Building Services Integration: A Technology Transfer Case Study

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ABSTRACT

This paper details the development of a relationship between Auckland University of Technology (AUT) and the Building Integration Software Company (bisco) and how projects have been initiated that add value to the bisco product range by conducting applied research utilising students from AUT. One specific project related to producing optimal layout designs is discussed in this paper.

Keywords

Technology Transfer.

1. Introduction

Technology transfer is the process of developing practical applications for the results of scientific research. In other words, the aim of technology transfer is to ensure that the knowledge generated through research has commercial value and that the knowledge itself is moved from the research domain into the industrial domain.

The Technology for Industry Fellowships offered by Technology New Zealand are one mechanism for promoting technology transfer as well as developing students' skills and knowledge within commercial R&D environments that are relevant to their expertise.

To utilize this funding source to its full advantage, there is a need to establish a relationship between the academic institution and the company, and to develop a shared understanding of aspirations and how the project can be designed to allow all of these aspirations to be met.

2. The Building Integration Software Company

Building Integration Software Company (bisco) Ltd is a business enterprise whose main product is information management software for residential house construction industry. The organization has been founded by the people who had identified the need of such centralized information management from their own extensive experience in the civil construction industry.

The premise of such a need is the fact that a typical house building project involves a number of different parties such as an architect, builders, city council, and others, who work in different ways and run their organizations for different goals. Although many have already adopted computer-based information systems, there is no automated means for communication with other parties. Only verbal and paper-based forms of communication are hitherto available to those parties to exchange information. It is not surprising that substantial amounts of money and effort are wasted during a project due to the lack of reliable and efficient communication system.

The core business of bisco is developing software to accommodate such communication needs. At the time of the writing, the prototype of the software is drawing close to finish, after which it will undergo a series of live tests before it is finalized for release to the market. The software has been given a commercial name bisco Office™.

bisco Office™ manages a range of information that is very diverse in terms of representation and usage. A typical bisco Office™ database for a house building project will include pictures and text, Computer Aided Design (CAD) drawings, letters, invoices, and a host of other documents. Such documents take various physical forms such as computer files, paper, and e-mail correspondence. Figure 2.1 shows the different parties interacting through bisco Office™ software.

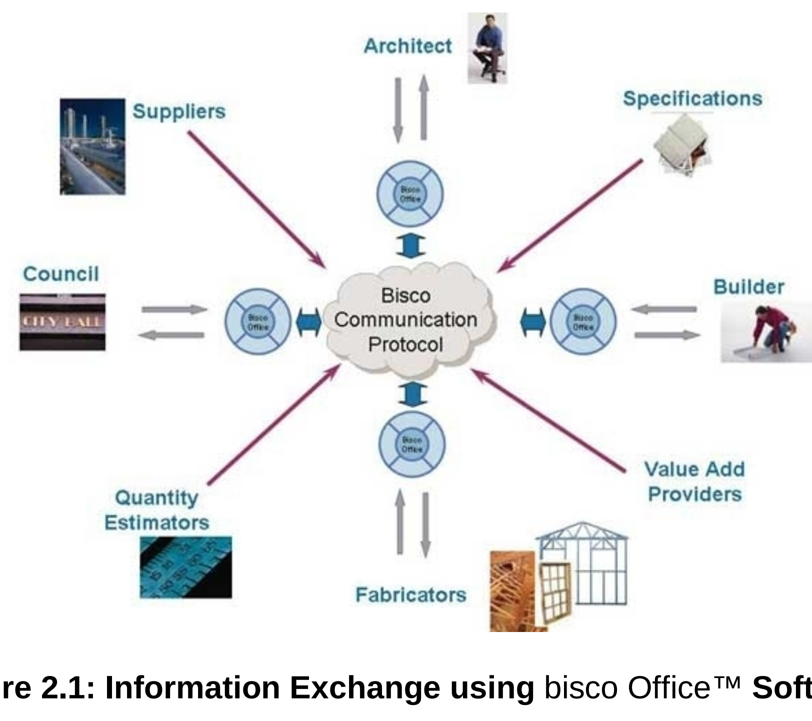

Figure 2.1: Information Exchange using bisco Office™ **Software**

The geometric data stored in the CAD drawings assumes overriding importance in the house building project's web of information. Many important documents created during the lifetime of the project, such as cost estimates, specification documentation, or project plans, are actually spawned from the CAD models. Consequently, the software engineering aspect of bisco Office™ at the current stage revolves primarily on extracting and making use of the CAD data.

The bisco Office™ product provides a framework for improving information exchange in the building services industry and for integrating existing tools in a more efficient manner. The framework also allows for the integration of new tools, such as the material optimisation approach outlined in section 3. However, the success of the approach depends on its ease of use and therefore a usability study is being undertaken, as outlined in section 4.

3. Material Layout Optimisation Project

3.1 Overview of Project Scope

Optimum two-dimensional layout is a class of problems encountered in many industries. The problems are characterized with the need to pack non-overlapping shapes in an enclosed plane with the aim of minimizing the area outside the boundaries of the shapes, therefore maximizing the utilization of the material in the base sheet. The two-dimensional layout problem exists in several variants. Among them are the *sheet layout* problem, *bin packing* and *strip packing* problems, *optimum floor plan* problem, and *cutting stock* problem.

The optimum two-dimension layout problem has an application in a wide range of industries. Industries such as textile, wood, glass, and steelworks regularly encounter the problem of cutting the material most efficiently so as to minimize waste. In a different context, *very large scale integration* (VLSI) design requires arranging a large number of transistors and other modules in a rectangular silicon chip.

A rather unique variant of the optimum two-dimensional layout problem is found in the construction industry. A polygon shaped area such as wall or ceiling is to be tiled with covering sheet material such as Gibraltar board or plywood. With such tiling, it is essential that the entire surface is covered with no gaps or overlaps. The panels are obtained from the supplier in a range of fixed size rectangles. Typically the individual panel is much smaller than the area to be covered. It is also anticipated that the enclosing area may have an irregular outline.

The problem is demonstrated in Figure 3.1. To keep the construction expenses under control, the builder must arrange the panels in a way that keeps the cost variables low. Such parameters include the number of panels allocated, the amount of discarded off cuts, and the amount of effort required for cutting the panels.

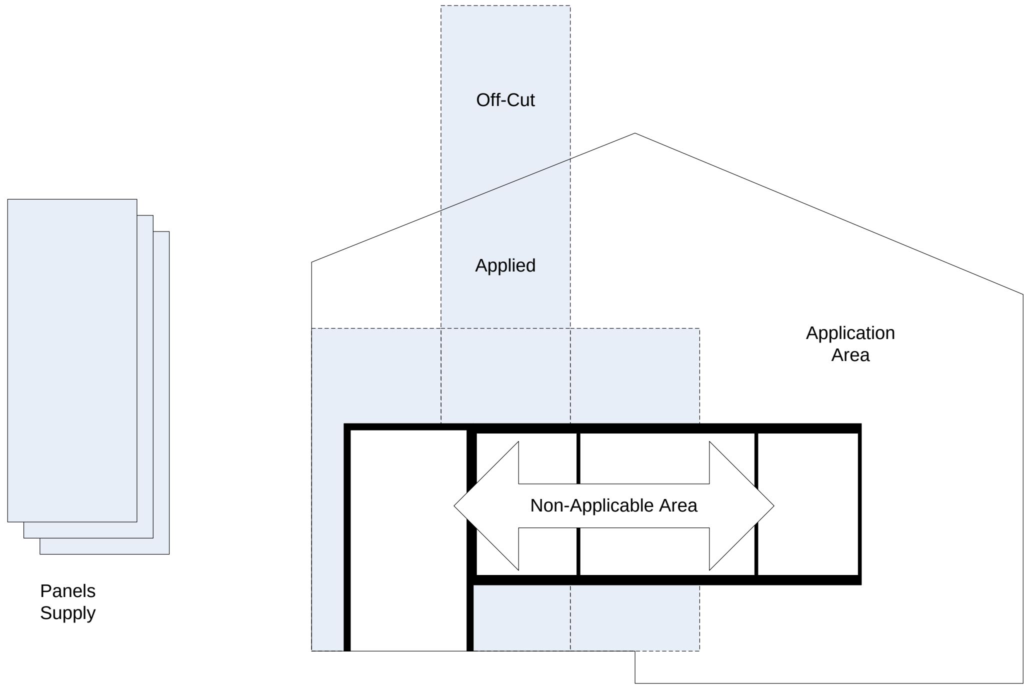

Figure 3.1: Wall Overlay with Fixed Size Panels

A similar problem has been encountered in the shipbuilding industry, particularly in cutting steel sheets to cover various parts of the ship. Adamowicz and Albano defined the problem for the operator (Adamowicz & Albano, 1976):

- A set of standard rectangular sheets of steel is provided
- An order is given to produce various types of shapes which include rectangular and irregular shapes
- It is required that no two shapes may overlap
- Waste is minimized

When the panel is homogenous, such as with sheet metal, it is desirable to reuse the off cuts to cover irregular regions at other places, as this has the potential to reduce the total number of sheets required. A particular example was made by Sibley-Punnett and Bossomaier (2001) regarding the reuse of off cuts from corrugated iron roofs. The justification for such effort is provided by the high cost of delivering the roofing material.

The diversity of materials used for constructing a building provides no guarantee that such homogeneity exists for materials used for a particular area. The implication is that the constraints for a particular section of the building cannot be predetermined. In response, a computer program used to resolve such problem must be capable of finding the solution under a varying set of constraints to allow it to be used for any specific instance of the general problem.

Closer examination of the problem reveals that polygon overlay problem is composed of two sub-problems which must be resolved sequentially, although each sub-problem still belongs to the same two-dimensional layout optimization. For a given enclosed area and a given dimensions of rectangular panels, the requirement is twofold:

- Find the optimum arrangement of whole panels in which the covered area within the enclosure is maximized. The by-product of this process is a set of irregular shapes which represent the remaining exposed areas.
- Resolve how such irregular shapes can be nested within the minimum number of panels. Shapes that are bigger than the panel itself are cut at angles parallel with the rectangle's axes to allow such nesting.

This decomposition into two sub-problems can potentially mask the complexity of the task of finding the optimum solution. It is important to recognize that in the construction industry, the actual size of the panels is in itself a design parameter. In some applications, the panel size will remain fixed for the two sub-problems whilst for other applications the panel size could potentially be varied. With this in mind, it becomes apparent that the problem is complex with potentially many locally optimum solutions.

At the end of the calculation process, the desired output consists of numerical and graphical information:

- The total number of panels, consisting of panels to be fitted whole and the remainder to be cut to produce the irregular shapes
- The nesting plan with which irregular shapes are cut from whole panels
- The area overlay plan with which whole panels and irregular cuts are fitted to the enclosed area

It is important to note that although the two sub-problems are similar, they are resolved with mutually unrelated and potentially conflicting objectives. As an example, the lowest cost solution for first sub-problem may be to cover as much area as possible with the least number of panels. However, the optimum solution for the second sub-problem may be the least amount of cutting (the panel may actually be a marble or granite slab, for instance). Hence a cheap solution in the first phase may lead to expensive penalties in the second.

4.2 Project Motivation

Apart from reducing the waste and reducing the associated cost, automating the panel placement design also greatly assists the builder in calculating the required material. When the calculation is done by hand, the common practice is to have a human expert work on the layout and to estimate the number of panels needed to cover a particular part of the building. A few extra panels must then be provided to anticipate the error in the calculation.

As the solution only applies to a particular part of the building, the work must be repeated for all other parts as well. The process becomes more tedious when different sizes of the panels are available to choose from. Exploring more than a few different configurations by hand is therefore an impractical proposition.

In general, the cost of the materials is low so that the additional time required to optimise the panel layout manually cannot be justified by the potential cost savings. The low value means even using computer optimisation would not be viable should it require additional work. As bisco Office™ makes the required geometric and building information easily available for use by an optimisation function the process becomes a viable option.

Another inherent problem in complex problems is the lack of guarantee that an optimum solution in the first phase will lead to an optimum solution of the entire problem. Coupled with the absence of a-priori knowledge about the cost of the subsequent phase, exploring the less-than-optimum first-phase solutions becomes a necessity. Seen in this light, making the process automatic offers the potential of discovering better solutions than that obtained by hand.

When computers are used, more possible solutions can be explored both for individual parts of the building as well as the sum of all those parts. The desired effect is that by providing the raw information to the software, in the form of a CAD model of the entire building, the builder obtains a detailed and accurate plan about the number of panels required and how they should be cut and installed for the whole structure.

In addition to this, some suppliers offer to package the sheet materials into “room lots” allowing their placement by crane into the room space prior to the erection of the building walls saving labour carrying the individual sheets by hand. Use of this technology will allow the use of length optimised packets increasing the effectiveness of this service.

3.2 Project Achievements

The project has been a great success with regards not only the outcomes of the research, but also in terms of transferring research knowledge into the industrial domain. Initially, the research focused on the underlying geometric operators required to manipulate the CAD data and panel shapes to allow the optimisation process to be realised.

The project also developed a range of algorithms that could be applied to the solution of layout optimisation problems in the building services domain. A comparative study has been undertaken to see which of the algorithms best meets the needs of the industry and this will be taken forward in the commercialisation phase of the project.

A software tool to perform the layout optimisation has been developed, as shown in Figure 3.2.

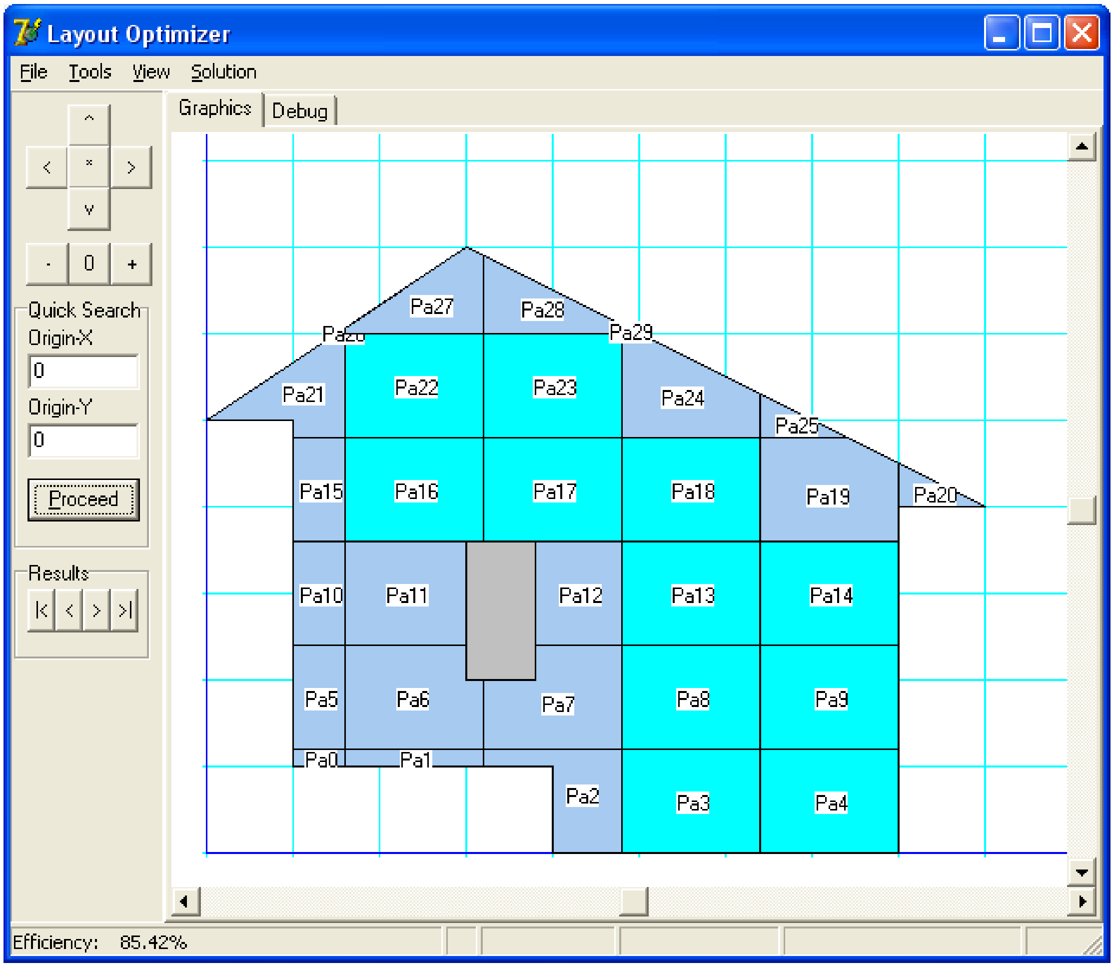

Figure 3.2: Layout Optimisation Software Tool

3.3 Project Status

This project, which is now complete, has been undertaken by a student on the Master of Computer and Information Sciences programme at Auckland University of Technology. The comparative study of different algorithms is complete, which has allowed the student to submit their Masters thesis for successful examination. The software tool used in the research is now being integrated into the bisco product range.

It is expected that the tool will be applied into a wide range or sheet or tiling situations within the build including wall linings, flooring material, external sheet cladding, and roof cladding.

5. Conclusions

The success of the material layout optimisation project has led to a strengthening of the relationship between bisco and AUT, and as a result further projects are being undertaken with both a short term and a longer term focus. Of particular note, the success of the material layout optimisation project has led to another successful grant from Technology New Zealand to extend the work into new areas, and allowing the student to enrol for a Doctoral programme. This opportunity will further increase the value of is research but looking at not only the impact of sheet layout decisions on the whole building, but to investigate how the building structure and layout can be modified to improve the design targets specified by the architect.

At present, one of the key challenges with the bisco software is the need to address the uptake of the technology with the end users, particularly mobile users. One of the further projects currently being undertaken is addressing the usability issues of TabletPC technology and other mobile devices and address whether this can assist in the interactions in the supply chain relating to building services activities.

There is opportunity to further increase the value of this research by looking at the impact of sheet layout decisions on the building. The sheet layout determines much of the underlying structure, for example the placement of studs or joists, and these have a material impact on the cost of the building. If we can better integrate the decision making processes that affect the layout of sheeting and the required support structures the potential should exist to reduce building costs without reducing the utility value of the structure.

References

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