The Effect of Time Advance Mechanism (TAM) in Modeling and Simulation: DES & DTS Comparison Analysis, Case Study: Combat Simulation
The Effect of Time Advance Mechanism (TAM) in Modeling and Simulation: DES & DTS Comparison Analysis

Case Study: Combat Simulation

Ali Al Rowaei

MOVES Student
MOVES R&E Summit 2011
Wednesday July, 13
Outline

• Motivations and Concepts

• Emergent Effects of TAMs
  Skipping Phenomenon
  – Scenario 1: Simple Agent Engagement
  – Scenario 2: The Littoral Combat Ship (LCS) Battle

• Conclusion
Motivations and Concepts

“All models are wrong, but some are useful.” (Box 1979)
...but how wrong can a model be before it's not useful?

– The effects of TAM are not well understood.
– The effects of $\Delta t$ are not well described in the literature.
– What are the limitations and strengths of each mechanism?

Discrete Event Simulation (DES) and Discrete Time Simulation (DTS)
Discrete Time Simulation (DTS)

**Time-Step Approach**

- \( \Delta t \)
- \( e_1 \)
- \( e_2 \)
- \( e_3 \)

\[ t_0 \rightarrow t_1 \rightarrow t_2 \rightarrow t_3 \rightarrow t_4 \rightarrow t_5 \rightarrow t \]

Discrete Event Simulation (DES)

**Discrete Event Approach**

\[ t_{e1} \rightarrow t_{e2} \rightarrow t_{e3} \]

\[ t_1 \rightarrow t_2 \rightarrow t_3 \rightarrow t_e \]
S 1.1: Simple Agent Engagement

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Red Agent</th>
<th>Blue Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Sensor Type</td>
<td>Cookie-Cutter</td>
<td>Cookie-Cutter</td>
</tr>
<tr>
<td>Sensor Range</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>Weapon Range</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>P_kill</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>MOE</td>
<td>Mean Casualty Percentage at 200 replications</td>
<td>5</td>
</tr>
</tbody>
</table>
S1.2 Simple Search & Detection Operation

Single moving searcher looking for stationary targets.

Searcher:
- speed: constant @ 7m/s
- sensor type: cookie cutter
- sensor range: 14m

Targets: 20
- distribution: randomly over combat area
- search pattern: Parallel (Washburn 2009)

Set-up:
- Grid: 2000 x 2000 m
- Replications: 200
- Measure: number of detected targets
S1.2 Simple Search & Detection Operation

Speed = 7 m/s, CC sensor range = 14 m, 20 stationary targets
S1.2 Simple Search & Detection Operation

Sensor agent event graph modeled in DES

3D View from MARSS (Dickie 2002)
S 1.2: Results and Observations

- 200 replications were conducted in MANA 5 and Simkit.

- How to ensure this phenomenon is detected in complex simulations, or it is not affecting non-visible variables?
S 2: The LCS Battle

- Original scenario is the work of an NPS Master Thesis (Jacobson 2010).

- Elements:

  1) 1 LCS equipped with 2 types of missiles:
     a- NLOS   b- Harpoon

  2) 1 Helicopter/UAV equipped with 4 types of missiles:
     a- Hellfire   b- LOGIR
     c- APKWS  d- DAGR

  3) 20 enemy boats equipped with only one missile type: C-802

- Purpose: investigate different weapons on the effectiveness of the LCS and Helicopter to neutralize enemy boats and essential engagement factors.

- Original Study Results: Firing rate is the most important factor, LSC missiles and capability need to be enhanced.
Our Study: Investigate the impact of TAM on the scenario results by comparing DES and DTS results.

LCS scenario in DAFS environment
Discrete Event Simulation (DES)

LCS scenario in MANA 5 environment
Discrete Time Simulation (DTS)
S 2: The LCS Battle

Results:

- Original study run 512 Design Points (DP) with 40 replications at $\Delta t = 10$ seconds.
- We found that more than 81 DPs can have significant change in outcome.
- MOE: 1. Number of kills (LCS and Enemy)
  2. Number of weapons fired (LSC and Helicopter)
- One DP focus: Varied $\Delta t$ values between 1.0 and 10 seconds in DTS
S 2: The LCS Battle

Results (cont…)
- Five DPs were tested in details for greater coverage.
  i. MANA 5 (DTS) environment with $\Delta t = 0.5$ and 10 seconds at 40 replications
  ii. DAFS (DES) environment
Results (cont....)
Discussions

- At large $\Delta t$ large number of enemy boats were not detected and “skipped” MH-60 sensor range.

- State transition update allowed only at the end of time intervals,
  - This introduces delays in rate of fire that leads to missing the enemy

- Difficult to notice these phenomena in complex/constructive simulations.

- Recommendations

<table>
<thead>
<tr>
<th>Large $\Delta t$ (DTS)</th>
<th>Firing rate, LCS capability/weapons</th>
</tr>
</thead>
<tbody>
<tr>
<td>DES and small $\Delta t$ (DTS)</td>
<td>Helicopter capability/weapons</td>
</tr>
</tbody>
</table>
Conclusions

• The choice of TAM impacts the simulation results.

• There are differences between approaches can leads to different results, outcomes and recommendations.

• The choice of $\Delta t$ can also introduce significant qualitative anomalies.

• There is no accepted methodology in M&S for selecting $\Delta t$.
  
  • Cannot separate time effects from system inherent properties

• DES models tend to produce less (or no) anomalous behavior.
Questions?

aalrowae@nps.edu
Back-up Slides
## Typical Combat Simulation Environments

<table>
<thead>
<tr>
<th>Discrete Time Simulation</th>
<th>Discrete Event Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MANA</td>
<td>Simkit</td>
</tr>
<tr>
<td>Pythagoras</td>
<td>JDAFS – DAFS</td>
</tr>
<tr>
<td>IWARS</td>
<td>Combat XXI</td>
</tr>
<tr>
<td>ISAAC</td>
<td>NSS</td>
</tr>
<tr>
<td>PSOM</td>
<td>OneSAF</td>
</tr>
<tr>
<td>JCATS</td>
<td></td>
</tr>
<tr>
<td>THUNDER</td>
<td></td>
</tr>
<tr>
<td>VIC</td>
<td></td>
</tr>
<tr>
<td>WARSIM</td>
<td></td>
</tr>
<tr>
<td>EADSIM</td>
<td></td>
</tr>
<tr>
<td>JICM</td>
<td></td>
</tr>
</tbody>
</table>