AI/CS4 Project Proposal

Title: A Rational Reconstruction of a full 2D Feature-Based Navigator for Mobile Robots.

Proposer: John Hallam

Possible Supervisors: Hallam, Forster, Smart

Requirements: C or C++, SUN3/160C workstation (gaia), Various useful library code.

Description:

Navigation for mobile robots is currently handled by beacon-based systems. A number of identifiable targets are placed around the area in which the robot is to work (or are selected by the vehicle from images of its environment) and their positions in the environment are assumed constant. The vehicle may infer them or be told them; the targets (or features) form the basis of the vehicle's frame of reference for navigation.

In the first two works cited below, a system similar to this is described for u[illegible].water vehicles. This project is to reimplement that system on the SUN workstation. A 3D version of a similar system is currently being developed on the same workstation so there is considerable expertise on the statistical filtering etc. already available and much of the library code for the 3D system could be used in this 2D one.

The basic tasks involved in the project are thus:
1. To understand the basic 2D system described in the first two references.
2. To redesign it in a more modular way (suggestions given in the first reference).
3. To implement it on the SUN3/160 and provide suitable display tools for interpreting its behaviour.

The crucial difference between the feature-based navigator and other contemporary systems is its ability to deal with moving beacons without any prior warning. Apart from implementing the 2D system, there is some experimental work on various methods of tackling this problem. The original system used a very straightforward local statistical method of determining significant proper motion of features; this was in some ways unsatisfactory, and the third reference describes a more elegant global but computationally much more intensive method of tackling the problem.

P[illegible]ible extension tasks are:

4. Investigating different methods of detecting feature proper motion; comparing the global and local methods and suggesting and trying heuristics to improve the efficiency of the global method.
5. Investigating in more detail the performance of the 2D system -- for example, using more complex trajectories than those in the references above and allowing both vehicle random motion and feature observation error. ← covariance matrix?
6. Enhancing the system to enable it to detect sharp changes in the vehicle heading (with or without warning from the control system) such as turning tight corners, stopping fairly abruptly, etc., and testing it with a realistic range of land-based mobile robot style movements.
7. Varying the availability of information to the system -- for example permitting direct odometry to give vehicle position information (ways of doing this are discussed in the first reference) or altering the observability of features (so that only bearing of features is available for example).

References:

Hallam, 1985, Ph D Thesis chapters 3-5.

Hallam, 1983, "Resolving observer motion by object tracking", Proc. IJCAI 8, Karlsruhe.

Hallam, 1986, DAI Research Paper 317.

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Feature-Based Navigation

The ability to navigate is essential for a fully autonomous robotic vehicle. It is needed when the vehicle must move to a sequence of places to carry out activities there (e.g. inspection) or for making sense of the data collected by its sensors at different times (e.g. during mapping). For underwater (as opposed to land) vehicles, the navigation problem is made harder by currents in the water: it is not possible to hold the vehicle stationary while the navigator computes where the vehicle actually is. The feature-based navigator devised here in the Artificial Intelligence Department solves this problem. The work on display is part of a collaborative project with the Marconi Maritime Applied Research Laboratory and is funded by the Marine Technology Directorate of the SERC. It is intended for use in exploratory situations where no map of the seabed is available. Similar ideas are in fact used in the navigation of planetary exploration vehicles.

The feature-based navigator works by keeping track of the vehicle's position with respect to features in its environment. Its sonar sensor scans the nearby water and objects which reflect sound (such as divers, rocks, fish, and underwater structures) are detected by their echoes. The range and bearing of any bright echo is measured by Marconi's sonar processor program and the relative position so obtained is passed to the navigator. Since the sonar provides a two-dimensional view of the world, a vehicle depth sensor supplements the input to the navigator.

Once a stream of feature positions is available, the navigator tracks each feature. Tracking allows the system to compute better relative position estimates for each feature than can be obtained directly from the sonar; the relative velocity of the feature is also computed by the tracker. Using the feature relative motions, the navigator infers the movement of the vehicle by reasoning about the causes of apparent movements. It can do this because movement of the vehicle and movement of the features cause different, characteristic, effects in the relative motion tracks. The system is therefore able to identify moving and stationary features, and to use the stationary features to infer the movement of the vehicle.

A simulation system provides test data sets for the development of the navigator. The navigator is also being tested on data sets generated by Marconi using a realistic simulation of a real sonar detector. Signal processing techniques, which are required to extract and recognise the features detected by the sonar, are the focus of Marconi's involvement in the project.

The navigator performs well in tests. It tracks the vehicle position with an error of approximately 1% – adequate for an exploratory mission – and correctly identifies moving features. It is currently being extended to infer vehicle orientation as well as vehicle position and velocity.

Although the algorithm is suited to the continuous navigation problem encountered by marine vehicles, it is equally applicable to the simpler navigation problems found with land-based mobile robots. This is because the navigation process works with any sort of feature, provided the features can be matched together between sightings (they do not have to be *recognised*, but only associated). Example applications include outdoor navigation and planetary exploration. The navigator uses sensors that an autonomous vehicle typically carries for other purposes, so is also inexpensive to implement.

PROVISIONAL.

Artificial Intelligence and Computer Science 4 1988-9

1 Introduction

This document is intended for both staff and students, and some parts will apply more to one group than the other. Quite a lot of it has been lifted from Gordon Brebner and Alistair Sinclair's equivalent description of Computer Science 4 and adapted for the joint degree. Computing facilities and seminars in the Artificial Intelligence department are described briefly.

AI–CS4 is the final year of the joint honours degree in Artificial Intelligence and Computer Science. It consists of six taught modules, at least two chosen from each department, and a substantial project carrying 50% of the available marks for the year. Students taking it have already completed AI–CS3, AI2, CS2, CS1 and they were highly recommended to take AI1. Final degree classification is based on performance in both of the third and fourth years.

A wide range of types of activity are used in order to aid in learning new knowledge and techniques. Some of these are familiar from earlier years; others involve the acquisition of important non-technical skills. The activities include:

- reading hand-outs, books, journals and conference proceedings
- writing essays and reports
- attending lectures, seminars and tutorials
- discussing subjects with individuals and groups
- giving oral presentations
- working in groups
- trying practical exercises.

Members of staff guide students towards relevant types of activity in most contexts, but students should exercise individual initiative in order to maximise the learning possible in a limited time.

AI–CS4 is a full-time course and the onus is on students to use the time productively. For administrative purposes, "full-time" means that students are assumed to be available during normal University hours throughout the academic year (all ten weeks of all three terms). For the purposes of this document, "full-time" means that work notionally occupies an average of about forty hours of work each week throughout a 25-week year (nine weeks in the first and second terms, and seven weeks in the third term); this results in a total workload of approximately one thousand hours. Clearly, different students can do different amounts of work in this time. The information here is meant to be a guide to apportioning this time between activities, and to scheduling activities, so that a balanced collection of work can be conducted over the year. However, it should be stressed that, in general, students have the final say in deciding how to organise their time effectively; this is a useful skill in itself.

2 Selection of topics by students

Students have a wide choice of topics to study, and must take care in making their selection. Interest value and usefulness are obvious factors to be taken into account, as well as relative enthusiasm for the activities associated with the different topics, but these issues must be considered in the context of the overall workload. It is important to balance both the range of topics and the timing and duration of the activities associated with them; otherwise, ennui or pressure of work is liable to be a problem. Much information is supplied in advance on each topic, but any student with specific questions is advised to speak to the member of staff who proposed the topic.

Directors of Studies and third year Course Organisers can supply information to students on their relative strengths and weaknesses in third year courses, to help in deciding which fourth year topics might be most suitable.

3 Projects

Students choose a project towards the end of the summer term of their third year, and are expected to do some preliminary study over the summer. The range of available projects should span the interests of members of staff of both departments so that students can choose projects which they find useful and interesting, and goals are usually flexible so that students can work to the best of their ability. Each project topic should try to combine aspects of Computer Science and Artificial Intelligence.

The project involves both the application of skills learnt in the past and the acquisition of new skills, on a substantial piece of independent work. The types of skill required vary from project to project, but five main areas of work are required:

- gathering background information
- solving conceptual problems
- design
- implementation
- writing up

In general, projects are intended to allow students to demonstrate their ability to organise and carry out a major piece of work. The relative amount of time spent on each of the above areas is variable; a project with a high conceptual content can verge on being research work, whereas a project with a high implementation content can verge on being routine hacking (whether programming, wiring or proving). No project consists of just implementation; much careful thought and planning is required in advance.

The project occupies about five hundred hours over the year and, given that courses are run during the first two terms, a typical allocation of time to the project might be one hundred hours in each of the first and second terms, and three hundred hours in the third term. However, spreading project work over the entire year is more important than adhering to a detailed distribution of hours; steady progress is far more likely to result in a satisfactory project than erratic jumps. Writing up will occupy a substantial amount of time which should not be underestimated, so it is important to make significant progress on the rest of the project well before the final term. At the outset of the project, students should be aware of the approximate depth to which the above five areas can be tackled. Then, during the year, they should always have a realistic view of project progress, and of the type of activities which can and should be worked on in the future. One or more members of staff supervise each project and assist students in forming this view on a frequent basis. To further broaden involvement in projects, students are divided into small groups of between four and six people which meet regularly, with supervisors in attendance, to discuss progress.

3.1 Proposal of Project Topics

The range of topics made available to students is, in the main, dependent upon suggestions made by members of academic staff, each of whom is expected to provide at least two new proposals each year. Research staff may also suggest topics.

Proposals are submitted to the Project Committee[1], which meets periodically, and either accepts proposals, merges proposals, rejects proposals, or returns proposals for modification. At the end of the second term each year, a list of available projects is prepared for circulation to students.

Project proposals must contain:

- title of proposal and name of proposer
- paragraph giving a technical description of the proposed topic which can be understood by a non-specialist
- paragraph describing the motivation behind the proposal, including academic objectives, pre-requisite knowledge and skills, and any relationship to other CS4 activities
- the approximate proportion of student time needed on each of the five main areas listed above, and an indication of the amount of work possible on each of the five areas
- suggested members of staff responsible
- equipment and facilities required

[1]The Project Committee for AI–CS4 consists of the Professors of Computer Science, the Head of Department of Artificial Intelligence, the Computer Science 4 course organiser and project organiser, and the Artificial Intelligence 4 course organiser.

- short list of accessible references, each classified *essential*, *strongly recommended* or *useful*.

The Project Committee uses this information to assess both the difficulty of the project, and the maximum mark which might be expected from the project. It is important to stress that projects must have both academic value and interest value; proposals should not merely be a list of tasks which the proposer is unable to get done by other means. The quality of proposals is vastly more important than the quantity. In some cases, proposals may be initiated after discussion with students who have specific interests.

3.2 Project Selection

Project selections are made during the third term of AI–CS3, so that students can do preliminary reading during the summer vacation. A list of available projects is given to each student at the start of the third term of AI–CS3; the information on each project is that given by the proposer, in the form described above, together with an indication of difficulty determined by the Project Committee. Given this, students are expected to gather further information about projects over a two-week period by reading background references and speaking to proposers. Students then submit an ordered list of the four projects which interest them most. Ideally, students are assigned their first project choice. In practice, this might not occur because either several people have chosen the same project or the Project Committee (assisted by the third year Course Organisers) feel that the choice is unsuitable. In either case, efforts are made to ensure that students are allocated acceptable alternatives. When no allocations can be made, students are interviewed by members of the Project Committee in order to determine a project topic. A list of all project assignments is published before the end of AI–CS3; assignment of supervisors, and the composition of project groups, is determined by the Project Committee before the start of AI–CS4.

3.3 Reviewing Progress

To provide a check on progress, students must submit a written report of about ten pages (printed, or in legible handwriting) at the end of the first and second terms, containing:

- description of the project, set in the context of published literature
- outline of the work done, and its relation to previous plans
- range and timescale of future work.

The report is scrutinised by both the project supervisor and the Project Committee, who supply feedback if necessary. Project groups meet at least three times in the first term, and twice in the second term; the times of meetings are arranged by the group members. At each meeting, each student gives an informal 15-minute talk describing progress on project work and future plans; constructive criticism from the audience is encouraged. The final meeting of each term is attended by some members of the Project Committee, and so each talk must also include brief background

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Assessment of Reports

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Course organisers should issue this document to all undergraduate students taking courses in the Department before they begin report writing.

1 Writing of Reports

By report we mean an essay, project report, dissertation or thesis submitted for assessment in a degree programme at undergraduate or postgraduate level.

Your report should start by indicating what the issue is that is being tackled and should include an outline of the structure of the report. It should show some knowledge of the relevant background reading. It should describe the algorithm used (if appropriate) in general terms before describing the program in detail. A running example is often useful for illustrating the algorithm in an informal way. It should conclude with some comments that show that you are able to distance yourself from the enterprise enough to see what has and has not been achieved. Annotated program code, user documentation, sample runs and traces should be included in an appendix.

A common error in report writing is to delve immediately into the minutiae of the program before setting the scene. Another common error is padding the report by including irrelevant material or by adopting an over-verbose style. You will be rewarded for succintness and relevance, and penalised for padding.

2 Need for Planning

The pattern of assessment of most candidates will require the simultaneous preparation of one or more reports together with revision for several examinations. You should give careful consideration to the planning of this work. You must not allow the preparation of a report to interfere with examination revision or the preparation of other reports, nor must they hinder your normal tutorial work, course work or lecture attendence. Several of your reports may fall due by the same date, and advantage should be taken of the full length of time available for their preparation in order that the writing of several lengthy pieces of work at the same time may be avoided. You should also allow sufficient time for the preparation of final typescripts and for photocopying.

If, for some legitimate reason, you are unable to complete a report by the deadline set, then contact your supervisor or course organiser as early as possible to request an extension. If there are good reasons why you will not be able to meet a deadline then you should apply for an extension to the deadline as soon as possible. Last minute applications for extension are less likely to be granted. Take with you any medical certificates or other supporting documentation. Extensions are not granted retrospectively.

3 Obtaining Feedback

It is always worth getting other people to read your report and to amend it in the light of their comments. You should acknowledge help obtained in this way. In the case of assistance with minor points a general acknowledgement at the beginning or end of the report is sufficient. In the case of assistance with major points a specific attribution is required in the body of the text.

If you have a supervisor it is normal for him/her to read your penultimate draft. You should also ask your peers: you may arrange to swap draft reports with one or more. In general, you should not ask examiners [1]. Be sure to leave plenty of time for your readers to read your report and for you to incorporate any amendments. Supervisors are often busy and may require several weeks to read reports, especially long ones.

4 Presentation

Reports must include, where appropriate, references and a bibliography. Look in Departmental Notice No. 25 for the conventions to be followed. (Departmental notices are available from any Departmental secretary.) Seek guidance from your supervisor or tutor on the presentation of your work.

Reports must be presented on A4 paper. The pages must be numbered and one side of the paper only should be used. The reports should be typed or printed out, double-spaced, though for long quotations single spacing may be used. A standard size type font should be used, e.g. 10 or 12 cpi. The first page must contain the title and a list of sub-headings where this is appropriate. Two copies must be submitted. Pay attention to the length limits prescribed for your report. You may be penalised or asked to rewrite if your report is too long or too short.

[1] Although internal examiners of postgraduate reports may be asked.

5 Late Submission

If you submit a report or any part of an report (including bibliography or appendices), after the deadline, and you have not been previously been granted an extension, then you will be penalised. The standard penalty for late submission is 1% of the awarded mark per day. If, however, you provide a written explanation for your failure to submit on time, together with relevant medical or other evidence, if any, the Board of Examiners may decide that the circumstances are such as to justify the waiving of the penalty.

You are, therefore advised to provide letters of explanation for any late submissions, backed up with corroborative evidence if appropriate; in particular, if the lateness was due to ill-health, it is advisable to provide a medical certificate. It should be noted that penalties for late submission become progressively heavier with the passage of time; it is generally advisable, therefore, once a deadline for a report has passed, to submit it as quickly as possible.

Total failure to submit a report will result in a fail mark for that section of the course. If the report is a compulsory part of the course [2] then this will result in failure of the whole course.

6 Plagiarism

Plagiarism is the use, without acknowledgement, of the intellectual work of other people and the act of representing the ideas or discoveries of another as one's own in written work submitted for assessment. To copy sentences, phrases or even striking expressions without acknowledgement in a manner likely to deceive the reader as to the source is plagiarism; to paraphrase without acknowledgement in a manner likely to deceive the reader is likewise plagiarism. Where such copying or paraphrase has occurred the mere mention of the source in a bibliography is not deemed sufficient acknowledgement; each such instance should be referred specifically to its source. Verbatim quotations must be enclosed in quotation marks and directly acknowledged. See Departmental Notice No. 25 for more details of the conventions to be followed.

The submission of a report will be considered by the examiners to be a declaration that it is the candidate's own work. Plagiarism is a serious offence and will be penalised. This may result in you failing the whole assessment, being disqualified, being asked to rewrite the report and incur a penalty for late submission, or some other disciplinary action. The Department reserves the right to vary these penalties according to the seriousness of the offence. For instance, in the case of deliberate cheating the penalties will be more severe.

[2] This is normally the case.