MAGENTA Technology: A Family of Multi-Agent Intelligent Schedulers

G. Rzevski, J. Himoff, P. Skobelev

MAGENTA Technology, 130 Shaftesbury Avenue, London W1D 5EU, UK
MAGENTA Development, 1a Ostipenko St. Samara, 443110, Russia

Abstract

The paper describes a family of Intelligent Schedulers (known as i-Schedulers) for a variety of applications based on Magenta agent technology, and characterized by a number of unique, advanced features such as event-driven, real-time, incremental, continuous scheduling and schedule improvement, scalability from small to very large enterprise networks, pro-active agent negotiations, multi-criteria schedule analysis and rich decision support for the user.

Two schedulers from the family have been developed and applied to commercial problems: a road transportation scheduler and an ocean fleet scheduler. The third member of the family, namely a project management scheduler, is in the design stage.

1. Application areas

The family of Magenta schedulers covers very diverse scheduling problems encountered in road transportation, ocean fleet scheduling and project management. Each is described, in turn, below.

1.1. Ocean Scheduler Applications

This section gives a description of the implementation of a Magenta Multi-Agent i-Scheduler for Tankers UK Ltd, the UK operations centre for Tankers International LLC based in Cyprus. The company manages a fleet of 48 VLCCs (very large crude carriers) which range in size from 260,000 mts to 440,000 mts. This represents approximately 10% of the world fleet of these huge vessels.

Ocean fleet scheduling involves planning multi-billion dollar cargoes, where the cost of even the smallest mistake is very high. A single ocean vessel journey may cost half a million dollars and bring to the operating company a return of two millions dollars, or more.

The oil transportation market in which Tankers International operates is characterised by the volatile nature of the trade in terms of both demand and price. Most cargoes are announced through the Spot Market and negotiations on price are conducted through multiple brokers with the price being totally dependant on market conditions. A smaller number of cargoes are given through a Contract of Affreightment (COA) where a customer agrees to provide a tanker company with a certain number of cargoes in an agreed period: example could be 8 cargoes of approximately 275,000 mts in next 12 months.

Oil transportation is a global business with the main load areas for VLCCs being in the Arabian Gulf, West Africa, North Sea and Mediterranean; the main
discharge areas being USA, Northern Europe, China and Japan.

Cargoes are announced to the market some 14-30 days in advance of the loading date; this introduces a problem for the tanker operator as a VLCC voyage may be as long as 8 weeks from Arabian Gulf to US Gulf and return via Suez Canal.

Vessel Operators will therefore anticipate demand and plan to have vessels in a load area for a likely cargo at the right time. As Tankers International has a large fleet there are many more possibilities which can be covered than for a small operator with only a few ships.

The following is a list of goals which the fleet operator attempts to achieve as part of the scheduling activity. Some of these are mutually exclusive so a balance needs to be struck:

- Ensure that all COA cargoes which have been announced can be carried
- Ensure that COA cargoes expected to be announced in the next few days can be carried
- Find the most profitable cargo for each ship
- Reduce the number of waiting or idle days between cargoes
- Reduce the number of days cruising in ballast; that is, increase the laden/ ballast ratio.

Due to the size of these vessels there are very few ports (relatively) which can accommodate them and as each vessel has different physical characteristics it is essential that the physical dimensions of the terminal at the port are checked in advance against those of the vessel both in ballast and when loaded with the cargo. It is easily possible for a vessel to be able to enter a port in ballast condition but as loading increases its draught for it not to be able to exit the port! Complex calculations therefore need to be performed to establish the final draught of the vessel after loading, which will depend on the specific gravity of the grade of crude oil being transported and the temperature of the Ocean at the time of loading.

The next constraint to consider is the date of loading and the distance and routing to the load port to check that the vessel is able to sail to the load port to arrive in time for the Laycan (the window in time during which loading must take place). Sailing speeds for all vessels need to be stored and precise distances from the port of discharge to the next load port need to be made available to the system from an external source.

There are also licences or legal considerations: certain countries will not allow vessels sailing under their flag to enter certain ports, particularly in war torn areas such as Iraq. There are restrictions on vessels entering US ports related to insurance cover, which not all operators will accept. Many ports these days will not accept vessels with single hulls due to the danger of oil spills in the event of a collision.

Vetting of vessels is conducted by the Oil majors for safety and seaworthiness; if a vessel fails inspection or if the vetting has expired some customers will not accept the vessel. The rules in this area are complex and constantly changing.

Finally there are customer preferences which are a series of ad-hoc rules, but these are more often ‘soft’ rules rather than absolute - the customer may accept this vessel if he receives some incentive – usually in the shape of a discount!

We shall describe here the planning of a single cargo some 14 – 30 days prior to loading. However, because vessels are delayed in ports, are affected by bad weather – such as hurricanes in the U.S Gulf – and suffer mechanical breakdowns, the plan invariably has to be modified.

The Magenta Ocean i-Scheduler is designed to cope with re-planning in a very effective way – by performing only a localised re-planning. This means that only the agents related to the vessel(s) affected are activated and start negotiations to find all possible options. The System makes calculations of profit for each option and presents all options which are achievable to the user - ranked by a set of agreed criteria.

It is this ability to calculate all possible options accurately and quickly and then rank them that makes the Magenta Ocean i-Scheduler so powerful.

Calculating the most profitable option is not simple. The cargo with the highest TCE (profitability) is not always the best option. Such cargos may require a large number of waiting days before loading commences, when the vessel is not being paid. The load port may be on the other side of the world so there is a long ballast leg before loading or the discharge port may be in an area far away from the next possible load port. The ideal scenario for a vessel is a long voyage, for example, from Arabian Gulf to U.S. Gulf (about 11,000 miles) and from there to take a relatively short ballast leg to West Africa (4-6,000 miles) then take a cargo to China (9,500 miles) then return to the AG (6,000 miles) this would give a high number of earning days – a good laden/ ballast ratio. Contrast this with a cargo from the AG to the U.S. West Coast (11,370 miles). As the Panama Canal is too small for a VLCC
the only option is to ballast all the way back to the AG as this is the nearest load area.

A fully loaded VLCC cannot pass through the Suez Canal but must offload much of its cargo before entering the canal and then pay for the oil to be transported via pipeline to the northern end of the canal – due to the time and expense of this the VLCCs usually sail around the Cape of Good Hope en-route to the U.S.

Today ocean fleet operators have to rely on human experts to perform these complex tasks. But the problem with human experts is that they are under constant time pressure and under stress of performing several concurrent tasks. Besides, there is always a high risk of losing control of a scheduling process if an expert is temporarily unavailable or leaves the company. Human experts also have a limit of how many vessels they can consider at one time and are therefore not capable of extending their knowledge over rapidly growing fleets.

One of the most valuable results that were achieved during the implementation of Magenta Ocean i-Scheduler was capturing and refining knowledge of experts with decades of experience in ocean transport scheduling.

The capturing and using this expertise enabled Magenta Scheduler to speed up the scheduling process and increase its accuracy. Whilst the best experts required 1-4 hours to plan a single cargo and produce a good schedule, the Ocean i-Scheduler takes around 10 seconds to calculate all feasible schedule options and present them to the operator in a user-friendly manner.

Another important result that was achieved is high transparency for operators, customers, brokers and other participants of the workflow process.

A major benefit of the system, as confirmed by the operators, is the clarity and usability of the user interface. Before implementing the Magenta Scheduler, scheduling experts had to refer to several screens and charts in order to understand the status of the fleet and to see important events. With the Ocean i-Scheduler they now have only one screen to refer to. The simplicity of the interface helps the user navigate through the system and easily find all up-dated information on numerous charts, tables and graphs.

An example of one of the quantitative results that was achieved during testing is that where a vessel was delayed in port by 2 days during discharge, this meant it would be late for its next planned cargo; all other vessels in the area also had planned cargoes and were steaming in mid-ocean towards their load ports. Experienced operators in two countries grappled with this problem for 4 hours before finally arriving at a possible solution. When all the data was input into the Ocean i-Scheduler it took only 36 seconds to arrive at the same answer.

The Magenta Scheduler tracks the entire flow from event to final decision and writes all related data to a new decision database. This database contains the status message, the event, the state of the fleet prior to the event, the options considered to respond to the event, the recommended option according to the company objectives, the decision from the operator (if there is one) and then the resulting state of the schedule. The solution can then also track the actual schedule performance to understand if the scheduling activity was achieved without exception or even re-scheduled due to another event.

Agents are then used to analyse this data to discover patterns that are causing inefficiency and/or inconsistencies with the best practice. As the data and analysis can be represented by a semantic network and the underlying ontology is in a similar format, this new knowledge can be inserted into the knowledge-base quickly. While the current view from users requires a process with human interaction, it is readily imaginable that more and more automation can accelerate this process of learning and adaptation.

1.2. Road Scheduler Applications

The first version of the Logistics i-Scheduler was tested on two sets of real-life data obtained from Client A (3rd Party Logistics Provider) and Client B (a provider of logistics and freight management services).

Client A Requirements were to create transportation schedules in real time for 200 transportation instructions and 51 trucks (36 own fleet trucks plus 15 third-party carriers) operating on the UK Business Network. The network included 9 Distribution Centres/factories, cross-dock points for primary/secondary moves consolidation, 3 truck bases doing shared operations. In addition to requirements discussed earlier client specified handling transportation instruction availability windows, backhaul, consolidation, vehicle capacity availability windows and constraint stressing.

Client B requirements were to create transportation schedules for 4000 transportation instructions and 200 trucks operating on the UK business network. The network included primary and secondary deliveries between about 600 locations, 3 cross docks, 4 secure trailer swap locations and other types of locations. The network was also characterized by considerable...
number of very small orders.

Special requirements included dynamic routing, cross-docking, handling location availability windows and driver breaks.

The Logistics i-Scheduler has completed a schedule for 200 transportation instructions in 8 minutes, planning 116 journeys of a total of 20790 miles. The quality compares well with the results of the current process which requires several hours to produce a schedule, and has two operators working on the basis of a plan day 1 for day 3 execution. With the Logistics i-Scheduler it would be feasible to plan day 1 for day 2 execution or even day 1.

For 4000 orders with dynamical routing through 3 cross docks it took the Logistics i-Scheduler about 4 hours to build a schedule. This schedule shows strong consolidation of small orders onto trucks. It is also capable of incrementally planning new orders in near real time (a few seconds for a new order). As far as we know, this has not been achieved by any other transportation scheduling system.

Road transportation logistics is amongst the most complex business problems. The complexity is caused by the exceedingly high variety of possible solutions (large solution space), which rules out traditional combinatorial search algorithms, and uncertainty due to high dynamics and volatility of the operational environment and openness of business networks, which makes optimisation impractical – a single optimisation run is typically an order of magnitude longer than a typical interval between two consecutive changes in operational conditions.

Resource allocation is an ongoing continuous decision making process in real time where criteria are changing “on the fly”. Therefore the two key capabilities currently required from schedulers are supporting complex business networks and planning in continuous mode.

An effective road transportation scheduler must handle transportation instructions (TI) from many different loading points to many different destinations (e.g. customer locations and cross docks where cargoes are offloaded and consolidated) and many different routes by which orders can be delivered. Choosing the best route from the point of view of consolidation or other criteria is referred to as dynamic routing. The scheduler must also be able to allocate cargos of many different sizes and weights to many different types of trucks and trailers; take into account preferences of owners, operators and drivers and fit the schedule into numerous constraints imposed by warehouse working hours, driver work rules, safety regulations and enterprise policies, eg, on choosing between own fleet and third-party carriers. Different companies have different critical constraints, e.g. permission to override time or other constraints to achieve a more efficient schedule. The schedule created must be not only feasible but also efficient, i.e. possibilities for backhauls and consolidations should be found.

Complexity is also defined by the number and variety of orders (and other events that affect scheduling) per day and the number and variety of transportation resources such as trucks.

In addition, the scheduler is expected to rapidly reschedule orders and transportation resources affected by unexpected events such as: the arrival of new orders, cancellations, failures, bad weather conditions, road works and no-show of drivers or loading crews.

To enable enterprises to plan and re-plan continuously, reacting to events in real-time, schedulers must support Planning / Commit / eXecute (PCX) stages and plan across a multi-day planning horizon.

An individual truck may be in a Planning stage where it is being assigned orders and a journey is being built for it. During this phase orders can be added or removed as a result of new events and the route taken by the truck can be changed.

At some point the scheduler must commit the truck. This will trigger communications to warehouses, driver shift planners, truck servicing etc to make ready the truck for its journey. During this phase changes to the truck schedule are feasible but of course there would be knock on effects in the warehouse, driver planning etc.

The eXecute stage is when the driver begins his pre-journey checks and continues until his debriefing at the end of his shift is completed. During this phase a high level of sophistication would be needed to alter the truck schedule in transit.

Magenta Logistics i-Scheduler supports PCX by allowing Commit of individual trucks from a rolling schedule.

To achieve competitive advantage schedulers must take into account real-time economy where decisions are based not on some average rule but on the detailed analysis of the current situation. For example, a truck loaded by only 10% with a special cargo may be very profitable whilst a rule-based scheduler would not allow a nearly empty truck to start a journey. The requirement is to assess the economy of each truck, each journey, etc., which implies using the activity-based cost model. The current generation of batch schedulers cannot satisfy these requirements; a
fundamentally new approach to the task of allocating resources in real-time is therefore needed.

Designing a scheduler that can cope with such a variety of operating conditions, handle uncertainty related to the occurrence of events and at the same time continuously produce schedules that maximise the specified value (or minimise transportation costs) is a real intellectual challenge.

1.3. Project Management Applications

Projects vary from those that can be implemented by 4-5 persons working in an office to multi-million construction works involving hundreds of people, machinery and materials. Scalability is therefore the key feature. Also, in contrast to a supply chain, projects have clear starting points and completion deadlines and are subject to even larger number of unpredictable events threatening the orderly execution. It is therefore of paramount importance to have a rapid and effective re-scheduling activity to keep project plans up to date. Magenta Project Scheduler is in the design stage at present.

2. Magenta approach to scheduling

The software that exists on the market is ignoring true complexity of scheduling in order to automate high volume business processes. Such tools rely on rigid business rules to optimize the process. They are not scalable or robust and often prevent business from growing. Conventional software handles the scheduling process in rigid batch mode, which means that each time batch operation is carried out the already built schedule needs to be completely broken and re-built from the very beginning.

The Magenta approach to scheduling described in this paper handles complexity by balancing and resolving conflicts of interests of many active players rather than by following given rules and satisfying specified constraints.

This is achieved primarily by assigning an autonomous agent to every player in the business process and tasking agents to obtain the best possible deals for their clients. Players here include the enterprise as a whole (represented by the Enterprise Agent) and all individual demands and resources (including crews and resource owners). Demands and resources that have common interests self-organise into groups represented by a single agent. Agents may decide to compete or co-operate depending on prevailing circumstances. Human operators are provided with facilities for monitoring the scheduling process and overruling the decisions made by agents. i-Schedulers support users in their interaction with the system by providing them with options and evaluating consequences of their decisions.

The scheduling process is event-driven, which means that whenever an event that affects the schedule occurs, agents re-negotiate the allocation of affected resources. This re-scheduling is local, only affected parts of the schedule change, and therefore reacting to events is rapid and disturbance of the schedule is minimised.

The scheduling process is also knowledge-driven (rather than rule-based or constraint-driven), which means that agents before acting consult domain knowledge available to them in Ontology. Knowledge on scheduling is separated from the resource allocation mechanism, which greatly simplifies updates and increases the reuse of code. The process of formalising domain knowledge helps in refining it and closing the gaps left due to the empirical nature of knowledge collection.

3. Architecture of i-Schedulers

The family of i-Schedulers is based on the standard Magenta software architecture as depicted in Figure 1 and described in [1] and [2].

![Fig. 1. Architecture of Magenta multi-agent applications.](image)

Ontology Management Toolkit) are generic and common to all Magenta multi-agent applications, representing approximately 50-60% of the total amount of code. The green components (Virtual Market Extensions, Agent Toolkit, Ontology, Scenes, APIs and User Interfaces) are designed for each application thus customising the scheduler for each client and each scheduling problem.
The software is powered by a Multi-Agent Engine which contains all runtime tools necessary for the agent operation. Formalised knowledge is in Ontology supported by a powerful ontology editor. Agents negotiate scheduling decisions in the Virtual Market.

The i-Scheduler family is implemented on a J2EE platform.

4. Ontology

Ontology is constructed as a network with nodes as Objects (order, transportation instruction, cargo, truck, vessel, etc) and links as Relations (Journey consist of TI, etc). It contains also Attributes of Objects like Truck capacity, Vessel capacity, etc.

Ontology is divided into three main parts. Basic part of ontology includes main logistics concepts. Schedule Ontology consists of schedule owners and schedules and contains references to the operations which constitute schedules, described in operation ontology. This structure allows the introduction of any type of operations into schedules.

Ontology provides critical functionality for large scale applications like multi-user support, audit, business processes support, security, support for large datasets etc.

Ontology Management Toolkit enables system designers to capture the concepts and the relationships between concepts in a problem domain.

4.1. Ontology for Ocean Logistics

Ocean Logistics Ontology includes all concepts relevant to ocean logistics, eg, ports, vessels, trade routes and customers as well as rules to support the decision making logic and customer preferences. This knowledge is used by agents when making decisions.

4.2. Ontology for Road Logistics

Road Logistics Ontology includes all concept relevant for road logistics, eg, orders, transportation instructions, journeys, crews, etc.

4.3. Scenes

A Scene is a model of the current real-life situation, depicting specific demands and resources together with their attributes and locations.

A typical Scene is shown in Figure 3. The scene representation is design to help the user to understand the network situation. Looking at “Client” it is possible to find out where all TIs are at any given moment. Looking at “Location” it is possible to see all Journeys that are planned to go through this location.

Scenes also make decision making logic more visual and understandable to the end-users.

Fig. 2. A sample screen of Ocean i-Scheduler Ontology.

Fig. 3. An Example of Scene.

5. Virtual Market

Virtual Market is a virtual environment in which agents negotiate the allocation of resources to demands. The allocation is governed by arrangements similar to those of Free Market. Every scheduler has a different range of types of Agents and different types of decision-making logic. However, because these differences are relatively small, we focus on the description of the Road Transportation Scheduler, which is the most complex.
The Virtual Market architecture provides stable, well-designed & elegant basis for rapid development of new applications in a wide range of new domains (supply chain, factories, containers, projects, finance, nurses, conference boxes, etc).

5.1. Agent Types

The Road Transportation i-Scheduler has a larger variety of types of Agents than other schedulers, including:

- Customer Agent – looks after the required Customer Service Level
- Order Agent – splits orders into transportation instructions (TIs) and monitors order Key Performance Indicators (KPIs). Finds TIs whose allocation is unsatisfactory and tries to improve their situation by searching for the best journey
- Transportation Instruction Agent – searches for the best journeys
- Journey Agent – looks for the best TIs, devises good consolidation, looks for the best routes with minimal mileage
- Cross-dock Agent – supports the schedule for cross-dock docks and allocates Journeys into time slots
- Group Agent – keeps similar TIs together
- Enterprise Agent – minimises fixed costs by decreasing number of trucks used; switches company strategies; monitors schedules and causes disturbances to destroy ‘bad’ journeys

Each type can act as a Demand Agent or a Resource Agent depending on the situation. Demand and Resource are the roles that agents can apply.

5.2. Agent Coalitions

The Road Transportation i-Scheduler has a virtual market architecture which enables agents to form natural coalitions, e.g. TIs on a Journey or Journeys which together constitute a Driver Shift (all journeys made by a driver during his working day). This means that virtual market is “multi-level”, with nested groups formed by common interests where each group has an agent representative (Group Agent) who monitors what is happening in the group. Agents can join the group and leave it. The whole group can move (e.g. Journey goes to another Driver Shift).

This architecture provides flexibility in developing communities of different types of agents which can work as coalitions. Such approach also gives more options to find right balance between interests of individual egoistic agents (TI, journey, etc) and interests of communities of agents (fleet, journey, etc). Also, this balance can be changed dynamically in reaction to events (X-Dock under terrorist attack).

Finally, this architecture forms the basis for ongoing self-improvement of schedules.

5.3. Agent Negotiation Strategies and Protocols

Every agent is given the task of obtaining the best possible match for its client and a right to drop a previously agreed match if a better opportunity presents itself as events continue occurring. The abandoned partner pro-actively seeks a new match.

Agents on the Virtual Market use enhanced Contract Net negotiations protocol. Within Contract Net protocol agents pass the following iterations:

- Ask for pre-matching (rough) estimation
- Ask for plan, if possible to allocate without drop
- Ask for complete plan (drop is possible)
- Accept proposal
- Receive notification that plan is applied/failed
At each stage agents can cut or prioritize negotiation branches, thus detecting uninteresting options with fewer calculations.

If a plan fails, the agent can re-send a corrected proposal.

If an agent has two equal options, one of which involves drop and another is without drop – it will prefer the option without drop, as it allows saving system time.

The protocol is decomposed into two parts: the contractor role and coordinator role. The contractor role is responsible for (and fully encapsulates) message exchanges between a particular pair of agents representing demand and resource.

Coordinator role contains decision-making logic of an agent at the protocol level and allows the demand agent to interact with several resources simultaneously (demand agent’s coordinator role) and resource agent – with several demands (resource agent’s coordinator role).

Magenta agents have multiple objectives, or criteria (quality, price, time, risk) each with a weight coefficient. This can be changed by the user for each individual agent. At any moment of time the user can increase the relative importance of the service level or maximise profit criterion. If for example orders from VIP customers are allocated and a new order comes from an even more important customer with tighter conditions, this may result in decreasing the service level for already allocated orders within the allowable interval. Changes in weight coefficients represent the change of agent strategy of working in the virtual market.

5.4. Microeconomics

The aim of microeconomics in Magenta multi-agent systems is to ensure that at any moment of time each agent knows which journeys are profitable for the company and which are not. There is a possibility to take into account not only “physical costs” but also the cost of planning. For this, the following principles are introduced. Each order finds out the cost of its transportation / implementation using price list and finds the most profitable journey / activity. The profit received from the order fulfillment is shared between participating Resource Agents. The microeconomics includes a system of taxation aimed to further improve scheduling efficiency. It does this by applying a penalty (tax) for making changes to the schedule close to Commit time. This ensures that only changes giving significant benefits are made as planning time runs out.

6. How the scheduling works

The process of scheduling will be explained using examples from Road Transportation. The Initial Scene, which is a model of the business process at the beginning of scheduling, is constructed by an operator using a user-friendly editor or imported from an XML file. The Scene depicts all participating resources (trucks, trailers, depots, warehouses, loading points, delivery points) and their locations on the transportation network. Goals, criteria, objectives (KPI), strategies and preferences are specified.

As the first order arrives, agents split the order into transportation instructions and allocate transportation resources to each TI. The Initial Scene is thus modified into the Current Scene, which is being updated after every event. The Current Schedule is extracted from the Current Scene and can take the form of a table or a diagram.

New events are added to the current schedule. They can be imported from third-party systems, from XML-files or added manually. Events are assigned individual objectives and strategies. When new events are entered into the system, the system stops other activities (or delays the incoming event) and starts TI allocation.

If events are entered in a batch, prioritization is carried out. Outstanding TIs can be prioritized with the help of prioritization logic defined in ontology or manually.
Next, new TIs are planned incrementally. TI agents pre-match by making rough option estimation and checking constraints. Next, they start negotiation with Journeys telling them the amount they are ready to pay for allocation. If TI is interesting for the Journey, it tries to allocate this TI using Open Slot, Shift or Drop algorithms. If an option is found, Journey makes the final option estimation and checks constraints. Journey sends message to TI to confirm allocation and informs other TIs belonging to it that new TI was allocated and they can re-calculate their values and costs.

If there are no new events, unsatisfied TIs, Journeys, Driver Shifts and Trucks could start proactive improvement of their allocation. An important advantage of Magenta’s software is that this proactive improvement takes place in the system constantly – the Logistics i-Scheduler continuously works towards the best possible schedule. Any type of agent can be proactive and agents who are unsatisfied with their current allocation are most likely to get proactive.

User can review results using a Gantt chart or a map and analyse reports. There is a possibility to manually adjust the schedule asking the system to suggest alternatives. The system can also highlight parts of the schedule that needs improving.

Each Journey has its individual commit time. As commit time approaches, the agents get more and more active to utilise the last chance to find a better option. After start of Journey’s commit time (e.g. 3 hours before the driver should set off) no further changes are made to this Journey’s schedule – Journey is passed to commit stage. In the current version committed journeys’ schedules are not changed. In future it will be possible to carry out additional scheduling at commit stage.

The incremental nature of Magenta scheduling and the use of different planning strategies means that the i-Scheduler will always produce a plan for an order, even if it is entered into the system very shortly before its commit time.

Agent decision making process is illustrated in Fig. 5.

In the Ocean Scheduler in addition to ontology scene where problem domain data is stored – there is also a scheduling scene. In scheduling scene information about vessels and cargo schedules is stored.

Up to 1,000 agents will be created by the system whilst scheduling an event. This will depend on the complexity of the options being created.

7. User interfaces

Each member of Magenta i-Scheduler family has a different set of user interfaces.

7.1. Interfaces of the Ocean Scheduler

When a new event comes into the system, the Ocean i-Scheduler quickly checks all possible options (e.g.: if a vessel can make it to the load port in time, if it can physically carry the cargo, has all required vetting, etc.). After evaluating all possible options the system then performs complex calculations of each option and presents options with calculations on a screen as shown in Fig. 7. A user then needs to analyze and commit an option that he has chosen. Complex cost analysis includes details of all consumptions and costs for the voyage and profitability represented by the industry known term of TCE – Time Charter Equivalent which equals to the daily rate at which the vessel would need to be chartered to another operator.
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Valid options will include simple allocations and re-allocations; the former is where a ship has no planned cargo, the latter where the vessel already has a planned cargo and therefore has to ‘swap’ the cargo with another vessel in the fleet in order to carry the new cargo.

The Ocean i-Scheduler will calculate all nested swaps as far as 7 vessels – that is to re-arrange up to 7 vessels in order to carry the new cargo as well as existing commitments. The ability to calculate all of these options is a critical feature of the product.

Once all options are created they are then ranked to show the options in the order which is the most interesting for a user. This uses the DML (Decision Making Logic) held in ontology which can be customized for different users according to their business processes.

The DML uses virtual money to give a value to each option starting from the TCE calculated above. Each rule within the DML is applied to adjust the notional value of each option to increase or decrease its value. For example: if a swap is required then decrease the notional value by 10% because customers do not like the hassle of changing their paperwork.

So the user is presented with all valid options, ranked according to the DML, and he/she is able to interrogate these options using sophisticated graphical visualisations to aid comparison. It is important to note that the user has total control to take whichever option he wishes and is not limited to the recommended option selected by the system.

The graphical displays enable users to review each option in great detail looking at different Key Performance Indicators (KPI’s) and reviewing the fleet performance before and after this decision. There are also many text based reports showing (for example) the full voyage calculations on which the decision is to be based.

Using agents in Ocean i-Scheduler allows the user to adjust agent strategies according to current business needs (for example, maximize own fleet optimization while ensuring the best use of 3rd party vessels). This makes the tool even more flexible to the changing business environment.

An agent’s goal is to raise its satisfaction level. The satisfaction level depends on the values of agent’s criteria. As some criteria may contradict each other, agent seeks to reach the most comfortable balance between those criteria. Users can set up different weights (importance) for each criteria (for single or a group of agents) to make sure agents are tuned in accordance to business priorities.

Ocean i-Scheduler also introduces pro-activity of agents, ensuring that users get notifications on important events. For example, if a vessel is very close
to not meeting its Laycan – a deadline of being on-time to the port.

Additional benefits to users of this software is user-friendly interface featuring easy and intuitive navigation, multi-user support, log of decision-making and manual re-work of the schedule.

7.1. Interfaces of the Road Scheduler

Fig. 9. Desktop Interface with Easily Configured Dashboard

Fig. 10. Schedule Gantt Chart

Fig. 11. Agent Inspector

Fig. 12. Agent Negotiation Log

8. Conclusions

The commercial results achieved with Magenta Intelligent Schedulers demonstrate the effectiveness of multi-agent systems in solving complex logistics tasks. Magenta agent-based schedulers can produce high quality schedules of resources with a high variety of attributes in highly volatile environments in real time. To the best of our knowledge no other technology can match this performance.

Magenta software development tools, such as Multi-Agent Engine, Virtual Market, Ontology Management Toolkit and Knowledge Management allow speeding up the implementation process and providing a working system for a particular business network in 2-3 months. This provides transportation companies with radically new opportunities to decrease costs, maintain high customer service level and
mitigate risks.

References