Lab 3: Feature Generation

Assigned: November 10, 2023 Due: November 24, 2023

Lab objectives

Using the raw sensing signals dataset in Lab 1:

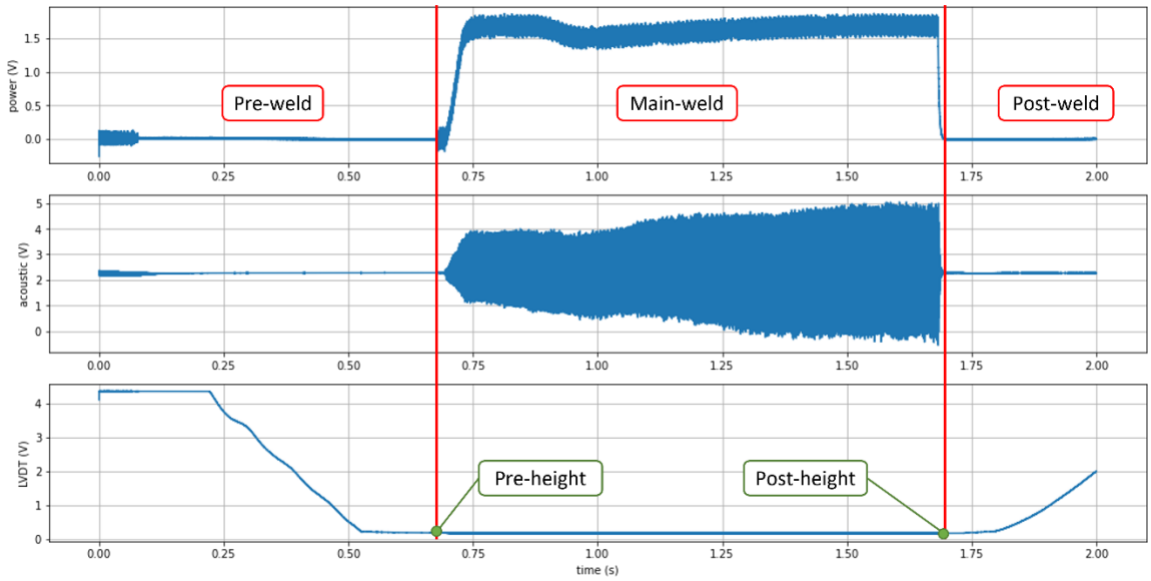
(1) practice data preprocessing
(2) generate time-domain and frequency-domain features
(3) explore the utility of control charts in process monitoring

Description of the data set

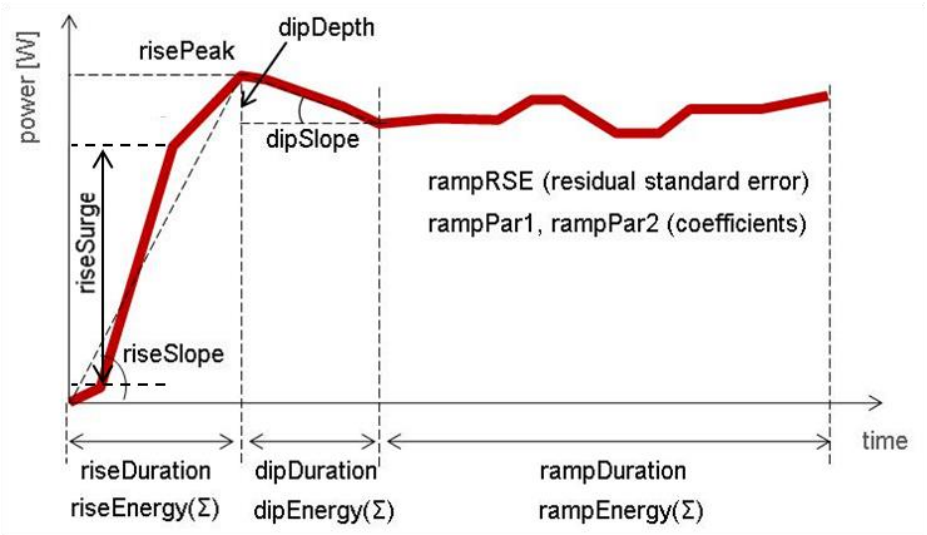
From the dataset in lab 1, we will focus on "50mm workpiece" and investigate the effects of surface conditions. In the dataset, we conducted welding experiments under three conditions level: clean, level 1, and level 2. Each condition was repeated 30 times. (90 welding data in total). In this lab, we will use the power signal, AE signal, and LVDT signal to generate features.

Analysis procedure

1. Data preprocessing. As shown by the figure in P.2, the power signals include a pre-weld segment, a main-weld segment, and a post-weld segment. Based on a physical understanding of the welding process, we know that the main-weld segment is the most informative for quality monitoring and our following analysis will focus on this segment only. Develop an algorithm to automatically extract the main weld segment for all welds. In the lab report, describe your algorithm briefly and demonstrate its effectiveness with one example for all three sensing signals, i.e., power, AE, and LVDT. (20 points)
2. Feature generation. Create features following the steps below and record all features in a csv file, where each row corresponds to one experiment and each column corresponds to one parameter/feature. The columns should follow this order: cycle number (in the order of clean, level 1, and level 2), three features from group a, three features from group b, and four features from group c. This csv file should be included in your submission.
    a. *LVDT signal*. Calculate pre-height, post-height, and height change from LVDT signals. Height change is the difference between pre-height and post-height. The pre-height and post-height are marked in the figure. (15 points)



b. *Power signal*. Brainstorm and generate three time-domain features from power signals. In the lab report, provide the definitions of all features and a justification for why these features may be helpful. The figure below shows some ideas. (15 points)



c. *AE signal*. Frequency-domain features from AE signals. Generate the following features: 1st peak frequency and magnitude, 2nd peak frequency and magnitude. (10 points)

3. Monitoring. Pick one feature from each signal in part 2 and construct 3-sigma X(I)-MR control charts following the procedure provided below. Note that sample size is 1 here because we are monitoring all welds.
    a. *Phase I*. Use the first 20 samples in the "clean" group to construct trial control limits. If there are any out-of-control points, assume that we can identify the root causes and eliminate these points and re-calculate the control limits. (15 points)
    b. *Phase II*. Plot the last 10 samples in the "clean" group and 30 samples from the "level 1" and 30 samples from the "level 2" group in the control charts. (10 points)
    c. *Monitoring performance*. Compare the effectiveness of features based on the above results. Possible metrics that can help with the discussion include Type I error, Type II error, and ARLs. (15 points)