Towards Ergonomic User Interface Composition: A Study about Information Density Criterion

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Abstract. One way to design new interactive system is to automatically compose from existing systems. An interactive system encompasses a functional core (FC) and a user interface (UI). Many studies of the software engineering community focus on design or runtime composition of FC through components or services. However, provide good quality UI is important to make the composed system acceptable to the users. To address this need, the HCI community has studied how to compose UI at different levels of granularity. The main challenge is how to choose the best composition option in order to provide UI of good quality from the user point of view. This paper presents a step towards this challenge by proposing the chosen of the best composed graphical UI considering quality ergonomic criteria that can be automatically measured. In particular, it focuses on the information density criterion. Information density concerns the users' workload from a perceptual and cognitive point of view with regard to the whole set of information presented to the users rather than each individual element or item.

Keywords: UI Composition, ergonomic, usability, criteria, metrics, measures, evaluation functions.

1 Introduction

One way to design new interactive system is to automatically compose from existing systems. An interactive system encompasses a functional core (FC) and a user interface (UI). In consequence, to compose an interactive system, it's necessary to compose FC and UI. Many studies of the software engineering community focus on design or runtime composition of FC through components [16] or services [11]. However, providing UI of good quality is essential to make the composed system acceptable to the users. To address this need, the HCI community has studied how to compose UI at different levels of granularity (see for example, UI generation [9], adaptive UI [17], Mashups [8], UI composition [3, 7, 13]). Several options of UI

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composition are available in these works. The main challenge is how to choose the best composition option in order to provide UI of "good" quality.

Several ergonomic criteria (Nielsen [10], Scapin and Bastien [14], ISO/IEC 9241 [5] SQuaRE [6], etc.) can be found in the literature. In this paper we present our study about the information density criterion defined by Scapin and Bastien [14]. Information density concerns the users' workload from a perceptual and cognitive point of view with regard to the whole set of information presented to the users rather than each individual element or item. Therefore, it is an important criterion since it is directly worried about the user point of view. In addition, this criteria can be based on objective and digital information, such as screen size or the number of labels, which facilitates the automatic evaluation Finally, information density has a great influence on other criteria (for example legibility or prompting).

This paper presents a step towards this challenge by proposing the chosen of the best composed graphical UI considering quality ergonomic criteria that can be automatically measured. The paper is structured as follows. Based on the literature overview (serction 2) on UI composition and measures of usability, we propose new measures to evaluate information density automatically (section 3). These measures are illustrated in a case study (section 4). Section 5 presents our conclusions and future works.

2 Literature Overview

2.1 UI Composition

The **CAMELEON** European project [1] identified key levels of abstraction in UI design. These levels are based on the general architecture of Model-Based Interface Design Environment. They distinguish the domain level (user tasks and concepts), abstract user interface (AUI), concrete user interface (CUI) and final user interface (FUI). This architecture is useful for UI composition at different levels in order to generate the final interface.

Currently, different approaches developed in parallel focus in UI composition more or less directly. These approaches can be organized into two categories depending on when the composition takes place: design time or runtime.Works about **UI composition at design time** are structured according to the level of abstraction of the composition. Amusing [13] composes UI described at AUI. The composition is made by operators of composition (functions that produce UI from different UI). ComposiXML [7] allows the composition of UI by the designer. It composes trees representing the UI. The composition is performed at CUI then extended at AUI. ComposiXML proposes unary or binary operators of composition. Works about **UI composition at runtime** are structured according to different approaches: composition of the task model of the composed UI by automated planning, UI generation [4, 9], Mashups [8], adaptive/adaptable UI [17]. COMPOSE [3] focuses on the composition of the task model to fulfill the user's goal. The composition of the task model is made by automated planning. Works about UI generation are a form of composition although this term and composition operators are not explicit. For example, SUPPLE [4] generates automatically different UI for different platforms. In contrast, Mashups allows final user to manually compose applications based on data. UI are generated at FUI level. Works about UI composition at design time or runtime do not take into account UI quality. The UI quality is manually supported ether by the designer at design time, or by the user at run time. These works use functions e to compose the UI: operators of UI composition.

Operators of UI composition are central concepts for understanding how to compose UI. These operators consider temporal and spatial aspects for an UI [2]. Temporal relationships are studied through works about task models. [12] define 5 task operators: enabling, choice, concurrency, interleaving, and interruption. We will use these operators to identify different types of compositions. The spatial aspect considers spatial relationships between UI. In mathematics, spatial relationships between regions are studied by [2]. They define six possible spatial relationships between regions (and 3 inverse relationships): disjoint, meet, overlap, equal, covers and contains.

2.2 Evaluation of UI Quality

Different domains (Software Engineering, HCI and Usability/Ergonomic) propose quality standards, criteria and/or measures for evaluating the quality of a UI. In general, the UI evaluation is based on two main features [10]: utility and usability. In this context, usability is widely used by standards and models, and in general, the ergonomic criteria are associated with this feature.

ISO 9241-11 offers 27 examples of measures to meet this definiiton [5]. SQuaRE [6], in turn, proposed measures divided into four usability characteristics (ease of understanding, ease of learning, ease of use and power of attraction). Although the criterion of information density is not explicitly defined in these standards, it is clear, as explain below, that it has a real impact on the results for the questions proposed by the two standards.

Scapin and Bastien [14] proposed eight criteria for evaluating UI usability: guidance, workload, explicit control, adaptability, error management, consistency, significance of codes and compatibility. These criteria are structured in 13 sub-criteria and are accompanied by recommendations. The information density criterion "concerns the users'workload from a perceptual and cognitive point of view, with regard to the whole set of information presented to the users rather then each individual element or item" [14]. The authors argue that the users' performance is negatively affected when the informational load is too high or too low. We must remove elements unrelated to the content of the task and prevent the user memorizing long and numerous information or procedures. Five recommendations are proposed: (1) limit the information density of the screen, showing only necessary information;

(2) the information must not require translation units; (3) use the minimum quantifier, especially in query languages; (4) avoid the user having to remember data from one page to another screen; and, (5) data that can be computed from those must be automatically computed.

2.3 Measures of Quality about Information Density

QUIM (Quality in Use Integrated Measurement) [15] is a model and automatic measures of usability computed before interaction of the user. This model encompasses 10 factors decomposed into 26 criteria. These criteria are also decomposed into 127 measures. In this work, we find issues about information density on two following criteria: workload (one of the criteria proposed by Scapin and Bastien) and understandability (a characteristic of usability proposed by ISO9126). In QUIM, these criteria meet the efficiency factor (usability characteristics proposed by ISO9241-11 [5]). Table 1 presents the QUIM model and measures that seem relevant to the evaluation of information density.

Table 1. Measures relevant to information density criteria defined QUIM [15]

Criterion	Measure	Description
Workload	Depth of the interface	It measures the degree of heavy of cognitive load on users by considering the mean of display information
	Number of icons	The more number of icons, the more the memory load of the user increases to recognize and distinguish them.
	Uniformity of layout	It indicates how the visual elements of the interface are well arranged.
Ease of understan ding	Local density	It measures the percentage of space used in each individual group of information.
	Global density	It measures the percentage of display used to present all information.

3 Proposed Measures of Informational Density

Based on the current related works and measures proposed by QUIM, we propose measures to evaluate automatically the quality of composed UI. Note that we mean by UI, a WIMP graphical UI composed from existing known components. Our approach is to define objective measures, i.e. measures that can be calculated automatically before UI composition and thus independent of subjective evaluation of a designer. Proposed measures are shown in Table 2. Measures 1 and 2 are based on criteria of Scapin and Bastien. Measures 3 to 9 are basic measures for the calculation of other measures (derived measures). Measures 6, 10, 11, and 12 are defined from QUIM (Table 1).

Table 2. Proposed measures of information density

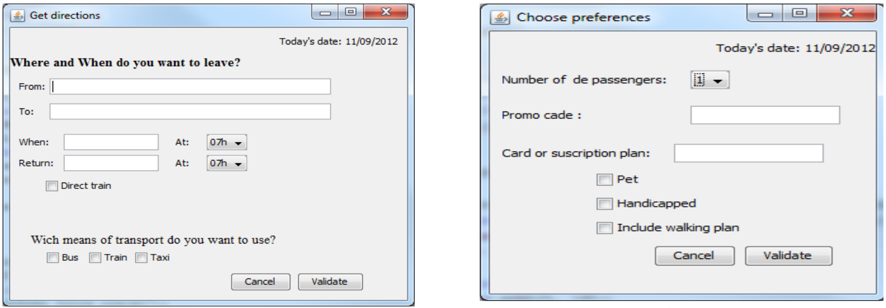
Mesure	Definition/formula
M1. Memorizing rate	(Number of data that must be stored from one screen to the other) / Total number of data
M2. Mental calculus rate	(Number of data that require calculation of the user when it could be done automatically) / Total number of data
M3. Number of inputs	Number of fields where the user must enter a value (e.g. text field, list)
M4. Number of outputs	Number of fields where the software displays a value (e.g. resulting information as a result of user input).
Number of labels	Number of entire labels, i.e., the complete sentence and not every word.
M5. Number of buttons/ icons	Number of buttons and/or icons with its label
M6. Number of pictures	Number of pictures used
M7. Number of screens	Number of screens used to perform user task
M8. Size of the screen	Size of each screen used to perform user task
M9. Density rate	(Nb inputs + Nb outputs + Nb labels + Nb buttons/icons + Nb pictures) / Nb screens
M10. Global density	Used space / total space
M11. Uniformity	It indicates how the visual elements of the interface are placed evenly between screens. It corresponds to standard deviation of densities of each screen.

4 Validation of Measures

4.1 Case Study

We present in this section a case study as an illustrative example for the application of measures of information density defined in Table 2. Consider the following scenario: *Yoann lives in Valenciennes. Its main objective is to* ***find a travel*** *that could be viewed on a map. Options are needed to drive research and others are selectable by Yoann for booking the travel he wishes (locomotion, number of people, etc.). The system should be able to advise if it wants to access a service (doctor, hotel, etc.).*

These UI allow Yoann to get direction of his travel (UI1, Figure 1a), to choose preferences as the number of passengers, etc. (UI2, Figure 1b) and to select related services as doctor, bakery, etc (UI3, Figure 1c). We suppose that the UI of travel planning system useful to Yoann can be composed from these 3 existing UI with three different operators. The first operator composes UIs in the same frame (Figure 2). The second and the third operator compose UIs respectively in tabs (Figure 3), and in sequence (Figure 4). For the designer at design time or for an adaptive system at runtime, it is an important issue to choose the best composition to produce the UI for the travel planning system. To address user needs (find a travel), using these composition operators and the evaluation of measures, we evaluate the three potential composed UIs and choose the best one considering the information density criterion.



Get directions

Today's date: 11/09/2012

Where and When do you want to leave?

From:

To:

When: At: 07h

Return: At: 07h

☐ Direct train

Wich means of transport do you want to use?

☐ Bus ☐ Train ☐ Taxi

Choose preferences

Today's date: 11/09/2012

Number of de passengers: 1

Promo cade :

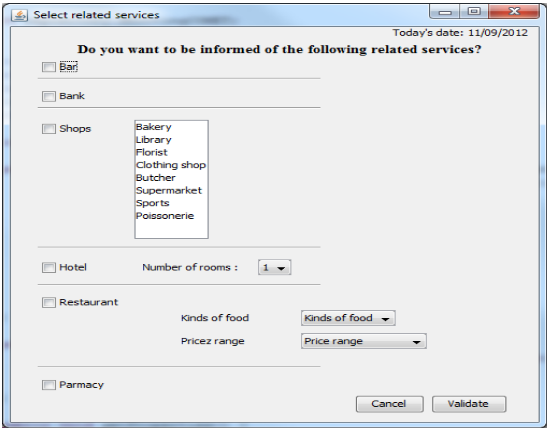
Card or suscription plan:

☐ Pet

☐ Handicapped

☐ Include walking plan

a) UI1. **b) UI2**



Select related services

Today's date: 11/09/2012

Do you want to be informed of the following related services?

☐ Bar

☐ Bank

☐ Shops

Bakery
Library
Florist
Clothing shop
Butcher
Supermarket
Sports
Poissonerie

☐ Hotel Number of rooms : 1

☐ Restaurant

Kinds of food: Kinds of food

Pricez range: Price range

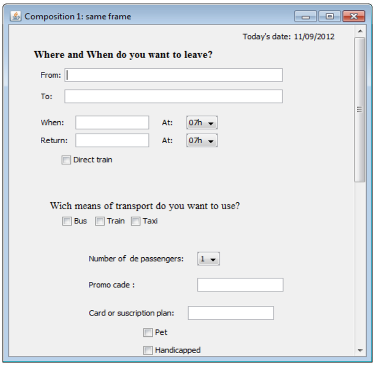
☐ Parmacy

c) UI3

Fig. 1. UI 1 to get direction, UI 2 to choose preferences and UI3 to select related services

4.2 Application of Measures on Our Case Study

From the three UI to be composed, three operators of composition have been applied considering the spatial and temporal relationships. The first composition is computed by the operators {orderIndependance, meet} with an option for the vertical placement of components (corresponding to the operator union [7] and [13]). With these operators, all information are made in a single screen, duplicate information (in this example: today's date) were placed only once (Figure 2). The second composition is computed by the operators {interleaving, equals}. It provides tabs composed of three screens corresponding to the initial UI (Figure 3). The third composed UI {enabling, covers} provides a sequence of three UI components (Figure 4). Note that the final composite UI are generated according to selected operators with the tool composition called COMPOSE [3] that composes UI dynamically.


Today's date: 11/09/2012

Where and When do you want to leave?

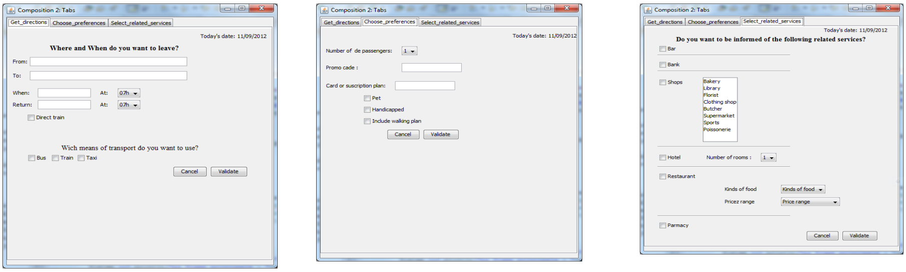
At: 07h

At: 07h

Wich means of transport do you want to use?

Number of de passengers: 1

Fig. 2. Composition 1 {orderIndependance, meet}: in the same frame


Today's date: 11/09/2012

Where and When do you want to leave?

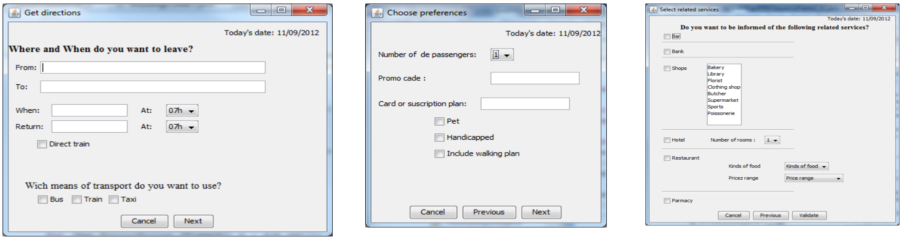
Wich means of transport do you want to use?

Number of de passengers: 1

Do you want to be informed of the following related services?

Number of rooms : 1

Fig. 3. Composition 2 {interleaving, equals}: a) UI'1, b) UI'2 and c) UI'3 in tabs


Today's date: 11/09/2012

Where and When do you want to leave?

Wich means of transport do you want to use?

Number of de passengers: 1

Do you want to be informed of the following related services?

Number of rooms : 1

Fig. 4. Composition 3{enabling, covers}: a) UI'1, b) UI'2 and c) UI'3 in sequence

We apply the proposed measures to these three compositions to compare its quality according to the information density criterion. Table 3 presents the results of measurements for the three possible compositions. In the first interface composed (Figure 2), we observe that since it has a lot of information, we must consider the need for navigation on the screen (vertical scrolling). So, there are two main ways to measure this composed UI: considering (1) the number of information visible for each navigation, or (2) all information on a screen. Since it is difficult to anticipate the number of required navigation and their results, we chose the second way, i.e., measures are performed for all information available on a screen. In consequence, in Table 3, we consider a single screen: local density corresponds to the global density

Table 3. Proposed measures applied to the three composed UI of the case study

M.	Comp.1	Composition 2				Composition 3			
		UI1’	UI2’	UI3’	Global task	UI1’	UI2’	UI3’	Global task
M1	0	0	0	0	0	0	0	0	0
M2	0	0	0	0	0	0	0	0	0
M3	26	10	6	10	26	10	6	10	26
M4	2	2	0	0	2	2	0	0	2
M5	29	13+3=16	7+3=10	11+3=14	28	13	7	11	31
M6	2	2	2	2	6	2	2+1= 3	2+1= 3	8
M7	0	0	0	0	0	0	0	0	0
M8	1	1	1	1	3	1	1	1	3
M9	521954	265468	265468	265468	796404	159960	102400	265468	527828
M10	59	28	16	24	58/3=19,3	27	15	21	67/3=22,3
M11	18,28	13,47	8,27	17,78	13,17	22,26	23,25	18,48	20,58
M12					4,76				2,52

(there are no measures of intermediate screens like the other compositions). For the other two compositions, measures of each screen are computed (thus three UI to measure for each composition) and then for the composed one (the sum for the base measures and the average for the derived ones). Thus, global measures correspond to meaningful measures for the user task (find a travel).

4.3 Results and Discussion

As the result of our case study we identified that the composition 2 is the best one because it has the lowest global density percentage (composition 2=13.17%, composition 1 = 18.28% and composition 3= 20.58). However, this finding is not completely generalizable, because it depends on the number of UI to be composed. Indeed, we note that in the case where the number of UI is important, the number of labels will be more important and will involve an increase of the corresponding measure then there will be no impact the other compositions (that means, the stability of the other measures). Composition 1 does not add information (label or button), it just increases the size of the screen. Composition 3 does not increase the need of information except for the navigation buttons (next and previous).

Note that the measurement of information density of the composition 1 gives a good result in placing all information on the same screen that is enlarged according to the number of information. Adapting the screen size is proportional to the amount of information preserves the measure of this criterion. However, it generates increased perceptive users'workload (criterion not studied here). We remember that information density criterion is one of 8 criteria proposed by Scapin and Bastien [14]. These criteria are interrelated, an individual one cannot allow the choice of the best composition in absolute. In consequence, as a perceptive, we will extend this work for studying other usability criteria.

Concerning the composition 1, as we said earlier, we have chosen to consider all the information on the total size of the screen. The user should navigate to access all the information and it could be interesting to consider subsets of information and a number of different screens. We justified this choice by the fact that it is difficult to know automatically which is the number of navigations (screen) and related information. However, a study on this issue would be interesting to measure the global density of the composition.

Measurement of uniformity allows knowing the standard deviation between the densities of individual screens. This can be noted in the composition 2, where the density is lowest because the three screens provided and presented in tab have the same size. This final size is the size of the largest initial UI to be composed. Thus, the global density measurement of UI'1 and UI'2, and composed UI are decreased. While in the composition 3, screen sizes are independent and thus the densities remain close to initial densities.

Moreover, we do not want to remove measures 1, 2 and 7 because they seem important for this criterion, even they were not completely illustrated by the case study. Other examples could be analyzed involving this information to conclude on their impact on information density.

5 Conclusion

At design time to ease the works of designer, as at runtime to provide a quality UI, the need to compose ergonomic UI is central. This article is a first step towards ergonomic UI composition. Note that this study focuses on WIMP Graphical UIs composed by a central orchestrator (corresponding to service orchestration) from existing component. This work proposed and applied objective measures to evaluate information density criterion. These measures automatically predict what the best composed UI according to this criterion. We are aware that criteria are interrelated and should not be evaluated only individually. Therefore, we are now working on the definition of measures for other ergonomic criteria.

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