You're Not Alone in Battle: Combat Threat Analysis Using Attention Networks and a New Open Benchmark

Soo Yong Lee [1], Juwon Kim [1], Kiwoong Park[2], Dong Kuk Ryu [2], Sangheun Shim [2], and Kijung Shin [1]

[1] KAIST, [2] Agency for Defense Development

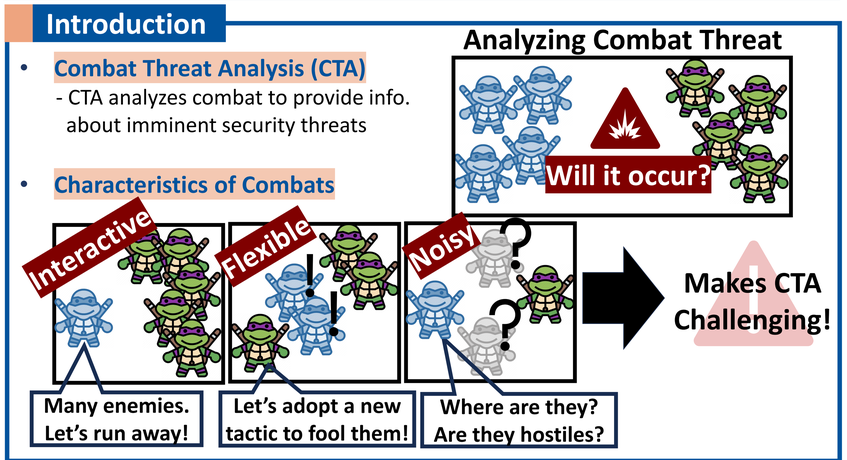
Code and Data: *https://github.com/syleeheal/SAFETY*

Summary

- **Benchmark Task and Dataset**
  - We propose the **first benchmark dataset** of combat simulations
  - We propose a **benchmark task** for realistic combat threat analysis (CTA)
- **Model and Experiments**
  - We propose a novel **spatio-temporal attention network** for CTA
  - Our proposed model shows the best performance in CTA

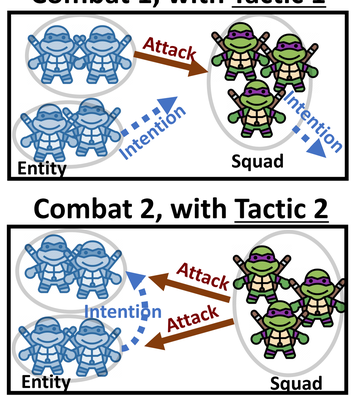
Introduction

- **Combat Threat Analysis (CTA)**
  - CTA analyzes combat to provide info. about imminent security threats
- **Characteristics of Combats**



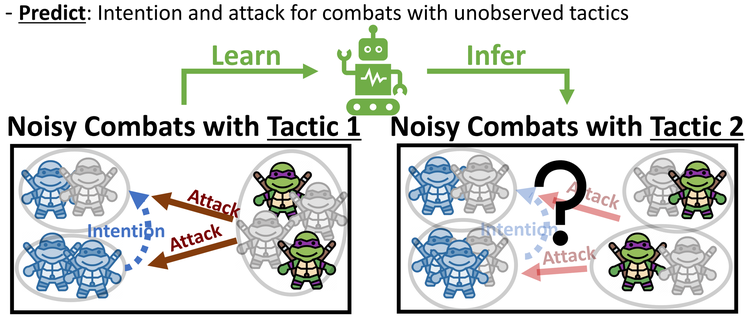
Preliminaries

- **Concepts and Definitions**
  - **Entity**: refers to the smallest force unit within a combat (e.g. a soldier)
  - **Squad**: refers to a set of few entities sharing the same intention
  - **Combat**: refers to a unit of battle over time
  - **Intention**: refers to the intended action of a squad in the combat
  - **Attack**: indicates whether or not an attack between a squad pair will occur during combat
  - **Tactic**: refers to the overarching strategy that a force share in combat



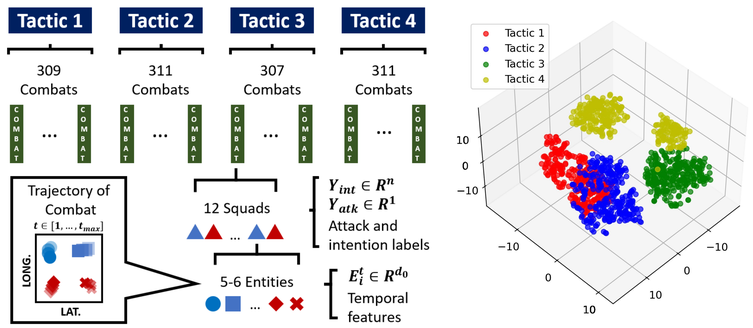
Proposed Benchmark Task

- **Problem Formulation for Combat Threat Analysis**
  - **Given**: Combats with noisy or missing features
  - **Predict**: Intention and attack for combats with unobserved tactics

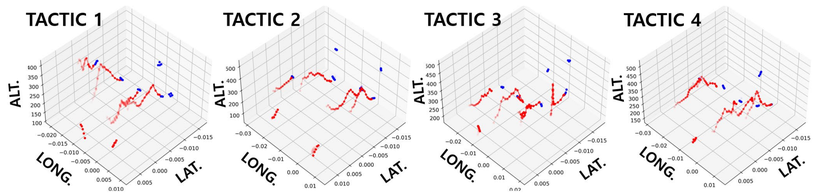


Proposed Benchmark Dataset

- **Dataset Overview**
  - A **synthetic dataset** based on computer simulations of ground force combats
  - It contains a total of **1238 combat simulations**, each with one of four tactics
  - Each entity has **temporal features**
  - Each squad has **intention labels**, and a squad pair has **attack label**
  - **TSNE** shows that combats with each tactic has distinct feature distribution



- **Trajectory Visualization**
  - Entity trajectories in each combat are similar within each tactic
  - Entity trajectories in each combat are different across different tactics



- **Dataset Statistics**
  - **Table 1 (Labels)**:
    - 6 intention labels
    - strong class imbalance
    - each tactic has different label distribution
  - **Table 2 (Time)**:
    - about 20 min. long combat
    - attacks/deaths occur after some time
    - each tactic has different time distribution
  - **Table 3 (Features)**:
    - total 11 feature dimension (10 shown)
    - variance in each variable differ significantly

Table 1: Label statistics per tactic

Tactic	Intention Labels #(TE)	#(MT)	#(CR)	#(SS)	#(FE)	#(SP)	Attack Labels #(Attacks)
Linear Advancement (1)	1236	1236	618	0	0	618	1916.
Sequential Progression (2)	4	1244	1862	0	0	622	2110
Flanking Maneuver (3)	0	0	1842	1228	0	614	2455
Direct Engagement (4)	0	0	1866	4	1550	312	3130
All Tactics	1240	2480	6188	1232	1550	2166	9611

• **Abbreviations**: TE = Tactical Engagement. MT = Maneuvering Techniques. CR = Coordinated Rendezvous. SS = Strategic Surprise. FE = Forceful Engagement. SP = Strategic Positioning.

Table 2: Time statistics per tactic (in seconds)

	Mean Run Time	StDev Run Time	Min Run Time	Max Run Time	Mean First Death
Linear Advancement (1)	1227	147	841	2018	564
Sequential Progression (2)	1320	177	1023	2565	571
Flanking Maneuver (3)	1600	179	1209	2345	1042
Direct Engagement (4)	1419	222	964	2191	892
All Tactics	1391	229	841	2565	767

Table 3: Trajectory feature statistics

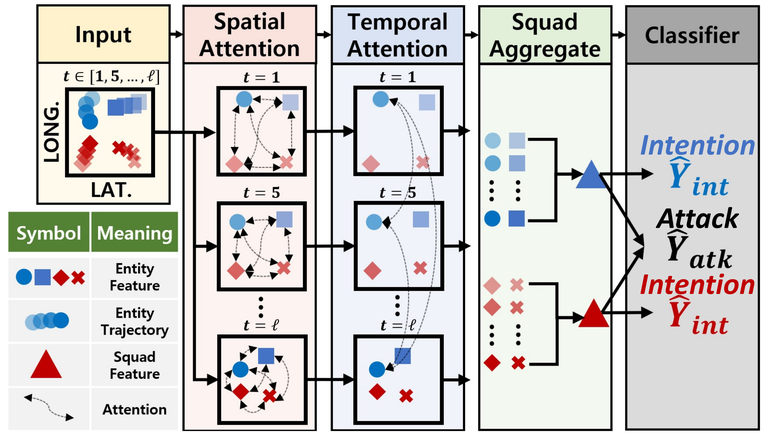
	Latitude (Degree)	Longitude (Degree)	Altitude (Meter)	Attitude (Yaw)	Speed (Km/h)	Terrain RD	Terrain FR	Terrain OL	Terrain HP	Terrain BD
All Tactics	37.9 ± 0.008	128.1 ± 0.012	667.0 ± 83.1	-27.8 ± 114.4	1.7 ± 2.4	0.221	0.666	0.068	0.040	0.005

• **Abbreviations**: RD = Road. FR = Forest. OL = Open Lane. HP = Hiding Place. BD = Building. **Continuous variables**: Mean ± standard deviation. **Binary variables**: The ratio of positive entries.

- **Dataset Quality and Semantics**
  - **Quality**: The simulations are crafted based on expert military knowledge, ensuring the realism of the combat situations represented
  - **Geography**: The geography where the combat occurs is generated based on an actual location
  - **Semantics**: Each tactic, label, and feature have meaningful semantics, which are constructed based on expert military knowledge

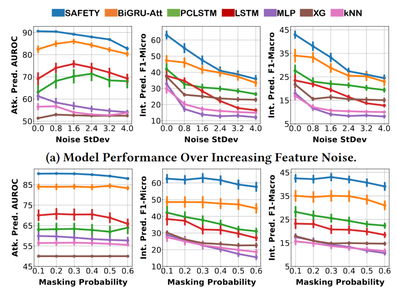
Proposed Model

- **SAFETY (Spatio-temporal Attention For ThrEaT AnalYsis)**
  - Composed of a **spatio-temporal attention**, **squad aggregation**, and a **classifier**
  - **Transformer**-style self-attention is applied
  - Predicts **intention** and **attack** probability



Experimental Results

- **Prediction for Unseen Tactics under Noise and Missing Features**
  - **Noise**: We add noise to input features
  - **Mask**: We randomly mask the input features to reflect missing features
  - **Unseen Tactic**: Models are trained on 3 tactics and evaluated on 1 untrained tactic
  - **Metric**: F1 for intention prediction; AUROC for attack prediction
  - **Results**: SAFETY significantly outperforms the baseline methods in both intention and attack prediction by a large margin



(a) Model Performance Over Increasing Feature Noise.

(b) Model Performance Over Increasing Missing Features.

Figure 3: Performance with increasing perturbations. Each error bar indicates the standard error. The results are the means over 30 trials.

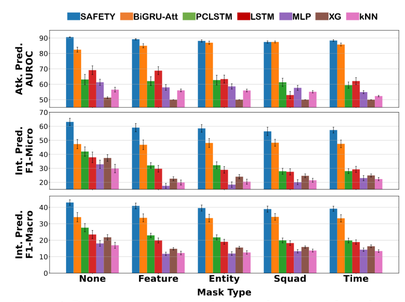


Figure 4: Performance with various mask types and masking probability 50%. Each error bar indicates the standard error. The results are the means over 30 trials.

Conclusion

- **Comprison to the Prior Works**
  - **Dataset**: This is the *first* open-source benchmark dataset for CTA
  - **Task**: We argue for the importance of predicting unseen tactics under feature noise
  - **Model**: We demonstrate importance of interaction modeling for CTA
- **Future Directions**
  - **Dataset**: More realistic combat dataset (e.g. introduce new squads over time)
  - **Task**: Our work did not predict time in which each attack occurs
  - **Model**: A scalable model that considers massive interactions of real-world combats