Engagement Decision Support for Beyond Visual Range Air Combat

Joao P. A. Dantas
Andre N. Costa
Diego Geraldo
Marcos R. O. A. Maximo
Takashi Yoneyama

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MOTIVATION

- Within Visual Range (WVR)
- Beyond Visual Range (BVR)
- Situational Awareness
- Simulation
- Decision Support Tool

LITERATURE REVIEW

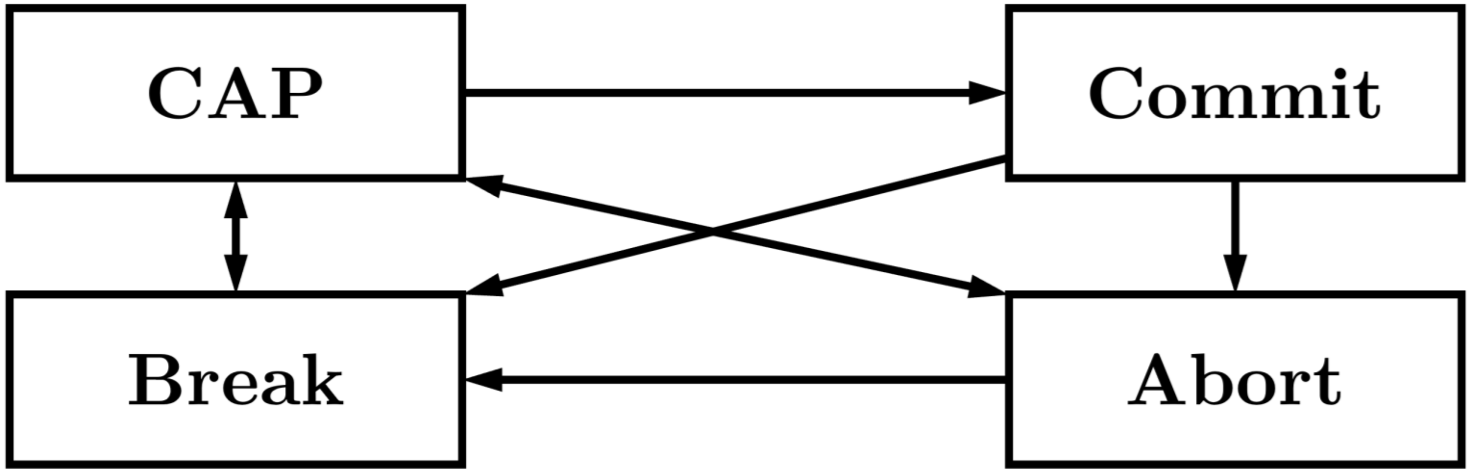
1. Bayesian Networks (Du and Liu, 2010; Rao et al, 2011)
2. Fuzzy Logic (Akabari et al, 2005; Prahu et al, 2014)
3. Agent-based Modeling (Heinze et al, 1998)
4. Influence Diagrams (Lin et al, 2007)
5. Reinforcement Learning (Toubman et al, 2016; Weilin et al, 2018; Hu et al, 2021)
6. Artificial Neural Networks (Yao et al, 2021)
7. Evolutionary Algorithms (Yang et al 2020; Li et al 2020)
8. MiniMax Method (Kang et al, 2019)
9. Behavior Trees (Yao et al, 2015)
10. Game Theory (Mukai et al, 2003; Karelahti et al, 2006; Ha et al, 2018)

OBJECTIVES

- Supervised Machine Learning model
- Based on Decision Trees (XGBoost)
- Features:
    1. 6DOF
    2. Multi-role combat aircraft
    3. Electronic Warfare Devices
    4. Datalink communications
    5. Active radar-guided missiles
- Sujects:
    1. BVR air combat scenarios
    2. Carrying out simulations
    3. Collecting and analysing data
    4. Using machine learning techniques

FIGHTER AGENT

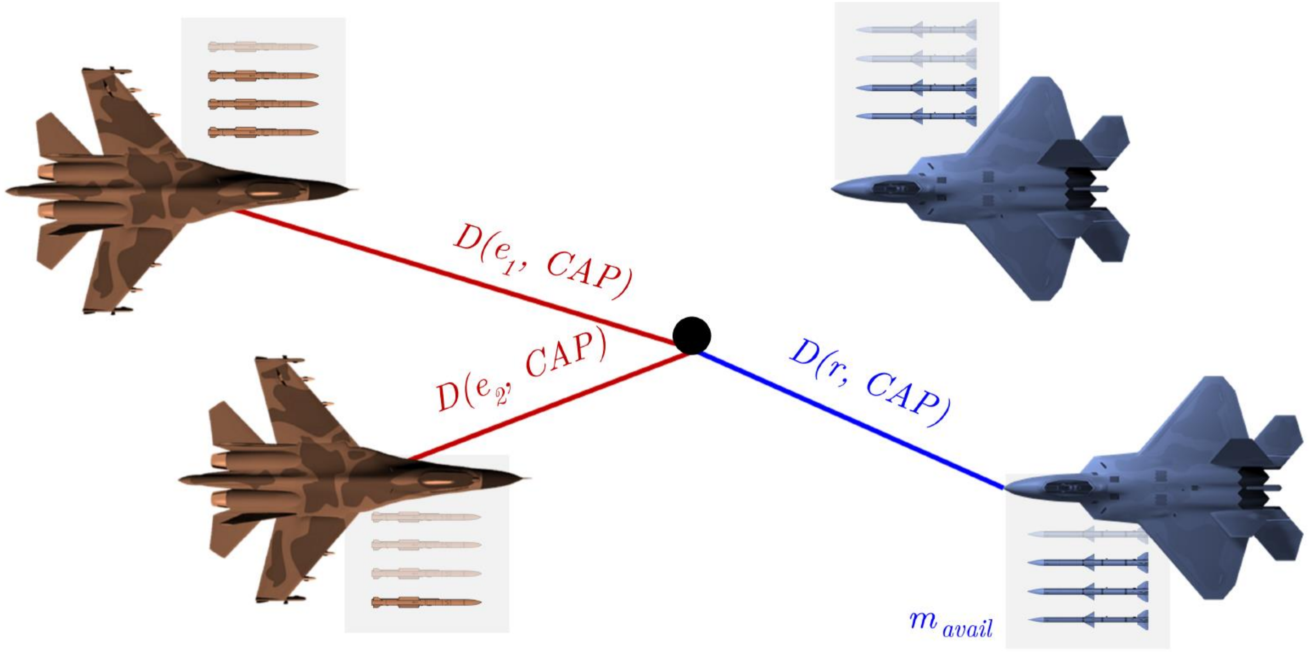
- Finite State Machine
- CAP, Commit, Break, Abort



DCA INDEX

- Index as a probability of success
- Ranging from 0% to 100%
- Principles
    1. Minimize the number of missile launched in the mission
    2. Minimize the reference distance from its CAP point
    3. Maximize the distance of each enemy to the CAP point

DCA INDEX



$$d_i = \frac{(y_{99\%,i} - y_{1\%,i})}{(x_{99\%,i} - x_{1\%,i})} \cdot [D(i, CAP) - x_{1\%,i}] + y_{1\%,i}$$

where: i $= r$ (reference) or e_n (enemy)
D_i = measured distance from the CAP point
d_i = interpolated distance for sigmoid input

$$I_{DCA} = w_1 \cdot \frac{m_{avail}}{m_{total}} + w_2 \cdot \frac{1}{1 + \exp(-d_r)} + w_3 \cdot \frac{1}{N} \sum_{n=1}^{N} \frac{1}{1 + \exp(-d_{e_n})}$$

SIMULATIONS SAMPLING

- Latin Hypercube Sampling
- 3,729 construtive simulations
- 10,316 engagements
- 12-minutes scenario
- 10 days (3x)
- Scenario: BVR 2x2

MODEL INPUTS AND OUTPUT

Parameter	Description
distance [m]	Distance between the reference and the target
aspect [deg]	Angle between the longitudinal axis of the target (projected rearward) and the line-of-sight to the reference
delta_head [deg]	Angle between the longitudinal axis of both aircraft
delta_alt [m]	Difference of altitude between the reference and the target
delta_vel [kn]	Difference of absolute velocity between the reference and the target
wez_max_o2t [m]	Maximum range of the reference's weapon (non-maneuverable target)
wez_nez_o2t [m]	No-escape zone range of the reference's weapon (target performing high performance maneuver)
wez_max_t2o [m]	Estimated maximum range of the target's weapon (non-maneuverable reference)
wez_nez_t2o [m]	No-escape zone range of the target's weapon (reference performing high performance maneuver)
vul_thr_bef_shot	Level of risk acceptance before shooting
vul_thr_aft_shot	Level of risk acceptance after shooting
shot_point	Missile firing point between the maximum range and the no-escape zone range of the reference
rwr_warning	Boolean indicating whether the aircraft is equipped with an active RWR
hp_tgt_off	High priority target offense index of the reference
hp_thr_vul	High priority threat vulnerability index of the aircraft that is threatening the reference
own_shot_phi	Reference shot philosophy
enemy_shot_phi	Estimated enemy's shot philosophy

SUPERVISED MODEL

- XGBoost
- Data Preprocessing
- Feature Engineering
- Hyperparameters Tuning
- Metrics: RMSE and R^2
- Cross Validation (80% and 20%)

MODEL RESULTS

- RMSE 0.0543 ± 0.0009
- R^2 0.8020 ± 0.0077

CONCLUSIONS

- Improve the employment of the best operational tactics for each situation
- Avoiding the incorrect and careless use of weapons
- Decrease the number of friendly aircraft lost in real-life

FUTURE WORK

- Number of simulations
- More variables to define the agent state
- Compare XGBoost with other regression algorithms
- Conception of other operational metrics

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