Estimating public transport congestion in UK urban areas with open transport models

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Urban transportation models

MATSim model: heterogenous data and integration of many sub-models

Source: [Balmer et al., 2009]

Land-use transport models

Land-use transport models as a progressive complexification through coupling of detailed sub-models

Models	Speed of change							
	Very slow		Slow		Fast		Immediate	
	Networks	Land use	Work-places	Housing	Employ-ment	Popula-tion	Goods transport	Travel
BOYCE	+				+	+		+
CUFM		+	+	+	+	+		
DELTA/START	+	+	+	+	+	+	+	+
HUDS				+	+	+		
IMREL	+	+	+	+	+	+		+
IRPUD	+	+	+	+	+	+		+
ITLUP	+	+			+	+		+
KIM	+				+	+	+	+
LILT	+	+	+	+	+	+		+
MEPLAN	+	+	+	+	+	+	+	+
METROSIM	+	+	+	+	+	+		+
MUSSA	+	+			+	+		+
POLIS		+			+	+		+
RURBAN		+			+	+		+
STASA	+	+	+	+	+	+	+	+
TRANUS	+	+	+	+	+	+	+	+
URBANSIM		+	+	+	+	+		+

Source: [Wegener and Fürst, 2004]

Relevance of large scale models

Large scale urban models are intrinsically flawed and do not reach their goals of long-term application to planning: **Requiem for large scale models in 1973** [Lee Jr, 1973]

Urban analytics and Smart Cities approaches may follow the same path if they ignore the past and the complexity of cities [Batty, 2014]

To foster relevance of large urban models:

- Transparency on data and implementation, reproducibility
- Validation of models and sub-models: from small simple models well validated to larger integrated models

$\rightarrow$ Open, reproducible urban models can be shared, coupled into modular integrated models, tested and validated [Banos, 2013]

Towards modular models using workflow systems

Scientific workflow systems

[Yu and Buyya, 2005] [Barker and Van Hemert, 2007]

→ Execution of numerical experiments and data processing in a systematic, reproducible and domain-specific way
→ Often coupled to High Performance Computing infrastructures
→ Flexibility with scripting languages and easier collaboration

Proposed approach

Build modular urban transportation models from the bottom-up using workflow systems, open source sub-models and open data

→ Sub-models coupled into the workflow, can be easily replaced
→ Reproducibility and transparency
→ Easier transferability of model application
→ Application of model validation methods

Case study: integrated models

Case study: *Construct a modular four-step multimodal transportation model using open source projects and data*

Integrated models:

- MATSim model (MATSim Community) for the transportation system `https://www.matsim.org/` [Horni et al., 2016]
- SPENSER model (University of Leeds) for the synthetic population `https://github.com/nismod/microsimulation`
- QUANT model (CASA, University College London) for spatial interactions to generate home-work plans `http://quant.casa.ucl.ac.uk/` [Milton and Roumpani, 2019]
- spatialdata library (OpenMOLE community) for data processing `https://github.com/openmole/spatialdata` [Raimbault et al., 2020]

Case study: data and implementation

Data:

Generic for any Functional Urban Area (GHSL [Florczyk et al., 2019]) in the UK: NOMIS census, OrdnanceSurvey roads, National

Workflow systems:

- DAFNI facility funded by UKCRIC `https://dafni.ac.uk`
- OpenMOLE software `https://openmole.org/` [Reuillon et al., 2013]

Implementation

- Currently integrated: synthetic SPENSER population with uniform job locations; simple home-work commuting plans; network and plans prepared into MATSim xml files and fed into a one-mode MATSim; models integrated as Docker containers.
- Work in progress: use the QUANT model to generate more realistic home-work flows.

DAFNI facility

Platform developed for infrastructure research, providing dataset sharing, model upload, High-performance computing, workflow system.

`https://dafni.ac.uk`

DAFNI workflow for coupled model

Monte Carlo experiments

Visualization within DAFNI

Simulation results: travel distances

Daily travel patterns

Role of stochasticity

Validation: towards spatial sensitivity analysis

Raimbault, J., Cottineau, C., Le Texier, M., Le Nechet, F., Reuillon, R. (2019). Space Matters: Extending Sensitivity Analysis to Initial Spatial Conditions in Geosimulation Models. *Journal of Artificial Societies and Social Simulation*, *22*(4).

Raimbault, J., Perret, J., & Reuillon, R. (2020). A scala library for spatial sensitivity analysis. *GISRUK 2020 Proceedings, 32.*

Raimbault, J. (2019). Second-order control of complex systems with correlated synthetic data. *Complex Adaptive Systems Modeling*, *7*(1), 1-19.

Raimbault, J., Perret, J. (2019). Generating urban morphologies at large scales. In *Artificial Life Conference Proceedings* (pp. 179-186).

OpenMOLE workflow engine

OpenMOLE model exploration open source software
[Reuillon et al., 2013]

Enables seamlessly (i) model embedding; (ii) access to HPC resources; (iii) exploration and optimization algorithms

`https://openmole.org/`

Coupling SPENSER and QUANT with OpenMOLE

New project | Test | Run

SpenserQuantCoupling

- test 4.00KB
- Quant.oms 1.65KB
- Spenser.oms 2.20KB
- SpenserQuant.oms 3.86KB

SpenserQuant.oms

```
//val indicators = Val[String] // FIXME this is dirty - would be better to have an array and collapse it - better hardcode it anyway?
val indicators = "CDiff,alpha,delta"
val cdiff = Val[Array[Double]] // for each year
val alpha = Val[Array[Double]]
val delta = Val[Array[Double]]

val quantcommand = "sh -c \"cd /home/Quant/QUANTAI;/usr/bin/dotnet run -- /home/pop.csv /home/nw.graphml /home/res.csv "+indicators+"\""

val quant = ContainerTask(
    //image = "justeraimbault/quant:1.0.4",
    image = workDirectory / "images" / "justeraimbault-quant-1.0.4.tgz",
    command = quantcommand,
    containerSystem = Singularity() // FIXME proot seems to have issues resolving symlinks
) set (
   (inputs,outputs) += (region,years),
   //inputs += (indicators),
   inputFiles += (msoayearlypops,"/home/pop.csv"),
   inputFiles += (nwchanges,"/home/nw.graphml"),
   outputFiles += ("/home/res.csv",quantresults),
   nwchanges := workDirectory / "data" / "testscenario.graphml"//,
   //msoayearlypops := workDirectory / "test" / "S12000030.csv"
)

val postprocessquantresults = ScalaTask("""
        |val rawres = quantresults.content.split("\n").toSeq.tail.map(_.split(",").map(_.toDouble)).sortBy(r => r(0))
        |val cdiff = rawres.map{r => r(1)}.toArray
        |val alpha = rawres.map{r => r(2)}.toArray
        |val delta = rawres.map{r => r(3)}.toArray
            """.stripMargin
            ) set (
    (inputs,outputs) += (region,years),
    inputs += (quantresults),
    outputs += (cdiff,alpha,delta)
)

val indics_hook = AppendToCSVFileHook(workDirectory / "exploration" / (((new SimpleDateFormat("yyyyMMdd_HHmmss")).format(new Date()))+".csv"),arrayOnRow = true)

val exploregions = DirectSampling(
   evaluation = (spenser -- processpop -- quant -- (postprocessquantresults hook indics_hook)),
  // Stirling, City of London, Manchester, Birmingham
  //sampling = (region in Seq("S12000030","E09000001","E08000003","E08000025"))
  sampling = (region in Seq("S12000030"))
)

exploregions
```

13.0-SNAPSHOT Shooting Star
built the 06/12/2020 17:31:52

Towards advanced validation experiments

OpenMOLE integrates methods for: sensitivity analysis, spatial sensitivity analysis, design of experiments, calibration, diversity search, inverse problems, model reduction.

Integration of OpenMOLE into DAFNI

Discussion

Developments

→ Dynamical strong coupling of QUANT and SPENSER

Applications

→ Validation of sub-models and integrated models using advanced model validation methods

→ Use MATSim outputs to quantify effective densities in public transport: potential exposure indicators in the COVID-19 context

→ Impact of policies and interventions on transport system dynamics and potential contaminations

Health indicators for public transport

Conclusion

→ Open, reproducible and validated urban models as elementary bricks towards larger integrated models

Open repositories

`https://github.com/JusteRaimbault/UrbanDynamics` for workflows

`https://github.com/openmole/spatialdata` for data processing

Workflow engines

DAFNI: `https://dafni.ac.uk/`

OpenMOLE: `https://openmole.org`

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