**PROJECT SUMMARY**

| **Project Title:** World Model-Based Test Generation In Autonomous Systems |
|-----------------------------|-----------------------------------------------|
| **Lead University:** University of Denver |
| **Principal Investigator:** Andrews |
| **Team Members:** Abdelgawad |
| **Funding Amount/Source:** |
| **Schedule:** |
| Start date: July. 2013 |
| End date: July. 2015 |

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<thead>
<tr>
<th><strong>Objective(s):</strong></th>
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<td>Develop and validate a scaleable approach to test autonomous systems in dynamic real-time scenarios based on their environmental factors.</td>
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<th><strong>Statement of Work (SOW):</strong></th>
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<tr>
<td><strong>Task1:</strong> Develop and formalize MBT method for testing Behavior and dynamically changing behaviors of autonomous systems.</td>
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<td><strong>Task2:</strong> Validate Method (apply to Autonomous City Vehicle)</td>
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<td><strong>Task3:</strong> Develop New Coverage Criteria</td>
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<td><strong>Task4:</strong> Study Efficiency, Scalability and Comparison</td>
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<td><strong>Task5:</strong> Generalize to other Models (e.g., CPN)</td>
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<th><strong>Deliverables:</strong></th>
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<tr>
<td>Systematic world MBT approach (World model construction.</td>
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<td>Coverage criteria, and test generation.</td>
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<td>Case study applications.</td>
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<td>Publications, Dissertation.</td>
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<td>Final report.</td>
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PROGRESS SUMMARY

Last Review Status:
None

Progress since Last Review:
• Formalization of method.
• Application to Autonomous Ground Vehicle System (AGV) that uses highway.
• Formalize new Test Criteria.
TECHNICAL SUMMARY

Process:

Phase 1
- World Models
  - Step 1: Structural Model
  - Step 2: Behavioral Model

Phase 2
- Coverage Criteria
  - Paths Combinations
  - Concurrent Coverage

Phase 3
- Test Generation
  - Sets of Behavioral Paths
  - Concurrent Test Cases

MODELING:
- Structural Model: UML Class Diagram.
- Behavioral Model: CEFSM

COVERAGE:
- Combine paths
- Concurrency

TEST GENERATION:
- Concatenated Abstract Behavioral Paths to generate WBTC.
TECHNICAL SUMMARY

Autonomous City Vehicle (ACV) and U.S. highway:

**Snippets:** Roadway, Ramp, Intersection, and Bridges.

**Actors:** Vehicles, Signal, Sign, Marking.
TECHNICAL SUMMARY Cont.

Individual Actors Behavioral Models:

**X5. Passenger Car**

- X5.1: (Move,→,→) / (Move,→,→)
- X5.2: (Move,→,get(mi)) / (Turn,→,actor.regulatory(‘Turning flash light’))
- X5.3: (Turn,→,→) / (Turn,→,actor.regulatory(‘Turning flash light’))
- X5.4: (Turn,→,→) / (Move,→,actor.regulatory(‘Turning flash light off’))
- X5.5: (Move,→,get(mi)) / (Stop,→,actor.regulatory(‘Stop light’))
- X5.6: (Stop,→,get(mi)) / (Move,→,actor.regulatory(‘Stop light off’))
- X5.7: (Turn,→,get(mi)) / (Stop,→,actor.regulatory(‘Stop light’))
- X5.8: (Stop,→,→) / (Stop,→,actor.regulatory(‘Stop light’))

**X6. Car In an Emergency Situation**

- X6.1: (D,→,→) / (Move,→,→)
- X6.2: (Move,→,→) / (Move,→,→)
- X6.3: (D,→,→) / (Slow,→,actor.regulatory(‘Stop light’))
- X6.4: (Slow,→,get(mi)) / (Slow,→,actor.regulatory(‘Stop light’))
- X6.5: (D,→,get(mi)) / (Turn,→,actor.regulatory(‘Turning flash light’))
- X6.6: (Turn,→,get(mi)) / (Turn,→,actor.regulatory(‘Turning flash light’))
- X6.7: (D,→,→) / (Speed,→,→)
- X6.8: (Speed,→,→) / (Speed,→,→)
- X6.9: (D,→,→) / (Emergency,→,actor.regulatory(‘Siren/Emergency-flashing’))
- X6.10: (Emergency,→,→) / (Emergency,→,actor.regulatory(‘Siren/Emergency-flashing’))
- X6.11: (D,→,get(mi)) / (Stop,→,actor.regulatory(‘Stop light’))
- X6.12: (Stop,→,get(mi)) / (Stop,→,actor.regulatory(‘Stop light’))
- X6.13: (Stop,→,get(mi)) / (Move,→,actor.regulatory(‘Stop light off’))
World Behavioral Model:

Entrance Ramp Snippet with four Actors

High-level view of behavioral model
TECHNICAL SUMMARY Cont.

Coverage Criteria:

1. Paths Combinations:
   - All Combination of paths (ACoC), \( C = \prod_{i=1}^{#M} P_i \)

2. Concurrent Criteria:
   - All concurrent possibilities Coverage (ACPC) = \[ \sum_{i=1}^{\left| C \right|} \frac{\left( \sum_{j=1}^{\left| C_i \right|} \left| p_{ij} \right| \right)!}{\prod_{j=1}^{\left| C_i \right|} \left( \left| p_{ij} \right| \right)!} \] 
   - Rendezvous-graph Coverage (RGC) = \[ \sum_{i=1}^{\left| C \right|} \frac{\left( \sum_{j=1}^{\left| C_i \right|} \left| p_{ij} \right| \right)!}{\prod_{j=1}^{\left| C_i \right|} \left( \left| p_{ij} \right| \right)!} \]
PLAN FOR NEXT REVIEW

• Method Efficiency.
• Scalability.
• Comparison.