State of the Art & Practice in Activity-Based Modeling

Part 2: Software & hardware architecture
Topics

- Software architecture
  - Data structures
  - Algorithms
  - Distributed computing
  - Outputs and visualization
- Hardware architecture
  - ARC ABM example
CT-RAMP: Software Design Concept

SANDAG
- UEC spreadsheets
- Market definitions

CT-RAMP:
- Model Flow
- Model Components
- Inputs/Outputs

Common Modeling Framework:
- Matrix Classes
- LogitModel
- Utility Expression Calculator
Common Modeling Framework

- A library of tools for building transport and land-use models
- Written in the Java programming language
- Open source (Apache public license)
- Collaborative
- Currently used by over 30 clients
Why Java?

- Java is a fully Object-Oriented Programming (OOP) Language
- Java is easy to learn and use
- Java encourages good software design
- Java natively supports multi-threading
- Java is architecture-neutral
OOP – Data Structures

Synthetic Population

Household 1
- Attributes
  - Household Size
  - Autos Owned
  - Number of Workers
  - Household Income
  - Household Location
  - Composition

Person 1
- Attributes
  - Age
  - Gender
  - Employment Status
  - Student Status
  - Work Location
  - School Location

Tour 2

Person 3

Tour 3
- Attributes
  - Number of Stops
  - Tour Mode
  - Persons on Tour
  - Primary Destination

Choice Models

Tour 4

Tour 5
Interaction between models and data

HouseholdDataManager

Person 1
- Attributes: Age, Gender, Employment Status, Student Status, Work Location, School Location

Household 1
- Attributes: Household Size, Autos Owned, Number of Workers, Household Income, Household Location, Composition

Person 3

Tour 2
- Attributes: Number of Stops, Tour Mode, Persons on Tour, Primary Destination

Tour 3

Tour 4

Tour 5

ChoiceModelApplication.java
- UtilityExpressionCalculator.java (Model specification, external data inputs, and utility terms)

DecisionMakingUnit.java (Relevant household/person attributes, other internal data)

LogitModel.java (Logit calculations, probabilities, get choice)

NYBPM Users Group Meeting, June 8, 2011
CMF Tools – Matrix Package

- Read/write to/from all major software (TransCAD, Cube, Emme, etc)
- Matrix calculations
- Random access (skims in memory, sparse matrices)
- N-dimensional matrix, iterative proportional fitting
CMF Tools – Model Package

• Create and apply discrete choice models
• Flexible in specification of nesting structures
• “Interface” pattern used – any object can be an alternative
• Extensive debugging features
/** A simple mode choice model */

public class MyModeChoiceModel {

    public runModel() {
        // instantiate modes
        DriveAlone driveAlone = new DriveAlone();
        Transit transit = new Transit();

        // instantiate model
        LogitModel model = new LogitModel;

        // add modes to model
        model.add(driveAlone);
        model.add(transit);

        // calculate utilities
        double logsum = model.getUtility();

        // choose Mode
        Mode chosenMode = (Mode) model.chooseAlternative();
    }
}

LogitModel.add() takes a Mode

getUtility() solves logit model, returns logsum

Uses Monte Carlo to select alternative according to logit probabilities and returns it.
CMF Tools – Calculator Package

- Activity-based models typically utilize many logit choice models, some with many alternatives
- Traditional software relies on hard-coded utility equations
  - Inefficient - Programmer responsible for coding utility equations
  - Inflexible – Requires programmer to change equations and recompile
  - Imperfect – Only one person typically reviews equations, which increases probability of bugs
- Utility Expression Calculator (UEC) developed to overcome these limitations
CMF Tools – Calculator Package

- The UEC is a Java package that reads and interprets an Excel workbook containing a logit model specification and its inputs.
- The UEC solves the utility equations for a given decision-maker.
- The UEC “opens up” the model specification – anyone can edit the spreadsheets, change inputs & parameters, check that the model is properly specified, etc.
### Table Data: CSV files of zonal, household, or person data

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### Matrix Data: Trip tables or level-of-service skims in zone-zone format (TPPLUS, TRANSCAD, EMME2, and/or BINARY formats)

(Sparse matrices can be compressed in memory)
### UEC - Model Page - Tokens

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NYBPM Users Group Meeting, June 8, 2011
UEC – Model Page - Utilities

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</tbody>
</table>

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Threading

Quad-core Intel Box with 4 GB RAM per process

Workplace Location Choice

- Thread 1: households 1-50,000
- Thread 2: households 50,001-100,000
- Thread 3: households 100,001-150,000
- Thread 4: households 150,001-200,000
Distribution

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Grid Computing via the Java Parallel Processing Framework
ABM Outputs

Household Data, Person Data, Tour/Trip List

<table>
<thead>
<tr>
<th>HID</th>
<th>PID</th>
<th>TID</th>
<th>PUR</th>
<th>MOD</th>
<th>SB</th>
<th>SA</th>
<th>OTA</th>
<th>DTA</th>
<th>S1TA</th>
<th>S2TA</th>
<th>TLOR</th>
<th>TLDS</th>
</tr>
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<td>1</td>
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<td>1</td>
<td>0</td>
<td>1</td>
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<td>0</td>
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<td>2</td>
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<td>2</td>
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<td>565</td>
<td>698</td>
<td>982</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Maps, Graphics

Trip Tables

Assignment

Other Summaries

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ABMVIZ: AB Model Visualization Dashboard

- Developed in Adobe Flex/Flash
- Design goal: Intuitive + Flexible
- Features Queries, Tables, and Lots of Visuals
  - Bar Charts +
    - Four Types of Maps
  - Time Use
  - Tour Tracing
  - Tree Maps
  - Radar Charts
  - Bar Chart
ARC ABM Reporting Database

• Stores ABM Output Tables, Travel Time Skim Data, and Select Inputs By Scenario
  • Around 15 GBs per scenario
  • Around 5–10 scenarios at a time in the DB
  • Can load survey data into DB as a scenario for comparison purposes
• Needs to be fast – not a traditional transactional DB, more a data warehouse
  • Use de-normalized data to avoid millions of joins each time for dynamic visualization dashboard
  • Read-only; minimal rollback features required
  • Parallel query functionality (SQL Server)
  • Needs excellent query caching functionality
• Use ARC Enterprise SQL Server with 4 Licensed Processors
ABMVIZ Queries

Interactive query builder with lots of default queries

Difference alternatives

Edit SQL if desired

Aggregations

Save Tables to Clipboard, Excel
Bar Chart and Map

- Can interactively hide/show bars and redraw plot
- Select field to visualize
- Cycle thru fields and redraw map
- Zoom in/out with “+”/”-“ or mouse wheel
Time Spent Traveling by Income & Person Type

- Low income time spent traveling
- Med income time spent traveling
- High income time spent traveling
- Very high income time spent traveling

Legend:
- Full-time worker
- Part-time worker
- Non-worker
- Retired
- University student
- Student of driving age
- Student of non-driving age
- Child too young for school
Transit Riders by Age – Base vs. Future

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Time Use

- Share of time use by purpose and person type

Can change person type
Tracing of Activities/Tours

Person id= 1018897 type= Full-time worker
Performance Measures with Radar Charts

- Compares independent measures across entities
Special Reports for Pricing

- Number of highway users (persons, vehicles):
  - Toll users:
    - Captive
    - By choice
  - Non-toll users:
    - Captive
    - By choice
- Toll revenue
- Equity analysis

AM Peak Toll Trips by Time Saved
ARC HOV2HOT Conversion Study

Toll Share of Toll-Eligible Trips by Time Saved

NYBPM Users Group Meeting, June 8, 2011
ARC HOV2HOT Conversion Study
Diurnal Distribution of Toll versus Non-Toll Work Tours
ARC ABM Hardware and Software Setup

- Three Windows Server 2003 64bit Machines:
  - Dual Quad Core Intel Xeon X5570 2.93 GHz with Hyper-Threading ⏞ 16 threads
  - 32 GB of RAM
  - Cube Voyager + 8 seat Cube Cluster license

- Total cost ~ $30,000 in 2009
Implementation Design Goals

• Overnight run time ¦ Model Relevance
  • Around 16 hours
  • Requires distribution and threading
  • Model runtime is roughly proportional to population size
  • Network skimming and assignment procedures are still proportional to the squared number of TAZs: ~50% or more of total model runtime

• Commodity hardware ¦ Minimize total lifetime cost
  • Hardware available today from common vendors; reasonably priced

• Easy to Setup and Use ¦ Staff acceptance
  • Not too complicated to setup, run, debug, etc
Distributing and Threading CT-RAMP

- Main Cube script calls the JPPF client to start CT-RAMP
- ~1.76 million households split into 880 tasks of 2000 HHs
- CT-RAMP data managed through:
  - Household Manager – manages all HH and person data into RAM for quick I/O
  - Matrix Manager – reads all the matrix data into RAM for quick I/O
- Run a sample of HHs to save time: 33% – 50% – 100%
- HHs and Persons store a random number seed to avoid random number sequence order of processing problems
- SPEED UP = 9X
ARC ABM Run Times

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Run Times (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Prep, Truck Model, Initial Skims</td>
<td>33/25</td>
</tr>
<tr>
<td>II Demand with CT-Ramp (33% Sample)</td>
<td>112/24</td>
</tr>
<tr>
<td>Convert Trip Lists to Demand Matrices</td>
<td>170/36</td>
</tr>
<tr>
<td>Highway &amp; Transit Assignment &amp; Skimming</td>
<td>165/36</td>
</tr>
<tr>
<td>II Demand with CT-Ramp (50% Sample)</td>
<td>170/36</td>
</tr>
<tr>
<td>Convert Trip Lists to Demand Matrices</td>
<td>173/75</td>
</tr>
<tr>
<td>Highway Assignment (AM, PM, MD, NT)</td>
<td>437/100</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>970/8795</strong></td>
</tr>
</tbody>
</table>

**Note:** Run times are presented in minutes.

- **No Threading/Distribution** (8 processors, 16GB RAM, 1 Computer)
- **Threaded and Distributed** (24 processors, 48GB RAM, 3 computers)

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