Ultrasonic Distance Mapper

Software Design Document

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# Introduction

## Purpose

This software design document describes the architecture and system design of an ultrasonic mapping sensor.

## Scope

This system is intended to display the ranges and positions of objects near the sensing device. The sensor will rotate so that a 360 degree (or otherwise specified) view of the surroundings can be displayed.

## Definitions and Acronyms

URF: Ultrasonic Range Finder

PWM: Pulsed Width Modulation

LV: LabView 2014 32-bit

# System Overview

An ultrasonic range finder works on principles similar to radar or sonar detection systems. In the function of the ultrasonic range finder, a sound wave at high frequency (greater than 20 kHz; beyond the range of human hearing) is generated from a speaker on the range finder. The wave then travels until it is reflected off of an object­—an “echo”—and is picked up by the microphone on the range finder. Since the speed of sound is known, about 344 m/s, we can calculate the distance to the object. The round-trip distance is given by multiplying the time between emission and detection of the sound wave and the speed of sound; we can halve the round-trip distance to give the distance from the range finder to the object. Our system uses an ultrasonic range finder coupled with a rotating stepper motor so that it can determine the distance to the objects around it.

The stepper motor functions via pulse-width modulation of a signal. The signal is generated and powers a series of electromagnets in the motor. Since the shaft of the motor is magnetic, it rotates as the electromagnets are powered in sequence. The signal is such that it powers the motors with precise timing for each pulse—each tick—that it sends through. This results in the shaft rotating by a precise amount; for our model, it completes a full revolution every 400 ticks. The spacing of these pulses dictates how fast the motor operates.

# System Architecture

## Architectural Design

The architecture consists of three modules. There are modules for control of the stepper motor, data acquisition from the ultrasonic range finder, and the user interface which controls the whole system. The stepper module writes commands to the stepper motor and allows for a change in the speed of rotation and the sweep angle. Commands written by the stepper motor are processed in WriteToPort.vi, whose sole purpose is to relay these commands. The data acquisition module activates the ultrasonic range finder and collects precisely one data-point: the distance from the object to the range finder. The data acquisition module has controls for the trigger and echo pin input locations on the DAQ (defaulted to Dev1/ctr0 and Dev1/ctr1). The front-end interface of the program integrates the stepper control module and the data acquisition module to independently run both of these modules and plot the data from them. The controls of the interface module are identical to those of the stepper control module and the ultrasonic range finder.

In the interface program all separate modules are run in their own instances. To communicate data between the separate parts, global variables are used. Data like stop signals, distance readings, and loop count could be then found or controlled in one program and thus reported and or analyzed in another

## Design Rationale

The architecture design was chosen so that the program could be as functional and accessible, should someone want to edit it, as possible. Additionally, this made the testing and integration into the interface of the stepper control and data acquisition models more manageable. Due to the immense delay caused by running the data acquisition module and stepper control module in the same loop–the motor was rotating prohibitively slowly–the modules had to be run separately in their own while loops. The distance data, from the data acquisition module, and the loop count, from the stepper control module, are stored as global variables in their respective module’s loops. The loop count global variable is used to correctly position the data point and the magnitude of the distance global variable is plotted at this position. This design preserves function while eliminating the aforementioned delay issues.

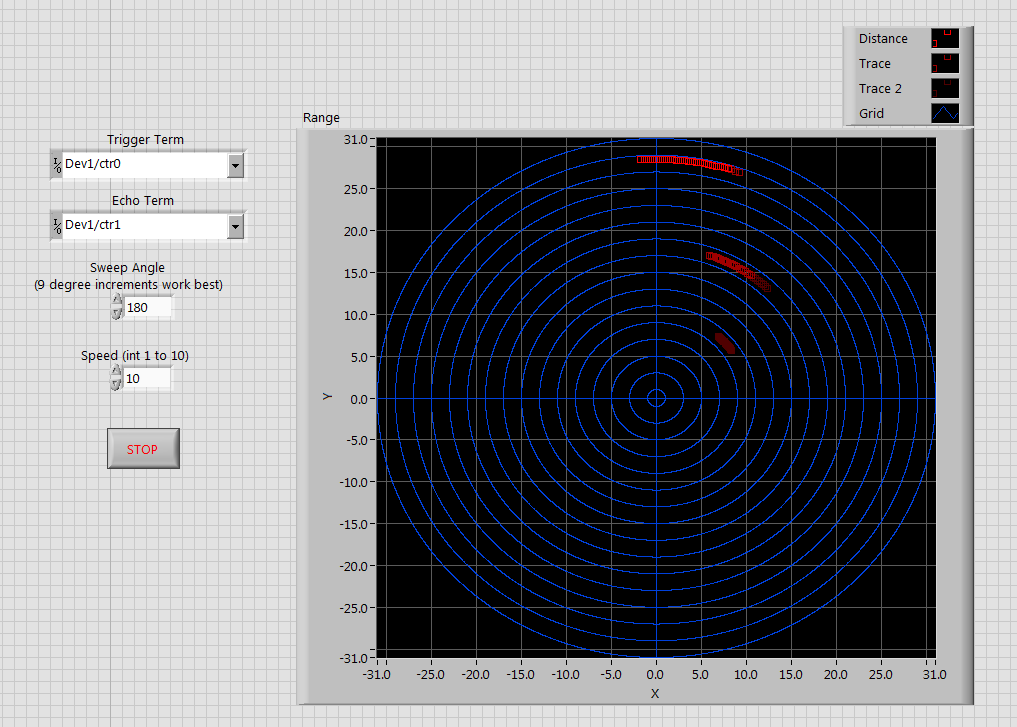
# Human Interface Design

## Overview of User Interface

The human interface of the program consists of four controls, a graph, and a stop button to abort all operations. The ‘Trigger Term’ control sets the input location for the trigger pin on the DAQ (Pin 77). The ‘Echo Term’ control sets the input location for the echo pin on the DAQ (Pin 89). The ‘Sweep Angle’ control sets bounds for what angle the motor will operate in–setting the sweep angle to 180˚, for example, will result in half-rotations back and forth. Integer multiples of 9 work best for the sweep settings due to the construction of the stepper motor. The ‘Speed’ control sets the rotation speed of the motor, with setting 1 being the slowest and setting 10 being the fastest. A series of rings are drawn on the graph to assist with readability of the data. The data collected from the ultrasonic range finder is plotted on the interface graph and fades away after a short period of time. The data is collected synchronously with the rotation of the stepper motor so that the data is plotted with respect to the orientation of the motor.

## Screen Images

The following is a screenshot of the human interface panel.



# System Build

Figure 1: Wiring Schematic

## Components

In order to assemble the system, several separate devices must be connected together. The devices needed are as follows:

* NI DAQ
* Stepper Motor Control Box
* Stepper Motor
* Ultrasonic Range Finder

The devices are assembled as follows:

## Assembly

Plug in the stepper motor control box into a power outlet; do not switch it on yet. Connect the SW1, SW2, SW3, and SW4 pins to the DAQ digital outputs. These will serve to relay commands to the stepper motor via WriteToPort.vi. Connect the GND pin to ground. You may now turn on the stepper motor control box. The stepper motor control box is now ready to operate and control the stepper motor.

Attach a wire from a +5V constant-current voltage source to the VCC pin and a wire from the ground used for the stepper motor control box to the GND pin on the ultrasonic range finder. Connect the Trigger pin on the ultrasonic range finder to ctr0 on the DAQ. Connect the Echo pin on the ultrasonic range finder to ctr1 on the DAQ. The ultrasonic rangefinder is now ready to operate and record data.

Figure 2: DAQ

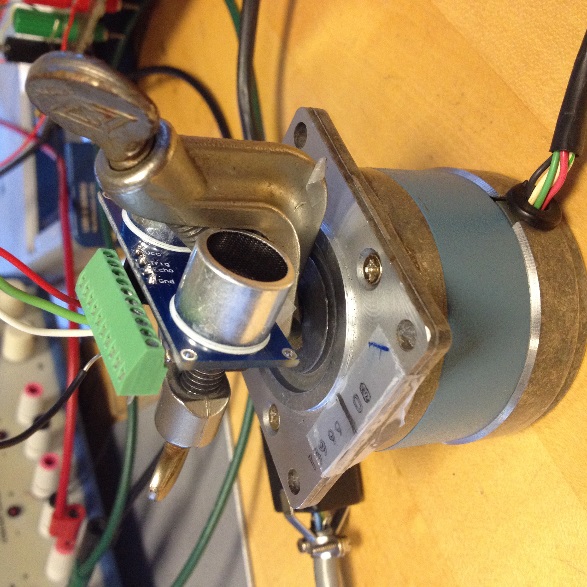
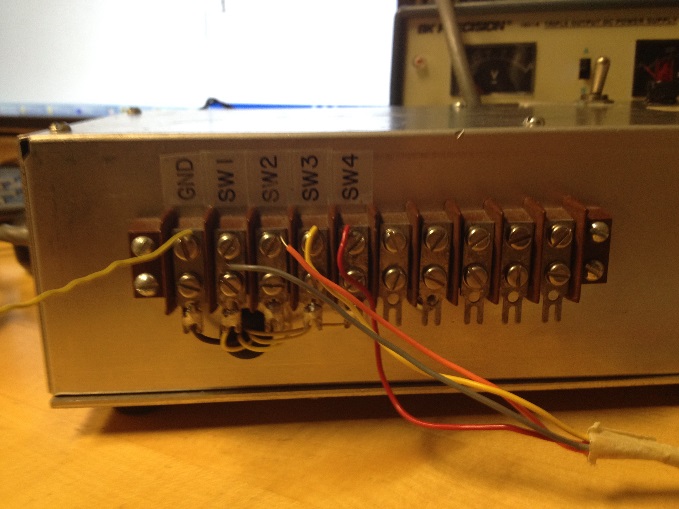
Mount the ultrasonic rangefinder onto the stepper motor (as shown in Figure 4) by unscrewing the top screw and fastening the ultrasonic range finder in place. The entire system is now ready to operate.

Figure 4: Ultrasonic Range Finder mounted on Stepper Motor

Figure 3: Stepper Motor Control Box