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Motion Classification using IMU for Human-Robot Interaction

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Abstract: This paper proposed the method for identifying motion of the robot using signals from an Inertial Measurement Unit (IMU). When human interacted with the robot, the motion of the robot needed to be classified in order to create the suitable emotions of the robot during the human-robot interaction process. The output data from the IMU were classified by applying heuristic conditions to the high and low frequency data. Wavelet transform was added in the pre-processing step for finding the starting point of the motion state. We found that most of our tested actions could be correctly classified using our proposed method with 100% accuracy.

Keywords: Motion Classification, Inertial Measurement Unit (IMU)

1. INTRODUCTION

This research focused on the motion classification of a humanoid robot by using an Inertial Measurement Unit (IMU). In our laboratory, IMU was used in terrain classification for an autonomous vehicle \[4\]. For this reason, the IMU was chosen to be used on the humanoid robot in this research. At present, emotional interaction between humans and robots has increasingly become a subject of interest. For example, Seong-Yong Koo et al \[1\] developed the bear robot, Gomy that could express its emotion when interacting with people. Gomy had an accelerometer, force-sensitive resistors, and a microphone inside its body for classifying its emotional state. Additionally, Jamy Li et al \[2\] studied gesture generation and gesture interpretation in order to allow humans to understand the messages from the robot. Li also studied the contexts that affected the communication between humans and robots. Moreover, there is a study about the robot design rubrics for interacting with children in the family context \[3\].

2. CONCEPT

Motion classification is important for identifying the appropriate emotional states of the robot. For understanding the robot's state, we used the heuristic method for classifying the robot's motion from IMU data. The data from IMU in this system consisted of roll (angular velocity around the x-axis), pitch (angular velocity around the y-axis), yaw (angular velocity around the z-axis), accX (x-axis acceleration), accY (y-axis acceleration), and accZ (z-axis acceleration). These data were transformed into angles, thetaZY (angle around the x-axis) and thetaXY (angle around the z-axis).

The concept of the state definition system was shown in Fig. 1. The system was divided into 3 main parts. There were data collection, pre-processing, and classification.

Fig. 1 The concept of the state definition system

2.1 Data Collection

The data were collected from an IMU at 171 Hz when the humanoid robot was "lifted up down," "picked up and swayed," "turned around," "shaken," "pushed," and "lifted up." The data that consisted of 3-axis acceleration and 3-axis angular velocity were collected 2 times for each kind of action.

2.2 Pre-Processing

The data were pre-processed using two methods for transform and with comparison: without wavelet transform, as shown in Fig. 2, and with wavelet transform, as shown in Fig. 3.

Fig. 2 Pre-Processing Method-I

Fig. 3 Pre-Processing Method-II

In both methods, we divided the pre-processing procedure into 2 steps which were: finding angles and applying the median filter.

2.3 Classification

In the classification part, first, we determined the appropriate cutoff frequency that can separate the signal into low and high-frequency signals. Then the rule-based decision logic was applied according to the cutoff frequency and the characteristic of low/high-frequency data. In order to explain this procedure, we divided the classification into 2 steps which were:

1. Finding angles

This step was to calculate angles from acceleration data. There were thetaZY (the angle around the x-axis) and thetaXY (the angle around the z-axis). These angles showed the relation between the robot and the vector that is perpendicular to the earth (refer to y-axis acceleration in Fig. 7). These angles could be calculated from the following relations.

thetaZY = tan^(-1)(accZ/accY)

thetaXY = tan^(-1)(-accX/accY)

2. Applying the median filter

The median filter is a non-linear digital filter that can remove high-frequency noise from data so that the characteristic of the data can be shown more clearly. This research apologizes, but the content you provided is incomplete, and the rest of the document has been truncated. If you have any specific questions or need assistance with a particular aspect of the paper, please let me know, and I'll be happy to help.