User-Interface Design for Medical Informatics: A Case Study of Kaiser Permanente

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Abstract

User interfaces (Uis) for client-server-and Web-based products and services must enable users around the world to access complex data and functions. Solutions to successful user-interface design, including information visualization, consist of partially universal and partially local solutions to the design of metaphors, mental models, navigation, appearance, and interaction. By managing the user's experience of familiar structures and processes, the user-interface designer can achieve compelling forms that enable the user interface to be more usable and acceptable to a wider range of users. The user will be more productive and satisfied with the product in many different locations globally. This article presents some guidelines for UI design and reviews the design of prototypes for Kaiser Permanente's Clinical Information System, with an emphasis on navigation and appearance improvements.

1. Introduction

Medical informatics, which typically must convey complex data and functions through lists, tables, charts, and diagrams, presents a challenge to users who wish to benefit from these displays. This case study examines certain aspects of the development of the graphical user-interface and information visualization (UI+IV) for a corporate-wide, Microsoft Windows-based client-server clinical information management system that Kaiser Permanente, in Oakland, California, was developing in 1996-8. Many of the concepts are relevant to current software development for medical informatics, including that for the Web.

The UI needed to facilitate access to medical records, clinical data, and scheduling information for users with diverse educational, computer, professional, and cultural backgrounds (in California, cultural diversity is particularly relevant). Users included physicians, nurses, therapists, medical assistants, pharmacists, and administrative personnel who need to review complex, extensive information and make appropriate, accurate, precise, and timely decisions based on the displays.

Products and services available through client-server networks, and through the Web, must make available easy access to information, as well as action plans. Successful products/services developed for different professional groups or markets, in different countries and among different cultures within countries or across countries, consist of partially universal, or general, solutions and partially unique, or local, solutions to the design of user interfaces. By managing the user's experience with familiar structures and processes, the user's surprise at novel approaches, as well as the user's preferences and expectations, the UI+IV designer can achieve effective, more compelling, more usable, and more acceptable solutions.

Demographics, experience, education, and roles in organizations of work or leisure can define users. Individual needs as well as their group roles can define their tasks. A user-centered, task-oriented design method accounts for these aspects in effective UI+IV design. Information visualization includes specific solutions for tables, charts, maps, and diagrams of structure and process. UI components, including those for IV, conceptually consist of metaphors, mental models, navigation, appearance, and interaction. The user-interface components may be defined in this way [12, 13, and 18]:

Metaphors: Essential concepts conveyed through words and images, or through acoustic or tactile means. Metaphors concern both over-arching concepts as well as individual items, like drag-dropping files and folders into the "trashcan" standing for their "deletion" within the "desktop" metaphor.

Mental models: Organization of data, functions, tasks, roles, jobs, and people in groups at work or play. The term, similar to, but distinct from cognitive models, task models, user models, etc., is intended to convey the organization observed in the user interface itself, which is presumably learned and understood by users and which reflects the content to be conveyed as well as users' tasks.

Navigation: Movement through mental models afforded by windows, menus, dialogue areas, control panels, etc. The term implies process, as opposed to structure, i.e., sequences of content accessed by users, as opposed to the static structure of that content.

Appearance: Verbal, visual (graphic), acoustic, and tactile perceptual characteristics of the displays. The term implies all aspects of visible, acoustic, and haptic languages, e.g., typography or color; musical timbre or cultural accent within a spoken language; and surface texture or resistance to force (see, also, [11]).

Interaction: The means by which users input changes to the system and the feedback supplied by the system. The term implies all aspects of command-control devices, e.g., keyboards, mice, joysticks, microphones, as well as sensory feedback, e.g., changes of state of virtual graphical buttons, auditory displays, and tactile surfaces.

This paper discusses appearance guidelines in a development process (planning, analysis, design, implementation, evaluation, and documentation) and the design of prototypes for Kaiser screen layouts.

2. Guidelines for Appearance

Detailed guidelines [12, 14, 5, 7, and 17] cannot be provided for all of the UI design components, but some visual and verbal appearance guidelines appear below.

2.1 Layout and Orientation

Because complex tables, lists, charts, and diagrams are inevitable in medical informatics, use a consistent, rectilinear layout grid with a maximum of 7±2 primary divisions in each direction, to organize content.

Always provide table and/or row labels as well as legends to assist interpretation.

As appropriate, adjust the layout of menus, tables, dialogue boxes, and windows to account for effective legibility and readability.

If dialogue areas use sentence-like structure with embedded data fields and/or controls, these items will need special restructuring to account for organized layout according to visual grids and for language changes that significantly alter sentence format. For example, German sentences often have verbs at the ends of sentences, while English and French place them in the middle.

As appropriate, change layout of imagery that implies or requires a specific reading direction.

Check for misleading arrangements of images that lead the viewer's eye in directions inconsistent with task flow and language reading directions.

Avoid disorganized sets of data fields and labels.

For references to paper and printing, use appropriate printing formats and sizes. For example, the 8.5 x 11 inch standard office letterhead paper size in the USA is not typical in many other countries that use the European A4 paper size of 210 x 297.

2.2 Icons and symbols

Avoid text within icons and symbols to minimize the need for different versions, languages, and scripts.

Use simple, clear, consistent elements, i.e., icon and symbol parts, like those for arrows, people, files, etc.

Adjust the appearance and orientation to account for size, technology platform (e.g., number of colors and screen size), and professional/national/cultural differences. For example, using a post letterbox as an icon for email may require different images for different countries. For example, a prototype for Sabre Group's Planet Sabre, one of the world's largest private extranets (whose UI+IV was designed by the authors' firm) used different mailbox icons to account for national differences (see Figure 1).

As a well-designed, universal sign-set reference, consider using basic icon/symbol sign references derived from the international signage set developed for international safety, mass transit, and communication. (See [1, 6, 9, 11, 18, 19, and 20]. For examples, see Figure 2, from [20]). At the same time, consider cultural bias toward/and against pictorial imagery [8].

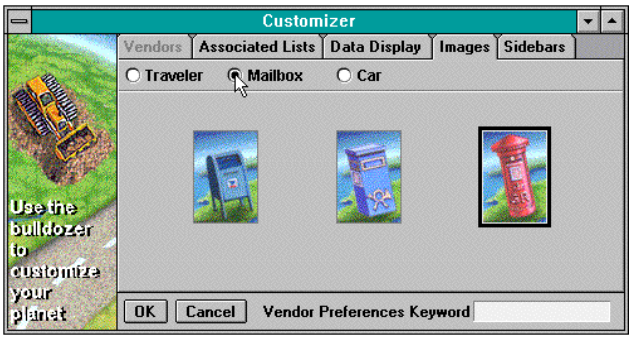

Figure1: Planet Sabre prototype international mailbox icons.

Figure 3: International pictograms from [20].

For global international, "universal" products, avoid puns and local references that will not transfer well from culture to culture. Note: many "universal" signs are covered by international trademark and copyright use. Examples include Mickey Mouse and the Smiley smiling face. In the USA, the smiling face is not protected, but it is in other countries.

Consider whether selection symbols such as the X or check marks convey the correct distinctions of selected and not-selected items. For example, some users may interpret an X as crossing out what is not desired rather than indicating what is to be selected.

For global products, consider: office equipment such as telephones, mailboxes, folders, and storage devices differ significantly from nation to nation.

Avoid the temptation to use "clip-art" icons and symbols as a stock solution; design an appropriate set.

2.3 Typography and Terminology

Use fonts available for a wide range of platforms and languages required for the target markets.

In texts, lists and tables, avoid using all caps, centered type, and justified type, which slow reading speed,.

Consider special font characters for medical, scientific, currency, time, and physical measurements.

Use appropriate decimal, ordinal, and currency number usage. Formats and positioning of special symbols vary from language to language.

Use appropriate typography and language for calendar, time zone, and telephone/fax references.

For ease of comprehension, provide options of terminology, i.e., lay terms and precise medical terms.

2.4 Color

Follow perceptual guidelines for good color usage [11, 12, and 14]. Examples: use warm colors for advancing elements and cool colors for receding elements; avoid requiring users to recall in short-term memory more than 5±2 different coded colors.

Avoid over-using color that becomes distracting.

Be consistent in color usage throughout displays.

Respect national and cultural variations in colors, where feasible, for the target markets. See [6, 23], which list typical international semantics of colors.

2.5 Aesthetics

Respect, where feasible, different aesthetic values among target markets. For example, some cultures have significant attachment to wooded natural scenes, textures, patterns, and imagery that might seem exotic, inappropriate, or unappealing by other cultures. For example, TeamWare's workflow software, developed in Finland, showed background screen patterns typical for Finnish landscapes and culture. They would not necessarily be appropriate for users in warmer climate, e.g., southern California or the Mediterranean.

Consider specific culture-dependent attitudes. Example: Japanese viewers find disembodied body parts, e.g., eyes and mouths, unappealing in visual imagery.

2.6 Language and Verbal Style

Consider unambiguous terms for key controls, e.g., from Simplified English for English, and which languages are appropriate for the target markets, including the possibility of multiple languages within one country. Example: English and French within Canada.

Consider which dialects are appropriate within professional, company, or language groupings. Check regional/national vocabulary carefully, e.g., for British vs. American English, Mexican vs. Spanish terms, or Mainland China vs. Taiwanese terms in Chinese.

Consider the impact of varying languages on the length and layout of text. For example, German, French, and English versions of text generally have increasingly shorter lengths.

Consider the different alphabetic sorting or ordering sequences for the varied languages and scripts that may be necessary and prepare variations that correspond to the alphabets. Note that different languages may place the same letters in different locations, for example, Å comes after A in French but after Z in Finnish.

Consider differences of hyphenation, insertion point location, and emphasis, i.e., use of bold, italic, quotes, double quotes, brackets, etc.

Use appropriate abbreviations for such typical items as dates, time, and physical measurements. Remember that different countries have different periods of time for "weekends" and the date on which the week begins.

3. Design of Prototypes for Kaiser

In 1996, the Clinical Information System (CIS) group of Kaiser Permanente, Inc., the largest health care provider in the USA, was in the process of developing an integrated graphic user interface (GUI), the Kaiser Interface Components for Heritage Systems (KICHS), for a corporate-wide Windows-based client-server information-management system. Aaron Marcus and Associates, Inc. (AM+A) assisted Kaiser by reviewing the metaphors, mental model, navigation, interaction, and appearance of the current state of the KICHS user interface, and by reviewing initial documents of the eventual user interface guidelines document. AM+A then

designed a series of prototype screens for the KICHS user interface and a guidelines document in both a paper- and an Adobe Acrobat PDF-format. These documents were used in focus groups to gain insight into significant needs of users and to gain buy-in of important decision-makers (physicians). AM+A specifically assisted Kaiser in the following ways:

Reviewed the organization, images, and concepts of the application as a whole with comparisons of Multiple Document Interface (MDI) vs. Single Document Interface (SDI) approaches. The investigation showed that users tended to become confused with an MDI user interface. This lead AM+A to design screens that emphasized stable, continually viewable panes of information whose sizes tended not to vary.

Reviewed initial designs and recommended useful techniques for user interface and document design.

Reviewed initial versions of the guideline documents, including the terminology, organization, images, and layout of the document as a whole.

Developed prototype screen design for the current three main screens of the user interface.

Developed an initial, 119-page UI Design Guidelines document for KICHS for use as both a print and Intranet document to assist in development.

The accompanying figures demonstrate primary alternative screens. The descriptions and explanations are intended to communicate significant intended improvements and the reasons for the changes.

3.1 Log-On Screen: Before and After

Figure 3 shows the original home screen in which the Kaiser corporate symbol and logo appear together with a sign-on pane. This area does not take up the entire high-definition screen area and contains an unused pane. Once the user signs in correctly, the user must confront another screen with primary navigation choices.

Figure 4 shows the revised home screen in which the entire screen area is devoted to conveying the visual conventions of the entire system, including typography, colors, and spatial grid. The navigation is simplified by providing the icons to the prospective user from the start. These icons would be shown in a not-selectable state until correct identification was entered and the pop-up sign-on dialogue box disappeared. (For clarity of print reproduction, all items in the figure are shown in selectable state.) The icon images are large and of photographic style, providing large selection targets to the user and providing an informative, appealing set of objects. This photographic style must be used with care, without human images, they can be helpful and not misguide or affect users with depictions of particular gender or race. Note that the e-mail icon is very culturally dependent and assumes a USA-localization. As indicated above, an alternative is more simplified pictographic signs. Initial photographic signs were considered more appealing because of the demographic characteristics of the novice, non-physician potential users.

The figure shows the home screen with underlying spatial grid displayed, which is specifically designed for large-screen high-resolution XVGA (approximately 1024 x 780, or 800 x 600) displays. Note: the 16 columns and 22, or 23, rows are separated from each other by a small number of pixels. These fundamental layout guides divide the entire screen into areas and are intended to be used repeatedly for organizing screen contents.

3.3 Schedule Screen: Before and After

Figure 5 shows the original schedule screen. The layout does not use the entire screen space, and the layout is not related to layouts of other forms displayed by the system. The icons at the top are typical of small tool-bars. The size of elements and the over-all visual density are more typical of users who are system administrators and programmers. Note that there is a background-color legend showing blue (booked), cyan (bookable), red (non-bookable), and an black-on-white (over-booked) to indicate conditions of time scheduling in the list at the left. Unfortunately, the screens apply the colors in a somewhat dysfunctional method: the times change color. This technique creates figure-background visual relations that are almost certain to be unreadable and possibly illegible. Note, also that all capital letters are used in the large form tabular lists, which makes the text more difficult to read. In addition, the data fields in the right side of the screen have unnecessary variation in their widths and locations, creating additional visual differences without semantic, functional significance.

Figure 6 shows a revised scheduling screen whose layout uses the entire screen display in a visual layout consistent with the approach intended to be used for all other screens. Note the use of large visual tabs identifying patients or caregivers with photographs for additional cues to identification. Note the repetition of the primary photographic global icons, together with space for supplementary icons local to this module of the system's operations. Other recommended changes include the following: The color key used in a small strip at the far left of the time-slot list. In this design, the colors show up clearly as small areas not confused with text, and the color legend is more obvious and less ambiguous. The proposed color code now is this: red (overbooked), black (booked), white (bookable), gray (non-bookable).

Note also that all text now appears in upper-and-lower case letters, thereby improving readability and legibility. In addition, the location and widths of data fields has been

simplified. As a suggested convention (not always supported by development tools or user expectations), the data field labels appear to the right of data fields whose contents are left-justified for text contents and right-justified for numerical contents. This layout technique guarantees an appearance and navigation ease for reading down through labels that are close to their respective data fields, unlike the original, but more commonly used convention.

One suggested improvement included the clear distinction between optional and required fill-in of data fields. Another was the use of small colored dots on small tab labels of data groups to indicate that they contain unfilled required contents and that system-supplied changes have been made in data, which would imply that a user might wish to review that content.

Figure 7 shows a revised schedule screen with the underlying layout grid displayed. Note how almost all data fields and labels have been reconfigured to conform to the grid's specifications. In large, complex tables, such as the form at the left, the field length and other layout requirements of data may not permit all columns to align with the grid's columns.

3.4 Summary Screen: Before and After

Figure 8 shows an original summary screen, which provides extensive tabular forms displays. In this case, the entire screen has been used.

Figure 9 shows another original summary screen of patient demographic data. Use of all caps as well as lack of consistent organization, layout, typography, and terminology add to the potential confusion for users.

Figure 10 shows a revised summary screen in which the two original screens have been combined efficiently into one. Demographic data appears together with tabular panes in an overall layout, typography, color scheme, and terminology consistent with other proposed displays, thereby reducing unnecessary and potentially confusing differences.

Figure 11 shows the revised summary screen with underlying grid displayed. Note that primary panes conform to the grid, but that many of the table columns do not because of the detailed requirements of data field lengths required.

4. Conclusions

The changes proposed in these prototypes are typical of improvements in information design and visual design of user-interfaces and information visualization. Prototypes developed for focus groups, manager- or investor buy-in, and for usability tests can benefit from this kind of care and attention to detail. Unfortunately, examples are prepared often without this level of design improvement and evaluations are made on the basis of deficient prototypes. Because the design space of options for all components of user interfaces and information visualization are very large, it is important to narrow the approach to initial, careful designs that can then be evaluated, analyzed, and revised further in a practical, limited timeframe and budget. The design firm has completed similar projects using the approach cited here, which benefited the development deliverables. In one case, program visualization, in which complex information must be conveyed, reading comprehension by novices was improved by 20 per cent. [11]

Kaiser conducted exemplary focus groups with physicians and nurses to determine desired directions. These prototypes were developed separately, but with the intention to support the results of the focus groups. The project manager noted there was a significant similarity in what these prototypes proposed and what the focus groups stated as needs and desires. Unfortunately, in this particular case, personnel changes, changes in decisions about platform and software building tools support affected the outcome of this project, and were not related to the prototypes themselves. Development was put on hold at the conclusion of the project (but has since resumed under different circumstances using a third-party software development firm). Nevertheless, the prototypes demonstrated that they could focus attention on specific improvements in metaphors, mental models, navigation, interaction, and appearance as development plans moved forward. Within the limited space of this paper, the discussion has focused on specific improvements in navigation and appearance.

5. Acknowledgements

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Figure 3: Original home screen

Figure 4: Revised home screen with grid displayed

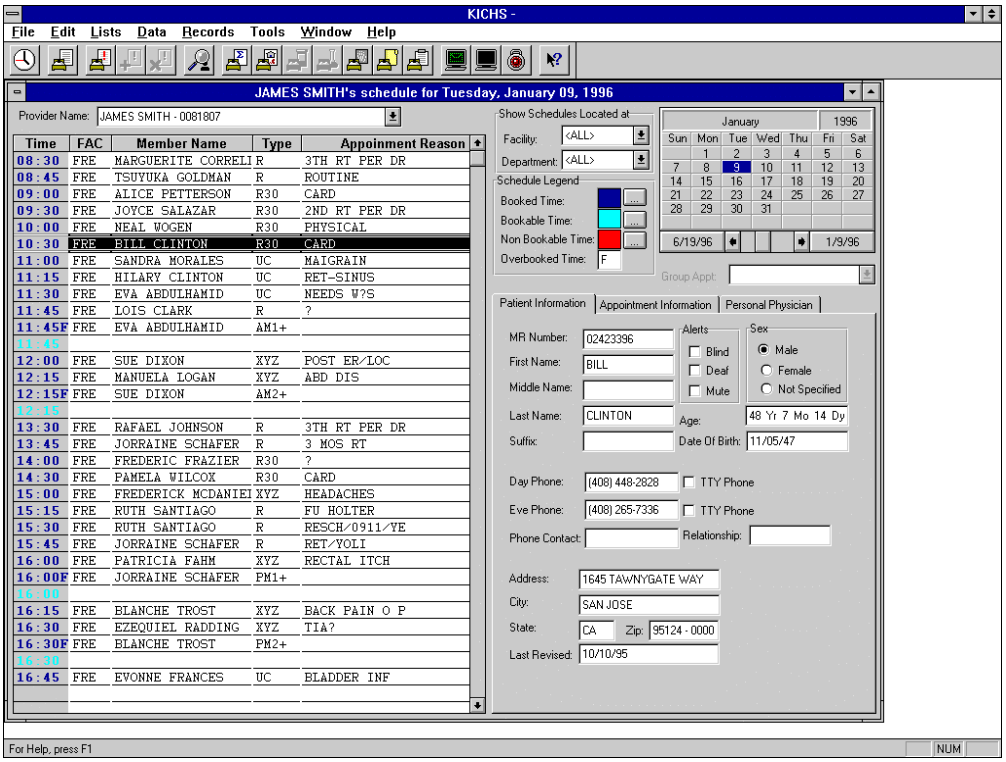

Figure 5: Original schedule screen

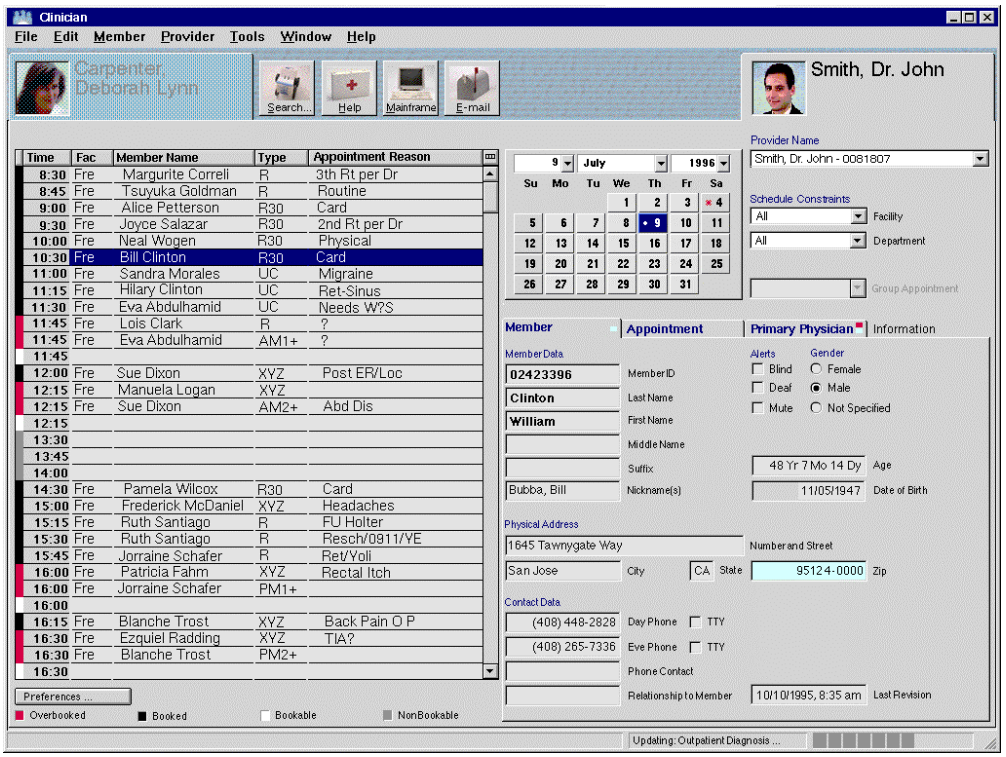

Figure 6: Revised scheduling screen

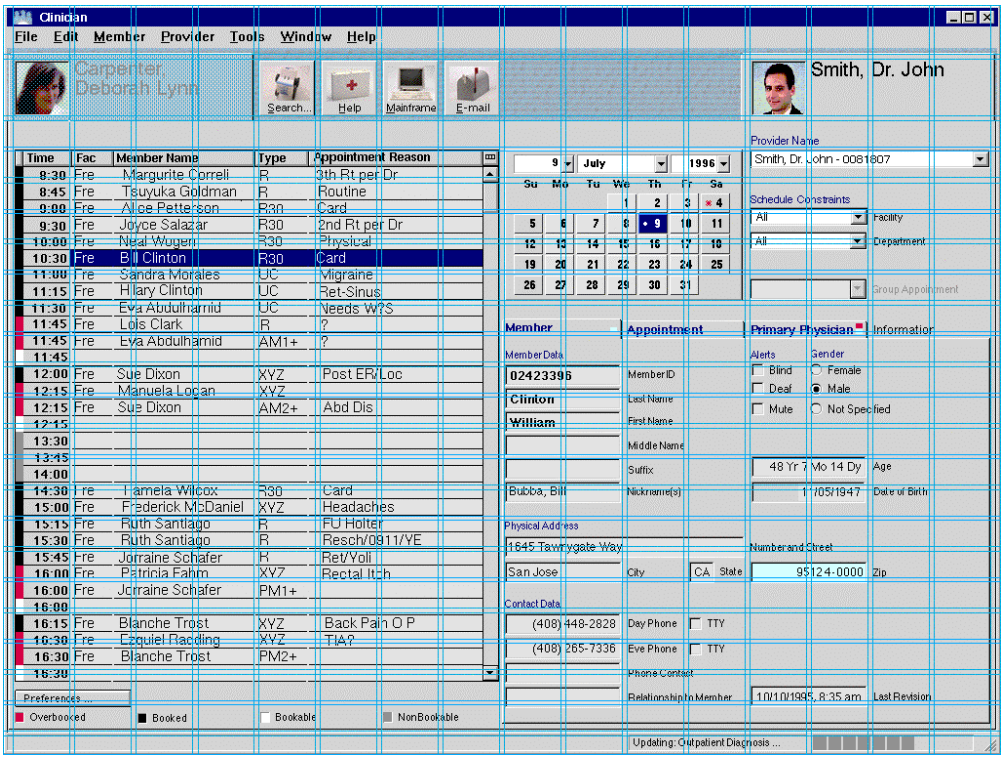

Figure 7: Revised schedule screen with grid

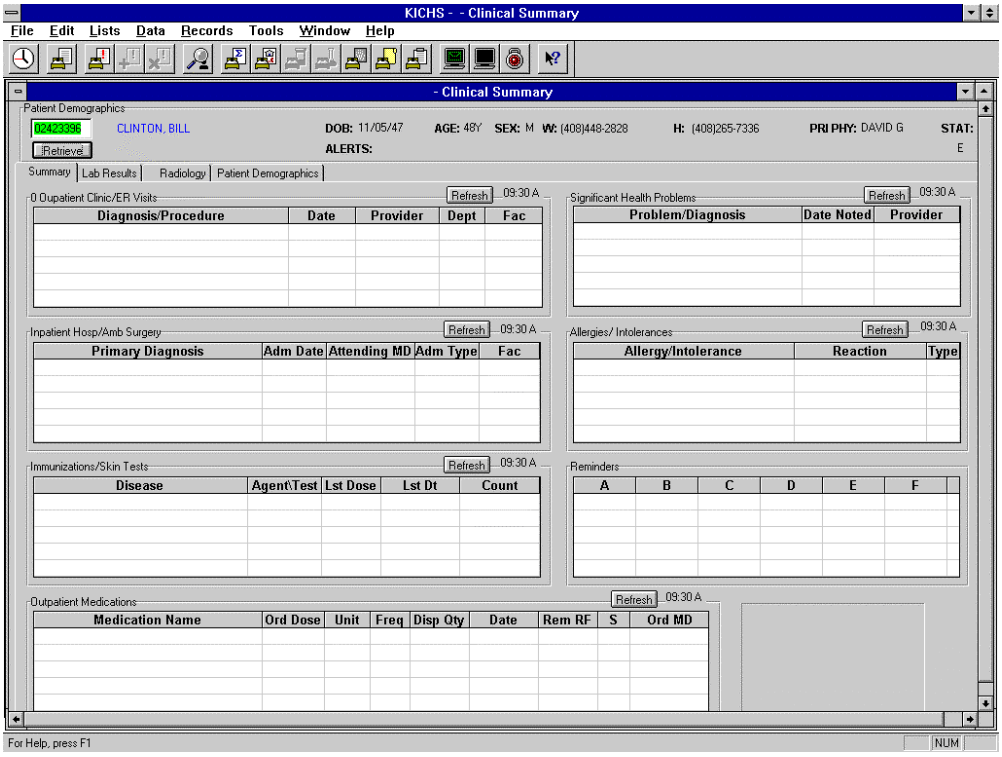

Figure 8: Original summary screen.

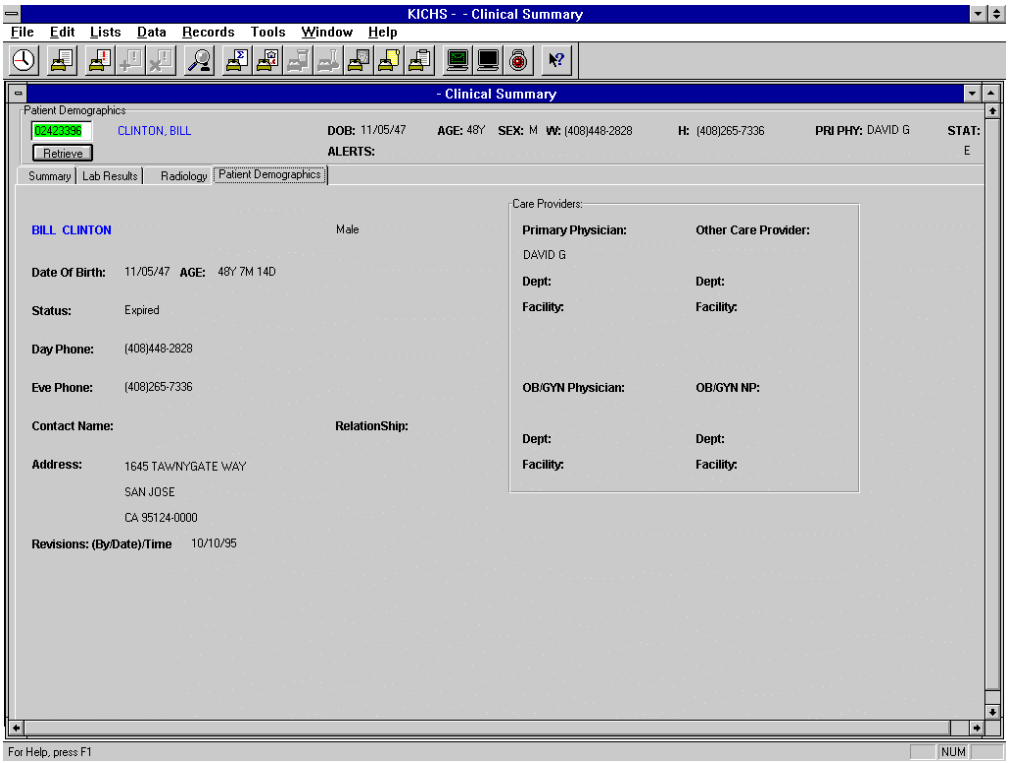

Figure 9: Additional original summary screen.

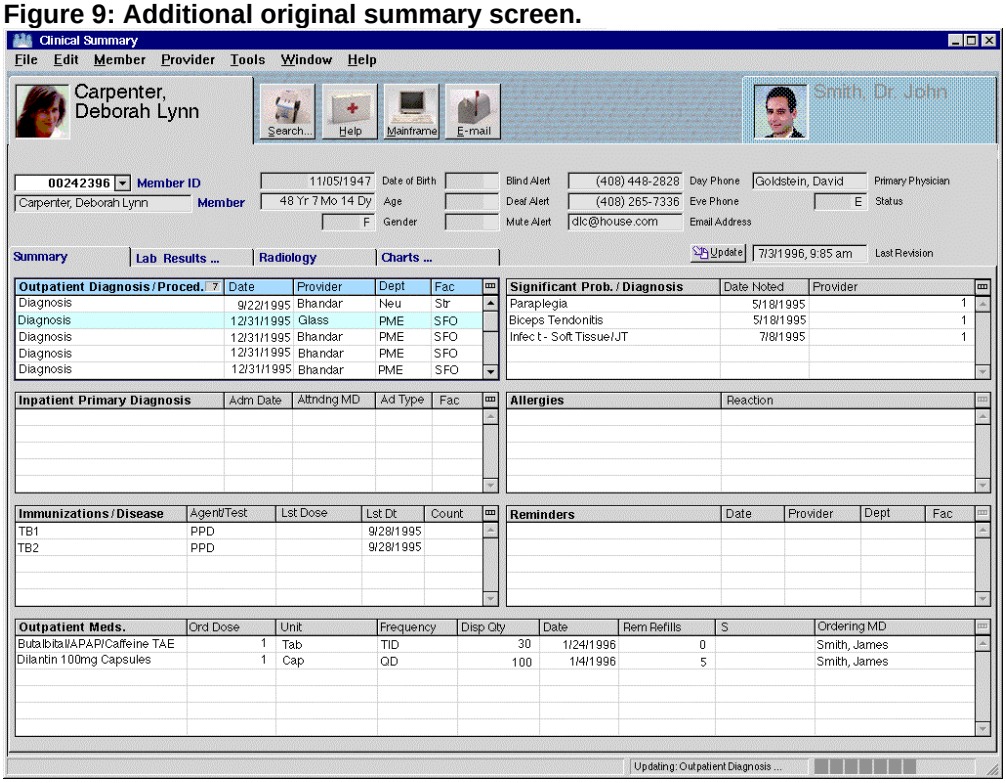

Figure 10: Revised summary screen.

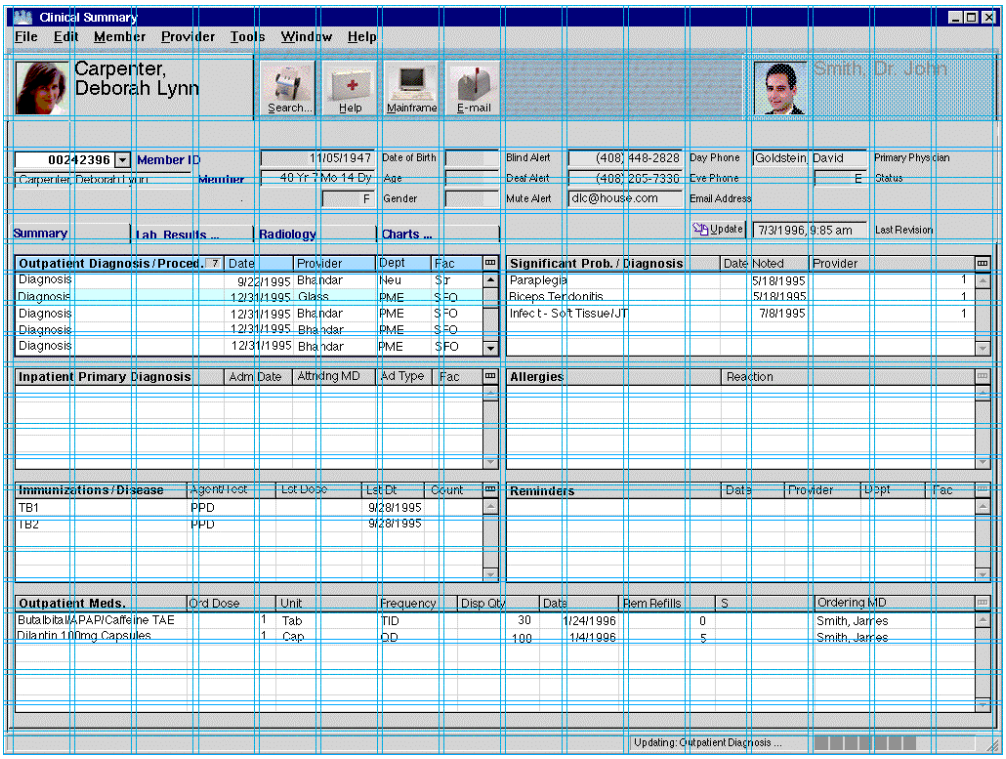

Figure 11: Revised summary screen with grid.