Heterogeneous Domain Decomposition for Multi-Scale Problems *

M. Garbey, F.Pacull and C. Picard
Department of Computer Science, University of Houston.

The understanding of blood flow phenomena relevant to vascular diseases is a critical and yet difficult issue. The initial formation of arteriosclerosis plaque, for example, depends on a combination of various factors. The impact of physical and geometrical properties is well documented experimentally. There is a number of evidence relating shear stress of the vessels to the pathophysiology of arteriosclerosis: arteriosclerosis plaques are frequently located at or near regions of bifurcations, multiple intersections, and high vessel wall curvatures. However, arteriosclerosis is a slow process influenced accumulatively by many parameters, including chemical agents, mutagen, hypoxemia and immunological factors on one hand, and microbiological factors such as bacteria, virus, or endotoxin on the other hand, which act on a much shorter time scale and in a more localized manner than the firsts. Therefore, in order to perform realistic simulations for cardiovascular physiology, one must address issues related to fluid and vessel wall interactions, and coupling of the aforementioned disparate time scales and length scales. Furthermore, one should develop a systematic way of calibrating the simulation to the medical imaging data. The mathematical problems to be solved are:

- The Navier Stokes equation to describe incompressible flow and eventually quasi non Newtonian flow.
- The coupling between the fluid flow equation and the soft tissue model for the artery wall.
- The boundary layer in fluid flow, and multiple scales in reaction diffusion convection of chemical species between the fluid flow and the multi layer material wall.
- The parameter identification and calibration of the mathematical model to medical imaging data or experimental data.

Such an endeavor involves substantial challenges arising from mathematical modeling, numerical techniques, computational modeling, image analysis, and experimental validation.

The aim of this paper is to present a set of domain decomposition tools that will allow to develop numerical efficient computation of multi-scale complex blood flow phenomena. We will restricted our development to two space dimensions while most of the concept can be extended to three space dimensions.

*This work was supported in part by NSF Grant ACI-0305405.