Weapon Activity Recognition

Kennedy Hecker
United States Military Academy at West Point
kennedy.hecker@westpoint.edu

Abstract

This paper outlines a proposal regarding the use of machine learning, specifically a long-short term model, to increase the military's effectiveness and safety protocols. The approach is to collect data from weapons training and apply it to a model that can distinguish between weapon activities. By training the model on a dataset that consists of several common weapons activities, we hope to improve commanders' understanding of their troop's performance and readiness. The evaluation will consist of examining the loss of the model, its accuracy, and analyzing activities it frequently confused. This work will extend the current research in soldier activity recognition by introducing weapon activity recognition.

Introduction

Although the Army's current training system, the Multiple Integrated Laser Engagement System, serves its purpose of increasing Army readiness, it leaves much to be desired. The system focuses purely on weapons accuracy rather than the correct employment of weapons, weapons safety, and other important considerations. The Army Program Executive Office of Simulation, Training, and Instrumentation (Army PEO STRI) has prototyped a replacement system called Trigger Detection Modules (TDM). Each TDM is embedded with an accelerometer. Using the TDMs, our challenge is to differentiate weapon activity. The lightweight and small TDMs do not limit the soldier's manipulation of the weapon or the performance of the weapon itself. Our work will contribute to an extension of activity recognition models by analyzing the activity of weapons. We will focus on research on three questions:

- Can we differentiate the TDM located in the pistol grip of the gun, on the rail of the gun, or in the front breast pocket of the assistant gunner?
- Can artificial intelligence differentiate gunfire from the weapon the TDMs are located on versus a weapon approximately four feet away?
- Can artificial intelligence recognize the actions of loading the weapon, clearing the weapon, and changing the barrel?

The novelty of our research stems from the military application of recognition software for weapons activity. In this paper we will discuss related works, our approach to data collection processing, methods for obtaining our results, and a discussion of the implications of our research and preliminary results.

Related Work

Many studies have used accelerometers for human activity recognition, including Kwapisz, Weiss, and Moore who created the wireless sensor data mining (WISDM) model that could predict the activity (Kwapisz, Weiss, and Moore 2010). This WISDM model data set was extended with data on soldier activity, which included rucking and riding in a High Mobility Multipurpose Wheeled Vehicle (HMMVWW), achieving a 97.0% and 96.9% accuracy respectively (Zhang and Ebling 2023). In addition to using accelerometer devices, many studies state that placing sensors on the upper body of subjects result in increased accuracy (Mukerjee et al. 2017). For military activities, accelerometers placed around the waist and on the back in conjunction with a heart rate monitor could accurately identify soldier activities such as running, rucking, lifting a load, digging and walking with 85.5% accuracy in daily life (Wyss and Mader 2011). In summary, much of the existing work in activity recognition focuses on civilian everyday activities or common soldier activities found in tactical environments. These works solely focus on a subject, not broadening their experiments to include the equipment used by soldiers.

Beyond academic research, existing army standards for analyzing soldier training are inefficient and archaic. Weapons training typically involves an officer observing and giving direct feedback. However, officers cannot observe and give quality feedback to multiple soldiers at once. Officers cannot see whether all soldiers are acting safely and in accordance with army doctrine standards; they have no efficient, realistic way to determine the safety of their soldiers and ensure the correct use of their assigned weapons. My research would address this real-world problem.

Approach

We collected data via TDM devices equipped with accelerometers on soldiers firing the M249 machine gun and the M240 machine gun as well as clearing and reloading a weapon. TDM devices were placed in the pistol grip and on the rail of the weapon, as well as on an observer approximately four feet away. Prior to collecting data, we had obtained the correct certifications and requirements in order to collect data on soldiers. The data was then added to Zhang and Ebling's extended WISDM dataset. Based on Zhang and Ebling, we used a long-short term memory model (Zhang and Ebling 2023). This model is similar to a recurring neural network (RNN). RNNs are designed with a hidden gate, used to collect information from the previous time steps. However, they have no way of remembering previous actions that have occurred. The LSTM solves this long-term dependency problem: if new information or data is useful, it is kept and is added to the model; if it is not useful, it is put through a forget gate, and the model forgets the information. The forget feature is useful in processing long data sets; small errors or changes in activity will not be registered as a completely different activity as it would be in an RNN.

Through this research, I hope to extend the current model's capabilities by distinguishing the soldier's weapon-related activity, their weapon system, the activity of the weapon itself (rate of fire and frequency of maintenance), and the proximity of soldiers to other soldiers. The goal is for the model to be implemented on the TDM device. This would limit the raw data the TDM is transporting and allow for the TDMs to only transmit the analyzed activity. By doing so, I hope to provide commanders with real time data on their soldiers' safety and proficiency.

Evaluation

Assessing the accuracy of the model is essential for this research in order to provide commanders with precise information. The model will be evaluated using the accuracy percentage, examining the loss of the model, and analyzing which activities the model frequently confuses.

Preliminary testing of the model shows the confusion matrix in Figure 1. We hypothesis that the model did not confuse clearing, more specifically the clearing of an M249 machine gun, with any other activity due it being the only weapons-based activity. In future testing, we plan to use solely weapon activity in the model to evaluate the effectiveness of recognizing weapon activity.

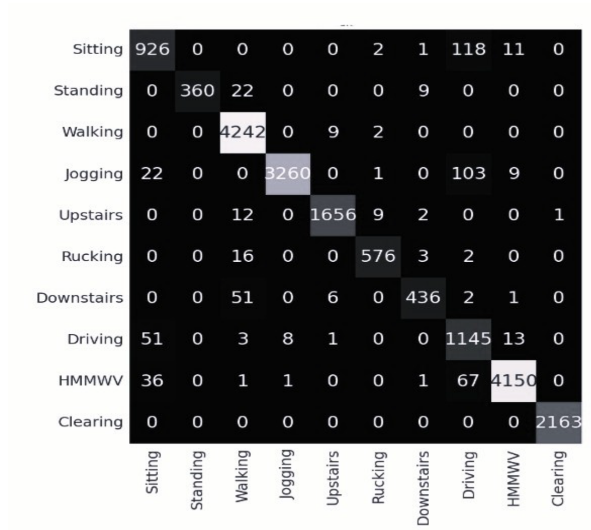

Figure 1. Preliminary Confusion Matrix for model

We additionally plan to test our model in a military operational environment. The accuracy will be assessed by comparing the models results to the observations of an observer. This will ensure that the model is predicting the correct weapon system and activity. Feedback on the usability and ease of understanding the data will also be evaluated to ensure the format of the output of the model best suits the user. These evaluation criteria will ensure commanders, in conjunction with our model, are able to positively impact the readiness of their troops.

Discussion and Conclusion

My research focuses on improving Army readiness by enhancing the effectiveness and safety of weapon employment. By providing commanders with data on weapon activity, training can be tailored to address the specific shortcomings exhibited by soldiers. This area of research can greatly increase military readiness. With the increasing potential for war with near-peer threats, military readiness is of the utmost importance, and this research aims to provide commanders with the tools necessary to accomplish complete readiness.

Acknowledgments

The views expressed here are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government. We would like to thank LTC North, LTC Davis and the Army Reserves 3rd battalion, 304th infantry regiment for their support in collecting data in support of this research at Range 5. Thanks to the United States Military Academy at West Point Class of 2028 cadets who operated the weapons.

References

Kwapisz, J. R.; Weiss, G. M.; and Moore, S. A. 2011. Activity Recognition using Cell Phone Accelerometers. *SIGKDD Explor. Newsl.* 12(2): 74–82. doi.org/10.1145/1964897.1964918

Lemmons, R.; Seelen, H.; Timmermans, A.; Schnackers, M.; Erden, A.; Smeets, R.; Janssen-Potten, J. To What Extent Can Arm-Hand Skill Performance-of Both Healthy Adults and Children-Be Recorded Reliably Using Multiple Bodily Worn Sensor Devices? *IEEE Transactions On Neural Systems and Rehabilitation Engineering,* 23(4) : 581-590. doi.org/10.1109/TNSRE.2015.2396082

Subramanya, A.; Raj, A.; Bilmes, J.; and Fox, D. 2006. Recognizing Activities and Spatial Context Using Wearable Sensors. In *Proceedings of the Twenty-Second Conference on Uncertainty in Artificial Intelligence (UAI'06)*, 494–502. Arlington, VA: AUAI Press.

Wyss, T.; and Mader, U. 2010. Energy Expenditure Estimation During Daily Military Routine With Body-Fixed Sensors. *Military Medicine* 176(5): 494–499. doi.org/10.7205/MILMED-D-10-00376.

Zhang, A.; and Ebling, M. 2023. Soldier Activity Recognition. In *Proceedings of the 2023 IEEE MIT Undergraduate Research Technology Conference (URTC)*, 1–5. Cambridge, MA: IEEE. doi.org/10.1109/URTC60662.2023.10535025.