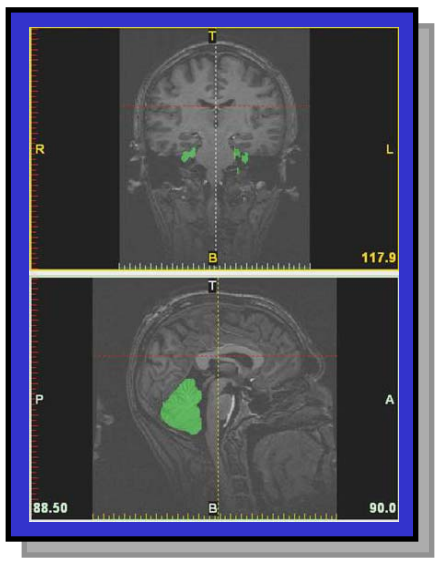
The Study and Control of Cerebral Haemodynamics based on a Mathematical Vasculature Model

August 2nd 2007



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Motivation/Objectives

Why study cerebral haemodynamics?

- **According to the WHO:**
  - 61 million people around the world suffer from cerebrovascular diseases
  - 1 out of 4 patients who enter a health care facility have a mental, behavioral or neurological disorder
- **Long Term Goals:**
  - To further the understanding of how our brain works
  - To make a contribution towards the study and treatment of cerebrovascular diseases

Objectives

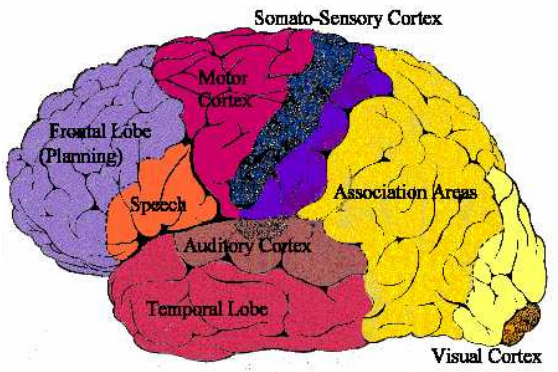
- Design and implement a control system to study and control blood flow distributions

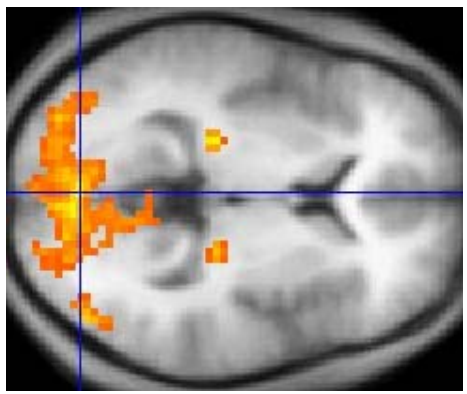
Possible Applications for Control Systems

Functional Hyperaemia – is defined as the ability of the brain to divert blood flow towards activated areas

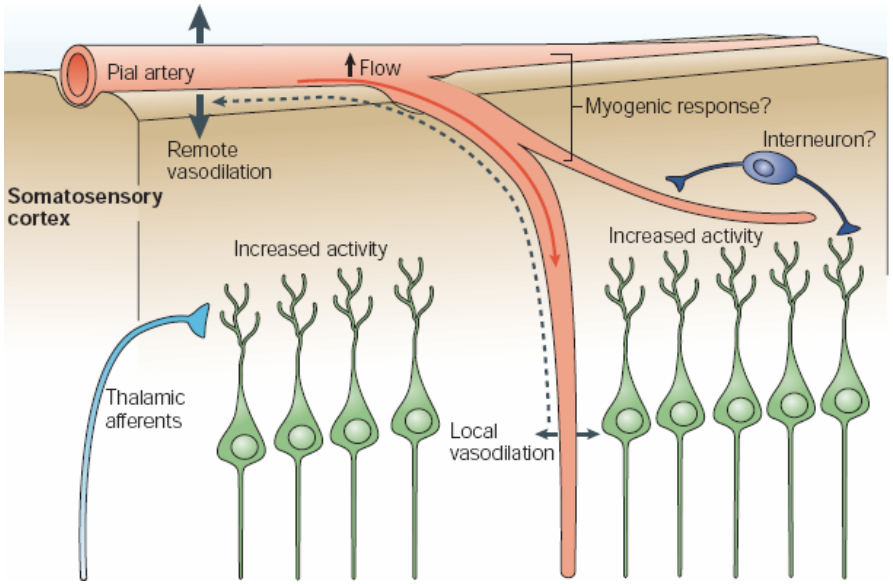
Observations:

- Hyperaemia occurs when we are listening, observing, moving or thinking
- 400% increase of blood flow to a stimulated area of the brain





Functional Hyperaemia

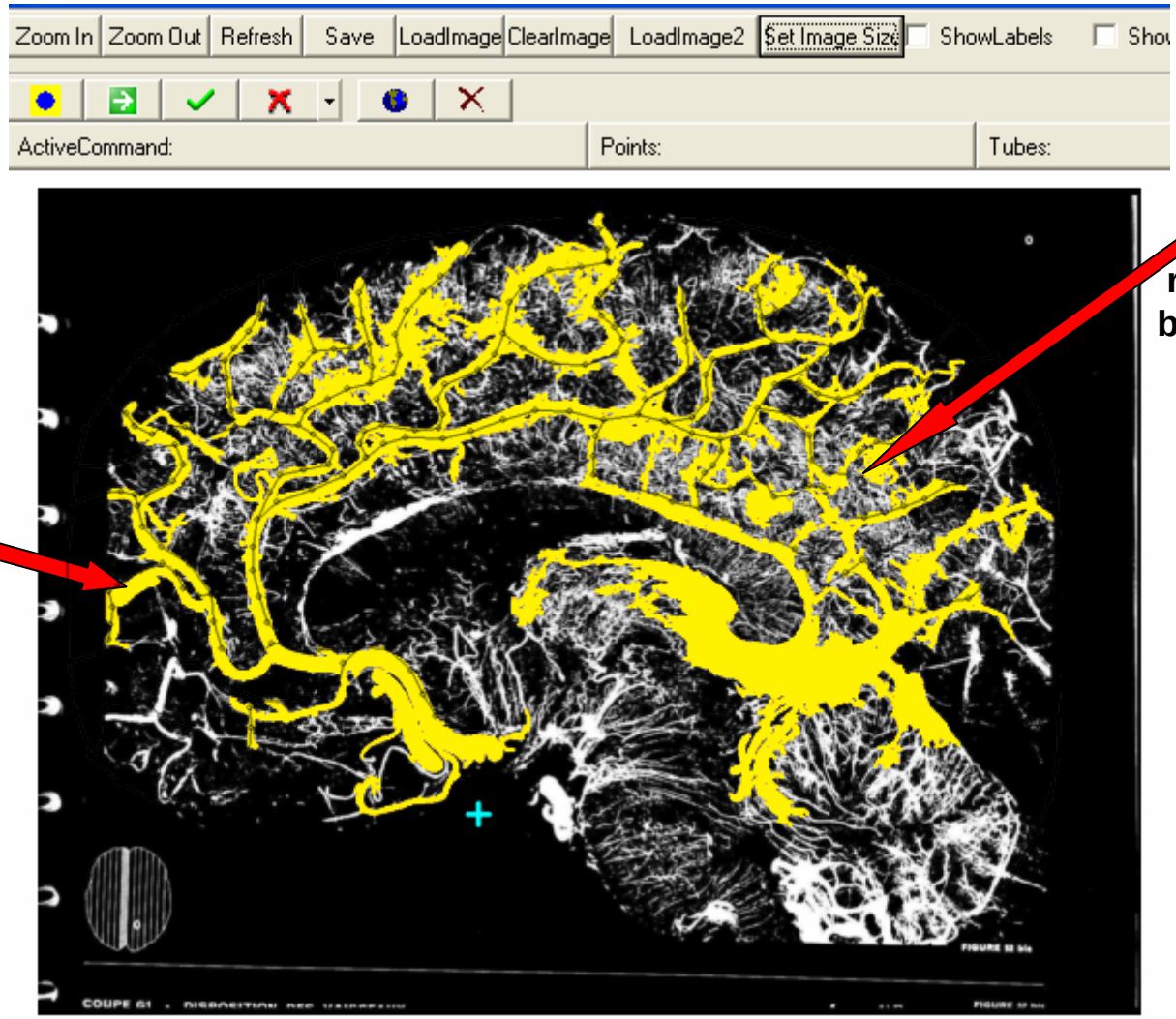


In this phenomenon:

- Increase in blood flow results from both
  - An increased diameter of local blood vessels
  - An increased diameter of upstream blood vessels via intramural vascular signaling

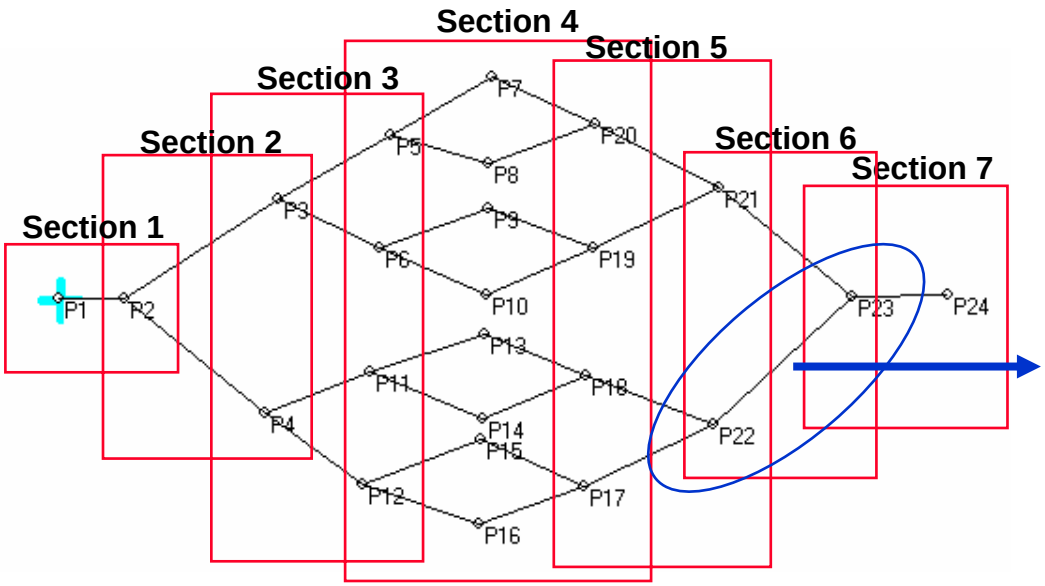
Intramural vascular signaling – an increase in the local blood vessel diameter will increase the flow velocity as well resulting in an increase in shear stress and thus triggering a vasodilation response in the upstream arterioles.

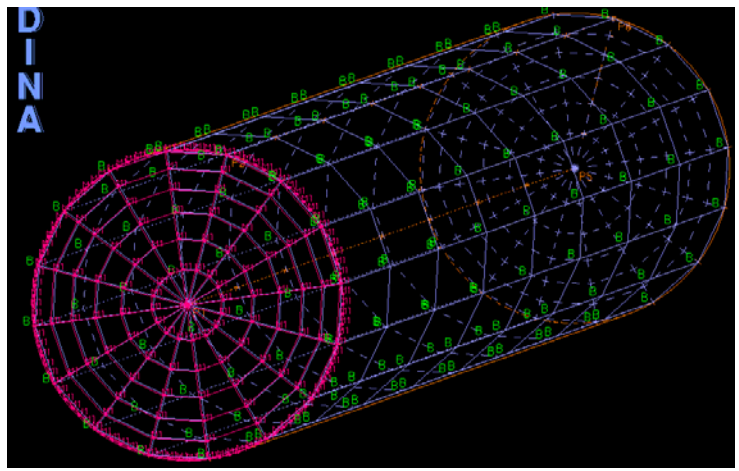
Applications



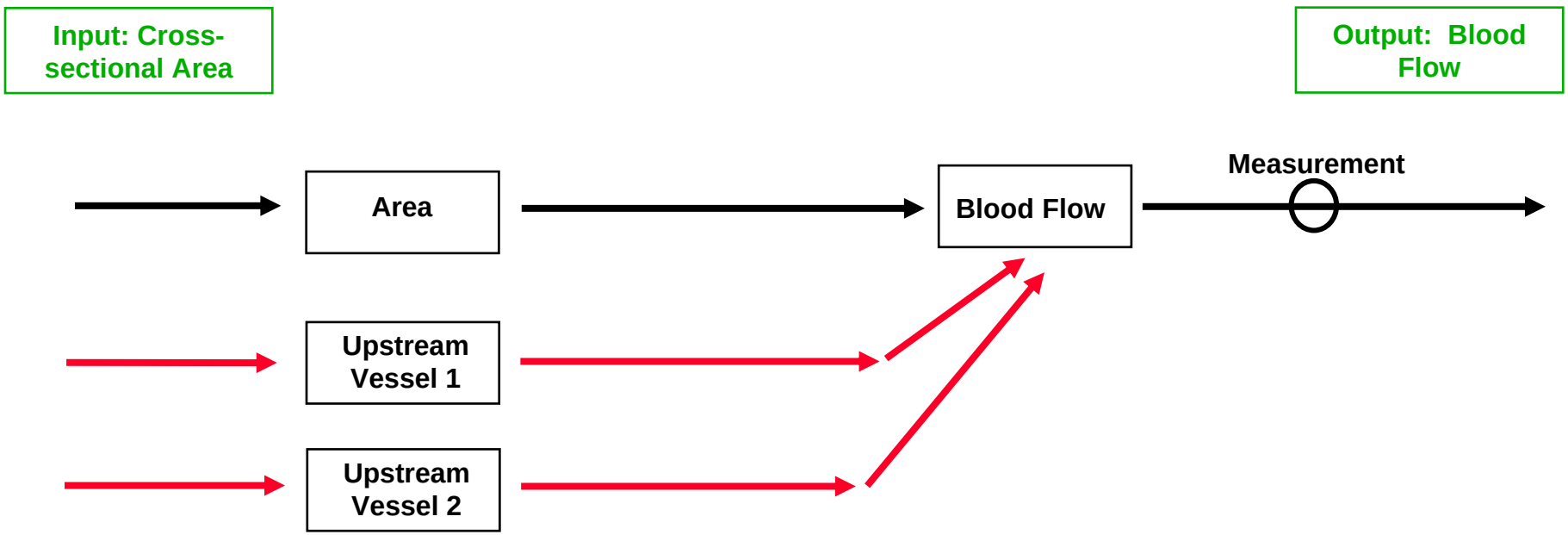
Network

	Length (cm)	Area (cm^2)	E (dyn/cm^2)	# of vessels	Vessel Name
Section 1	25	0.06	300800	2	Anterior Cerebral Arteries
Section 2	10	0.022	330900	50	Main Branches of Cerebral Arteries
Section 3	3.5	0.0018	364000	3900	Pial Arteries
Section 4	0.5	0.003	440400	202000	Microcirculation
Section 5	3.5	0.00406	130000	3800	Pial Veins
Section 6	5	0.046	51700	40	Cerebral Veins
Section 7	15	0.049	50000	10	Veins

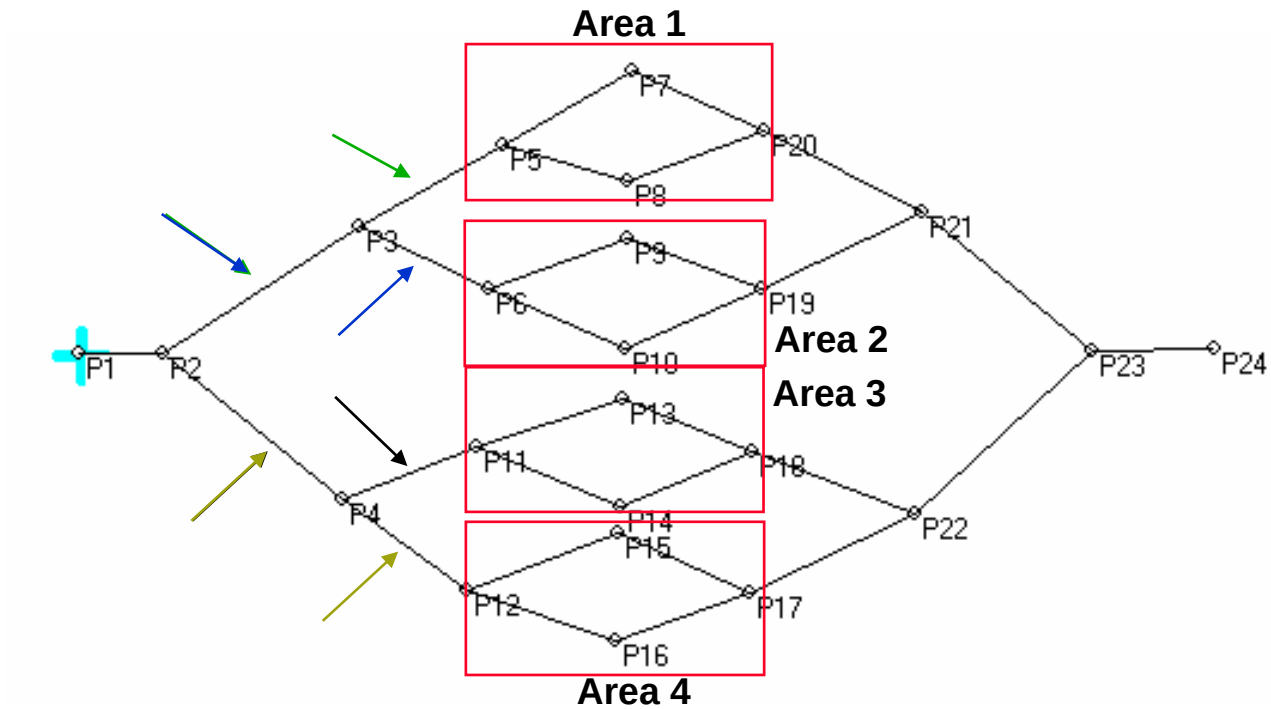




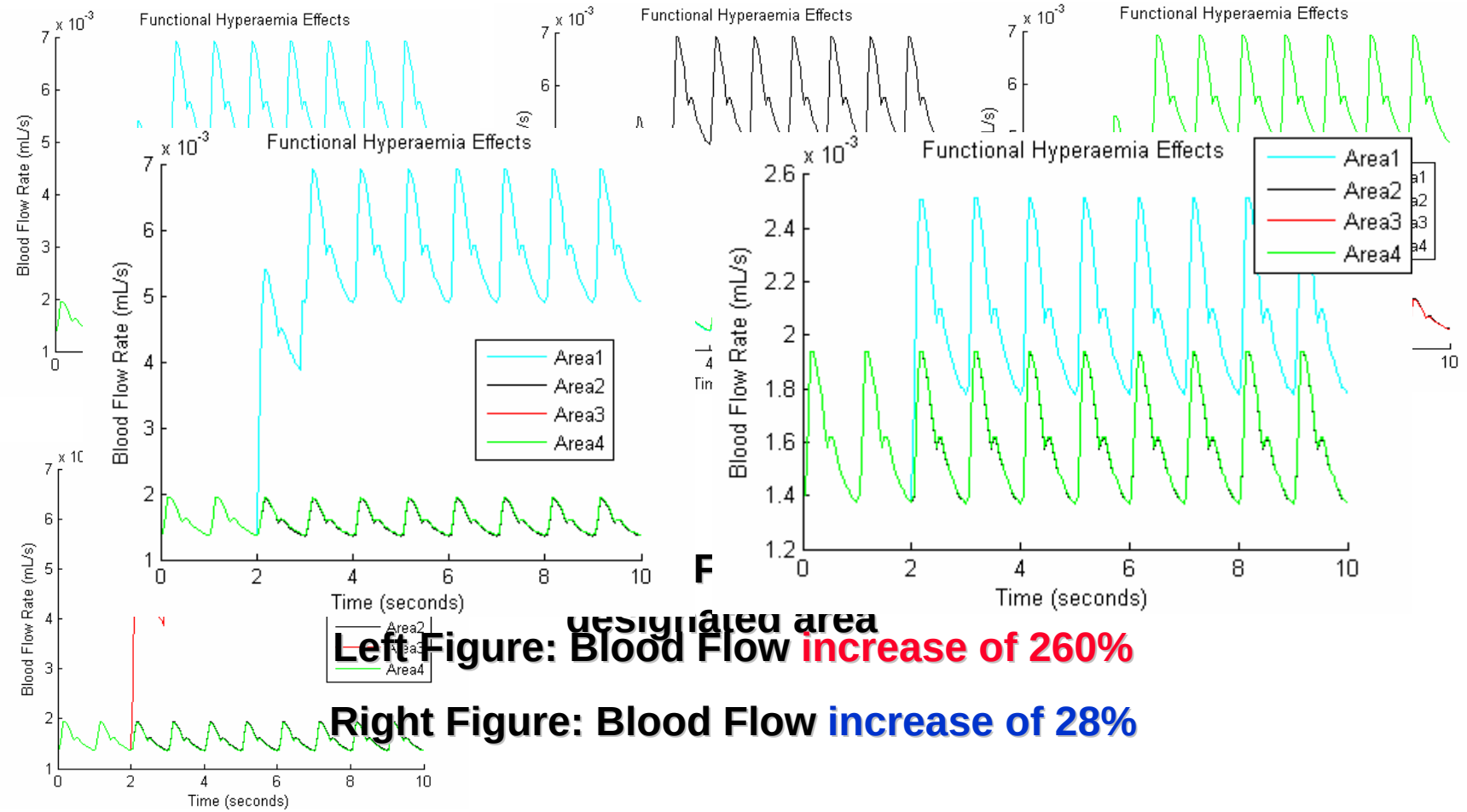
Open-Loop Network



Open-Loop Method



Open-Loop Control Results



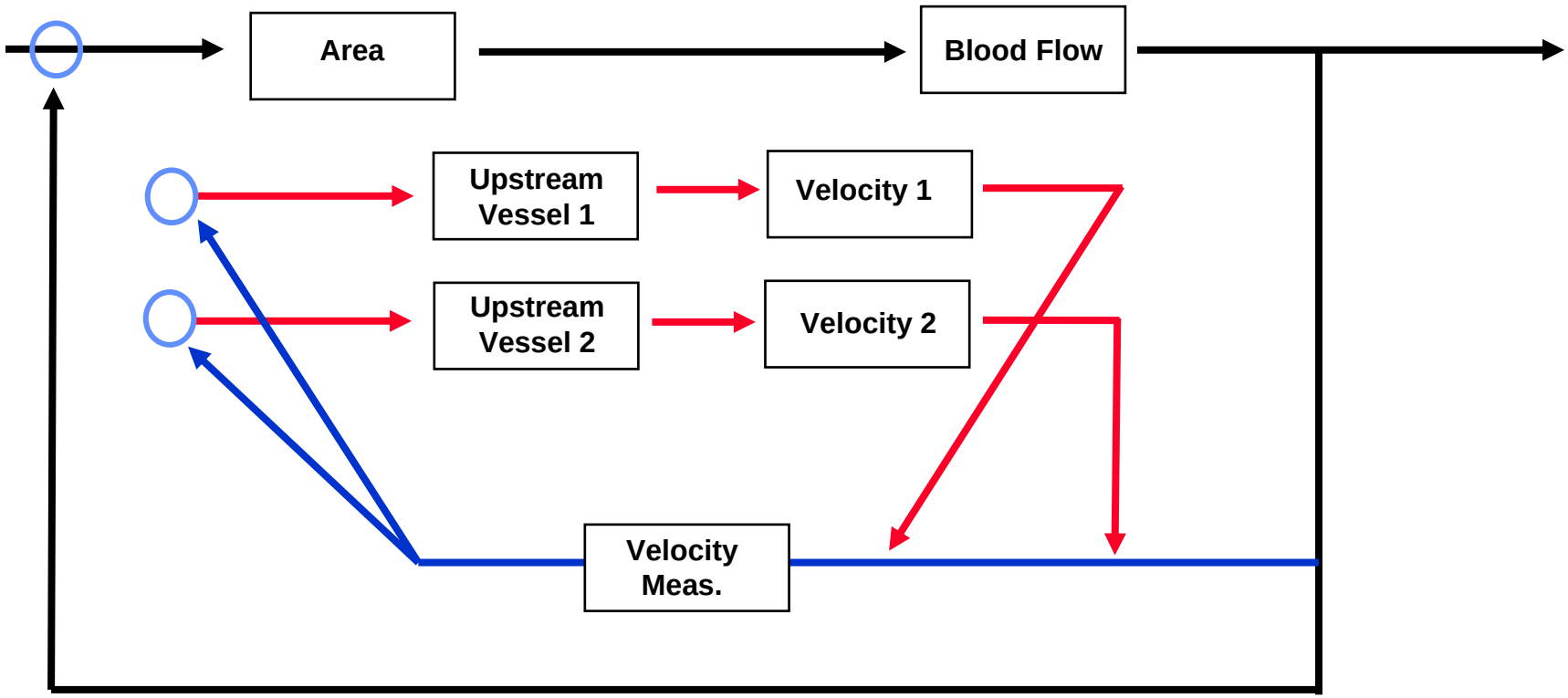
Left Figure: Blood Flow increase of 260%

Right Figure: Blood Flow increase of 28%

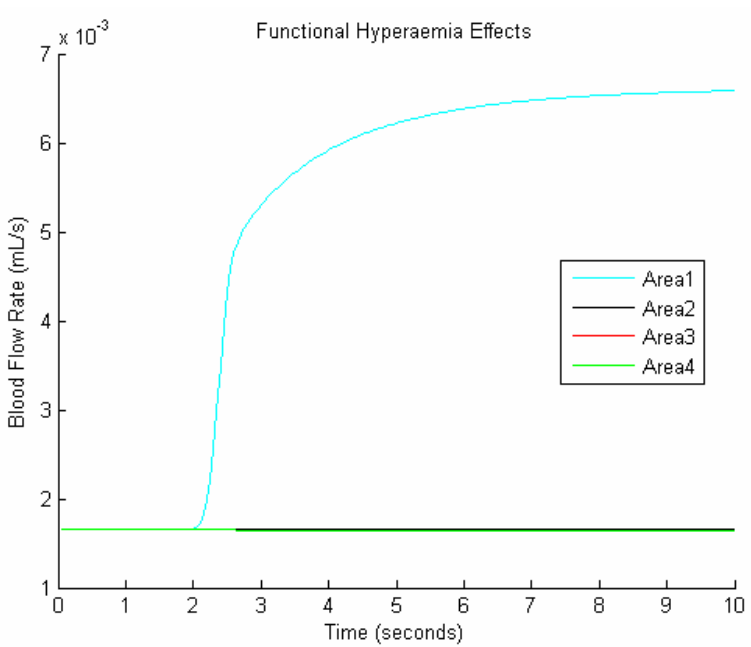
Closed-Loop Control

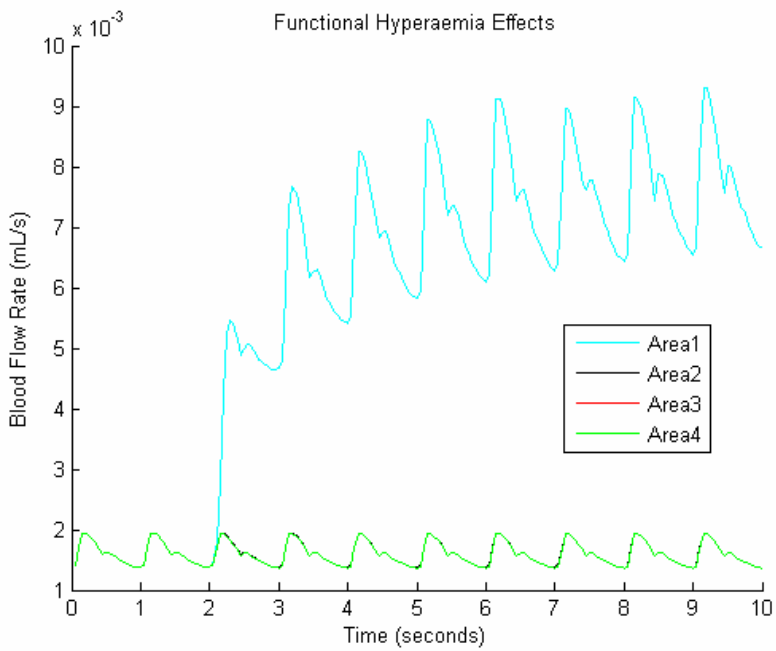
Input: Cross-sectional Area

Output: Blood Flow



Closed-Loop Method/Results





Diameter increase of approximately:

- **70% in local Area 1**
- **119% in upstream blood vessel 1**
- **45% in upstream blood vessel 2**

Conclusions/Future Directions

1. **Based on the results of our model, it seems that quantitatively, the model can still use some work on. However, qualitatively, it is reasonable to conclude that the control system does work as it is intended to work.**

2. **Possible future directions for this project include**
    - » **The incorporation of the control system into a more complex vascular network**
    - » **Applying other types of phenomenon that occur in the brain on the model**
    - » **Altering the equations that govern fluid flow as to make the model more consistent quantitatively when mimicking different phenomena**

Acknowledgements

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