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Preface

This volume contains the texts of papers presented at the Second Irish Conference on Artificial Intelligence and Cognitive Science, held at Dublin City University in September 1989. This Conference has now become the major annual forum in Ireland for the presentation and discussion of current research work in the multi-disciplinary area of Artificial Intelligence.

Papers in this volume have been divided into seven sections which vary in their subject matter. Image processing, human-computer interaction, planning, applications and theory of expert systems, learning, speech, and natural language processing and semantics represents as broad a spectrum of AI and AI-related topics as can be found in current AI research. This harmonises quite well with the aims and scope of the AICS'89 conference which were to provide a forum for industry and academic research to discuss AI and AI-related topics and we were delighted that such a broad coverage of topics was achieved. Despite the broad nature, however, none of the papers are primarily review articles; each paper presents new research results within its own specific area.

In the first section on image processing, both the papers present current research on geometric object recognition. The paper by Hudson et al. deals with two-dimensional objects and the paper by Cowie et al. works in three dimensions. In the section on human-computer interaction, Benslimane and Ducateau describe an expert system approach to intelligent tutoring. Sheehy then presents work done on using nonverbal communication in a man-machine interface and McKevitt and Pan discuss how to represent general effects in a question-answering system about operating system commands. The third section of this volume is about planning and, in this section, Shadbolt examines the relationship between planning and dialogue. The paper by Morris and Feldman describes a method for increasing the efficiency of the search process in automatic planning.

The section on expert systems contains the largest number of papers in this volume and covers both the application and theory of expert systems. The paper by Guan and Lesser investigates a method for computing approximate probabilities, which could have application in representing uncertainty in expert systems. Servajean and Ducateau present a paper describing an expert system which is used as a software engineering tool. Liu et al. describe PEMES, an expert system designed to solve problems in petroleum exploration. Guan, Pavlin and Lesser then describe a computationally efficient method for combining evidences in the Dempster-Shafer theory of evidence, another method which could be used for representing uncertainty in expert systems. Finally, Dai et al. describe HOPES, an expert system which has application in real-time signal processing.

The fifth section in this volume covers learning and, in the first paper, Kinsella suggests improvements in learning algorithms as used in neural networks. McMullin describes a new direction of machine learning based on Darwinist principles, and Thornton tackles problems of how higher levels of description can be learnt. Heise and McDonald describe a system in which robots learn tasks rather than being programmed how to perform these tasks. The single paper in the section on speech, by Ambikairajah et al., presents a model for the human ear, based on physiology, which is being developed as a front end processor for a neural network based speech recognition system.

The seventh and final section of this volume, on natural language processing, contains two papers which use machine readable dictionaries (MRDs) for language processing. Guo uses a MRD to try to automatically derive a natural set of semantic primitives and Nutter uses the same MRD to build a large lexicon containing both syntactic and semantic information. The final paper in the volume, by Ramsey, presents an analysis of the semantics of WH-clauses as they occur in natural language.

There are many people we would like to thank for helping make AICS'89 a success. Michael Ryan, Head of the School of Computer Applications at DCU, deserves special thanks for allowing us to use the facilities of the University to run the conference. The program committee members who refereed papers at very short notice also deserve our acknowledgement and thanks. The sponsors of the AICS'89 conference were EOLAS (the Irish State Agency for Science and Technology), Digital Equipment Corporation, Wang (Ireland) Ltd., Peregrine Expert Systems and Expert Edge Computer Systems. Our gratitude for their sponsorship must also be mentioned.

Finally, we hope that by reading these proceedings you, the reader, will broaden your knowledge and your appreciation of Artificial Intelligence. We have certainly enjoyed preparing them.

A. F. Smeaton
G. McDermott

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Section 1:

Image Processing

Application of Artificial Intelligence to Two Dimensional Assembley Tasks[1]

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ABSTRACT

In this paper an artificial intelligene based technique to solve a class of two dimensional polygonal assembly problems is reported. Two dimensional assembly problems resemble solving jigsaw puzzles without the picture clues. The problems considered include ones in which angles and holes were repeated on a number of pieces, thereby making he assembly task inherently difficult. The limitations of the system presented here are discussed. Possible approaches to improving the intelligence of the system are considered.

1 Introduction

The development of intelligent assembly systems is one of the most pressing requirements for modern manufacturing industry. In complex manufacturing situations or environments, versatile and intelligent robotic systems are required [4]. A complete vision system will enable a robot to handle a class of general construction tasks.

The task considered here is the assembly of a number

[1]This Research is funded by EOLAS, The Irish Science and Technology Agency, Strategic Research Contract ST/67/86.

[2]Currebt Address: Silicon and Software Systems Ltd., Ballymoss Road, Sandyford Industrial Estate, Dublin 18, Ireland.

of simply connected planar pieces into one or mo
(see fig. 1).

The task is inherently difficult because there i
priori information about the number, shape, size, po
or orientation of the pieces or holes. The vision ta
twofold: firstly to extract shape descriptors from a
and secondly to use these descriptors in an intel
subsystem to assemble the puzzle.

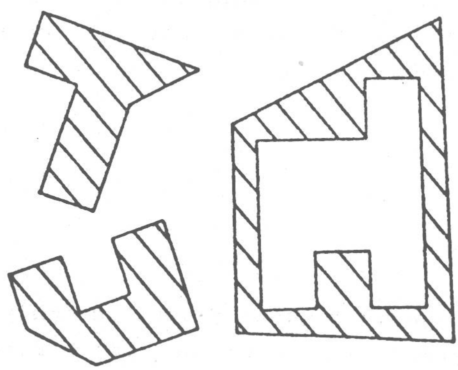

Figure 1. A Typical Assembly Task

The assembly of the puzzle requires rotating
translating the pieces so that they fit together wi
overlaps or holes. The only features used in determ
this are the boundaries of the pieces :- the task is
the same as solving a conventional jigsaw puzzle
pictorial information is available.

Jigsaw puzzle solving by computer and related pro
have been tried by various researchers. Wolfson *et al*
developed a system which could sort two 104 piece ji

reassemble the pieces. The descriptors used were ygonal approximations and the puzzles were conventional puzzles. The difficulty of the problem arose because y of the pieces are similarly shaped. However, the ution by Wolfson *et al* depended on the puzzle having a ad-like form, and the boundaries being subdivided into ar subcurves at sharp corners. Radack and Badler [7] used different description technique: boundary centered polar coding. However they restricted their work to puzzles nsisting of pieces which were sufficiently unique that ey could be assembled without backtracking. Avnaim and issonnat [1] dealt with the subproblem of polygon ntainment under translation only. The work presented in] is restricted to one, two or three polygons. In the se of three polygons to be fitted the hole is restricted be a parallelogram. The treatment is mathematical and esents upper bounds for the computational work required r various algorithms presented.

The layout of this paper is as follows. In section 2 e image acquisition and descriptor extraction system are iefly outlined. The matcher algorithm and the rule base re described in section 3. In section 4 the results btained for different tests are presented, and the erformance and limitations of the system are discussed.

Descriptor Extraction

The images used for the present study are 512 x 512 ictures of pieces of black card lying on a white ackground. The scene is viewed orthogonally from above. ll objects lie completely within the field of view and do ot overlap each other.

The original greyscale images are binarised, segme into distinct regions, and a chain-code description of boundary of each is generated. The area, centroid principal axis of each region is calculated. Polyg descriptors for each region are extracted using either Hough transform [2] or the Outline Corner Fi method [3].

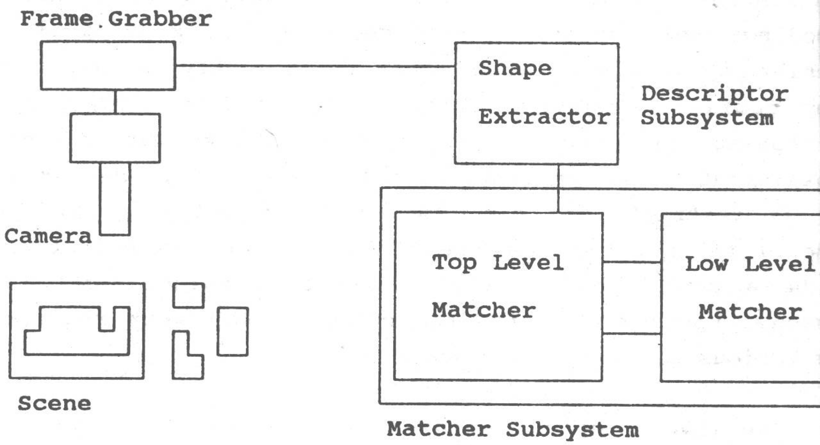

Figure 2. Block Diagram of the System

3 Shape Matcher

The matcher algorithm is based on a heuristic sea The heuristic search solves the problem by successiv matching individual pieces and holes, in an ordered w until the completed assembly is found.

Using the heuristic search formalisation, a solut state will be one configuration of the pieces and holes the work surface. The initial state is the configuration described by the input data (generated from the cam image). The final state is one in which no pieces or s remain unmatched. Intermediate states are igurations which include matched, partially matched and tched objects.

The matcher system is written in Turbo Prolog on an PC-AT. The data for each object is asserted as a set of s. Backtracking during the searching for a solution is litated through the inherent backtracking available in og.

The object data from the descriptor subsystem is the it data for the matcher subsystem. The operation of this system begins with the rationalisation and normalisation the object database. In each object descriptor list les close to 180^{o} and short lines are removed. Where re is more than one copy of an object, the complete data all but one is removed, and a fact is asserted which ords the repeated occurrence(s) of that object. Within database as a whole the objects are listed in order of a, beginning with the largest, and within each object criptor list the sides are listed in a clockwise ection beginning with the longest.

The heuristic search uses two levels:- a Top Level cher (TLM) and a Low Level Matcher (LLM). During the rch three lists are maintained: a list of heuristic es, a list of valid piece-hole pairs, and within the LLM ist of pairs (i,j) where i is a piece vertex and j is a e vertex. The TLM generates an ordered list of available ce-hole pairs. The elements in the list are in the order $_1,p_1), (h_1,p_2),\ldots, (h_1,p_n), (h_2,p_1),\ldots, (h_2,p_n),\ldots ,(h_m,p_n)]$, where h_1 is the hole with the largest area, the hole with the second largest area and so on. ilarly p_1 is the piece with the largest area, etc. This t of pairs is updated at each stage of the search. All rs which contain a matched piece or hole are removed from the list. Subholes generated by a match are calculated. The set of pairs consisting of the unmatched pieces and the new subholes is generated and each pair is inserted into the list at the appropriate place.

The user interface prompts the user to supply an ordered list from a set of six heuristic rules. This method of selecting the heuristic rules facilitates the study of the effectiveness of particular rules sets without modifying the system. The rules are given in Table 1 and illustrated in fig. 3. The rules form a plausible set for conducting a heuristic search, but they are not exhaustive.

<u>Table 1</u> Table of Heuristic Rules Available to the Matcher

For piece vertex i and hole vertex j

Rule 1: $pl_i = hl_j \;\&\; pa_i = ha_j \;\&\; pa_{i+1} = ha_{i+1}$

Rule 2: $pa_i = ha_j \;\&\; pl_i = hl_j \;\&\; pl_{i-1} = hl_{j-1}$

Rule 3: $pl_i = hl_j \;\&\; pa_i = ha_j$

Rule 4: $pa_i = ha_j \;\&\; pl_i \leq hl_j \;\&\; pl_{i-1} \leq hl_{j-1}$

Rule 5: $pa_i = ha_j$

Rule 6: $pl_i = hl_j$

where pl_n is the length of side n of the current piece,
pa_n is the size of angle n of the current piece,
hl_m is the length of side m of the current hole,
and ha_m is the size of angle m of the current hole.

All of the equality tests are toleranced.

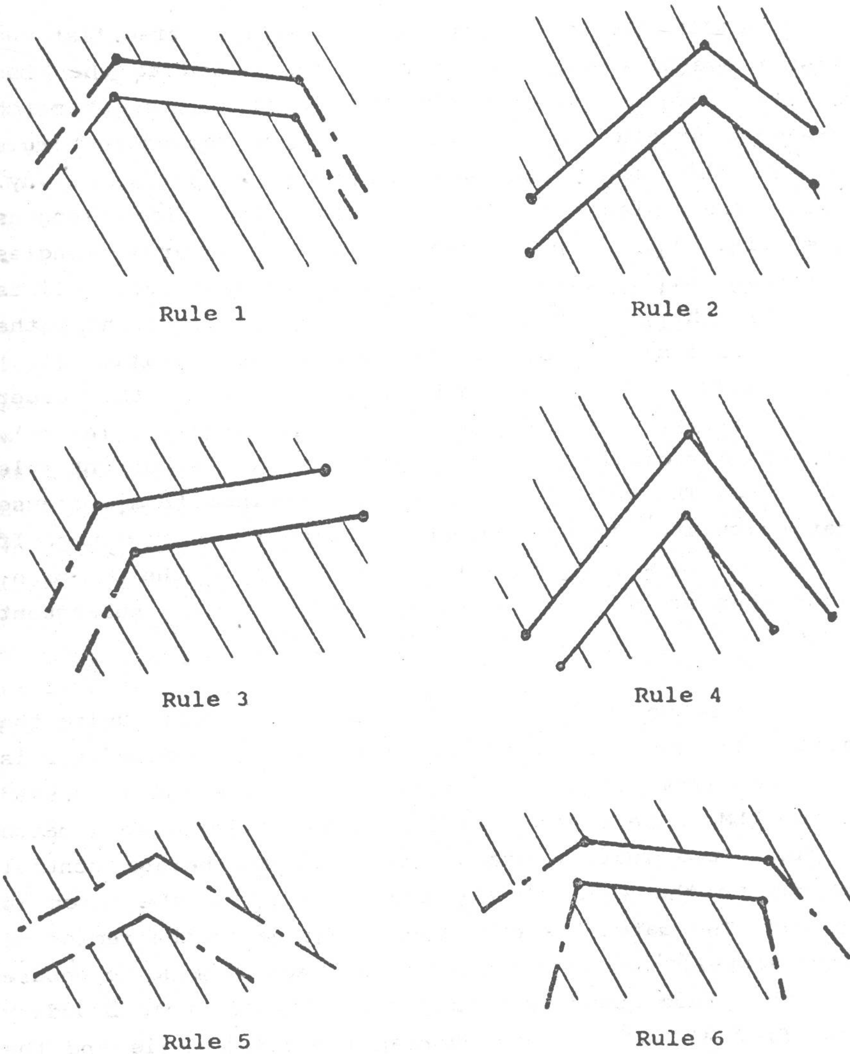

Figure 3. The Six Heuristic Rules

The TLM selects the first rule in the ordered list and first piece-hole pair, which are then passed to the LLM. The LLM conducts an exhaustive search for a correct match between a single piece and hole. It uses the current rule to find the first successful matching position, if any. Given the piece descriptor list of side lengths $L_p = [pl_0, pl_1, \ldots, pl_n]$ and list of internal angles $A_p = [p\alpha_0, p\alpha_1, \ldots, p\alpha_n]$, and hole descriptor lists $L_h = [hl_0, hl_1, \ldots, hl_m]$ and $A_p = [h\alpha_0, h\alpha_1, \ldots, h\alpha_m]$ the search for a match proceeds from the current position (i,j) and checks the piece and hole sides in the order $(i,j), (i+1,j), \ldots, (n,j), (i,j+1), \ldots \ldots, (n,j+1), \ldots, (n_1,m_1)$, until a pair of sides (i_1,j_1) that satisfy the current rule are found. The values n_1 and m_1 are obtained from a clause that calculates if any object has rotational symmetry. If an object does have rotational symmetry in the first n_1 sides then no new matches will be found in the subsequent sides.

If a match between the first piece-hole pair using the first rule cannot be found then the next piece-hole pair is extracted from the list of piece-hole pairs and is passed to the LLM to be tried with the current rule. When a match is found two further steps are performed before control returns to the TLM. Firstly the validity of the match is checked. The match has only been verified in the region of piece vertex i and hole vertex j. A check is made to ensure that the piece boundary does not overlap the hole boundary (see fig. 4). If it does overlap the match fails and the LLM tries the next vertex pair in the list. The second step is to update the list of piece-hole pairs in the manner described above. If no vertex pair for a given piece-hole pair produce a match with the current rule, control returns to the TLM.