Internet of Microscopes (IoM) for Biomedical Imaging

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Project Description

Imaging enabled by advances in microscopy and software has played an important role in biological research and medical diagnosis. µManager is an open-source, cross-platform desktop application, to control a wide variety of motorized microscopes, scientific cameras, stages, illuminators, and other microscope accessories [1, 2]. Since its development in 2005, µManager has grown to support a wide range of microscopy hardware and is now used by thousands of researchers around the world. Combined with ImageJ [3], a public domain, Java-based image processing program developed at NIH, the application provides a mature graphical user interface and can be used to automate various microscope and imaging operations. One of outstanding features of µManager is that it provides hardware abstraction interface that allows writing hardware-independent open programs using common programming languages such as Java (**Figure 1**). For example, a developer can write a java application that interacts with any microscope camera, regardless of type, manufacturer, and driver, using such abstraction. In summary, ImageJ and µManager provide flexibility, interoperability, and sustainability that commercial products often lack. The PI proposes an open-source project "Internet of Microscopes (IoM)" that will augment the benefits of ImageJ/µManager by adding the cloud.

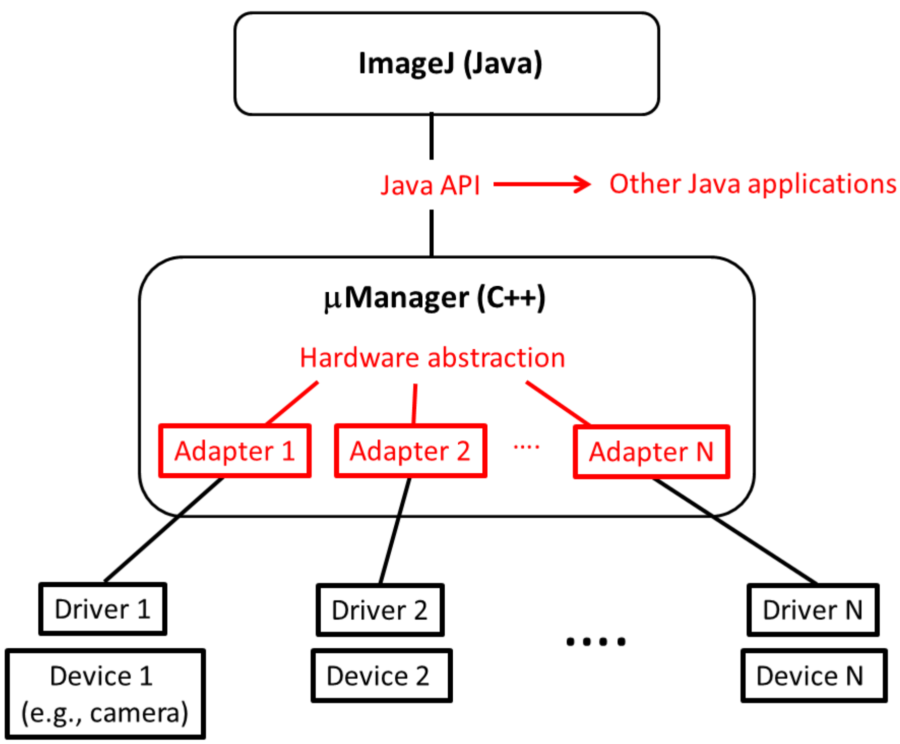

Figure 1. Block diagram of ImageJ/µManager software architecture [1].

<u>This project will give additional benefits, such as real-time remote control and online collaboration, to biological research and medical communities.</u>

Microscope and imaging operations done by any human user can be understood in the context of closed feedback control loop (**Figure 2A**). In the figure, the user is a controller receiving data from sensors (e.g., microscope camera), processing the data, and controlling actuators (e.g., camera shutter, microscope filter, light source, stage manipulator, etc.) using the computer connected to the microscope. IoM can be achieved by adding cloud computing to this system as shown in **Figure 2B**. The user now interacts with the cloud environment, which communicates with the microscope computer in real time across the internet. An autonomous, intelligent IoM system can also be developed, which does not require human intervention (**Figure 2C**). The communication between the cloud server and the clients can be achieved using SignalR, a real-time bi-directional communication and broadcasting technology that enables "true" web service capability [4-7]. Unlike conventional web services such a RESTful web service, SignalR-based web services can make diverse applications written in different programming languages use each other as "libraries" across the internet. For example, an application written in Java, C++, or Javascript on the client side [5-7] can call and use the methods provided by the cloud server application written in C# and vice versa. This project will also use Microsoft Azure as a cloud platform. The reason established technologies such as SignalR and Azure are used is to

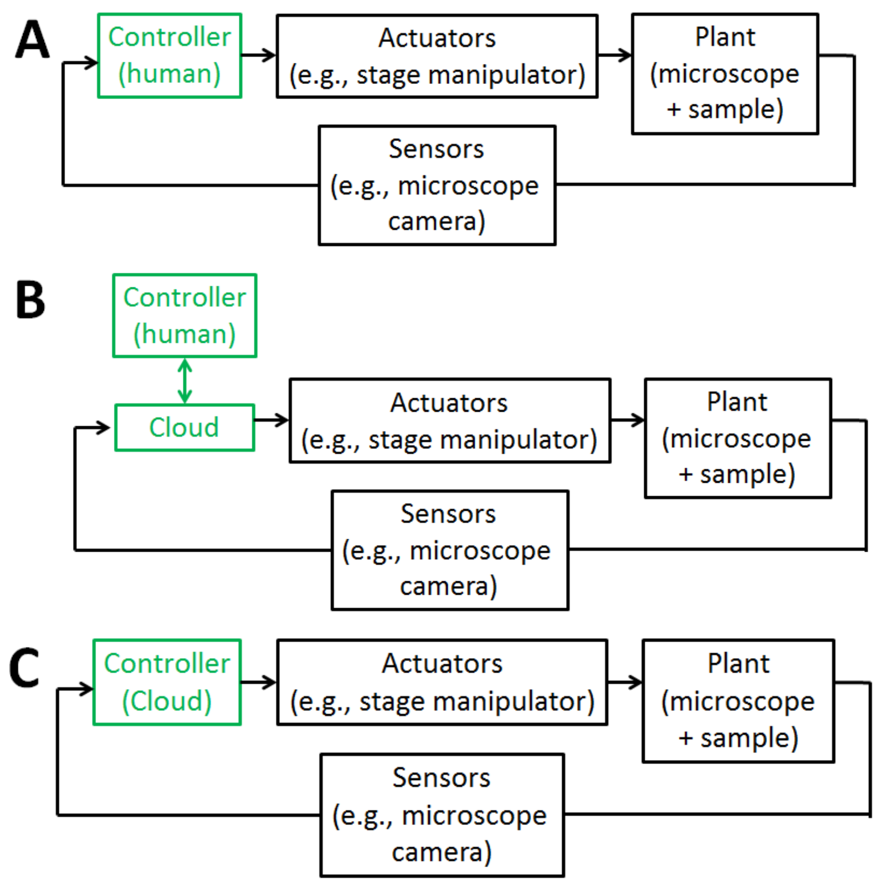

Figure 2. Closed feedback control models for microscope and imaging operations. A) Human controller model. B) Cloud-based human controller model. C) Cloud controller model.

focus on productive development of a new biomedical Internet of Things (IoT) application and not on network/cloud computing issues, such as robustness, resilience, stability, privacy, security, etc., although they are important in their own right. Using IoM, biologists and health professionals can remotely control microscope and imaging operations with mobile devices such as smart phones or tablet PCs any time anywhere (**Figure 3**). Furthermore, since SignalR supports broadcasting, multiple clients or users can work together in real-time while operating microscope. This feature can be used not only for research and clinical practice but also for education.

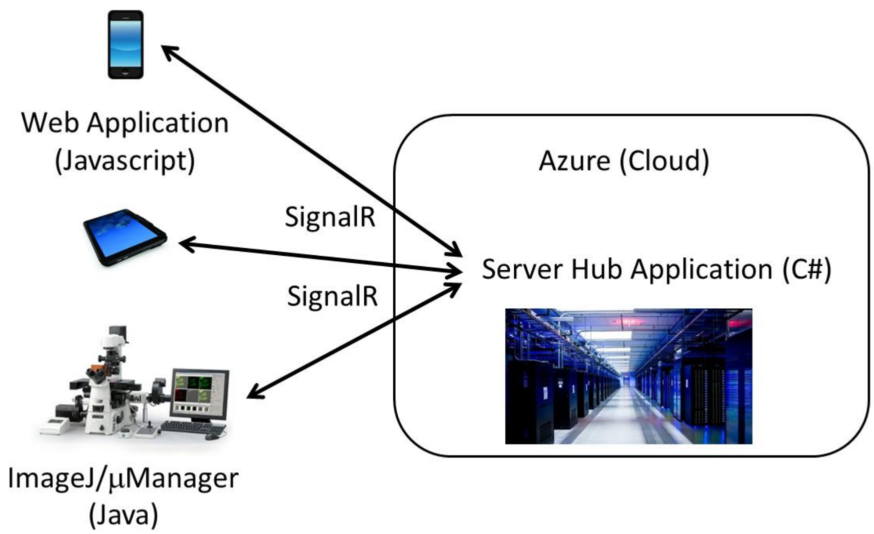

Figure 3. SignalR-based IoM.

Available resources:

1. Microscope: The PI is currently working on an optogenetics/synthetic biology project with Prof. Yongku Cho (UCONN Chemical and Biomolecular Engineering) who is also interested in sharing his fluorescent microscope for this project.
2. Cloud environment: In May 2015, the PI, Prof. Rajasekaran (UCONN Computer Science and Engineering), and Prof. Ramprasad (UCONN Material Science and Engineering) jointly received $1.4 M for building a cloud-enabled HPC infrastructure on campus, which will be used for building a private Azure cloud platform described in this project. The PI also received Microsoft Azure Research Award twice (2014 and 2015) and has required experience of using Azure cloud resources and services for the project.
3. Development environment: NetBeans (Java), Visual Studio Community 2015 (C#), and IntelliJ IDEA (Javascript), and GitHub are freely available and will be used for the project.

Required resources: 1 graduate student RA support for 2 years

References

1. μManager https://www.micro-manager.org/

2. Arthur D Edelstein, Mark A Tsuchida, Nenad Amodaj, Henry Pinkard, Ronald D Vale, and Nico Stuurman (2014), "Advanced methods of microscope control using µManager software", Journal of Biological Methods 2014 1(2):e11 doi:10.14440/jbm.2014.36
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4. SignalR http://www.asp.net/signalr
5. SignalR Java Client https://github.com/SignalR/java-client
6. SignalR C++ Client https://github.com/aspnet/SignalR-Client-Cpp
7. SignalR Javascript Client https://github.com/SignalR/SignalR/wiki/SignalR-JS-Client