Scheduling Home Control Devices:  
A case study of the transition from the research project to a product

Catherine Plaisant¹, Ben Shneiderman², Jim Battaglia³

¹ Human-Computer Interaction Laboratory  
Center for Automation Research, University of Maryland

² Human-Computer Interaction Laboratory  
Computer Science Department, University of Maryland.

³ Custom Command Systems, Inc., 115 Paint Branch Drive, Suite 3181,  
College Park, Maryland 20742-3261, (301) 403-8140

Introduction

Many electronically controlled devices are now found in modern homes, e.g. VCR's, heating and cooling systems, or security systems. One of the benefits of home automation systems (Time, 1989; Smith, 1988) is to provide integrated control of those devices, therefore allowing the use of a single consistent interface to schedule any device to turn ON or OFF or perform a complex function at a later time.

This case study describes the transition from a research project on scheduling home-control devices to a product integrated in an existing home automation system. First we describe the research that explored several designs to schedule devices over time periods ranging from minutes to days: four designs were compared, three of them prototyped and tested. One of the designs was selected for implementation in the commercial system. We then categorize the actions that were taken in order to improve and mold the prototype design into an integrated product. Finally we report on an additional study that emerged from the first one - the scheduling of periodic events - and on the extensions of the scheduler interface design to other aspects of home automation.

A joint project:

In 1987 the Human-Computer Interaction Laboratory was contacted by Custom Command Systems, Inc. (previously American Voice and Robotics Inc.) and with the support of the Maryland Industrial Partnerships program we were able to start a long and beneficial relationship. Custom Command is a growing company and a participant in the University of Maryland's Technology Advancement Program, a state-sponsored initiative designed to support local high-technology companies. Custom Command specializes in the development and marketing of integrated entertainment, security, and automation systems for homes and commercial conference rooms. Their focus is on providing state-of-the-art systems that are easy for the novice homeowner to use. Custom Command's systems incorporate all of the major electronic subsystems typically found in the home, such as audio/video entertainment, security, lighting, heating and cooling, energy management, telephone, information services, and a variety of convenience features. The systems are controlled through the use of touch screens, hand-held remotes, voice recognition, touch-tone telephones, and programmable wall switches.

After a first review of Custom Command's product, the scheduling interface was identified as one feature that could benefit from improved human factors design. It was decided to explore possible alternatives to the original interface, which required a long and tedious process of incremental specification of dates, times and states through a deep menu structure.

The requirements:

The new scheduler has to simply replace the existing one, therefore it must be consistent with the existing environment: The control of the scheduler is through a touchscreen interface. The home owner sees the screen flush mounted into a wall or custom built into furniture or cabinetry. The MicroTouch or Elographic touchscreens that are used return a continuous flow of coordinates with a 1024x1024 resolution. (This allows the dragging of objects, the identification of sliding motion and the use of a lift-off strategy for selection. This strategy reduces the error rates (Potter, Shneiderman, and Weldon, 1988) and allows the selection of small targets, as small as one pixel (Sears and Shneiderman, 1989)). The color, graphical screen displays are implemented under MS-DOS in EGA mode (640x350 pixels). The
touchscreen and the home devices are controlled by a
AT class microcomputer.

The scheduling interface has to be general
enough to be used with all the devices controlled by
the home automation system. Some examples of the
items to be scheduled are:

- VCR
- Lawn-watering system
- Heating and cooling system
- Lights
- Audible reminders/announcement

In Custom Command’s current system users first
select a device to be scheduled and then are
presented with the “standard” scheduling interface
labeled with the device’s name. It is the redesign of
this “standard” interface that we will now discuss.

1 - The research project

Examples of the difficulties encountered by
occasional users dealing with scheduling tasks are
commonly reported, especially with VCR’s which are
well known to be frustrating (Nemy, 1989; Norman,
1988). Nevertheless only a few studies are
attempting to understand or solve this problem
(Robson, 1990; Sebillote, 1990).

Our initial research goal was to raise the issues
involved in designing scheduling interfaces. In our
designs we tried to make the best use of direct
manipulation techniques and also to take advantage
of the common representation of time (calendar,
clocks, etc.) We selected four designs including a
digital clock scheduler (Figure 1), a dual 12-hour
clock scheduler (Figure 2), a 24-hour dial scheduler
(Figure 3) and a 24-hour timeline scheduler (Figure
4).

First the four designs were compared on a

feature by feature basis (Plaisant and Shneiderman,
1989). For example we compared the average
number of actions required to perform various tasks
and found the digital clock at a disadvantage.
Because the advantages and disadvantages of the
digital clock are well known and that we wanted to
explore novel ways to do scheduling we prototyped
only the 3 remaining designs and conducted a
formative usability study (Plaisant and Shneiderman,
1989) with 14 subjects to identify strengths and
weaknesses of each design and verify our intuitions
about potential problems. Additionally remarks and
problems encountered by about 30 reviewers were
collected and taken into account. Subjects were
retired volunteers and non-technical employees of the
University. After a very brief demonstration, subjects
were given a set of scheduling tasks to perform and
used all three schedulers for a total of about an hour.
Subjects were videotaped and they were asked to
order the schedulers by preference and ease of use.

Summary of the usability study results:

Each of these versions has its strengths and
weaknesses, and the usability test showed that all
three could be used by novice users. A wide range of
personal preferences was observed. Each version had
its defendants.

Subjects had no difficulties selecting dates even
on the smaller calendar: the lift-off strategy allows a
box to be shown surrounding the day currently
pointed at and its location can be adjusted if
necessary before lifting the finger off the screen.

Contrary to our initial expectation the 12-hour
clock was not the easier to use and was the only one
with which errors occurred (when subjects forgot to
set the AM/PM properly). The smooth manipulation
of the clock’s hands is widely appreciated but
some difficulties appear when the hands are close
together and the selection mechanism has to be
mastered.

The 24-hour dial was felt to be easy to use
but many subjects had to be reminded about the
right sequencing of operations to be performed
(e.g. first set the hand then press ON). The
reading of a 24-hour dial (especially the pie-
shaped feedback given on the calendar) was often
found confusing because of the overwhelmingly
widespread use of the 12 hour scale. This
representation also brought up many hot debates
between military time (1-24) defendants and the
others.

A little bit to our surprise the linear
scheduler did not present any difficulty to the
subjects. Many comments were made about the
information that could potentially be added on
the line (daylight duration, weather forecast, etc.)
The only negative comments were made about the
limited precision on the line. At the time of the test we didn’t use any stabilization technique for the touchscreen, therefore the flag/cursor kept jumping a few pixels around the touched point and only 10 minute intervals could be selected, which is sufficient for most devices.

The presence of the 2 lines allowed users to set events over several days with complete feedback on the screen but the existence of the 2nd line was found annoying when not used. We believe that the advantage of the linear scheduler is that it requires only one concept (operation/principle) to remember — set flags on a timeline. The sequentiality of operations is also reduced to a minimum and it even includes the editing and canceling of previous events with no increase of complexity (unlike the other schedulers which would require additional developments.)

Many extensions are possible with the linear scheduler. Other types of flags can be used in addition to the ON and OFF flags (e.g. a ON-for-half-hour flag for a sprinkler, a ON-until-done flag for the pool cleaner, a do-this-everyday flag for the security system, etc., as well as scheduling a sequence of more complex actions). Many more lines could be used to allow multiple device scheduling with synchronization.

Our conclusion was that the usability testing and the number of potential extensions favored the linear scheduler. It was then selected to be included in Custom Command’s home automation system and we will now describe the steps taken to mold the prototype design into a product.

2 - From a research prototype to an integrated product

Once the design was selected a specification document was prepared by Custom Command in an attempt to describe the piece of software to be included in the complete system. The overall design of the scheduler was respected. Nevertheless we identified four directions in the modifications made to the original design in order to produce the commercial product (Figure 5):

(1) Incorporation of usability testing suggestions,
(2) Style consistency with the other elements of the product
(3) Compensation for minor hardware differences,
(4) Adaptation to the available devices to be scheduled.

2-1 Incorporation of usability testing suggestions

Only one line was used. The touchscreen position was stabilized in order to allow more precise positioning of the flag. A precise tuning was made available by + and - arrows once the flag was dropped on the line. Other revisions were made to respect aspects forgotten in the prototype: e.g. the calendar - first object to be used - was move to the top left.

2-2 Style consistency with the other elements of the product

Size and shape of the buttons were modified to match the ones used in other parts of the Custom Command product. The always
available QUIT and BACK buttons were placed at their usual locations. The use of color and highlighting to show selectable items and their various states was done consistently with the rest of the system’s interface.

2-3 Compensation for minor hardware differences

The research prototype was implemented in a very close variant of the product equipment (same graphic resolution, same type of CPU, etc.) which avoided the need for a complete redesign as is often the case when sophisticated technologies are used to do the prototyping. Nevertheless we encountered some differences in speed and touchscreen technology when the transfer to the product environment was made. Unlike the touchscreen used in the prototype (capacitive touchscreen) the product’s touchscreen is of resistive technology and requires a slightly greater pressure to be applied for a touch to be identified. Practically it means that a lift-off can be wrongly detected while dragging an object, causing users to “lose” the flag. To compensate for this problem another strategy for positioning the flag was added: it is now possible to touch the flag pile then the destination on the line. Better touch interaction algorithms were also developed which alleviated this problem.

2-4 Adaptation to the available devices

The prototype scheduler gives a very clear feedback about the scheduled state of the device at any time. A colored line is used to mark the ON time of the devices. But practically most of the devices receiving remote commands still have direct controls on them that allow anybody to change their state at anytime without making that information available to the central system handling the scheduling database. Therefore the state shown on the line cannot be guaranteed. A new generation of appliances will soon make this two way communication possible. Custom Command decided not to show a state that couldn’t be guaranteed. Only the commands sent to the device (i.e. the flags) are shown on the line. On the calendar color dots indicate the presence of flags for the day. The research team felt this was a draw back from the original design but it was a necessary step for the scheduler to match practical hardware limitations.

The scheduler is now installed in homes and is being used successfully. We are now eager to be able to evaluate the daily use of the scheduler in a real home environment.

Figure 4: When a date is selected from the calendar the corresponding 24-hour timeline is displayed, along with a group of ON and OFF flags. Users can drag the appropriate flags onto the line to schedule events. The position of the flags can be adjusted or they can even be removed from the line. Red lines show the duration of the event on the line and on the calendar.

3 - Reaching out for new extensions

Two types of extensions to the scheduler prototype were made. First the use of the linear scheduler was extended to the scheduling of periodic and non-periodic events. In parallel, Custom Command has used elements of the scheduler design in other applications where the placement of items on a line is an effective method of representation.

3-1 Repetitive scheduling

We studied the large number of possible cases of repetitive scheduling, including periodic and non-periodic events. To allow the creation of all types of schedules and their editing implies a rather complex interface. Our approach was to select a subset of

Figure 5: The final version currently used in Custom Command’s system.
schedule types including the most common repetitive schedules and allowing a consistent interface with a relatively small menu structure.

Periodic scheduling is fairly straightforward. To be consistent with the interaction style of the original schedule the desired period is selected first (for example "weekly" is selected, then "Tuesday" if an event to be repeated every Tuesday is scheduled). Then a line appears, representing the selected period (e.g. every Tuesday) and flags can be moved to the line (Figure 6). Periodic flags are visible on the "Every Tuesday" line as well as on the lines of the corresponding individual days. They are graphically different than regular flags to remind users of their special status. Periodic events can be edited globally by moving them on the corresponding line (e.g. on the "every Tuesday" line), or an occurrence can be moved individually by moving the flag on the individual line (e.g. the "Tuesday October 24th" line), but in this case the periodic flag is "degraded" to a regular flag for that day which is memorized by the scheduler as an exception.

Non-periodic schedules are more complex if unlimited sets of days and periods are to be allowed for scheduling and editing. For example the scheduling of a event for the 10th, 11th and 22nd of May is done by selecting each day (Figure 7) then touching Set Complete, and placing the flags. The editing of those events requires a way to specify the set of days originally chosen. This has been done by giving a name to the set of days, which can be retrieved from a list at a later time. Even if a touch keyboard could be used without difficulty to enter a name for the set our quest for overall structure simplicity pushed us to reject this option. Therefore non-periodic schedules can be created (as a fast way to create multiple copies of regular flags) but they cannot be edited globally as a set.

Despite our effort to describe those functions in simple terms, the previous two paragraphs illustrate the complexity of repetitive schedules. The main difficulty for us was to decide on the level of complexity to be allowed in the user interface versus the level of flexibility offered by the system. A user interaction strategy which may be very flexible, i.e. accommodate virtually any scheduling situation, may end up being more complex and thus less satisfying than one which say accommodates only those situations that are most frequently used.

A prototype was made for repetitive event scheduling and Custom Command is currently implementing it in its product.

3-2 Extrapolating to other parts of the system.

This is the second type of extension to the original project. To take advantage of the simplicity of placing or adjusting items on a line (and also to support consistency) similar user interfaces were used in other parts of the system. The best example is the climate control user interface. As shown in Figure 8 the temperature of each room can be set by selecting the room from a map of the house. Markers are then slid along a thermometer to indicate normal and setback temperatures for both heating and cooling.

Conclusion

About the university/corporate collaboration:

We believe that this university/corporate collaboration was beneficial to both partners. The university researchers were offered a serious challenge that led to innovative designs, advancing the state-of-the-art in touchscreen applications and direct manipulation designs. We explored the advantages of multiple metaphors and refined our understanding of perceptual, cognitive, and motor skills for user interfaces. We had the opportunity to follow on the development of the product in all its phases. Custom Command found that the relationship with the university substantially improved its image in the minds of purchasers and investors. The attention to usability issues (e.g. their presentations could add a phrase such as “usability tested with elderly users”) was perceived very positively.

The University of Maryland has filed for a patent on the scheduler. Custom Command’s systems, including the scheduler interface, are being featured in several private homes and in home automation demonstrations sponsored by Bell Atlantic Corporation, General Electric, the
available about the type of repetitive scheduling useful in the home. When home automation systems start to be more widely available, we will be able to better assess the needs of home-owners confronted with large numbers of electronically controlled devices and suggest useful additional features. Home-automation systems are a new challenge for user interface designers because of the diversity of potential users that have to be considered as novice users as well as regular user.

As researchers we might have preferred a series of more controlled psychologically oriented experiments with a small number of independent variables. Such experiments might produce more fundamental results and support perceptual, cognitive, and motoric theories, however the sense of progress and insight from the usability studies was greatly encouraging. We did not demonstrate that we developed the best possible interface, but we have a great sense of confidence that we make an important step towards a breakthrough in design.

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Send correspondence to Catherine Plaisant, CFAR, A.V. Williams Bldg., University of Maryland, College Park, MD 20742.

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