IMPROVED CALIBRATION FOR RADIO DIRECTION FINDING SYSTEMS

THE EFFECT OF GUIDANCE SYSTEM ON CIVILIAN CASUALTY POLICIES

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Civilian casualties in war are a perennial problem. In the second world war alone over 45 million civilians died. Civilian casualties have still been high in modern conflicts such as the Iraq war (Khorram-Manesh et al. 2021).

Intentional civilian deaths have been banned by international law since 1977 via a new Protocol I of the Geneva Conventions. However, the United States has not signed on to this only signing onto civilian rights in occupied territories, combat zones still being unregulated. Even without legal protection the United States generally does not engage in intentional civilian death (Aldrich 1991).

This could be due to differences in policy, but it could also be improved targeting as the bombs or missiles actually hit their intended targets instead of nearby civilians. Targeting systems first began to be used in the Second World War with the V2 rocket made by Werner von Braun. It was the first intercontinental ballistic missile and had flight times and covered distances that were too large to simply be precalculated or estimated (Tomayko 1985). Guidance has become a mainstay in defense with modern aircraft being armed with exclusively guided missiles only legacy systems like the B52 from the 1950s still use “dumb” bombs albeit the use has stopped recently (Philipps 2015). Various categories of missiles have been created to cope with the ever-increasing variety and guidance systems of new missiles (Siouris 2004). The sociotechnical project will focus on iz despite all the advances in guidance technology civilian deaths have remained mostly constant relative to the size of the conflicts.

Additionally, policy may have changed because of the ability to be more accurate. Missile guidance can generally be broken down into two major categories: thermal and radio.

Both technologies can be broken down into further categories. Radio guidance can either be active such as radar or passive such as detection or direction finding. The technical intervention will focus on passive radio direction finding calibration. Calibration is important for the overall accuracy of antenna-based systems. I will focus on calibration for training manifolds, a technique to take into account antenna properties (Aumann et al. 1989) (Friedlander, 2018).

Technical Project

This project is to improve the calibration of an existing radio direction finding system. The research question will be does the new calibration result in more accurate results for direction finding systems? Radio direction finding systems detect radio transmitters and then determine the direction in which the signal came from, often termed "angle of arrival". Another commonly used term is "line of bearing" (LOB) which can provide a visual representation of the angle of arrival by displaying a line on a map (Bole et al. 2014).

These direction-finding systems use a variety of different antenna types and signal processing to obtain angles of arrival. This intervention will focus on a special type of antenna specifically designed for direction finding. It consists of a cylinder with its inside wrapped with copper. This copper is cut in half along the axis of height with connection to the other half at two points. This allows for the measurement of the E field via the two halves forming a capacitive plate and measurement of the H field via the current induced in the loop formed by the connection of the two halves. This allows for the reconstruction of the Poynting vector which is the direction in which the wave is going to the opposite of which is where the wave came from (McCorkle 2016).

The current method of calibration of these systems consists of a two-part system with a mast and the system itself. The mast is affixed with an antenna on the top. This functions as the transmitter for system calibration. The system itself is placed on a turntable which is again attached to a mast. The transmitter then transmits at various different frequencies while the turntable turns to a set of known angles thus providing a known dataset. All the relevant components are on a mast to prevent ground effects from entering the calibration data.

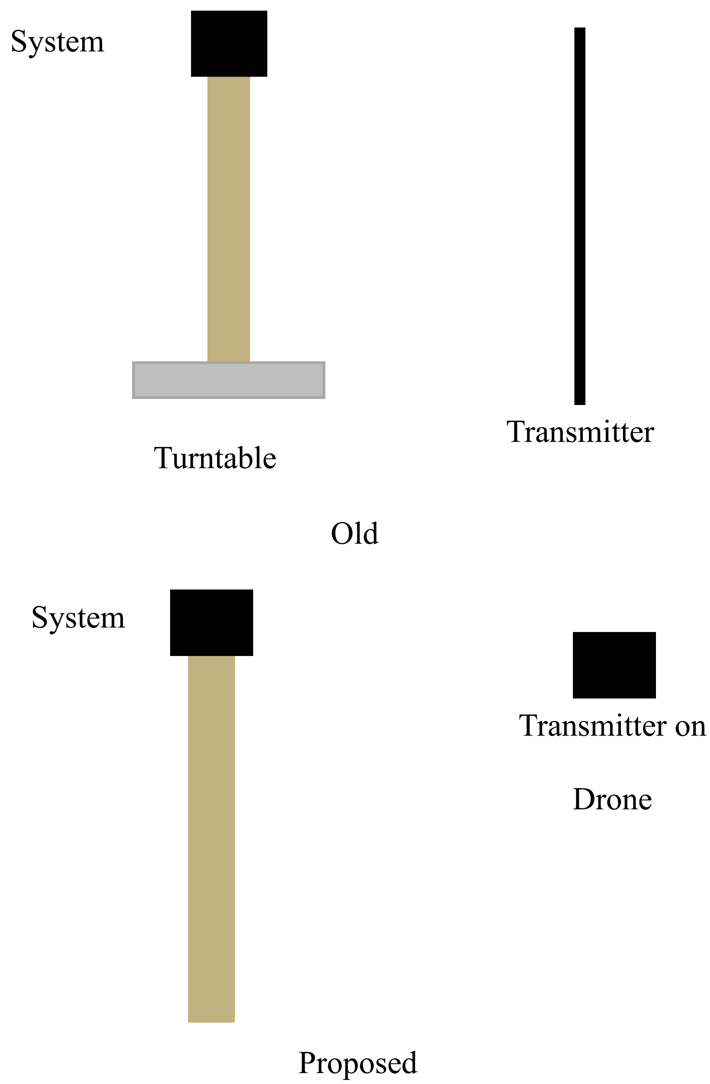

Figure 1: Old and Proposed Calibration Systems

There are multiple limitations to this setup. First, it provides no information about elevation for calibration. To define the direction of a vector in three dimensions two angles are needed yaw (left/right angle) and pitch (up/down angle). The current calibration method only deals with yaw and has a fixed pitch. This is particularly problematic in the air for both aircraft and missiles and the pitch angle would greatly change targeting.

Other limitations are more in the physical realm. The calibration setup is difficult as multiple masts must be put up and then taken down each time resulting in day long calibrations. Since these calibrations are so difficult it is not effective for the system to be calibrated in its actual final configuration, on a vehicle or other object.

To resolve these issues, the technical intervention would, instead of the current setup where the transmitter is still and the system rotating, make the system is stationary and the transmitter is placed on a drone which is then flown around the system at various heights and angles. This is a proven method as it has been done for radio telescopes (Martínez Picar et al. 2015). This will solve the problem of lack of elevation measurements by allowing for free motion in that direction. This will also solve most of the physical problems as now only the system must be put atop a mast as the drone is free flying. Additionally, since the system does not have to rotate the system, the turntable is unnecessary thus allowing for calibration of large vehicles with the system in its deployment environment. This will allow for very accurate calibration of the system including effects from the vehicle, device, or environment in which the system is installed.

The exact intervention will involve a payload attached to a drone. The payload will consist of a B200 mini radio, a latte panda microprocessor, and an antenna. The latte panda will control the B200 mini via USB and GNU Radio (*GNU Radio*) (Ettus). The latte panda will, in turn, be controlled via a REST interface through the built in Wi-Fi capabilities of the latte panda. The drone will be controlled by flight planning software. This calibration will then be compared to the current calibration in the field.

Sociotechnical Project

This project will explore the relationship between targeting systems and civilian deaths. Civilian deaths have been falling as targeting systems have improved but this does not mean targeting systems are the cause of the fall (Khorram-Manesh et al. 2021) (Siouris 2004).

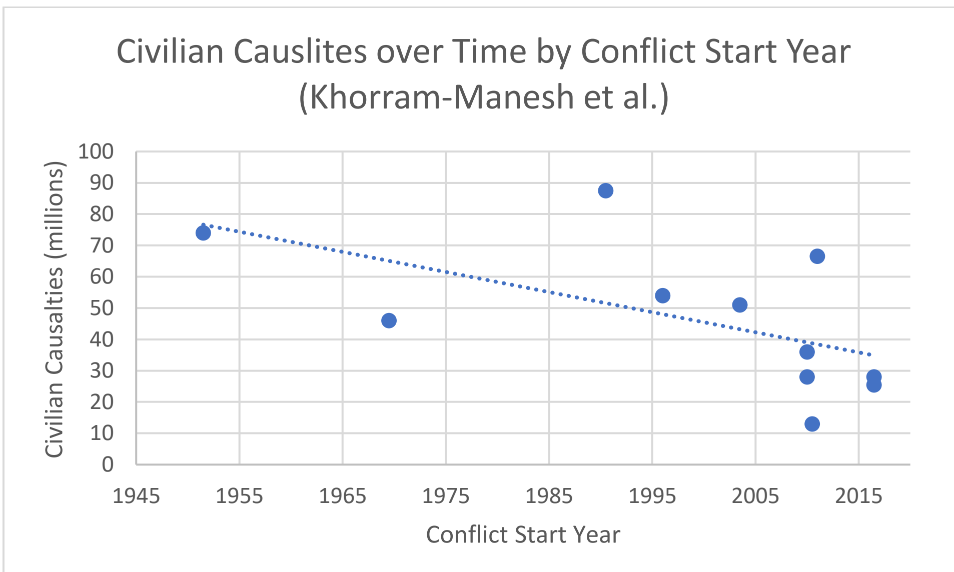

Figure 2: Dropping Civilian Casualties over Time

Absolute deaths as a measure for civilian casualties is not necessarily a good metric because deaths do not account for the total size of a conflict. Border skirmishes result in slim to no casualties because there is often only one battle generally not even near large civilian populations whereas the second world war took place across a continent with significant amounts of urban combat. Thus, the casualty ratio was developed comparing civilian deaths to military deaths. This still does not take into account the entirety of the conflict such as location but does help differentiate between a border skirmish and a full-scale war. Using civilian combat ratio, the numbers of civilian deaths actually seems to remain constant. This would imply that one of the fundamental premises is wrong. (Eckhardt 1989)

However, modern conflicts also have a very different character than older conflicts. Compare the second world war to the Iraq war or Afghanistan war. The second world war was a conflict between mostly evenly matched states whereas the Iraq and Afghanistan wars were a global superpower attempting to remove a regime from power and replace it with a democracy against a country that only took weeks for the formal government to capitulate. Thus, in modern conflicts there was significantly more guerilla warfare which has higher civilian risks as combatants are more likely to be surrounded by civilians compared to a traditional front of a war (Eckhardt 1989).

Air campaigns were the largest source of civilian deaths by the United States armed forces in 2020. In fact, there was only one incident that resulted in a civilian death that was not the result of an air strike (Annual Report on Civilian Casualties, 2020). Modern airstrikes almost always use some form of guidance (Pickrell 2019). Thus, there is a probable connection between any changes in civilian casualties being a result of changes in airstrikes and thus improved guidance systems and thus should be investigated further.

Guidance systems are only useful insofar as the target that has been chosen to hit is accurate. Thus, even with super accurate modern weapons without intelligence on who or what is where, or the decision-making apparatus caring or taking into account civilian deaths these improvements are useless. Thus, department policies on use of force and the types of munitions that are used for various risk levels are important to examine as they can affect levels of civilian victimization (Downes 2006).

Department of Defense policies specifically mention “precision munitions”. These kinds of munitions are allowed to be used where other methods would not be. For example, the threat level can be lower when using these munitions (Chairman of the Joint Chiefs of Staff, 2012). This suggests that the department of defense believes that these munitions are less likely to cause civilian harm. This is an example of Technological Determinism where technology determined the social outcome, in this case policy (Smith 1991).

These changing policies combined with the fact that civilian deaths have, in fact not decreased, may imply that there is a general sense of an acceptable number of civilian deaths that has been constant over time. For example, precision munitions are allowed in situations where conventional weapons are not. In the past these strikes may have simply not been done. The military would be willing to order 100 strikes with a 5% chance of killing civilians now and in the past were only willing to do 10 with a 50% chance of killing. This does line up with other advances in technology such as average commute times always being approximately 30 minutes despite large growth in size of cities and transportation technology (Marchetti 1994).

I will look at policy documents and explore why have civilian deaths not decreased even with newer better weapons that should allow for fewer deaths. For these policy documents I will explore if there are reasonings given to the policy changes that were explored above and why those reasonings have not, in fact, lead to fewer deaths. For example, have they simply opened up more opportunities to order a strike since they have new weapons and not increased the general thresholds.

Conclusion

The sociotechnical connection between guidance systems and casualties will be explored. The project will determine what kind of relation guidance has on civilian casualties and how that is borne out in policy making decisions. This is particularly important because even though each individual strike may kill fewer civilians the military simply uses more of them.

The technical project will create a new and better calibration method for radio direction finding system. This will allow those systems to be more accurate particularly in terms of vertical angle of arrival. It will also allow for calibrating in the effects of whatever device the system is installed in.

The sociotechnical project is important because if we cannot determine why the military seems to keep the civilian casualty rate constant, we cannot work to reduce it.

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