

### **Use of smartphone sensors to quantify the productive cycle elements of hand fallers**

Rob Keefe, Eloise Zimbelman and Ann Wempe

University of Idaho

Analysis of time and motion study data is central to forest operations research. Sensor-based activity recognition has been studied for a variety of human movements in recent years. We show that the sensors built into common smartphones can now be used to quantify many of the tasks that ground workers complete during day to day work activities on logging operations. Accelerometers, gyroscopes, magnetometers, GNSS, light and proximity sensors, and decibel meters built into phones can record data at frequencies measured in tenths or hundredths of seconds. Several available phone applications make it possible to record that data for subsequent analysis. In summer 2017, we observed and manually timed productive cycle elements (travel, acquire, fell) and delays for 3 hand fallers cutting on industrial cable logging operations in North Idaho. Each faller carried a phone and sensor data were recorded at a frequency of 10 Hz using the AndroSensor phone app. To keep the data orientation-independent, we focused only on the magnitude of three sensors (acceleration, linear acceleration, and gyroscope) as well as sound level. Four time domain features (mean, standard deviation, interquartile range, and skewness) were extracted for each of the four sensor values using 10 different moving window sizes (ranging from 1 to 10 s), for a total of 16 variables. Calculations were performed two ways for each window size. In the first approach, calculations were restarted each time a faller switched cycle element. In the second approach, calculations were performed continuously for each faller. A random forests (RF) machine learning algorithm was used to predict individual elements from the sensor measurements. Models with and without sound were also compared. A total of 40 models were created using the 10 window sizes (1 to 10 s) and 2 variable sets (with and without sound) for the 2 moving window calculation approaches (with and without gaps between cycles). In all cases, prediction error decreased as window size increased. For datasets calculated with gaps between cycles, the models without sound predicted cycle elements correctly between 66.1% (for 1-s windows) and 98.6% (for 10-s windows) of the time, while the models with sound predicted cycle elements correctly between 76.5% (1-s windows) and 99.6% (10-s windows) of the time. For datasets calculated without gaps between cycles, the models without sound predicted cycle elements correctly between 65.9% (1-s windows) and 98.1% (10-s windows) of the time, while the models with sound predicted cycle elements correctly for between 76.3% (1-s windows) and 99.3% (10-s windows) of cases. The two calculation methods did not appear to result in a noticeable difference in prediction error, but the inclusion of sound decreased error in all models. Development of solutions for quantifying forest operations based on mobile device sensors is an important step for advancing real-time analysis of productivity on active logging operations for improved reporting and decision-support.