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PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	**X**
CO	Confidential, only for members of the consortium (including the Commission Services)	

Investment decisions related to site energy utilisation frequently depend on conflicting objectives, which must therefore be considered jointly for the achievement of long-term benefits.
The overall profitability of investments, such as the Net Present Value (NPV) (or, equivalently, the minimization of costs, if the investment decisions are a consequence of normative rules) is an ever present target, which is generally limited by conflicting technical requirements.

Process managers are generally faced with two types of decisions. Given a maximum amount of capital available for investment, they have to select (after a suitable ranking procedure) the most promising projects and decide for each of them the optimum values of the operational variables that determine cash-flows in each period of the life cycle of the project considered. Additionally, the operational variables, with respect to which the overall optimisation problem has to be solved, are related by equality or inequality constraints, which account for technical and financial limitations.

If, as is usual the case, the break-even times of the projects extend over periods during which parameters capable of affecting the cash flows fluctuate considerably, the uncertainties brought about by these fluctuations must be taken into account.

Thus, a stochastic multi-objective optimisation problem subject to general non linear constraints has to be solved. The complexity of the task makes it difficult to tackle this class of problems with traditional techniques (such as Mixed-Integer Nonlinear Programming or Global Programming tools).

Fortunately the current level of sophistication of Heuristic Methods makes it possible to obtain satisfactory solutions even for highly demanding tasks, such as the optimisation of site energy utilisation under uncertainty.

We have widened the traditional scope of stochastic multi-objective optimisation in some significant ways:

a) Companies may invest in different projects (some of which are not necessarily related to energy saving technologies). Thus, a positive NPV is not a sufficient result for the implementation of a project. Rather its position in a ranking list has to be considered.
b) The only significant factors that determine the position of each project are profitability and financial risk.
c) Since the risks are related to the uncertainties of factors which can be (and frequently are) present in more than one project, common risks (as given by the covariates of profit volatilities) must be considered in the identification of the minimum risk (or maximum profitability) of the final solutions.

These enhancements have required the revision of existing algorithms, because there is no available off-the-shelf software capable of tackling the overall problem. In particular the traditional two-stage approach has been replaced by a three-stage algorithm, the additional stage being the final optimisation in the profit-risk space.

SOFTWARE IMPLEMENTATION

The algorithm developed was implemented into a general software application, whose components are sketched in Figure 1.

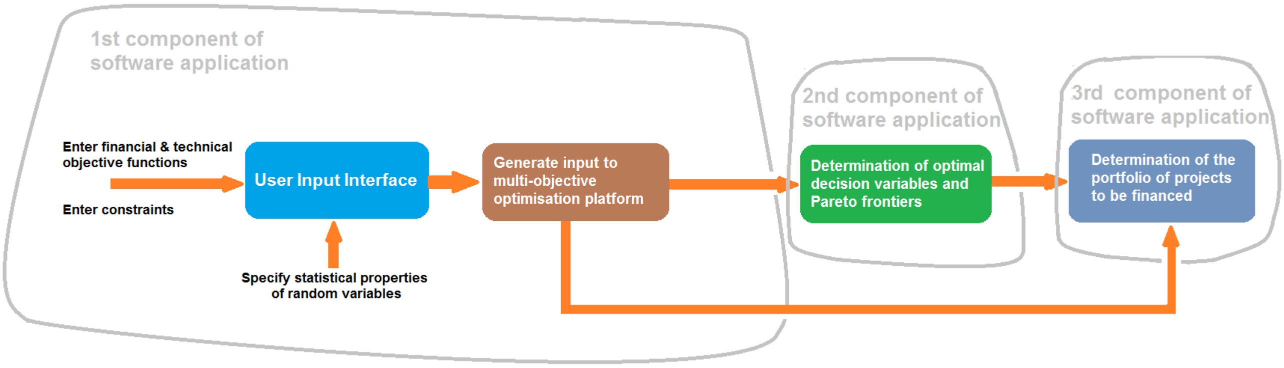


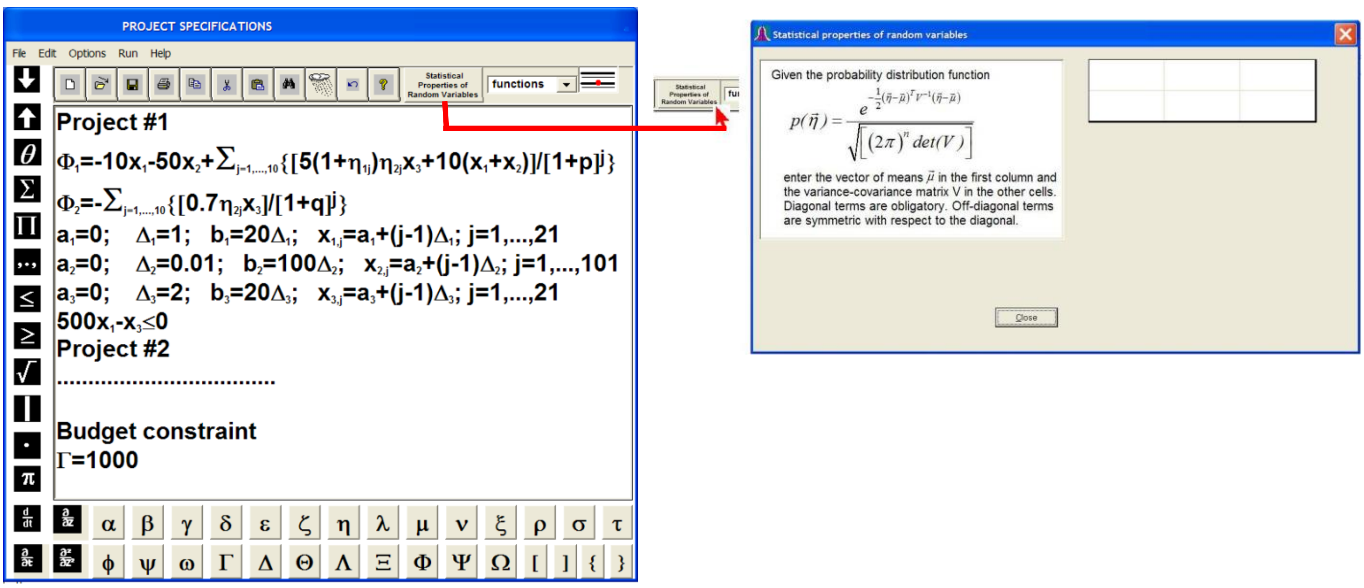
Figure 1: Structure and components of the software application

Each component is independent of the other two and the user must operate them sequentially (possibly omitting the third stage, if the optimal portfolio can be identified by simple inspection.

User Input Interface

An interface with simple syntax rules has been developed to allow the user to enter in a simple and natural way the information necessary to carry out the optimization task.

Figure 2 and Figure 3 are explicative of how financial and technical objective functions, as well as constraints and the statistical properties of the random variables can be entered.



The user input interface generates an input file to the multi-objective optimizer for each project entered, as well as a file containing the information necessary for further elaboration by the third component of the software application (corresponding basically to the Branch&Bound binary linear programming task described in previous sections).

Selection of Multi-objective Optimisation Platform

The platform selected for the solution of the multi-objective optimization task and the generation of the Pareto frontier is the public domain jMetal software.

Details of its main features can be found in [7]. The reasons for selecting jMetal are twofold:

1) *Ease of use*. Indeed the input to jMetal (generated by the 1st component) is straightforward. Similarly the output, in addition to providing the possibility of inspecting the results visually, gives

all the numerical output required for either carrying out the linear programming task or taking decisions on the basis of the values of the results only. The typical window of jMetal is shown in Figure 4. Since the procedure has to be repeated for all projects considered in the first stage, the ease of use is an added advantage.

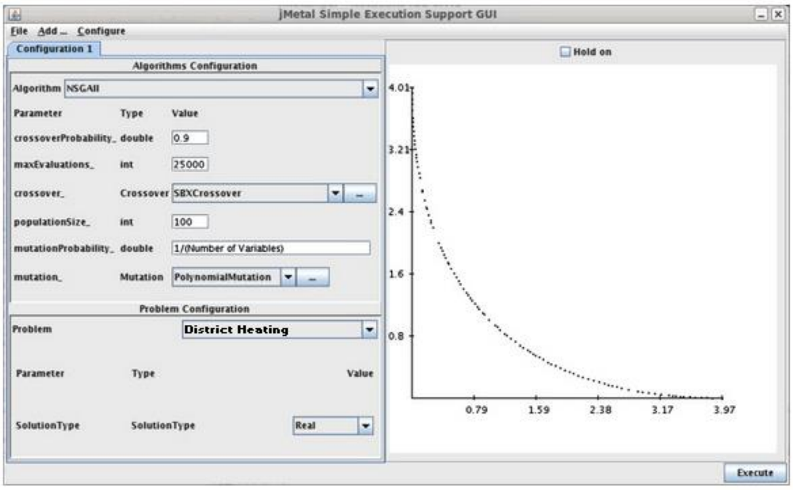


Figure 4: jMetal's typical interface window

2) *Flexibility in the choice of the optimization algorithm*. As shown in jMetal's web site and reported in Figure 5, a considerable number of algorithms can be selected. This makes it possible to repeat the optimisation process using a different algorithm with minimal effort, if the results obtained by the default NSGA II option are not completely satisfactory.

Algorithm Type
Hybrid: scatter search + genetic operators
Hybrid: cellular genetic algorithm + differential evolution
Particle Swarm Optimization (indicator based)
Differential evolution
Genetic algorithm
Evolutionary algorithm
CHC
Cellular genetic algorithm
Decomposition based evolutionar algorithm
Parallel (multithreaded) version of MOEA/D
Decomposition based evolutionar algorithm
Genetic algorithm
Steady-state version of NSGA-II
Random variation operator selection NSGA-II
Adaptive variation operator selection NSGA-II
Parallel (multithreaded) version of NSGA-II
Particle swarm optimization
Evolution strategy
Particle swarm optimization
Parallel (multithreaded) particle swarm optimization
Particle swarm optimization (indicator based)
Genetic algorithm

Figure 5: algorithms available in jMetal

OPTIMAL PROJECT PORTFOLIO SELECTION USING MILP

The binary linear programming task is carried out using the public (http://lpsolve.sourceforge.net/5.5/). While there are several methods for stand-alone executable from the command line has been selected due to its s input file contains the information generated by both the the user input interfa

No further integration has been considered, owing to the comparatively infrequent use of the linear programming approach for the determination of the optimal portfolio, generally identified by simple inspection when the number of projects is limited to two-three options.

EXPECTED APPLICATIONS

When examining alternative projects in energy efficiency investments, managers are frequently faced with a variety of solutions, most of them subject to some form of uncertainty, which cannot be accurately compared without a systematic, quantitative framework like the one developed.

This decision-making tool though specially developed for estimating energy efficiency enhancements of the Efenis project, can be applied to a large number of situations in general investment project selection and therefore it can be considered as a significant result on its own.