medical background. The other particles of organs were passively deformed.

As a result, every organ in this simulation moved smoothly during the whole swallowing period. The large deformation such as hypopharynx was simulated stably by auxiliary potential forces and HMPS using hyperelastic constitutive laws. There were little volume changes of organs and no unnatural behaviour of particles such as passing through each other.

In future, we will validate these results by comparing with swallowing pressures from human measurement. We will develop a method of simulation with external force that reflects the power of the muscle instead of giving the coordinates.

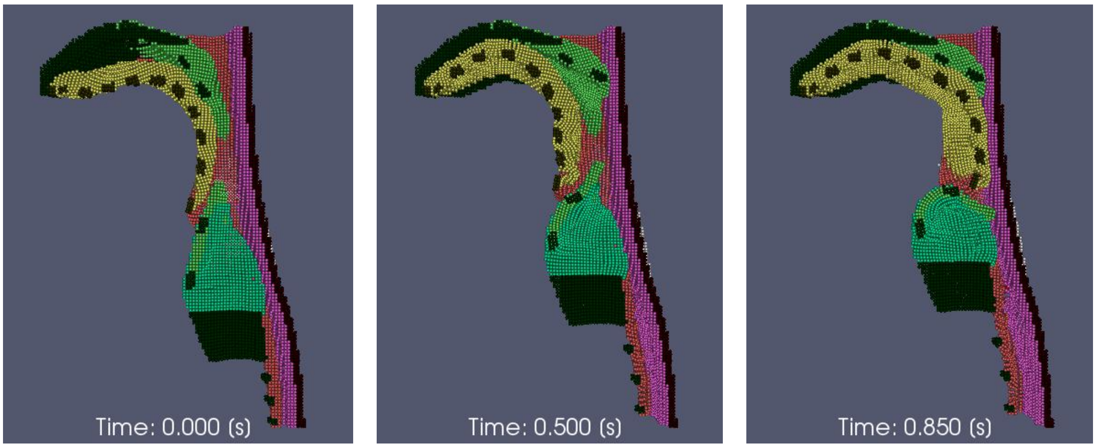

Fig. 1 Simulation of swallowing (Black particles were control points.)

REFERENCES

[1] M. Sonomura, H. Mizunuma, T. Numamori, H. Michiwaki and K. Nishinari, Numerical Simulation of the Swallowing of Liquid Bolus, *Journal of Texture Studies*, Vol. **42**, pp. 203-211, 2011.

[2] Y. Suzuki and S. Koshizuka, A Hamiltonian Particle Method for Non-linear Elastodynamics, *Int. J. Num. Methds. Engrg.*, vol. **74**, pp. 1344-1373, 2008.

[3] M. Kondo, Y. Suzuki and S. Koshizuka, Suppressing local particle oscillations in the Hamiltonian particle method for elasticity, *Int. J. Num. Methds. Engrg.*, vol. **81**, pp. 1514-1528, 2010.