*Research Proposal*

**Pre-Shot Anti-Sniper Detection**

*Version 3.0*

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# Glossary (PM)

**Artificial Intelligence (AI)** For the definition of Artificial Intelligence we refer to the approach as defined by Russel and Norvig (2022): as the field devoted to building intelligent/rational agents, which are functions taken as input sequence of percepts (sensors) from the external environment, and producing behavior (actions, actuators) on the basis of these percepts.

**Deep Learning (DL)** Is a branch of machine learning that deals with the problem of modelling machine learning algorithms following as closely the architecture of biological neurons. The term deep learning refers to machine learning using multiple layers of simple, adjustable computing elements. Russel and Norvig (2022).

**Machine Learning (ML)** When the intelligence/rational agent is a computer, then it is called machine learning. It is a subfield of AI that studies the ability to improve performance based on experience. Russel and Norvig (2022).

**Sniper** is a [military](https://en.wikipedia.org/wiki/Military)/[paramilitary](https://en.wikipedia.org/wiki/Paramilitary) [marksman](https://en.wikipedia.org/wiki/Marksman) who [engages](https://en.wikipedia.org/wiki/Engagement_(military)) targets from positions of concealment or at distances exceeding the target's detection capabilities. Snipers generally have specialized training and are equipped with [high-precision rifles](https://en.wikipedia.org/wiki/Sniper_rifle) and high-magnification [optics](https://en.wikipedia.org/wiki/Telescopic_sight), and often also serve as [scouts](https://en.wikipedia.org/wiki/Reconnaissance)/[observers](https://en.wikipedia.org/wiki/Forward_observer) feeding tactical information back to their units or command headquarters. Wikipedia.org.

**YOLO (You Only Look Once)** A single neural network that predicts bounding boxes and class probabilities directly from full images in one evaluation (Redmon et al., 2016)

**CVAT.ai** is an image and video annotation toolset distributed by OpenCV. https://opencv.org

# 1. Introduction

## Background

Enemy snipers are a growing threat to army forces worldwide. Snipers had played an important role, especially in urban warfare, where the challenges for snipers and counter-snipers factored heavily in battles. The use of snipers has changed with technological development since the end of World War II. Sharp shooting in contemporary technology-intensive wars requires pro-activeness and has also commenced the development of systems for finding the counter-snipers positioned against snipers (Barışık and Baltacıoğlu., 2014). As reported by NBC[[1]](#footnote-1) snipers, armed only with a rifle, have rapidly become one of the deadliest threats.

Several initiatives by MOD have led to the design of many (also commercially) available anti-sniper systems, merely based on radar, infrared (thermal) and sound signaling processing. The majority of these systems however detect snipers *after* a sniper weapon is fired. Currently no anti-sniper system exist that provides a seamless response at a so-called pre-shot sniper (i.e. detection of a sniper *before* a sniper weapon is fired) detection. In accordance to MOD US9488442B2[[2]](#footnote-2). The MOD strives to equip soldiers with effective and overall anti-sniper detection capabilities.

The aim of Military of Defence (MOD) is detecting and defeating this sniper threat by using and combining different and new technologies. For this purpose and application MOD decided to study the feasibility of latest YOLOv8 (You Only Look Once) algorithm, mainly because YOLO is currently proven and substantially (based on different independent research) being the best detection algorithm concerning real-time detection speed and accuracy results in live military operational environments using highly quality and performance camera-systems. This research must contribute to the knowledge that computers can better/faster detect snipers in rural and/or urban environments then men, by focusing on different aspects or characteristics.

## 1.2 Literature Review

A research field which is most closely related to the anti-sniper detection domain - using YOLO computer vision technology - is weapon detection in civil surveillance domain.

Weapon detection using AI has gained significant attention in recent years, and numerous research studies have been conducted in this area. As noted by Murugan et al. (2023) computer vision technology has been use for real-time weapon detection, and YOLO object detection algorithm has emerged as a popular and efficient technique for this purpose, but further research and development are needed to improve the accuracy and reliability of weapon detection systems to ensure their responsible deployment in real-world settings.

Murugan et al. (2023) remarks that there is no standard dataset for weapons detection and recognition. They do emphasize the importance of quantity and quality of the training data to achieve high accuracy. They trained a YOLO model using a dataset of 17k images annotated weapon images with bounding boxes containing more than 8 classes i.e. firearms, knives and other weapons. They experienced to achieve higher accuracy to remove irrelevant object in each weapon image. Also, to use these techniques for weapon detection, it is necessary to obtain a dataset of images that includes a variety of different type of weapons in various contexts and in different lightning conditions and backgrounds according to the content. The dataset should also include images of non-weapons to help the algorithm learn to distinguish weapons and other objects.

the most important and crucial part of any application is to have a desired and suitable datasets in order to train the machine learning models (Narejo et al., 2021). Yadav et al (2023) evaluated 8 different public available weapon detection datasets originated from 2016 to 2021 that can be used to classify and weapons. They conclude there are still certain challenges in the field of weapons detection that need to be addressed, such as a lack of (large and well-balanced) datasets, the detection of weapons in a variety of lighting conditions as well as that only a few researchers have tackled the subject of partial occlusion of weapon. Another significant problem is the capability of detecting different kinds of weapons and the detection of small sized weapons.

## 1.3 Research Problem Statement

While there is a growing body of knowledge in the field that is described in the literature review chapter, there are some knowledge gaps that this research can contribute to.

Our literature review reveals that much research on detecting weapons uses public (labelled) datasets with images of all kinds of fire weapons (i.e. guns, pistols, rifles), which are -in general- not very suitable for the pre-shot detection problem. Mainly because they do not represent typical and substantial sniper rifles and - most importantly - they do not represent parts (partial occlusion) of a sniper rifle. This, however, is a very important aspect of an anti-sniper detection system, because sniper and/or sniper rifles are mostly not visible as a whole.

The main problem with snipers is the gap or challenge to effectively detect real-time enemy snipers ***before*** they (can) fire their deadly weapons and kill soldiers and/or civilians instantly. This is especially true in rural environments but also in urban environments.

Snipers’ most important equipment is the sniper weapon i.e. sniper rifle. The most obvious pre-shot detectable target(s) snipers is most probably in detecting uncamouflaged (parts of a) sniper equipment i.e. the weapon itself, in particular part of a sniper rifle i.e. the rifle barrel of the weapon, any rifle barrel muzzle break, rifle suppressors/silencers and/or in most cases any (part of a) riflescope. Sniper rifles almost naturally come installed with the attributes like barrel, muzzle break, suppressors and/or riflescope. A sniper rifle without a riflescope is not less a sniper rifle, but less effective. Also, detecting a sniper rifle in military or hostile circumstances almost inherently detects or expects a sniper presence and/or sniper location as well.

Detecting pre-shot snipers based on the presents of sniper rifles is challenging. There is a lack of useful and purposefully labelled images, which can contribute to the detection of pre-shot snipers using computer vision methods. Although many public images datasets do exist, none of them consist of specific and/or applicable labelled images in detecting (parts of) sniper rifles such as barrel, muzzle break, suppressors and/or riflescopes.

## 1.4 Research Goal

In this envisaged research, MOD aims to construct a prototype pre-shot anti-sniper detection system to extend their knowledge of how to effectively detect snipers *before* a sniper rifle is fired using state of the art detection algorithms. The results of this research (including performance measurements) are reported in MOD protocols for future anti-sniper system studies and developments.

For this purpose we formulate the following main research question:

*How to construct a pre-shot anti-sniper prototype that satisfies a fast and accurate detection (i.e. classification and localization) of snipers before a sniper rifle is fired, so that army forces can save more lives of soldiers and/or civilians in the growing threat of enemy snipers in rural and urban military/battle field conditions.*

## 1.5 Research Objectives

To investigate the main research question the following sub research questions are relevant:

1. What is the minimum number of images required for training the pre-shot anti-sniper detection system to a predetermined threshold?
2. What is the influence of the variability of the background? Is the sniper easier to notice in certain backgrounds?
3. Does it matter how tight the bounding box is? Should one spend the extra time to get the bounding boxes just right, or is it better to annotate more images, but care less about the bounding box?

# 2. Data Collection

## 2.1 Selecting Pre-Shot Sniper Riffle Images

Images to extend the public available weapon dataset will be collected by Python script (scraper) using BING search engine. Useful and purposeful images must be selected by hand. Selecting these images will be time-consuming. At first glance about 100-500 images will be selected for labeling and answering research sub questions purposes. Depending on the accuracy of the model more images will be selected and labelled.

## 2.2 Labeling/Annotate Pre-shot Sniper Riffle Images

Selected images will be labelled by hand using internet available free tool CVAT.ai and annotating these images with the corresponding object classes will be the most labour intensive and time-consuming part but is an important step in reaching quality of the custom per-shot sniper dataset.

## 2.3 Training and Validating

The constructed labelled dataset will be divided into training and validation datasets. For specific and practical YOLO issues and training settings we make use of publicly available guidelines, best practices, GitHub sources and YouTube/Pytube sources to assist our experiments as wel as build our knowledge.

# 3. Methodology

This chapter presents the methods that will be used in order to answer the research (sub) questions as listed in chapter 1 and to reach the goal of this research.

## 3.1 Design Science Research

The core idea is to propose an innovative and high quality pre-shot sniper detection dataset. For this, empirical evidence is needed of the working of different methods to undertake high accurate detection of pre-shot snipers in rural and urban circumstances. This calls for the design of an artefact that embodies the knowledge needed by MOD and can be used in practice by MOD. For this science research it is chosen to use the design science research methodology, as this methodology allows for the design of guidelines for training Pre-Shot Sniper Detection models and datasets suited for application in practice. In the process of designing and evaluating artefact, knowledge is gained on what works and why, thus contributing to theory (Hevner et al., 2004). The relation between context, problem, artefact, knowledge gap and knowledge base is schematically depicted in figure 1.

**Environment Design Science Research Knowledge base**

MOD

Snipers

Accuracy Requirement

Battlefield

Sniper dataset construction

MOD protocol

**Develop/Build**

Prototype Pre-Shot Anti- Sniper Detection

Applicable Knowledge

Business needs

Assess

Refine

**Justify (validate)**

Experiments Pre-Shot Anti- Sniper Detection case studies and simulation

Application in appropriate environment

Additions to the knowledge base

Figure 1: Detecting pre-shot snipers applied to the design science framework of Hevner et al. (2004)

In this research we refer to this artefact as guidelines to construct a Pre-Shot Sniper Detector. This research will deliver the guidelines to the construction of a high quality pre-shot dataset, and the knowledge that was required to come up with the construction and its evaluation. Peffers et al. (2007) describes six elements that in sequence form a design research methodology:

1. Identify the problem to be solved
2. Define the objectives for an artefact that helps solving the problem
3. Design and develop an artefact
4. Demonstrate the working of the designed artefact
5. Evaluate how well the artefact contributes to solving the problem
6. Communicate about the first five steps.

The six and final action is to communicate about the first five steps, thus sharing the knowledge derived from the design process. This communication will be done by the research report (a.k.a. MOD protocol).

## 3.2 Training

The pre-shot sniper detection algorithm is based on the YOLOv8 ([github](https://github.com/ultralytics/ultralytics)) model made by Ultralytics. In order to speed up the process of learning to detect snipers, fine-tuning will be applied to the YOLOv8m weights that are pretrained on the COCO dataset. The model will be trained with the standard values according to the documentation: 100 epochs with a confidence of 0.25 and image size of 640.

One common metric used for object detection models like YOLO is the mean average precision (mAP). This metric considers the precision and recall of the model’s predictions and provides a single numerical score for the model’s performance. In addition to evaluating the performance of the model on the test set, it is important to analyze the types of errors the model makes to understand where improvements can be made. This can be done by analyzing the confusion matrix, which shows the number of true positives, false positives, true negatives, and false negatives for each class (BhattiI et al., 2021).

The model will first be fine-tuned on 100 images, this amount will be incremented by 50 images until we reach MOD goal of > 85% mean average accuracy (mAP) in testing. With every updated working dataset, we will start finetuning from the baseline YOLOv8m weights.

## 3.3 Inference

After training, if project time allows, we will also run inference on videos to check the real-world performance of these models. This will give us a better idea of the best model. To test our model in a scenario as close as we can get to the real context, we will run inference on a YouTube video about snipers. The Yolov8 model can run inference on online media by passing the url to the “source” argument.

# 4. Research Project Plan & Time Frame (PM)

|  |  |  |
| --- | --- | --- |
| Activity | Description | Deadline |
|  |  |  |
| Submit Research Proposal |  | xx-10-2023 |
|  |  |  |
| Submit Peer Review |  | 10-11-2023 |
|  |  |  |
|  |  |  |
| Submit Research Report |  | 02-02-2024 |

# Bibliography (PM)

Barışık, E. & Baltacıoğlu, G.(2014). The Employment of Sniper in Modern Battlefield.

<https://dergipark.org.tr/en/download/article-file/177629>

BhattiI, M.B., Khan, M.G., Aslam, M.,& Fiaz, M.J. (2021). Weapon Detection in Real-Time

CCTV Videos Using Deep Learning. [Weapon Detection in Real-Time CCTV Videos Using Deep Learning | IEEE Journals & Magazine | IEEE Xplore](https://ieeexplore.ieee.org/document/9353483)

Hevner, A.R., March, S.T., Park, J., & Ram.(2004). Design science in

information system research. MIS Quarterly: Managament Information System, 28(1), 75-105. <https://doi.org/10.2307/25148625>

Kunmar, R. (2011). Research Methodology a step-by-step guide for beginners. 3rd edition.

Murugan, P., Merry ida, A., Aashika, R., Amshiga Brillian, S.,Seals Ancy, M.,& Sneha.

S.(2023). Weapon Detection System Using Deep Learning. <https://ijirt.org/master/publishedpaper/IJIRT160929_PAPER.pdf>

Narejo, S., Pandey, B., Esenarro vargas, D., Rodriguez, C., & Anjum, R. (2021).

Weapon Detection Using YOLO V3 for Smart Surveillance. SystemDOI:[10.1155/2021/9975700](http://dx.doi.org/10.1155/2021/9975700)

Peffers, K., Tuunanen, T., Rothnberger, M.A., & Chatterse, S. (2007).

A Design Science Research Methodology for Information Systems Research. Journal of management Information Systems, 24(3), 45-77. <https://doi.org/10.2753/MIS0742-1222240302>

Redmon, J., Divvala, S., Girshick., R., & Farhadi, A. (2016). You Only Look Once:

Unified, Real-Time Object Detection. [1506.02640v5.pdf (arxiv.org)](https://arxiv.org/pdf/1506.02640v5.pdf)

Wieringa, R.J. (2014), Design Science Methodology for Information Systems and Software

Engineering. DOI 10.1007/978-3-662-43839-8

Yadav, P., Gupta, N., Kumar Sharma., P.(2023). A comprehensive study towards high-level

approaches for weapon detection using classical machine learning and deep learning methods. <https://doi.org/10.1016/j.eswa.2022.118698>

1. <https://www.nbcnews.com/id/wbna15336981> [↑](#footnote-ref-1)
2. <https://patents.google.com/patent/US9488442B2/en> [↑](#footnote-ref-2)