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The C2NET Optimisation Solution

La solución de optimización C2NET

Sanchis R , Andres B[1], Poler R[1], Mula J[1], Díaz-Madroñero M[1]

[1] rsanchis, bandres, rpoler, fmula, fcodiama@cigip.upv.es). Research Centre on Production Management and Engineering (CIGIP). Universitat Politècnica de València (UPV). Calle Alarcón, 03801 Alcoy (Alicante), Spain.

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Abstract: Today's lack of competitiveness of European enterprises has led to the Cloud Collaborative Manufacturing Networks (C2NET) European funded project to develop an optimisation solution to provide enterprises, particularly small- and medium sized ones (SMEs), affordable and easy-to-use means to optimise their planning activities to improve their efficiency and competitiveness. This paper focuses on the C2NET optimisation solu-tion, constituted mainly by C2NET Optimiser module components: (i) optimisation algorithms; (ii) the solver manager; (iii) the optimisation problem configurator; (iv) processes of the optimisation of manufacturing assets manager. To perform optimisation, it is necessary to provide the previous components with the needed input data, which can be done within the data collection framework module by defining a standardised data model (STables). Another data model is defined to show optimisation results to SMEs, namely the plan data model (PTables). The C2NET Optimisation Solution supports manufacturing networks, especially those composed of SMEs, and is based on the optimisation of manufacturing and logistics assets by the single and/or collaborative computation of production, replenishment and delivery plans.

Keywords: Optimisation algorithms; C2NET; standardised; data model

Resumen:La actual falta de competitividad de las empresas europeas ha llevado al proyecto Europeo C2NET a desarrollar una solución de optimización que proporcione a las empresas medios sencillos y económicos para optimizar sus actividades de planificación y mejorar su eficiencia y competitividad. Este artículo se centra en la descripción del Optimizador, así como del Marco de Recopilación de Datos, en el cual se ha definido el modelo de datos estandarizados para proporcionar de manera normalizada, los datos de entrada para la optimización, y el modelo de planes, como resultado de la propia optimización.

Palabras clave: Algoritmos de optimización; C2NET; Estandarizado; Modelo de datos

1. Introduction

Enterprises, especially small- and medium-sized ones (SMEs), need new mechanisms to become more com-peti-tive in today's complex context. If lack of competitiveness is treated from the beginning with planning activities, enterprises will enhance both their competitiveness and efficiency.

C2NET (Cloud Collaborative Manufacturing Networks) is a European-funded project whose main goal is to cre-ate cloud-enabled tools to support the SMEs supply network optimisation of manufacturing and logistics assets based on collaborative demand, production and delivery plans (Andrés et al., 2016). The project's exploitable results are based on three main modules:

- The Data Collection Framework (DCF), is in charge of continuous data collection from both legacy and Internet of Things (IoT) systems. Data are collect-ed from supply network partners through a dedicated middleware on the company side. They are stored on the C2NET cloud platform to be used by the other two C2NET modules: the optimiser and collaboration tools (Agostinho et al., 2016).

- The C2NET Optimiser (OPT) solves planning problems and maximises the efficiency of supply network planning activities by computing production, replenishment and delivery plans to achieve shorter delivery times, faster speed and better consistency of schedules, bettter use of productive resources and more energy savings.

- Collaboration Tools, are in charge of managing the agility of collaborative processes to formalise a clear vision of the collaborative situation and to propose dynamic adjustments (Benaben et al., 2016).

Finally, the C2NET Cloud-based Platform hosts these three main modules, and provides a scalable real-time ar-chitecture, platform and software to confer SMEs access to tools for optimising processes with no re-strictions given their limited capacity and resources (Ramis-Ferrer et al., 2016).

This paper focuses on the optimisation module, used as a driver to face enterprises' lack of competitiveness. The C2NET OPT is, in turn, composed of four main components, which also need to interact with C2NET DCF to manage both the input data needed for optimisation and the output data as a result of the computed optimisation. Therefore, the objective of this paper is to describe the optimisation solution of the C2NET project as an open source solution from which European enterprises can benefit to optimise their planning activities, while the research community can also take advantage of further developments.

The rest of the paper is organised as follows. Section 2 provides an overview of the C2NET optimisation solution. Section 3 describes all the components needed to perform optimisation. Finally, Section 4 outlines the main conclusions.

2. The C2NET Optimisation Solution Overview

The module in charge of providing valuable information about the best alternatives to perform production, re-plenishment and delivery plans is the Optimiser (OPT). This module, as shown in Figure 1, is composed of four main components: (i) the Optimisation Algorithms (AO), (ii) the Solver Manager (SM), (iii) the Optimisation Problem Configurator (OPC) and (iv) the POMA (Processes Optimisation of Manufacturing Assets) Manager. Besides these components, in order to launch optimisation and to obtain useful information about production, replenishment and delivery planning activities, it is vital to provide C2NET OPT with the necessary input data to compute the different optimisation problems. To do so, a Standardised Data Model, called Standardised Tables (STables), structured within the DCF, was defined. Finally, the optimisation results are also held in another data model, called Plan Tables (PTables) as they offer the planning activities to be performed (see Figure 1).

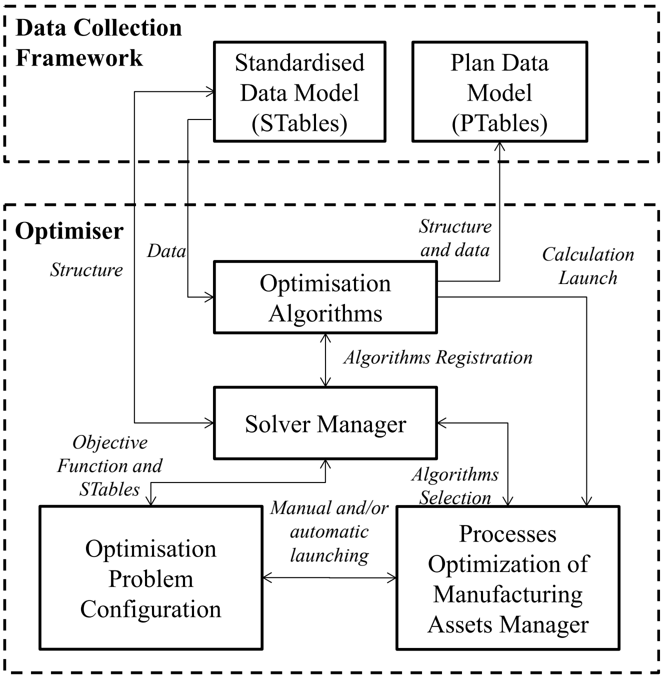

Figure 1. Definition of the components to perform optimisation.

Table 1 provides a description of each component required to perform and solve a specific optimisation prob-lem.

Table 1. Description of the main components involved in optimisation

OPTIMISER
Optimisation Algorithms (OA)
This component hosts a set of 48 optimisation and heuristics algorithms, modelled using JuMP (Julia for Mathematical Optimisation), an algebraic modelling language embedded in Julia (Julia, 2017). These algorithms are classified according to the type of problem to be solved.
Solver Manager (SM)
It is the component in charge of managing algorithms. As such, it allows to create, edit, categorise and delete algorithms and objective functions. It places at the disposal of the OPC and the POMA Manager components the set of methods that allow them to validate if an optimisation problem can be solved. It also provides the most appropriate algorithm to be applied according to some criteria (such as gap and solving time.).

Optimisation Problem Configurator (OPC)
It is in charge of creating, defining and configuring the different optimisation problems. It manages optimisation problems and proposes solutions to optimise the manufacturing and logistics plans based on the available input data.
POMA Manager
It is in charge of computing and calculating the optimisation of a specific optimisation problem. To do so, the optimisation problem should already be configured using the input data stored in Stables. By applying the optimal algorithm managed by the SM, the optimisation results are achieved and shown to users. This component also manages the cancellation of optimisation computation, and the acceptance, rejection and deletion of the optimisation results.
DATA COLLECTION FRAMEWORK
Standardised Data Model (STables)
It is a meta-structure organised to store the data that come from the legacy and IoT systems of enterprises, especially SMEs. The data model definition was been based on the principle of standardising terminologies to manage information. The data model provides a common structured terminology to offer a shared understanding of all the different needs in collaboration and optimisation terms to support the definition and calculation of replenishment, manufacturing and delivery plans (Andrés et al., 2017).
Plan Data Model (PTables)
Following the same principles as STables, the PTables offer a standardised meta-structure to hold the optimisation results. This data model is named Plan as the results of optimisation provide companies with valuable information about the planning tasks to be performed.

3. C2NET Optimisation Solution Components

This section provides a detailed description of all the components involved in performing optimisation.

3.1. Standardised Data Model (STables)

The OPT need's to manage different data from various resources was the reason to develop STables. The C2NET project includes four managerial pilots from Spain, Portugal, France and Finland. Besides the language differences to designate the same term, if we used the same language (English), differences would also appeared in the way to name the same concept; e.g., for the current inventory of a specific product, some companies in-volved in C2NET used the inventory; others, stock, or product stored, etc. Therefore, it was necessary to define a common term which, in this case, was coined as AvailabilityAmount to designate the number of units of a spe-cific product available in the inventory. The same procedure was performed for all the concepts. Moreover, the same process was replicated to extend and generalise the meta-structure of STables for future optimisation needs.

The current Standardised Data Model is composed of 87 tables with 246 different fields and more than 675 fields in all. Any enterprise interested in optimising its planning activities could provide the necessary input data through the available fields defined to perform its optimisation.

The Standardised Data Model is composed of two main types of STables:

(i) one-dimensional Stables; they contain the master information about the company; e.g., all the data related to the different company references (finished products, components, subcomponents, raw materials, etc.) are organised in STable: Part, the data on machines and equipment are arranged in the one-dimensional STable: Machine, and so on.

(ii) combined STables; they combine two one-dimensional Stables, or more; e.g., STable: Machine_Tool relates the machines in which a specific tool can be set up (Andres et al., 2017).

Figure 2 offers an example of a set of STables that includes a one-dimensional STable: Tool and the combined STables associated with such a master Stable, with five in all:

- Tool_Period: it associates a period with a tool (the tool can be available or not during such period, or another status).
- Machine_Tool: it associates a tool with a machine (the machine needs such as a tool to work, e.g. an injection mould).
- Tool_Labour: it associates a (type of) labour with a tool (the tool needed for the labour to perform a task).
- Operation_Tool: it associates an operation with a tool (the operation needs the tool for it to be performed).

- Part_Tool: it associates a part with a tool (the part needs the tool in order to be produced).

All the STables are characterised by related identifiers; e.g., in STable Machine_Tool, identifiers are related to machines and tools. In this case, input data such as: SetupCost (cost of setting up the tool in the machine), Set-upMaximumAmount (number of setups allowed per period of the tool in the machine), SetupTime (time needed to set up the tool in the machine), etc., are needed to perform optimisation.

The rest of the STables organisation is structured following the same configuration shown in Figure 2. Currently, the data model is composed of 14 one-dimensional STables (Container, Customer, Labour, Machine, Operation, Order, Part, Period, Person, Route, Site, Tool, Vehicle and Warehouse), and also of the combined ones of the previous master tables, including all the fields needed to perform optimisation.

3.2. Optimisation Algorithms (OA)

The second element of the optimisation solution is OA, which was developed based on a literature review and ad hoc developments to response to enterprises' needs.

Currently, 48 algorithms are defined. These algorithms are classified according to the following aspects:

- Type of Optimisation Problems to be solved. The Problems' Type is based on the Supply Chain Opera-tions Reference model (SCOR) (Huan et al., 2004). C2NET considered the following planning processes included in the SCOR model: (i) Source; (ii) Make and (iii) Deliver, as the amount of items to be or-dered, produced and delivered, respectively, per periods in a planning horizon. C2NET also considers the problems that are the combination of two planning processes or more, such as Source and Make (problems that deal with the optimisation of the procurement of goods and their transformation into finished products to meet demand; Make and Deliver (problems that deal with the optimisations of the transformation of raw materials into finished products and delivering them according to received or-ders); Source, Make and Deliver (problems that deal with the optimisation of all the previous processes) (Andrés et al., 2016b).

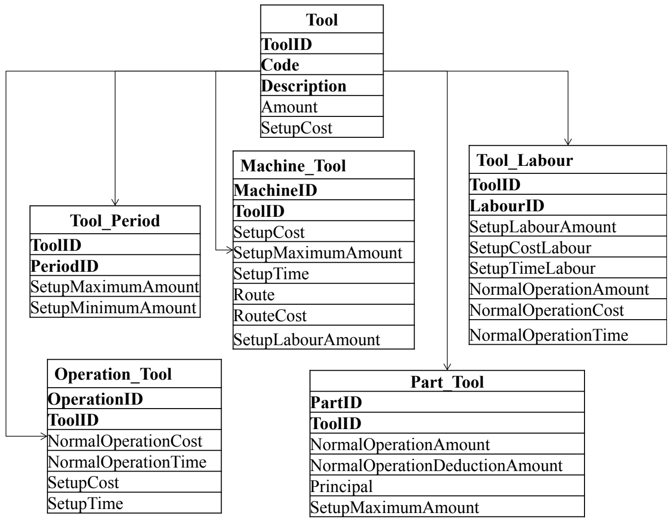

Figure 2. Example of a one-dimensional STable (Tool) and its combined STables.

- Subtype of Optimisation Problems to be solved. For each Type of problems, there is also a sub-classification to more specifically categorise optimisation problems; e.g., Type Make is, in turn, com-posed of the following subtypes: production planning, assembly planning, production scheduling and production sequencing to detect the main features of the problem, and to easily identify the most appropriate algorithms to solve the problem.

- Type of Algorithms. Algorithms are classified by optimisers or matheuristics.

- Objective function. Most objective functions of the algorithms focused on minimising costs, such as production, transport or inventory, etc.

- Calculation time. Algorithms are also classified depending on the time required to solve an optimisation problem. This calculation time was set through different tests in which different sizes of input data sets (small, medium and large) were used. The classification by calculation time is due to the fact that some companies require quick responses for their optimisation problems. Thus most complex algorithms with longer calculation times will not be the most appropriate ones for such problems. So they will be the most convenient ones when the company expects optimal results when considering many variables.

- GAP. The distance between the optimal result offered by the optimisation algorithms and an accept-able solution.

3.3. Solver Manager (SM)

Once all the codes in Julia of the 48 optimisation algorithms are set in the component OA, the SM is able to acti-vate all these algorithms. Thus the activation of each algorithm requires the characterisation (type and subtype of the optimisation problems performed in the OPC), the instantiation of the objective function according to the type and subtype, the definition of the input data in the form of Stables, the output data as PTables, the calculation time and the gap.

This component is able to activate and disable algorithms if they are not useful or need modifications. It is im-portant to provide the possibility of disabling algorithms when SM returns the best algorithm to solve a given op-timisation problem according to the solving time available and the gap. This option is vital to offer real alterna-tives.

3.4. Optimisation Problem Configurator (OPC)

This component offers the mean by which end users can define and configure their optimisation problems through its user interface. To do so, the end user defines a name and description for optimisation problems. Moreover, the optimisation problem type and subtype to be solved (based on the types and subtypes defined in the AO – Section 3.2) are also defined. The objective function is chosen by users from a set of available objec-tive functions depending on the needs of companies and their preferences as to what they expect to minimise.

The OPC also offers the possibility of defining the execution programme, which could be manual, scheduled or triggered by an event.

- Manual execution means instantaneously launching the optimisation computation.

- Scheduled executions are based on periodicity issues (e.g. to optimise the Material Requirement Planning every Monday at 06:00h).

- Triggered executions are also defined by setting the events in charge of triggering an execution of a specific optimisation problem (e.g. to optimise production planning when the stock value goes below a specific quantity).

Moreover, the OPC also allows users to define the maximum calculation time as an optimisation problem may require a longer calculation time to solve such a problem than that users are willing to wait for. So it is important to define the maximum solving time and, although the solution is not an optimal one, it offers users good results to support them in their planning activities.

Finally, this component also offers functionalities to end users to validate the suitability of input data sets to ob-tain an appropriate optimisation result when an optimisation algorithm is used. If input datasets do not match the predefined input datasets of the existing algorithms, users receive a warning with a suggestion about the missing specific input data.

3.5. POMA Manager

The POMA Manager is responsible for launching the computation of an optimisation problem and for managing the optimisation results.

Regarding the first computing optimisation functionality, the launching type was defined in the OPC by taking into account that three types of optimisation execution methods exist: manual, scheduled or triggered.

Regarding optimisation results management, the component offers different options, such as get PTable information; accept, reject, edit or delete an optimisation problem result, etc. This component also offers information about the algorithms used to solve the optimisation problem configured in the OPC. For each optimisation problem, the following information is offered to users: code of the algorithm used to solve the optimisation problem, the time in which the optimisation is launched or algorithm status (calculating or executing), etc.

3.6. The Plan Data Model (PTables)

Output Data, e.g., the optimisation results, are created and shown, and also follow the foundations and standardisation principles of the STables but, in this case, through PTables.

The nomenclature used to denote the optimisation results, in the form of Plans, is as follows: Type of Optimisa-tion Problem_SubType of Optimisation Problem_A, B, C…_TimeStamp. For instance, PTable: S_PSE_A_20170925165638 is the result of an optimisation performed with a Type of Optimisation Problem: Source and SubType: Production Sequencing and it is

Table A (an optimisation result can provide several tables, e.g. A, B, C, D, etc.) and “20170925165638” is the Time Stamp.

By way of example, PTable S_PSE_A offers for each MachineID, ToolID, PeriodID, and PTable offers information about:

- Sequence: a binary variable whose value is 1 if the tool is activated for the first time during the period, which is the tool set up in a machine; 0 otherwise.

- SetupAmount: binary variable whose value is 1 if the tool works in the machine during the period, and 0 otherwise.

4. Conclusion

C2NET offers an open source optimisation solution to solve current enterprises’ planning problems. The C2NET optimisation solution is composed of components, understood as gears, which are all interconnected and syn-chronised to perform optimisation.

The standardised data model offers the way with which the data requirements to compute optimisation are fulfilled. This data model provides a common terminology for all the stakeholders involved in optimisation. In light of this, any company willing to improve its planning activities will provide the necessary data and their accord-ing STables to compute an optimisation problem. Likewise, the optimisation results are provided to companies through the plan data model (PTables), which also follows the same principles as the input data model.

The computation of optimisation algorithms provides companies with valuable information to support the deci-sion-making processes about planning their activities with the solver manager in charge of managing all issues related to algorithms.

Users, through the optimisation problem configuration, can define and configure their specific planning problems, which are computed by the POMA manager that offers optimisation results to companies.

Further research is oriented to develop and test more algorithms to solve other optimisation problems that the present research does not contemplate.

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