Case-Based Stowage Planning System

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Abstract

The computer support in stowage planning today is limited to the calculation of the state of ship, e.g. concerning the ship's stability and strength or hazardous cargoes check. Stowage planners have to perform the core of the planning process manually. The growing size of container ships and the tight shipping schedule illustrate the increasing burden to the planners and its risk. A new method for semi-automating the process of stowage planning, called Casestow, is proposed. Casestow encompasses the difficulty of knowledge acquisition of stowage planning. It assists the planner to create a stowage plan by remembering how a similar planning problem was solved.

1 Introduction

Stowage planning problems are old, the problems are as old as the history of the ship itself. It is the task to allocate containers to be loaded to slots on board the ship. In spite of the advancement of the information technology, and computers have become indispensable to conduct daily planning tasks, the core process of planning, namely creating the plan itself is still performed manually. The planner still has to create the plan himself, then when the plan is finished he checks, if the criteria are met or not.

Today stowage planning software provides powerful modules which enable the planner to obtain information on the state of the ship and its cargoes concerning the stability, strength, dangerous cargoes, crane split, draught, trim and visibility check. Those modules expedite the calculation tasks. If the plan shows that ship

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does not have a sufficient static stability, for example, the user is not assisted with any help as to what to do, which containers have to be moved and to which slots. A number of efforts have been undertaken over the past three decades, see Figure 1[1].

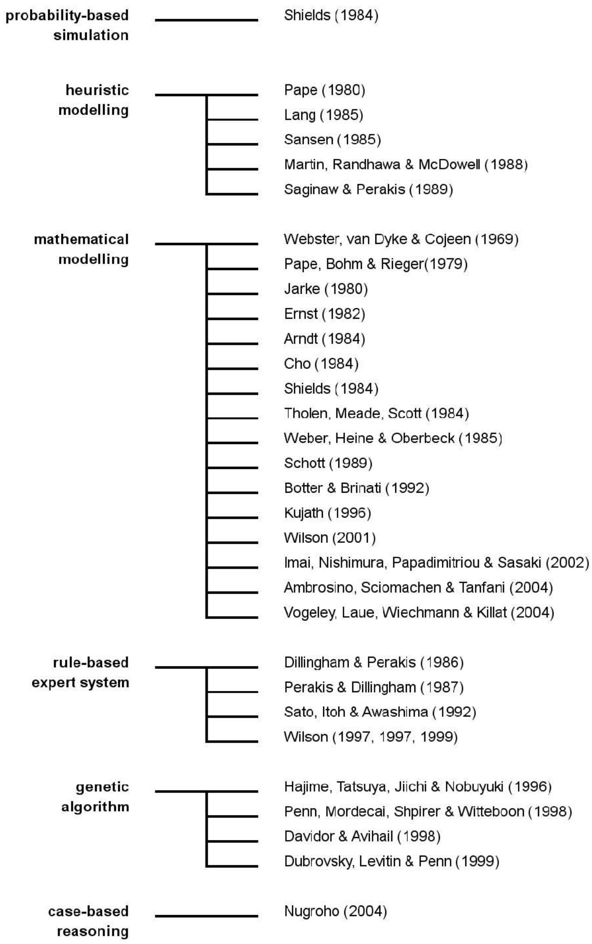

Figure 1: Past research in stowage planning system developments [1,2,4,5,10,11,12,14]

[1] The categorization of the methods is initially based on that of Wilson et al [Wilson_etal2001]

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2 Foundation

In view of the research efforts made in the last decades, it is of necessity to take few steps back, to rethink what we understand under stowage planning. Stowage planning a search problem and it is a constraint satisfaction problem too [7]. It is a chained process, a modification in a stowage plan of a loading port will change all plans of the following ports. And stowage planning covers more than the technical aspects of planning, it involves some aspects of authority with the decision making process in the company. It is not unusual that important clients want that their cargoes are stowed in specific slots. At this point, technical stowage planning considerations alone are not adequate to address the problem. Commercial considerations play a more important role. Therefore the sales or marketing department' decisions will contribute in determining the end look of the stowage plan.

Every ship, every route is specific. Each has its own typicality. Even sister ships trading the same route under different ship operators, may have different stowage plans. Furthermore situations may change, some are predictable, some other are not. Therefore we believe it hardly possible to formalize the knowledge contained in the stowage planning objectively in terms of mathematical formulas or if-then rules. We should find an alternative direction to address the problem effectively.

Creating a stowage plan means also accepting a fact that the container loading list (CLL) is less correct and less precise. The loading list may change during loading and until short before the departure of the ship, the degree of precision and correctness improve in the course of time.

The knowledge for creating a stowage plan is not stored centrally. It is spread among many, i.e. books (concerning the technical aspects of planning such as stability, strength or dangerous cargoes), human (stowage planning, sales and operations departments) and past stowage plans. The type of knowledge can be formal, such as stability, or informal, such as subjective preferences or rules of thumb. It is hardly possible to define desirable properties of a stowage plan precisely and consistently. In daily practices one knows if a stowage plan is favourable or less favourable, *after* seeing it and comparing with his expectations. But a planner cannot define precisely what we understand under a good stowage plan[2].

As we have learned form the history of technology advancement, the nature has been our great inspiration for solving various problems. In stowage planning, the success story is not far away out of reach. A human planner solves planning problems everyday. He succeeds addressing planning problems satisfactorily. Planning is in fact an easy task for a human planner, but it is still difficult to automate [9]. Viewing the stowage planning as a search process, a planner does

[2] Survey at a Hamburg-based shipping company and two container terminals in Hamburg and Bremerhaven, 2001.

not apply a brute search force, exploring all possible combinations of slots. He does not need reinvent the wheel. From experience he has collected numerous problem-solving sessions. Therefore he is in position now to use this knowledge effectively. He can select only one or a few planning concepts which may likely lead to an acceptable solution. In fact he reuses old solution concepts, with few modifications or improvements when necessary.

The strategy must be pragmatic, in order to make it useful and applicable in practice. A new method must be capable to assist the planner accordingly, in the stages of planning [3]. The method is not designed to generate a fully finished plan in the first place. The final goal is the duration of planning will be shorter, and the input data (CLL) will be more accurate.

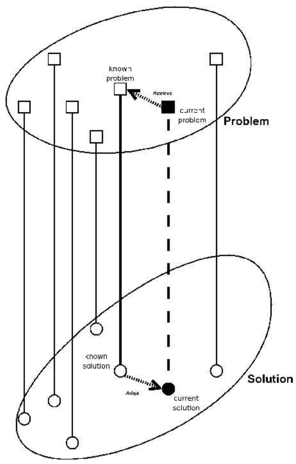

Figure 2: A similar problem tends to have a similar solution [6]

3 Case-Based Stowage Planning System (Casestow)

We can safely assume that all planning problems are unique; they are different from each other. Taking a closer look at it, it is easy to recognize that a majority of problems show a certain degree of resemblance. That explains why an experienced planner knows instantly, how to approximately solve a majority of problems. Case-Based Reasoning (CBR) methodology, a branch of the Artificial Intelligence, rests on the idea that if two problems are similar, its solution is perhaps similar too, see Figure 2 [6]. CBR solves a problem by remembering how a known similar problem was solved .

The usage of the Case-Based Reasoning approach is inspired by the ideas of CLAVIER applied at the Lockheed Missiles and Space Company in California [8,13], where approaches such as rule-based expert system, thermodynamic modelling and inductive learning were considered impractical. The Case-Based

Stowage Planning system, called Casestow, solves a new planning problem by remembering how a similar planning problem was solved. Its way of solving the planning problem is borrowed or even copied to solve the new planning problem.

3.1 Procedure of Casestow

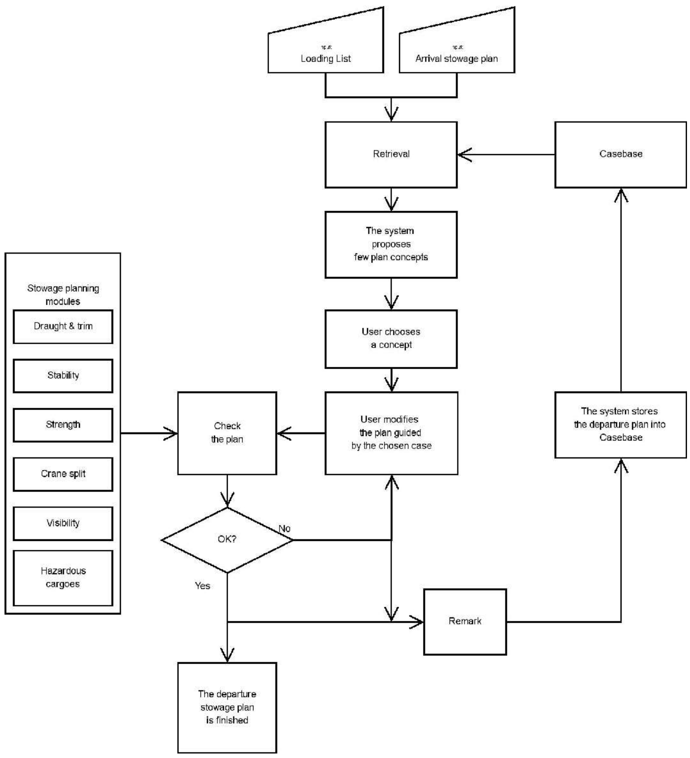

Figure 3: Procedure [10]

Every stowage plan contains information how a planning problem is solved. In Casestow it is not attempted to extract the knowledge of planning from the plans in the form of mathematical formulas or if-then rules. The planning sessions are stored systematically in the casebase.

The procedure of Casestow is shown in Figure [3]. After receiving the input, means that the problem is there. The planner is in position to draw a stowage plan of a port of loading (POL) now. The input consists of the arrival plan[3] and the container loading list. Its solution is the departure stowage plan.

[3] The arrival plan itself can be derived from the departure stowage plan at the previous port of loading (PPOL) and its container discharging list (CDL).

problem = < arrival stowage plan prior to loading, container loading list >
solution = < departure stowage plan >
remark = < quality or comments on the plan >

A case is a finished planning session consisting of a stored problem, its solution and its remark. The actual stowage planning task is called query consisting only one element: the actual problem.

case = < stored problem, stored solution, stored remark >
query = < actual problem >

The new problem is compared with all problems stored in the casebase. There are two types of data to be compared: numerical (CLL) and graphical data (stowage plan). The numerical similarity value is computed using a trapezoidal fuzzy membership function, see Figure 4. The value of the actual problem is interpreted as an approximation.

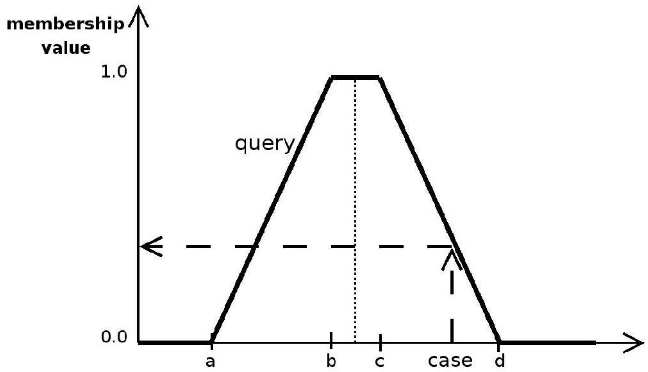

Figure 4: Trapezoidal fuzzy membership function

To calculate the graphical similarity value the graphical properties of the plan must be taken into account, longitudinally and transversally. The cross section of the ship, the bay, is sub-divided into a few partbays. Containers placed with the same partbays are considered equivalent or its similarity value is 1.0. Containers stowed symmetrically along the centre line are considered equivalent. Figure 5 shows the graphical similarity criteria. Longitudinally, the vicinity criterion plays a role, i.e. containers stowed close to each other in longitudinal direction are considered equivalent or similar.

After computing the combined similarity values, the cases are then indexed and ranked according to the similarity values. Few most similar cases are proposed to the user. Now the user has the opportunity to choose the solution concept which he find the most desirable or favourable one. The chosen case will act as a guide to modify the arrival plan to the departure plan. Its way of solving the problem can be applied, i.e. borrowed or even copied, to solve the new planning problem.

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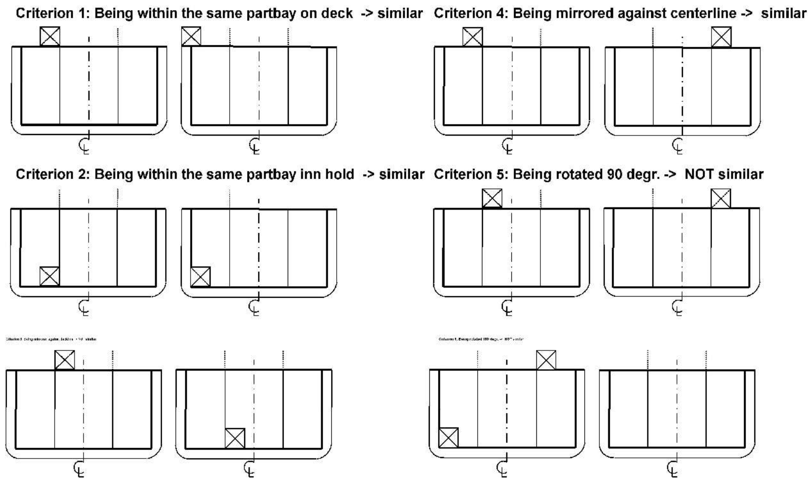
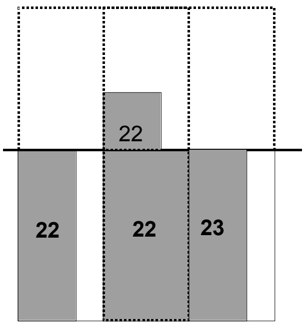


Figure 5: Cross section's similarity criteria

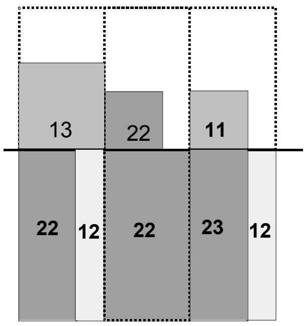
Figure 6 shows the usage of the chosen stowage planning concept to help solve the new planning problem. The upper row is the chosen case consisting of three elements, from left to right, (a) the arrival plan prior to loading (b) CLL and (c) the departure stowage plan. The lower rows are of the new problem, (d) the arrival plan and (e) CLL. To create the departure plan, the way of allocating containers, modifying an arrival plan into a departure plan (c) can be reused, immitated or copied. A planning problem may have more solutions; a stowaeg planning task may also have more than one solutions (f) and (g).

The finished plan is then checked using available modules, e.g. stability, strength etc, if it meets all those criteria. Both favourable and less favourable plans can be useful for future planning sessions. All information concerning the stability, strength etc can be included in to the remarks. In general remark contains information on the quality of the plan either favourable, less favourable or neutral, textually or numerically. The newly created plan is then stored into the casebase, and it is immediately available for use in the next planning session. This last part is the learning mechanism of the system.

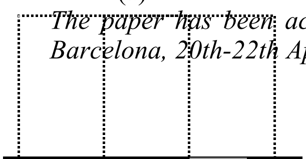
The CLL is usually changing over time. It is usual too that for a particular voyage more planning sessions are performed. The produced departure plans may be of various qualities. Those all may contribute in enhancing the richness of the casebase's contents, see Figure 7.



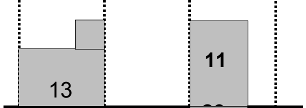
From Port 21 to Ports	Number of containers to be loaded
11	4
12	12
13	9
21	0
22	0
23	0

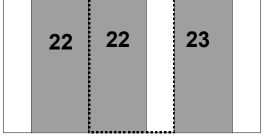


(a) (b) (c)



From port 21 to Ports	Number of containers to be loaded

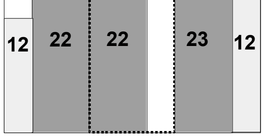




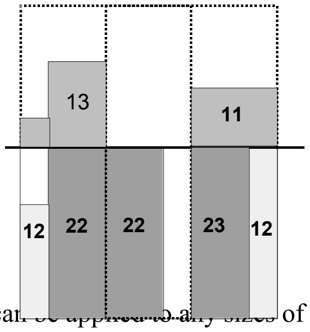
(d)

12	10
13	7
21	0
22	0
23	0

(e)



(f)



(g)

4 Properties

The system is scalable. It can be applied to any sizes of vessels and for any routes with a minimum adaptation effort. The system has the capability of learning. Every newly created stowage plan is stored into the casebase. This increases automatically the capability of the system to propose solution concepts to the user.

This approach assists the human planner in a natural way. It enhances the remembering capability of a human, by storing and retrieving cases accordingly whenever required. The system respects subjective preferences which mark the daily stowage planning tasks by providing the planner to choose a solution concept which best suits him.

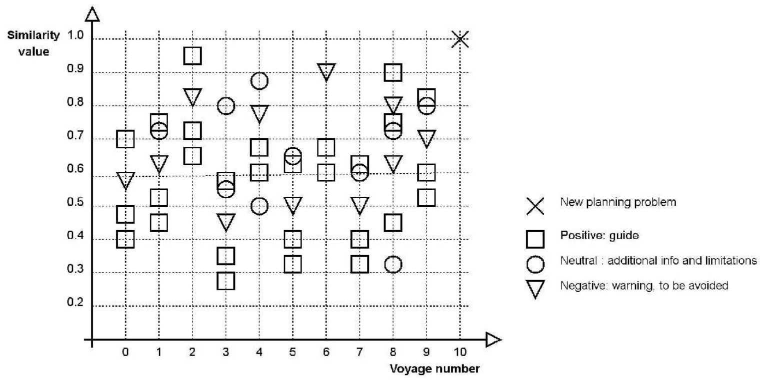


Figure 7: Contents of casebase

The system is applicable for addressing stowage planning problems of the whole ship or a part of it, for example for refrigerated containers. A central aspect of the method is its capability to recognize and retrieve similar problems stored in the casebase.

The approach enables the planner to produce a stowage plan faster and of the same quality. The quality improvement is achieved as the duration of planning becomes shorter, and the CLL accuracy improves.

5 Conclusions

Reusing a similar solution concept enables the planner to create a stowage plan faster. Casestow solves a new planning problem by remembering how a similar problem was solved. Existing stowage planning modules can seamlessly be integrated into the Casestow architecture.

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Reference

[1] Daniela Ambrosino, Anna Sciomachen, and Elena Tanfani. Stowing a Containership: the master bay plan problem. *Transportation Research Part A*, February 2004.

[2] Yuval Davidor and Moshav Avihail. Method for Determining a Stowage Plan. page 11, 15 1998. US Patent number 6809 489.

[3] Joseph Fiksel and Frederick Hayes-Roth. Knowledge Systems for Planning Supports. *IEEE Expert*, 1989.

[4] Akio Imai, Etsuko Nishimura, Stratos Papadimitriou, and Kazuya Sasaki. The Containership Loading Problem. *International Journal of Maritime Economics*, (4):126-148, 2002.

[5] Sabine Kujath. Entwicklung eines Objektorientierten Systems zur Stauplanung. Master's thesis, Arbeitsgruppe Diskrete Mathematik, Fachbereich Mathematik, TU Berlin, 1996.

[6] David B. Leake. *Case-Based Reasoning: Experiences, Lessons & Future Directions*, chapter CBR in Context: The Present and Future, pages 3-30. AAAI Press/ MIT Press, 1996.

[7] William Mark. *Machine Learning Methods for Planning*, chapter Adapting Plan Architectures, pages 435 - 465. Morgan Kauffmann, 1993.

[8] William Mark, Evangelos Simoudis, and David Hinkle. *Case-Based Reasoning: Experiences, Lessond & Future Directions*, chapter Case-Based Reasoning: Expectations and Results, pages 269-294. AAAI Press / MIT Press.

[9] Steve Minton and Monte Zweben. *Machine Learning Methods for Planning*, chapter Learning, Planning and Scheduling: An Overview, pages 1–27. Morgan Kaufmann, 1993.

[10] Setyo Nugroho. Case-Based Stowage Planning for Container Ships. In *International Logistics Congress 2004*, pages 609-618. Dokuz Eylül University, Turkey, Dokuz Eylül Publications, 3 December 2004.

[11] Rainer Schott. *Stauplanung für Containerschiffe*. Verkehrswisssenschaftilchen Studien aus dem Institut für Verkehrswissenschaft der Universität Hamburg. Vandenhoeck & Ruprecht, Göttingen, 1989.

[12] Heike Vogeley, Frank Laue, Jan Wiechmann, and Ulrich Killat. Stauplanung für Containerschiffe. *HANSA - Schiffahrt, Schiffbau, Hafen*, (11):20–27, November 2004.

[13] Ian Watson. *Applying Case-Based Reasoning: Techniques for Enterprise Systems*. Morgan Kaufmann, 1997.

The paper has been accepted to be presented at PORTS 2005 Conference in Barcelona, 20th-22th April 2005.

[14] I.D. Wilson, P.A. Roach, and J.A. Ware. Container stowage pre-planning: using search to generate solutions, a case study. *Knowledge-Based Systems*, (14):137-145, 2001.

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