A PROTOTYPE FOR INTERACTIVE ROBOTICS APPLICATION DEVELOPMENT

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Abstract

A number of techniques, grouped under the general umbrella term of *usability inspection*, have been devised in recent years to help software developers focus more closely on the needs of end-users during development of interactive applications. Central to the use of such methods is the question of how proposals can be tested before a finished system has been implemented. This paper discusses the role of high and low-fidelity prototypes used for this purpose in software development and proposes the use of a "variable-fidelity" prototype as an aid to the development of interactive robotic systems. The approach is explored and illustrated through the example application of an Interactive Robotic Visual Inspection system developed for use by a person with limited physical manipulation skills.

Background

Techniques and theory surrounding the design and evaluation of Human Computer Interfaces (HCIs) has developed rapidly over the past decade.

The success of increasingly user-centred development methods has promoted growing interest from software developers further motivated by the demands of an ever widening user-base. Usability engineering is now seen by many software houses as a key part of successful product development and has led to a growing body of research in this area.

Meeting the needs of the end-user

An account of how an awareness of human-factors can be applied in HCI design is offered by the creators of the original "Star" user interface Card, Newell and Moran [1]. Here a number of experiments are used to substantiate a process-oriented view of human performance referred to as the *Human Model Processor*.

Being able to formulate and therefore calibrate the processes of human interaction in terms of expected performance metrics also provides a valuable framework from which to assess the logistics of operation and appropriate specifications of a robotic system.

The predictive power of such a model has clear applications in user-centred design work. However, as with all predictive methods, the likelihood of the expected tallying with the observed depends on the validity of initial assumptions. It is advisable, therefore, to look for ways to verify these empirically before investing too much time in their development. This need has been recognised within the HCI research community and structured methods for facilitating and carrying out this kind of validation are well represented [2].

The use of prototypes

In order to be able to deploy usability inspection methods early in development it is necessary to have, not just a common language which can be understood by members of a design team, but a clearly demonstrable representation of the product which can be examined by evaluators and tested with end-users. A prototype has the potential to fulfil this need.

The term *fidelity* is often used to distinguish between different kinds of prototype, high-fidelity corresponding to a representation of the system where most of the materials and hardware used for construction are faithful to those which will appear in the finished product, low-fidelity referring to a minimal representation which may be constructed in a completely different medium. There are associated trade-offs and benefits for each form of approach.

High-fidelity prototypes of software applications may be quickly constructed through the use of rapid development tools. A high-fidelity prototype of this kind has value later in the development cycle because it focuses attention on finer details but by this time the design should already embody the general requirements of the finished product.

Low-fidelity, such as paper prototypes can be useful aids during early stages because they are easily manipulated. However, whilst a medium which is easy to handle promotes free experimentation it does not naturally address the inherent strengths or weaknesses of the target technology.

The variable fidelity prototype

Since the requirements of the design process change over the duration of a project an optimal approach to the problem would be one where the level of a prototype's fidelity is geared to reflect the current stage of the design cycle and fully supports the current objectives of each of the members of the development team.

The development of multiple prototypes can be time consuming and of limited benefit. To avoid this kind of overhead we propose an extension of the notion of prototype fidelity to address this problem and to cope with the need for concurrent engineering required in interactive robotics application development, through the use of what might be described as a "variable-fidelity" prototype.

What distinguishes the variable-fidelity prototype from other types of on-line demonstration software is that it is developed to encompass not just the appearance and functionality of the user interface or the mechanical properties of robotic hardware but the underlying architecture of the complete system.

A variable-fidelity prototype first takes form as an interactive sketch which embodies the approximate requirements and parameters of an early floating specification. Physical characteristics of the product can be represented through the use of 3D graphics and any moving parts can be simply animated at first to explore issues such as changing footprint and how the product may fit into its intended working environment.

As specifications become more concrete, more detailed information can be stored in the prototype and it begins to take the form of an engineering model. In the case of robotic hardware details which become important at this stage are operational limits such as maximum velocities and accelerations and the form of protocols used to drive actuators. Once key features of the mechanical structure have been defined kinematics schemes can be developed, a user-interface can be added and the prototype gradually becomes both a demonstration and a development platform.

An example application: IRVIS

An Interactive Robotic Visual Inspection System (IRVIS) formed the principal deliverable of a previous project carried out within the Cambridge University Engineering Department [3].

IRVIS was designed to provide a semi-automated alternative to current manual inspection methods used within the hybrid microcircuit industry. A high-fidelity (physical) prototype system was tested in action in the context of a production-site environment.

Current work is focused on upgrading the technology previously used [4] and on clarifying and solving usability problems highlighted during the user-trial. A variable-fidelity prototype, illustrated in Fig.1, has since been developed and is currently being used to further these aims.

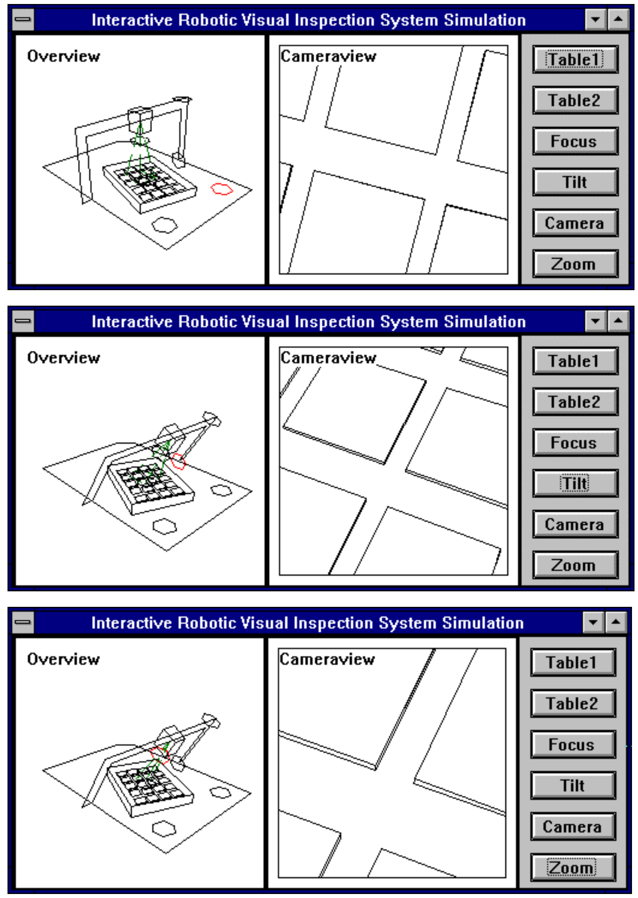

Fig.1 The variable-fidelity prototype: sequence showing image rotation, tilt and zoom.

The underlying structure of this simulation has been geared to reflect the architecture of the physical system. The physical properties of the robot and its video camera have been modelled through the use of 3D graphics providing user-interaction with a virtual inspection system. This offers a vehicle for involving users throughout redesign of the interface, has facilitated a more thorough exploration of the precise nature of kinematics schemes required to facilitate user-driven viewpoint control and also allows flexibility with respect to development of the mechanical specification.

Conclusions

A prototype of this form promotes experimentation at a number of levels of robotic system design. It does not require the presence of physical hardware but is structured enough to reflect most aspects of a mechanical specification. Furthermore, since the structure of the software prototype can be designed to reflect the architecture of the final system, much of the low-level work invested in its construction is readily transferable through each stage of development. This means that appropriate engineering solutions can be explored within the technical constraints of the proposed system whilst the needs of the user continue to take first place.

References

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