The Left Ventricular Assist Device (LVAD) is a rotary mechanical pump that is implanted in patients with congestive heart failure to help the left ventricle in pumping blood in the circulatory system. The rotational speed of the pump is adjusted by varying the pump motor current to control the amount of blood flowing through the LVAD. One important challenge in using such a device is the desire to provide the patient with as close to a normal lifestyle as possible until a donor heart becomes available. The development of an appropriate feedback controller that is capable of automatically adjusting the LVAD rotational speed is therefore a crucial step in meeting this challenge. In addition to being able to adapt to changes in the patient's daily activities, the controller must be able to prevent the occurrence of excessive pumping of blood from the left ventricle (a phenomenon known as ventricular suction) that may cause collapse of the left ventricle and damage to the heart muscle and tissues.

In this dissertation, we present a new suction detection system that can precisely classify pump flow patterns, based on a Lagrangian Support Vector Machine (LSVM) model that combines six suction indices extracted from the pump flow signal to make a decision about whether the pump is in suction, approaching suction, or not in suction. The proposed method has been tested using in vivo experimental data based on two different LVAD pumps. The results show that the system can produce superior performance in terms of classification accuracy, stability, learning speed, and good robustness compared to three other existing suction detection methods and the original SVM-based algorithm. The ability of the proposed algorithm to detect suction provides a reliable platform for the development of a feedback control system to control the LVAD rotational speed while at the same time ensuring that suction is avoided.

Based on the proposed suction detector, a new control system for the rotary LVAD was developed to automatically regulate the pump current resulting in a rotational speed that avoids ventricular suction. The control system comprises of an LSVM suction detector and a feedback controller. The LSVM suction detector is activated first so as to correctly classify the pump status as No Suction (NS) or Suction (S). When the detection is "No Suction" the feedback controller is activated so as to automatically increase or decrease the LVAD speed in order that the blood flow requirements of the patient's body at different physiological states are met according to the patient's activity level. When the detection is "Suction" the LVAD speed is immediately decreased by reducing the pump current in order to drive the pump back to a normal No Suction operating condition. The performance of the control system was tested in simulations over a wide range of physiological conditions.

Approved for distribution by Dr. Marwan A. Simaan, Committee Chair, on July 24, 2013.
The public is welcome to attend.