ODD –PyEMLab-AGG

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Agent Model Description ODD Protocol

ODD Model description

The agent based model presented herein is described in accordance with the ODD (Overview, Design concepts, and Details) protocol [1-3]. In addition Müller et al., [4] extended the ODD methodology to include for human decision making (ODD D+ (decision plus)). Although this thesis does not strictly follow the additional categories outlined in ODD D+, descriptions are added where it was felt appropriate[1].

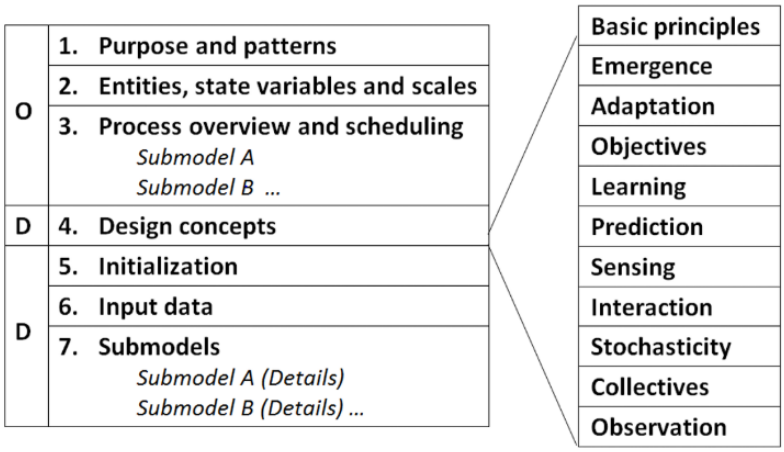

Figure 1: ODD framework: Reproduced from Fig 1 from [5]

1. Purpose: This model has been developed to simulate a low-carbon distribution network where customers provide flexibility via a bidding market managed using aggregators and an ISO. The effect of corporate behaviour (aggregator companies

[1] Mainly on agent decision making

with risk management) and more human like customers (emotional and bidding behaviours) have been included to provide a more holistic view of how this market might operate in the future.

2. Entities, state variables, and scale: In this model, agents are individual households (domestic customers), small and medium sized entities (industrial customers), aggregator companies, generators and the Independent System Operator (ISO).

Domestic Customer agents are characterized by the state variables: identity number, Marginal cost (for Up and Downward volumes – this is a starting value), up and downward flexibility volumes (MW), expectation for yearly revenues (£ per year), cluster ID number (type of customer e.g. affluent with 2 EV's, or customer with limited flexibility), contract types and conditions e.g. price payment terms. Revenues from biding per contract year (running totals) are also stored, as well as the last bid (volumes and price). Domestic customer agents keep track of their emotional state about particular aggregators using an Agent_Zero framework described in section 5.4 of the thesis. They can also change contracts with Aggregator agents yearly.

Industrial Customer agents are characterized by the state variables: identity number, Marginal cost (Up and Downward), up and downward flexibility volumes, current aggregator and contract terms with aggregator. They are similar to Domestic customer agents, but do not utilise the Agent Zero logic and do not change Aggregators during the course of the simulation, nor contract type. They simply bid marginal costs volumes.

Aggregator agents are characterized by the state variables: identity number, name, latest contract offers, capital and operating costs, portfolio bucket volumes, bidding prices for aggregation and disaggregation. The number of up/down bid buckets, option/hedging values, clearing price forecasts, price volatility values and various status flags/values such as Risk/Hedging on, a risk aversion factor and the current business model. Aggregators keep an account of their costs and revenues generated using an internal set of matrices (P&L matrices).

ISO agents are characterized by the state variables: identity number, name of ISO, reserve volume % and Volume of lost load (VOLL) value. In the current simulation, only one ISO agent is present. Its primary purpose is to "clear" the market, store bids and inform bidders (aggregators and other larger entities such as generators) of their winning bids in the market and to pay them as necessary. In the current simulation, the ISO does this at zero cost.

Generator agents represent large generation assets i.e. power plants of different types and associated costs. Costs are fixed at the beginning of the simulation. Agents are characterized by the state variables: identity number, generator name, technology type, Marginal cost (Up and Downward), up and downward flexibility volumes, expectation for yearly profits (£ per year) and an update price methodology (a number which is used to determine how bidding prices will be updated). A record of the revenues and profits generated from bidding are included in a set of profit and loss matrices,

Simulation steps occur every hour for 5 years.

3. Process overview and scheduling— In this model, users control the process by using a python scripting language that specifies what procedures/modules need to be run and in what order. Users can therefore run the model with and without social message propagation for example. The base model uses the following procedures that are run hourly, weekly, monthly and yearly as described in more detail in section 6.x of the thesis.

Initialization

Read in customer (Industrial and Domestic), aggregator, generator, flex demand data from CSV files.

Create and Initialise agents using Agent Factory's[2]

Initialise various in-memory arrays to store data

Hourly

- *Domestic Customers Create And Send Bids to its current aggregator*
- *Industrial Customers Create And Send Bids to its current aggregator*
- *Generators Create And Send Bids directly to ISO*
- *Aggregators forecast future price volatilities and clearing price probabilities based on historical data*
- *Aggregators aggregate bids from Industrial and Domestic customers into multiple buckets e.g. 10*
- *Aggregators Risk Manage – estimate risk of each bucket and decide whether to hedge. Calculate and account for cost of hedge*
- *Aggregators send bucket bids to ISO*
- *ISO takes bids and clears the market using economic dispatch – and calculates a clearing price where demand = supply. ISO sends out cleared bids (i.e. bucket bids and generator bids) that have been accepted.*
- *Aggregators disaggregate: Takes cleared bids and apportions these cleared bids to the various customers. Accounts for payments to individual customers. Model assumes instant payment.*
- *Generators update accounts of cleared bids*
- *Aggregators Update Accounts (daily monthly) & use Zip trader algorithm to adjust future bids*

[2] The factory pattern [6] E. Gamma, R. Helm, R. Johnson, J. Vlissides, and D. Patterns, *Design Patterns: Elements of Reusable Object-Oriented Software*. Addison-Wesley Publishing Company, 1995. is a common design pattern to create objects. The objects in this case are a collection of homogenous agents.

- *Customers (industrial and domestic) process Cleared Bids and update internal accounts of agents*
- *Update customer zip trader to enable adjustment in customer bid level*
- *Update generator bids and accounts*

Weekly

- *Update Customers Agent_Zero (AZ) modules – Updates emotions etc.*
- *Propagate Messages (Social Media) to connected agent (if thresholds in customer AZ module are met).*
- *Calculate Hurst exponents and Store*
- *Collect dispositions etc. and Store weekly stats*
- *Update propagations and effects on Agent Zero models within Agents*

Monthly

- *Update Agent_Zero Scores using Social Scores from other connected agents*
- *Aggregators review performance of existing contract and choose new contract type and terms if applicable*
- *If domestic customer is due to renew the customer compares and selects from aggregator offered Contracts.*
- *Calculate elasticity Impact on monthly demand by comparing last months average Clearing Price with this months*
- *Collect monthly stats and store*

Yearly

- *Assess aggregator yearly performance and aggregator checks for market exit*
- *Aggregator Business Model (BM) Assessment And Selection change BM*
- *Calculate yearly elasticity effect on demand*
- *At end of simulation, store various in-memory matrices into hdf5 database.*

The model synchronously updates. All agents bid at the same time and currently order does not matter.

Each simulation time step represents 1 hour.

4. Design concepts

Emergence: Emergent phenomena are expected to be seen in this model as it is a complex simulation that includes adaptive behaviour with emotions. The use of Hurst coefficients/exponents have been used to detect such emergent behaviour.

Adaptation: Agents adapt to changing prices and offers made to them by aggregation agents. Social media in the form of a network is used to transport

messages to from connected domestic agents. Messages on aggregator performance as well as price bidding information is used.

Objective: Different agents have different objectives. These are summarized in Table 1.

Agent Type	Objective
Domestic Customer	To achieve its expected yearly revenues (an input), or to follow clearing prices if this is higher. Daily bids are adjusted using Zip Trader Algorithm (see Chapter 5)
Industrial Customer	To bid its marginal cost as per input assumptions. This is provided to the simulation using an input file (CSV).
Generators	To bid its marginal cost as per input assumptions. This is provided to the simulation using an input file (CSV).
Aggregator	1/To maximise its profits and also to meet minimum Return on Equity Target over the year. Daily bids are adjusted using Zip Trader Algorithm (see Chapter 5). Target prices are set in a manner discussed below 2/ To apportion bids into 10 buckets or bins so that it maximises its profits under different contract terms 3/ at year end to selct an appropriate Buisness model that will provide the greatest economic value to the Aggregator 4/ To adjust contract terms monthly (for new contracts) to maximise profits
ISO	Simply to clear the market using an Economic dispatch algorithm. Future work will include an AC OPF formualtion wihich will be used to clear the market at minimum cost.

Table 1: Agent Objective Summary

Interaction: Domestic Agents who are located in the same groups interact among each based on their position on a social network. Different networks are able to be assigned to the model and affects propagation mechanics and results output. Every hour/week/month (timeframe can be changed), domestic customers agents interact

by sharing bid price information and their views on their current aggregator with their neighbours.

Aggregator Agents "capture" domestic customers by advertising contract details monthly, prices type of contract etc. Domestic customers evaluate said contracts at the end of their contracts and based on this may choose to change their aggregator relationship e.g. leave the current one for a new one with a contract with better terms. Only a certain proportion of the agents reach the end of their contract in any one month and is based on OFGEM data on contract renewals throughout the year.

Aggregators collate bids from domestic and industrial customers and package these bids into a number of buckets – Ten[3]. That is the aggregator presents ten bids to the ISO. These bids are submitted to an ISO agent who also receives bids from generator agents. The ISO agent clears the market and notifies aggregator and generator agents of the current clearing price and the volumes that were accepted. In some cases some of the aggregator buckets bid might not be cleared.

Learning: Agents use a ZIP Trading algorithm to alter their bid prices. In the case of Domestic customers, the ZIP algorithm uses a set point (target) that is a combination of past clearing prices and expectations about revenues. The customer agent has a view on what level of revenues it wishes to earn over the year (input data driven), but will also be swayed by the value of the recent historical clearing prices.

In the case of the aggregators, they estimate setpoint/target prices that should 1/ cover their operating and capital costs and 2/ provide them with the maximum

[3] This can be changed.

profit.

Aggregators also collect data during the simulation and use optimisation routines to change their offers to domestic customers. These offers represent potential new contracts. In the current simulation Generators, Industrial customers and the ISO agent have no learning abilities, although this can be easily extended.

Decision-making: Currently only the Aggregator and Domestic Customer agents, are making decisions during the simulation. This is summarized in Table 1

Agent Type	Decision	Description
Aggregator	Risk management Infrastructure Investment	Whether to pay for additional equipment/hardware if not already risk managing
	Hedge	Whether to pay for the cost of the hedge and buy an option to cover potential revenue reductions
	New Business Model	At year end decides on whether to change its business model - Revenue generation model and risk management stance
	Contract Terms	Decide on the contract terms to offer to new and expiring customers- uses optimisation. Changes monthly
	Bucket Bid Price	Adjusts bucket bids using a ZIP trader algorithm adjustment factor
	Bucketing Algorithm	Current runs are fixed with one type but some options allow for the number of buckets to be changed during the simulation. The Bucket edges eg 20-60 £/MWh; 61 -200 etc are apportioned during the bucketing process using predictions of clearing price
	Exit Market	After X years of losses whether or not to exit the market
Domestic Customer	New contract	At end of existing contract, choose from offers from the various aggregators or not at all
	Bid Price	Uses previous or base marginal costs for flexibility adjusted by a factor which is adjusted using a ZIP

		trader algorithm
	Exit market	If after x years of not meeting customer expectations whether to leave the market or not
	Volume of flex to bid (option)	Currently all sims use the max volumes of flex. The model is able to adjust those volumes. E.g. should a customer only supply 50% of the max volumes

Table 2: Decision making in key agent types

Prediction. To evaluate and choose bucketing ranges the aggregator uses historical data to estimate a probability distribution function (PDF) of clearing prices. This PDF is used to apportion bids to buckets so that the Agent is likely on a probabilistic basis to maximise its revenues.

Sensing: Agents update emotions based on the interactions with other agents on a social network. Clearing prices produced by the ISO from economic dispatch of power are broadcast to all agents, who can analyse such data to improve bids. This data is used by the ZIP trader routines. Aggregators also publish their new contract terms monthly (type and values) and are shared with domestic customers – who use such data to assess whether they would like to take a new contract.

Stochasticity: The bidding algorithms used by the various agents have a random element within them. Analysis has shown that clearing prices could have a variability of +- £5-15/MWh dues to such random fluctuations.

Current Customer input data has been randomised. E.g. Expectations, Customer location on social network randomised

Propagation of messages between domestic customer agents depends on probabilities associated with an emotion value stored within the agent. Higher

emotion values have a higher probability of being sent. A base receive probability of 30% is used[4]. That is, if a random number is <=30% messages sent by connected agents over a social network will be received.

Observation: Data is collected and collated into in-memory arrays and output into an hdf5 database at the end of the run. Data collected includes around 50 sets of variables some stored as three-dimensional arrays so that data is split by customer type and by aggregator. Histograms and distributions of contract terms (e.g. prices, margins) are also collected through time. Agent_Zero values for key agents are also collected.

Data output and trends have been plotted using Excel as a basis although software packages such as Miner3D [7, 8], SPSS [9-11] have also been used.

5. Initialization: A total of 50,000 Domestic customer agents, 4500 Industrial customer agents, 59 Generator agents and six Aggregator agents were created, using Agent Factories. Agents' characteristics were initialized with data collected for households' locations and socioeconomic characteristics. Model parameters such as simulation length, time steps, propagation probabilities etc. are initialised at start up. Data is read in from CSV files.

6. Input data: The model uses input data in the form of CSV files.

7. Sub models: The model consists of a number of sub models as outlined below.

7.1Agent_Zero (AZ): The AZ framework [12] has been adapted to allow customers to keep track of emotions social interaction scores and incorporate logic associated with contract performance (see thesis section 5.4). The AZ framework is embedded in domestic customers and keeps track of emotions and provides a score

[4] This can be changed and could be assigned individually to individual agents

which is used to assess relative aggregator performance.

7.2 Risk Evaluation: Agents calculate risk values by using an algorithm discussed in section 4.7 & 4.8 of the main part of the thesis.

7.3 Zip Trader: See section 5.2. Dave Cliffs ZIP trader [13] has been used to adjust bids during the simulation.

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