DESIGNING A SOFT PREFERENCE BASED SEARCH INTERFACE FOR THE HOUSING MARKET

Kevin Oudshoorn

University of Amsterdam
Centrum Wiskunde & Informatica
The Netherlands

ABSTRACT

Websites aiming to assist users in finding a new house are becoming increasingly popular. Finding a potential relevant house is based on the users' search criteria and the ability to define these criteria in an easy-to-use search user interface. Due to hard constraints, over-specification is one of the problems many users encounter when searching for a house online. In this paper, we propose a soft constraint based search user interface for the housing domain. Our analysis of existing websites and user opinions suggests the need for an interface with more flexibility towards the user, with a focus on ranking relevant items according to the user's weighted importance for selected filters. The proposed interface design is evaluated with five potential users and reflects on the impact and possible improvements.

***Index Terms*—** user search interface, soft constraints, searching, housing, usability, System Usability Scale, ranking

1. INTRODUCTION

Optimizing (search) user interfaces has been a field of study since the increasing popularity of the Internet [23, 25, 28]. With a lot of alternatives for almost every domain, it is becoming more important to focus on usability and functionality to keep (potential) users interested in your application. Our main objective is to determine difficulties in current interfaces and interface development, determine the requirements for an interface improvement and present functionalities to satisfy these requirements. Our focus is on using soft preferences within the housing domain to support users.

Search tasks in the housing domain range from relatively simple low level queries to extensive constraint based searches. For example, a user can search for a house in Amsterdam with a price range between € 200.000 and € 300.000. This basic query will result in an abundance of matched results. After all, it is likely that thousands of houses in Amsterdam are within this price range. In this particular example, the user will have to browse through a large number of houses that do not match the criteria, apart from the price and city. However, current websites in the housing domain offer extensive filtering to narrow the search scope [6, 9, 10], by defining values for different features. With this filtering, the user can easily specify constraints for a search task. Although this option increases the usability of a search interface, it also introduces new challenges and poses new problems. Over-specification by filtering is a well known problem in many industries [20]. As a result of applying too many constraints to a search query, the results will be over-specified, causing the number of results to decrease. The constraints on housing websites are *hard*, meaning there is no measure of satisfying the constraint. If, for example, a user searches for a house in Amsterdam, the system will *only* search within the boundaries of the city of Amsterdam. The opposite of hard constraints, *soft constraints*, allow the system to search outside the boundaries of the defined constraint and therefore *soften* the preferences with a *margin*.

This study has been carried out in order to explore the possibilities to solve some of the existing problems in the housing domain. As mentioned above, over-specification is one of the problems users encounter in their search for housing. By specifying all the preferences a user has, it is likely to come to a point where not enough items are retrieved by the system to make a well evaluated decision. Therefore, it is likely that a user is going to change, or exclude, certain values of the query in order to retrieve more results. Consequently, the results will become less relevant and more widely spread. This problem is caused by *hard constraints* in the matching algorithms of existing search engines. Another problem users face is the lack of ranking. If, for example, 20 items are retrieved based on the user's query, no ranking within this list of results is applied. Although some items are likely to be more relevant than others, the user has to consider each item in order to conclude which items are most relevant with respect to the search criteria. This study aims to solve the visual aspect of both these problems by presenting an interface that allows users to define soft preferences during a search.

Our study consisted of three stages. The first, the preliminary study, was constructed to analyze how existing search engines assist users in their goal to find houses that match

their criteria and how users experience these websites and what their likes and dislikes are. Based on this preliminary study, the requirements for a soft constraint based interface were specified. During this second phase of the project, mockup interface designs were made to visualize the suggested methods to satisfy the requirements. Finally, in the third phase, an evaluation study was carried out to test the usability of the interface. This paper will discuss the three stages of the research project.

2. RELATED WORK

For this study we illustrate three related fields. First we consider search and comparison systems in multiple domains. We then discuss problems with basic search engines and how current developments pose a solution for increasing the precision of retrieved documents. After mentioning a practical and relevant example in the travel industry, we conclude by mentioning a study about making tradeoff decisions in order to satisfy a desired outcome.

The search industry and housing market are directly associated with this study. Current state of the art search and comparison tools are widely spread over multiple domains [1, 4, 5]. Within the housing market, an increasing number of websites aims to assist the user in their search for housing [6, 9, 10]. At this moment, these websites do not offer ranking of search results; where the most relevant items are placed on top of the list. The websites also lack any form of soft navigation; where users are allowed to weight different features to increase the relevance of the ranked results [29]. Defining soft constraints has proven to increase the relevance of the search results [30]. Another missing element, currently found on many search- and comparison websites is the ability to compare multiple retrieved items with each other.

By giving users the freedom to finetune the search query, more relevant results can be retrieved. An example is the Strategy Builder™[21], developed by the CWI Spin off company Spinque [13]. The search engine was demonstrated during the Cross-Language Evaluation Forum of 2009 [3] and retrieved five times as many relevant patents at the PatOlympics [12] as any other team, by modifying the search strategy during the search session, as opposed to being hardwired. However, the Strategy Builder™is currently more focussed on the technical framework. To successfully implement the search engine in other domains, an interface needs to be developed to complement the technical framework. The interface should incorporate intuitive methods of defining soft constraints in order to potentially improve the user's search results.

An example of soft constraints being utilized in a search interface is VindEenReis [16]. This website, focused on the travel domain, provides a playful and intuitive way of defining soft constraints. By dragging icons, with a predefined preference or constraint, into a two-dimensional area with *non important* on one side and *important* on the other side, users can fine-tune their query. For example, when searching for a hotel in Barcelona, a user can decrease the importance of a swimming pool and increase the importance that pets are allowed. The retrieved suggestions will likely be of more relevance, compared to search engines that do not offer this functionality. Apart from an expected increase in the precision[1] as well as recall[2] and an expected decrease in fall-out[3], this method of soft constraints can save time when looking for a holiday location. Directly applied to the housing domain, this could result in more relevant items with a better ranking within the retrieved results.

Pu en Faltings [27] state that *"Preference construction is rather straightforward as long as outcomes more or less satisfy all of the users' preferences. However, in most practical situations, there is no outcome that satisfies all preferences. In this case, finding a solution requires making a tradeoff: accepting an outcome that is undesirable in some respects but advantageous in others."* Although their research is mainly focussed on the technical and mathematical layer, in essence their solution for the hard constraint problems found in modern search interfaces is directly applicable to the practical problem presented in this paper. A soft constraint based system has to make a trade-off in order to rank results by relevance.

The outcomes of these related studies and examples support the assertion that soft preferences are being used to solve practical problems in the search industry. The positive outcome of the Strategy Builder™and the implementation of a soft constraint based search interface for the travel industry shows potential improvement for the retrieval of relevant search results in other domains. This study is focussed on searching for houses, containing many different features. Making a tradeoff based on the importance of different filters and values, is directly applicable to this domain.

3. PRELIMINARY STUDY

The three goals set for the preliminary study are: (1) gain insights in current website content and functionalities, (2) examine development processes and discover difficulties and challenges of experts within the domain and (3) determine users' opinions about current websites and investigate the support for new functions.

The first of three steps was to analyze the content and functionalities of existing websites. Four leading websites in the housing domain chosen were: Funda [6], Jaap [10], Huizenzoeker [9] and Niki [11]. These four website are considered to be leading in the housing domain [8]. To sget a better understanding of available functionalities on current web-

[1] the fraction of retrieved documents that are relevant to the search

[2] the fraction of the documents that are relevant to the query that are successfully retrieved

[3] the proportion of non-relevant documents that are retrieved, out of all non-relevant documents available

sites in the domain, we identified the differences - and similarities - between these websites, with a content- and functionality comparison. This included searching, browsing and filtering. The functions were categorized and summarized in a matrix for easy comparison (Fig. 8 to 11 of Appendix A).

To get a better understanding of the housing domain and the challenges of providing a search interface, in-depth interviews were scheduled with experts working for three of the biggest companies in the housing domain. For privacy reasons, the companies will be referred to as C1, C2 and C3. The head of user experience at C1, the managing director of C2 and the CEO of C3 each participated in an hour-and-a-half long in-depth interview to discuss various topics, difficulties and challenges on which this study was focussed. For later analysis, the interviews were recorded with the consent of the interviewees.

To gain insight in user experiences and to gather quantitative user data of different functionalities currently being offered, a user survey among end-users was carried out. The survey consisted of 34 questions[5] (see Appendix B). The first 5 questions (Fig. 12 of Appendix B) captured the demographic profile of the respondent. Questions 6 to 8 (Fig. 13 of Appendix B) determine whether the respondent had bought a house, when this house was bought and whether or not this house was bought using a housing website. The 18 questions that followed (Fig. 13 to 19 of Appendix B) were to determine how the respondent perceived the existing functionalities, which preferences might be important and how the respondents would rate potential new functionalities.

The results of the analysis, expert interviews and user survey were used as input for the requirements and interface development process.

3.1. Results

3.1.1. Content- and functionality comparison

The results of the analysis (Fig. 8 to 11 of Appendix A) gives a comparison of functionalities of the four websites. We divided the four websites into two categories: *advanced* websites, containing Funda.nl, Jaap.nl and Huizenzoeker.nl, show similar basic initial search options such as *city, radius, postal code, price range* or *specific address.* The second category, the *basic* website, containing Niki.nl, gives no support to search for a specific postal code or within the radius of a certain city or postal code. It does, however, enable a user to search within a province or in multiple cities. This website is solely intended for people interested in buying newly built or to be built houses.

Where 2 of the 3 *advanced* websites have the option to search with a map, the *basic* website does not have this option. Another result is that only one of the *advanced* websites provides information about related topics outside the main goal of the website. This particular website provides information about moving, mortgages and real estate agencies, as well as a forum, a blog and a webshop.

One of the differences found during the analysis was that not every website provided the same sorting options. Two of the three *advanced* websites have the ability to sort by address, postal code, square meters of living area, square meters of ground area, date, asking price, price change or by real estate agency. Only one *advanced* website has the option to sort the results by city or number of rooms. The *basic* website has the fewest sorting options. It only allows an end-user to sort by city, type of house and asking price. Although none of the *advanced* websites have the option to sort by type of house, it is presented as a filtering option. Users can define a single type of house, for example an apartment, and *filter* out all the other types of houses.

Furthermore, the analysis has shown that none of the websites appears to be using ranking for their result list. Although sorting is optional for the user, the retrieved items, based on the search query, are initially unsorted. Also, none of the websites seem to be using weights for filters. All of the constraints are therefore *hard* and are not subject to different levels of importance.

3.1.2. Expert interviews

During the interviews, the experts were asked to describe the development process of their company's website from the beginning to the end. The outcome of the interviews shows a difference in approach for all websites. C3, for example, explained that a small web-design company did all their development, based on sporadic requests from the client. The lack of innovative design and functionalities was the result of this development approach. At the other end of the scale was C1, with an in-house team of 15 programmers, 4 interaction designers and one head of user experience. Both companies claimed to have never conducted a usability test among users. At C1, website development is based on an evolution model, where new functionalities are completely based on in-house ideas and expertise. The modules are built and integrated in the lower levels of the existing structure to start as a secondary functionality. Based on web-statistics, like Google Analytics™[7], the developers can determine whether the new module is working or not. If the results are positive, the module or functionality is given a primary position in the framework, where users can interact with it more intensively. If the results of these statistics are unsatisfying, the entire functionality is discarded or redesigned. C2 does conduct user surveys and usability tests among existing users with the online usability tool Usabilla [15]. New ideas and functionalities are presented to a panel of end-users and thoroughly tested, before the new module is implemented in the existing framework.

The experts have confirmed the findings from the anal-

[5] the 8 open questions of the survey are not included in Appendix B for privacy reasons

ysis regarding the ranking and soft constraints. The results are unsorted at first, where sponsored houses - the houses of real estate agencies that pay extra to be placed high in the list - are placed on top. These houses are not necessarily more relevant than the retrieved houses placed on the bottom of the list. These sponsored houses have proven to be within the boundaries of the specified criteria. However, no ranking other than commercially based, was applied. The lack of ranking is partly because of the lack of soft constraints. Users do not have the opportunity to weigh their personal criteria by importance. For example, if a user values the presence of a garden more than, for example, 4 rooms, it is impossible to define this difference in personal preference. With hard preferences, all items within the boundaries of the constraints are considered equally relevant. Because none of the items are given a score, ranking based on relevance or match percentage is therefore *impossible*.

None of the interviewed companies did any research about search strategies or trends within the housing market.

3.1.3. Online user survey

A total of 50 respondents participated in filling out the online survey (Fig. 12 to 19 of Appendix B). 56% were male and almost half of the respondents were between 26 and 34. The ages 17-25, 35-44 and 45-55 each represent around 15%. Of all the respondents, 82% bought a house and 54% did this more than 4 years ago. All of the respondents had used a website for housing purposes before, although not always linked to the actual bought house.

The website with the most houses and unique visitors each month [8] - Funda - was also the most popular. 98% of the respondents claimed to have visited Funda at least once. In second place was the second largest website [8]: Jaap with 46% of respondents. Marktplaats, the biggest online marketplace [14] in the Netherlands, turned out to score third place with 30%.

The results in figure 1 are based on questions where the respondent could indicate the importance of the suggested functionality[1]. The results show that *plots on a map, comparison with a table* and *showing partially matched results* are most important to the users. The *sponsored houses, mortgage offers* and *searching in multiple cities* are considered the least important. In addition to the quantitative data from the survey, some qualitative findings were gathered. The majority of users consider the existing websites useful because of the available number of houses. Although not every house for sale can be found on the internet, the majority of respondents consider the websites *complete*. A large group of respondents filled in that the number of pictures per house was the main reason to use a housing website. Only 4 respondents claimed that filtering was the reason for their visit. This could indicate a level of ambiguity for this functionality. The usage

[1]Five point Likert scale: 1: very unimportant 5: very important

Fig. 1. Average score per statement

statistics, although unfortunately not public, should indicate whether the filters are actually not used as much as the companies expected. Experts have stated that an average between 3 and 4 filters are used.

To the (open) question what people missed on current housing websites, 10 respondents mentioned previous prices of similar houses and 10 considered information about the neighborhood to be very useful. The rest of the respondents all replied differently, ranging from floor plans to a social aspect of searching for a house.

The majority of respondents complained about the amount of advertisement and the *illogical* sorting of houses.

3.2. Key findings

The content comparison provided insights into the functionalities and content currently found on websites. The majority of websites offered similar search options. On all websites, users have the ability to sort and filter results.

The results from the survey showed that end users appreciate a support where items that do not match the complete set of criteria, are shown nonetheless. The ability to compare individual items with each other in a table was positively rated by the users.

Negative elements identified were the abundance of irrelevant advertisements in the form of banners and that sponsored houses are placed in the top of the list. Although mortgage offers from various banks can be considered relevant for the housing domain, users rated the importance of these offers very low. The sponsored houses in the result list appear to be within the criteria boundaries, however, users did not agree with the method of ranking found on the selected websites.

4. REQUIREMENTS

Based on the findings of the preliminary study, we specify a number of user requirements. Note that regular requirements like searching, browsing and sending inquiries are intentionally left out, since they are fairly common to search interfaces

and not specifically for the housing domain. Therefore, we consider these basic search requirements self-evident.

4.1. Matching

Due to hard constraint algorithms, most existing search interfaces currently do not show items that do not completely match users' constraints [22]. Two of the three experts confirmed that over-specification is one of the problems users encounter. The retrieved items based on the given query and constraints, exclude items that could be relevant to the user. A small portion of respondents to the online survey indicated that over-specification poses a problem for them and the risk of missing something that would suit their wishes, keeps them from fully utilizing the potential of filtering.

The user needs a search interface that prevents over-specification caused by hard constraints. The potentially relevant items that are excluded in the current retrieval systems, should be displayed to the user, indicating their relevance for the specified query and filters. The anticipated improvement in precision and recall is likely to result in a higher degree of satisfaction for users.

4.2. Ranking

Experts have indicated that none of the websites examined in this study use any kind of ranking when displaying the search results. Currently, the retrieved list of items is sorted by a commercial point of view. Real estate agencies can decide to pay an extra fee to receive a higher ranking for a particular item. Of the respondents, 94% indicated not to be interested in these sponsored items and would prefer to see more relevant items to their own interest, placed higher in the list.

To increase the usefulness of a ranked list, a user should be able to define the importance, or weight, of a constraint. Therefore, the user should be offered a search interface where the retrieved list is ranked according to their specified preferences and filters. The items should be sorted by their relevance, where the most relevant items are placed on top.

4.3. Comparison

Current search websites within the housing domain do not offer the option to directly compare multiple items in an efficient and commonly known format. The option to compare features such as the number of rooms, size of the living area or the energy label assigned to the house is currently not available. During the interviews, experts stated that easy comparison of items in a single interface has not been made available partly because of the inconsistency in data and partly because of their, unfounded, expectation that users do not consider this function useful. Although websites in the housing domain do not offer any type of comparison, similar comparison needs and their respective solutions have found to be successful in other domains. In, for example, the consumer electronics domain, Dell [4] and Apple [2] offer the ability to compare products in a very intuitive and user-friendly way. Although the leading websites in the housing domain do not offer a solution to the stated requirement of comparison, 69% of the survey respondents consider comparing items as a very valuable functionality.

The user needs to be provided with the option to compare items. This comparison should be a primary functionality, where all the features of a house can be compared with minimum effort.

5. INTERFACE

In the design phase, we designed an interface that would satisfy the user requirements. The interface screens were made using a low-fidelity sketch technique and resulted in 4 *mock-ups*. These mockups focus on usability, rather than design. To support the basic activities of online searching, the mock-ups are based on existing search interfaces. For the evaluation study, four states of the interface were made to accompany the different tasks.

Note: high resolution versions of the 4 interface screens can be found in Appendix M to P.

5.1. Interface description

The first screen (Fig. 2) is a basic search field with tabs to distinguish houses that are for rent and houses that are for sale (A1 of fig. 2). On the left there is a Google Maps^{TM}integration to define a location (A2). The red dot in the center is the absolute location, for example the center of the city of Amsterdam, and the slightly bigger circle is the defined radius. On the right of the map, an input field for city, postcode or streetname is placed (A3). Right of this input field is a drop-down menu for the desired radius (A4). To define the price, a single slider is placed beneath the input field (A5). The button to search is placed in the bottom-right corner, displaying the number of relevant found items.

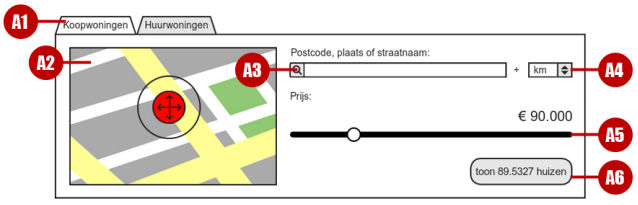

Fig. 2. *search interface screen 1*

The second screen (Fig. 3) is the result page. The retrieved

items are placed in a list view with a checkbox to select individual items, a series of buttons to add an item to the favorites, send a message to the real estate agency and e-mail an item to a friend (A3 and A5 of fig. 3). To the right, a label is placed with the relevance to the search query, in percentage (A6). A label with '100' indicates a full match, coloring the label *green*. Anything between '50' and '100' is a partial match, coloring the label *orange* and anything under '50' is considered no match, coloring the label *red*. The picture of the retrieved house (A7) is located to the right of these buttons and is followed by a description (A4). The features shown in the list view are the number of rooms, size of the living area and price (A2). The list can be sorted by either of these features. The personal search strategy (B) is placed on the right of the screen with the chosen filters in a list (B2). Each filter is accompanied by either a slider or a drop-down menu and a 5-star ranking. At the bottom of the personal search strategy box is a button to save the particular search strategy to the users profile (B3). At the bottom-right of the screen are additional, inactive filters (C). On the top left, the user is able to switch between the list view and the map view (A of fig. 3).

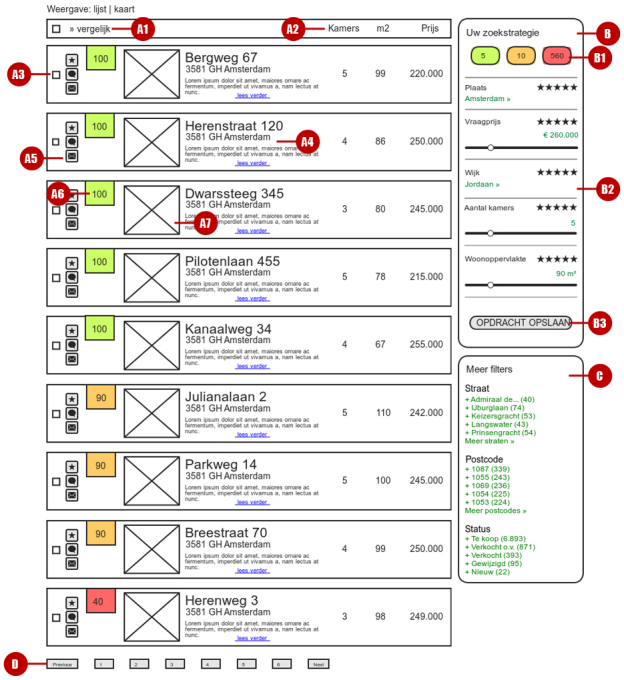

Fig. 3. *search interface screen 2*

The third screen (Fig. 4) is the map page consisting of a Google Maps^{TM}integration to view the plotted houses (A1 of fig. 4). The personal search strategy section is identical to the second screen (Fig. 3). Plotted houses on the map show a pop-up with more information, when the user moves the mouse over an item.

Lastly, the fourth screen (Fig. 5) is the comparison page

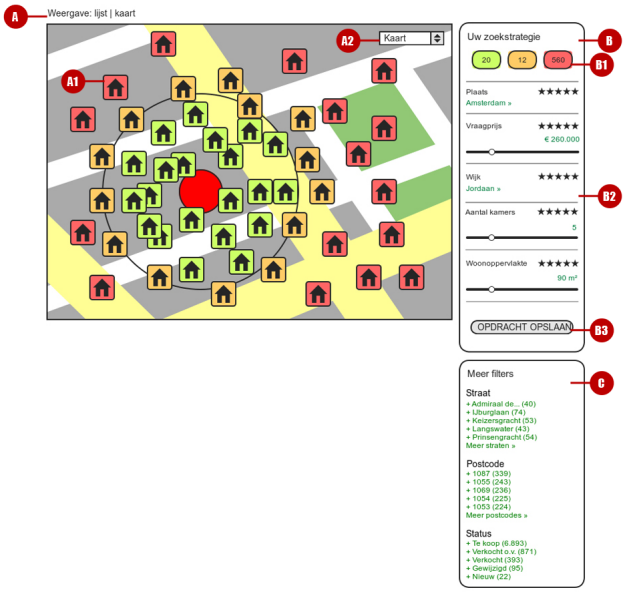

Fig. 4. *search interface screen 3*

with a table of the selected houses. On top of the columns are options to add the house to the users favorites, e-mail the house to a friend and delete the house from the comparison table (A1 of fig. 5). The rows represent the features (A3) and on the bottom is a button to go back to the list view (A4).

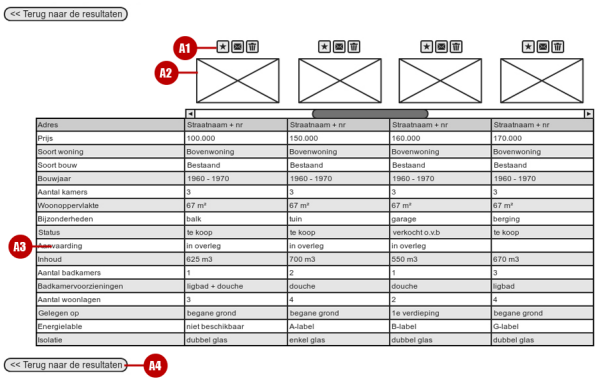

Fig. 5. *search interface screen 4*

5.2. Rationale

Because the suggested mockups are intended as solutions to the defined requirements, we will discuss the functionalities of the interface based on these requirements.

5.2.1. Matching

To support matching, an existing functionality found on all the example websites in the domain has been incorporated in the search screen. The user has the ability to specify a soft constraint for the area to search in. By adding the option to define a radius, a typical hard constraint, like the city of Amsterdam, is softened and could include an area around Amsterdam. If a user does not have a strict preference to explicitly live in the city boundaries of Amsterdam, the radius function will increase the number of houses retrieved by the system and will also increase the possibility that more items match the user's criteria.

To further support matching, the result screen (Fig. 3) visually informs the user of the matched results by labeling the retrieved items with one of three colors: (1) green, a full match, (2) orange, a partial match and (3) red, no match at all. On the right of the screen, the three colors are shown with their respective number of retrieved items. The colors *green, orange* and *red* were chosen because they are often used in different contexts to represent similar meaning. For example, green is commonly known as a color that indicates a pass or a good/high value. Orange is often used to indicate a medium value and red is frequently used in many contexts to indicate a low or bad value. Below these three items, the personal search criteria is shown with a 5-star ranking scale to define its importance to the user. By assigning a higher rank of importance to, for example, the price, opposed to a lower rank of importance for the location, in this case Amsterdam, the matched results change to better satisfy the user's personal preference and the importance of each filter. We have chosen to use a 5-star ranking scale for it is often recognized as a rating device. During the design process, we have considered another approach for the weighted constraints. At first we wanted to represent the list of chosen filters as a ranked list. A user would be able to drag a filter to the top of the list and rearrange specific filters to distinguish their importance. However, if, for example, two filters are equally important to the user, it is impossible to assign the same weights to these filters. The 5-star ranking in our interface allows the user to weight multiple filters the same.

For particular filters with defined values, for example the number of rooms or the size of the living area, decreasing the importance could result in retrieved items that show slightly different values for these features. The margin for these filters increase, as the importance of the filter decreases. This is visually supported by color variations on the slider[1], indicating a wider, or narrower, margin. For this solution to the matching requirement, we have considered another option. By adding a second selector to the slider, the user would be able to define a minimum and maximum value. Although this increases the flexibility of a filter, it poses a new problem. Combined with the 5-star ranking, the second slider becomes obsolete. After all, decreasing the importance of a value, automatically allows the search engine to search within a soft margin. Therefore, we consider a single selector slider to be the most effective.

On the map screen (Fig. 4) the user is again informed by the match score of the items. Fully matched items are green, partially matched items are orange and non matched items are red. The map will also show the defined radius.

[1]The color variations are not shown on the interface screens

5.2.2. Ranking

The list on the result screen (Fig. 3) is always ranked, based on the relevance of items according to the search criteria. This is visually supported by green, orange or red labels per item in the list. Within this ranked list, a user is able to sort on the number of rooms, size of the living area and price. This will change the order of the list, based on the feature to sort by. However, more relevant items are still ranked on top, within the selected sorting. In this case, the relevance will be the *primary* sorting and the chosen feature will be the *secondary* sorting.

5.2.3. Comparison

To support the comparison requirement, the results screen (Fig. 3) shows the option to select multiple retrieved items with checkboxes. These selected items can be compared by clicking the compare button. This button will show the comparison screen (Fig. 5). The user is able to compare the selected houses in a table. The features for each house are placed on the rows of the table, whereas the values of these features are shown in columns, where each column represents a single house. The user has the ability to add houses to their favorites, delete houses from the comparison table and send a single house per e-mail to a friend.

6. EVALUATION STUDY

To evaluate the proposed interface elements for soft preferences, we conducted an informal usability test [24]. Studies have shown that 5 participants can identify up to 85% of the major usability problems in the early stages of interface development [26]. We asked 5 participants to perform predefined tasks using static, non interactive, mockup interfaces presented to them. Three of the participants were from the University of Amsterdam. One is studying Psychology and two are studying Computer Science. The remaining two participants are highly educated, but less experienced in modern interfaces. During the evaluation, the participant's spoken words and performed actions were recorded for later evaluation. Because static mockups were made, the evaluator had to 'play' computer and describe the interactions with the system. For example, if a user clicked on a button, the evaluator described the system's action. During the evaluation,

we tested how well the search tasks were supported by the proposed functionalities, based on the user requirements.

The participants were each given a simple scenario:

> *"You are 34 years old, living in a rental house in Utrecht. You have found a new job in Amsterdam and decided to move to Amsterdam with your partner and 2 children of 5 and 6. You and your partner earn enough to be able to afford a house of €260.000. Your partner is working part time at home and you enjoy sitting in the sun at home in the summer. You consider a good neighborhood for the children very important and are willing to live just outside the city center, so your children can play outside safely."*

With this scenario in mind, the participants had to perform a series of five tasks. Each new task was an addition to the task before and would in the end result in the completion of a primary goal: *find a suitable house for your family, based on the user's situation and preferences*.

The tasks were as follows: (1) search for a suitable house in Amsterdam, (2) search for a suitable house in Amsterdam for your family and wishes, (3) considering your situation, find a suitable house for your family, (4) view the retrieved houses on a map and (5) compare all the features of the first five houses.

While performing the task, the participants were strongly encouraged to *think-aloud* [18, 24, 31] in order to gather as much qualitative data as possible. This think-aloud method as an analysis protocol has been used in many usability studies and is a popular qualitative and informal evaluation method, especially for explorative studies such as the one presented in this paper. In addition to the standard think-aloud method, we carried out a short survey after each performed task to instigate a dialog with the participant about the performed task.

6.1. Results

6.1.1. Matching

During the evaluation we observed how the participants would recognize the elements incorporated in the interface to satisfy the matching requirement, while performing 5 tasks.

During the first task, users had to interact with a commonly known option, where the the radius to search in had to be defined (A4 of fig. 2). This function is intended to increase the retrieved number of houses and therefore include potentially relevant houses. Of the five participants, four identified this functionality correctly and used the option to specify the search area. The last participant mentioned the need for an advanced search option.

During the second task, the labels on the retrieved items (A6 of fig. 3) to indicate the match were correctly interpreted by three of the five participants. However, after explaining the labels to the other 2 participants, all of them agreed it was a useful addition. The three different colors on the right of the screen were identified correctly by three of the five participants (B1 of fig. 3). Three of the participants were confused by the changing number of houses in the red label and four considered knowing how many items did not match their criteria, completely irrelevant.

For the third task, three of the participants used the 5-star ranking function (B2 of fig. 3) to decrease the importance for the price and increase the importance of the number of rooms and specified neighborhood, in this example Jordaan, in an attempt to increase the accuracy of the ranked list of items. The remaining two participants chose to sort the list by price or number of rooms in an attempt to complete the task (A2 of fig. 3). During the survey, it became apparent that these participants did not interpret the 5-star ranking as the importance of the respective filter. One of them considered the stars as a matching indication and the other one as a user rating for, for example, the city of Amsterdam. After clarification by the evaluator, four of the participants considered the functionality useful, if understood or explained within the interface, correctly.

During the fourth task, all of the participants could correctly identify the matched, partially matched and non matched items (A6 of fig. 3 and B1 of fig. 3). However, the red items on the map were considered irrelevant by four of the participants. The interface matched the expectations of the participants for a pop-up functionality for the houses plotted on the map. On the map, the red dot and circle were, again, identified correctly as the search location and it's (soft) radius, respectively.

6.1.2. Ranking

To meet the ranking requirement, the result list is sorted by the user's defined criteria and their rated importance. Although the evaluation was carried out with static mockup designs, four of the participants mentioned their expectations regarding the sorted list. At first, three of the participants investigated the list and the order it was in. Because sorting based on feature values was not applied, all three participants concluded that ranking was based on their defined personal preference, and therefore sorted by relevance. Combined with the green labels for each item (A6 of fig. 3), it appeared to be clear to users that this ranking would change according to their personal preferences. For this evaluation, the evaluator had to play computer and explain the change in ranking for every decision made by the participant. One of the participants actually correctly expected the list to be ranked by relevance and the last participant was unsure how the list was sorted and found it, after explanation of the evaluator, an unnecessary addition to the interface. Three of the participants wanted to sort the list by *price*, *living area* or *number of rooms* and two of them expected the list to be secondarily sorted by

their chosen feature and still respect the ranking by relevance, and sort them primarily based on relevance.

Although the ranking is part of the underlying technical framework of the interface, the visual elements to support this functionality were understood by the majority of participants.

6.1.3. Comparison

During the evaluation we also observed how the comparison requirement was satisfied with the proposed solution. Four of the participants recognized the compare button (A1 of fig. 3) and correctly performed the fifth task in a minimum of steps. The option to compare the selected items remained unnoticed by one participant. This was in his opinion, because of the lack of design. He stated to be unfamiliar with low fidelity mockup designs and considered some of the tasks difficult to perform. However, all of the participants considered the compare option very useful and could successfully compare the selected houses, and therefore perform the task. Two of the users mentioned the need to manually sort important features by dragging them to the top (A3 of fig. 5).

6.2. Secondary findings

Part of the explorative usability study was to interact with users in order to analyze possible bottlenecks and problems with the interface. The survey at the end of each evaluation gave users the opportunity to suggest improvements.

Although the function is, at this moment, unavailable on most popular housing websites, the evaluation discovered that all of the participants wanted to select multiple values per filter. For example, every participant clicked on *garden* and *balcony* as extra features to filter by. However, in the mockup design, this option was unavailable. For each filter, only one value could be chosen. The filter was added to the specified search area, where it could either be deleted or changed. Three of the participants suggested checkboxes to select multiple values per filter.

Although the ability to search in multiple cities scored low during the user survey, three of the participants showed a desire to add multiple cities in order to search in the area around Amsterdam.

The 5-star ranking of importance per filter was, see paragraph 6.1.1, not as successfully received as anticipated. Where we naively expected to be using a commonly known rating functionality, some of the participants used the 5-star ranking in the complete opposite direction. When asked to use the rating, three of the participants clicked on the first star, to rate it the highest. In fact, this would result in the lowest rating possible on a five-item scale.

Furthermore, all of the participants mentioned their preference for margins, as opposed to a fixed value. For example, when performing the second and third task, the participants all questioned why they could only chose a single value for the number of rooms. It was unclear that by lowering the importance for this value, using the 5-star ranking, the system would search with a soft margin and therefore look for houses with -1 or +1 of the specified number of rooms. After an explanation from the evaluator, this function was considered useful by the participants. However, all the participants still preferred to specify a margin, as opposed to a single value.

After each task, the participants were asked to rate how difficult it was to perform the task. In figure 6 the average score per task is displayed[1]. It shows that each additional task became increasingly difficult, as more interface elements had to be considered. Although the fourth task, *compare houses*, was considered useful and rather easy, it took the participants relatively long to perform.

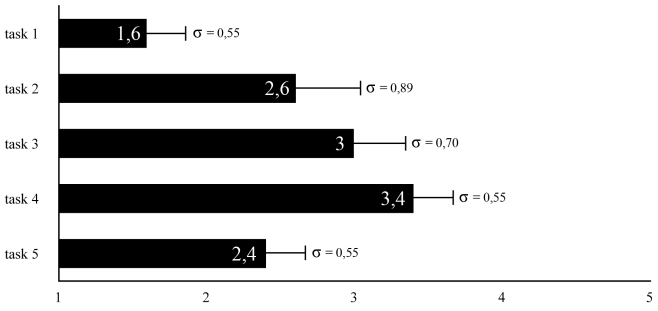

Fig. 6. Average score per task. Population: 5 participants.

6.3. System Usability Scale

On completion of all five tasks, each participant was asked to fill in a System Usability Scale (SUS) [19]. The SUS is a simple, ten-item scale, giving a global view of subjective assessments of usability. This scale focusses on the interface as a whole and does not assess individual items or tasks. The results of the SUS per user is shown in figure 7. SUS scores range from 0 to 100.

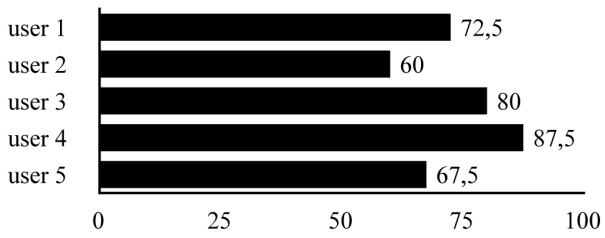

Fig. 7. System Usability Score per user

[1]Rating based on five point Likert scale, 1: very easy to 5: very hard

With an average SUS score of 73,5, the interface lies within the lower regions of the *acceptability range* [17]. The interface can be considered *good*. However, some improvements could increase the score.

7. DISCUSSION

The results of this research indicate the need for soft preferences while searching for a house online. The majority of users claimed to be very interested in houses that, by some degree of uncertainty, lie outside the boundaries of their specified search criteria. However, during the evaluation study, the chosen form of defining soft constraints turned out to be difficult to understand. We consider two reasons for this. Firstly, due to the low fidelity mockups, we did not have the advantage of a working system to support the functions presented with the interface. The interactions had to be mimicked by the evaluator and could therefore not help the users to understand various elements. Secondly, we have to acknowledge the possibility that the interface elements insufficiently match the users' expectations.

The visual indications of matched, partially matched or non matched items were positively received by users. Although, initially, some users had doubts about the exact meaning, it became clear that this functionality was considered as a major improvement over the current ranking found on similar website for the housing domain. The non matched items, colored red in our interface, were considered highly irrelevant by the majority of participants. Although based on the principle that all houses are ranked according to the users (soft) preferences, items that are a complete mismatch can be considered irrelevant, and should therefore be left out of the result list. The partially matched items were considered useful.

Furthermore, our findings confirm the expected need for intuitive comparison. The majority of survey respondents claimed to be very interested in a comparison functionality for houses. Although satisfying this requirement could be done in various ways, we have discovered that successful method, like comparison tables, used by popular online catalogs, are positively received by the users.

8. CONCLUSIONS

We have presented a soft-preference based search interface for the housing domain, inspired by the Strategy Builder™, to satisfy the user requirements. The system incorporates weighted constraints as well as ranking by relevance and was well received by the participants during the evaluation period. Some of the elements required an additional explanation. Although findings in this study indicate the importance of soft constraints in a search interface for the housing domain, designing methods that would intuitively present these functions to users has proven to be a challenge. The suggested method of weighting preferences was insufficiently supported by the users. All of the participants preferred margins for filter values, as opposed to the fixed value solution, presented in this paper. Nonetheless, the interface evaluation has indicated that the proposed improvement over existing interfaces has great potential in the future.

9. FUTURE WORK

In the future, the results of this study can be used to develop an improved interface for the existing search interfaces for the housing domain. In particular, the Strategy Builder™, could benefit from the findings. However, more research is needed to determine how soft preferences can become less ambiguous in a search interface. For example, in our interface we have chosen to represent importance on a 5-star scale. Other methods of defining soft constraints need to be researched. A next step would be to evaluate the interface elements in this paper on a working system and possibly compare the results with existing interfaces in the housing domain. For an extended evaluation, the Strategy Builder™could provide the framework needed to actually retrieve items from a relational database and investigate the performance with real data. The existing test interfaces for the Strategy Builder™currently do not have the ability to select soft filter margins. As all the participants prefer to set, for example, a price range, this could be an important improvement to the existing single value input.

10. ACKNOWLEDGEMENTS

We thank the housing domain experts for their time and effort regarding this project. We thank the Centrum Wiskunde & Informatica for the financial support and available facilities. We thank Lynda Hardman for the opportunity to carry out this study, and her feedback in hard times. We thank Wouter Alink for the Strategy Builder™demonstration and support. Last, but certainly not least, we thank Vera Hollink and Arjen de Vries for their feedback and support.

11. REFERENCES

[1] Amazon - http://www.amazon.com.

[2] Apple - http://www.apple.com.

[3] Clef 2009 - http://www.clef-campaign.org.

[4] Dell - http://www.dell.com.

[5] Ebay - http://www.ebay.com.

[6] Funda - http://www.funda.nl.

[7] Funda - http://www.funda.nl/about/default.aspx.

[8] http://www.woonnieuws.nl/artikel/60/funda-onbedreigd-aan-kop.

[9] Huizenzoeker - http://www.huizenzoeker.nl.

[10] Jaap - http://www.jaap.nl.

[11] Niki - http://www.niki.nl.

[12] Patolympics - http://www.ir-facility.org/events.

[13] Spinque - http://www.spinque.com.

[14] Stir - http://www.stir.nl/resultaten/archief/2010.

[15] Usabilla - http://usabilla.com.

[16] Vindeenreis - http://www.vindeenreis.nl.

[17] A. Banger, P. T. Kortum, and J. T. Miller. An empirical evaluation of the system usability scale. *International Journal of Human Computer Interaction*, 24(6):574–594, 2008.

[18] R. Benbunan-Fich. Using protocol analysis to evaluate the usability of a commercial web site. *Information and Management*, 39(2):151–163, 2001.

[19] J. Brooke. Sus - a quick and dirty usability scale. *Redhatch Consulting Ltd.*, 1986.

[20] A. Coman and B. Ronen. Icarus' predicament: Managing the pathologies of overspecification and overdesign. *International Journal of Project Management*, 28(3):237 – 244, 2010.

[21] A. de Vries, W. Alink, and R. Cornacchia. Search by strategy. *ESAIR'10*, October 30, 2010.

[22] R. Dechter. *Constraint processing*. Morgen Kauffmann, 2003.

[23] W. O. Galitz. *The Essential Guide to User Interface Design*. Wiley Publishing, Inc., 2007.

[24] M. A. Hearst. *Search User Interfaces*. Cambridge University Press, 2009.

[25] R. Jeffries, J. R. Miller, C. Wharton, and K. Uyeda. User interface evaluation in the real world: a comparison of four techniques. In *Proceedings of the SIGCHI conference on Human factors in computing systems: Reaching through technology*, CHI '91, pages 119–124, New York, NY, USA, 1991. ACM.

[26] J. Nielsen. *Why you only need to test with 5 users*, volume March 19. Jakob Nielsen's Alertbox, 2000.

[27] P. Pu and B. Faltings. Decision tradeoff using example-critiquing and constraint programming. *Constraints*, 9:289–310, 2004. 10.1023/B:CONS.0000049205.05581.24.

[28] D. E. Rose and D. Levinson. Understanding user goals in web search. In *Proceedings of the 13th international conference on World Wide Web*, WWW '04, pages 13–19, New York, NY, USA, 2004. ACM.

[29] F. Rossi, K. B. Venable, and T. Walsh. Preferences in constraint satisfaction and optimization. *AI Magazine*, 29(4):58 – 68, 2008.

[30] M. Stolze. *Soft Navigation in Product Catalogs*. 1998.

[31] P. Wright and A. Monk. The use of think-aloud evaluation methods in design. *ACM SIGCHI Bulletin*, 23(1), 1991.

A. CONTENT- AND FUNCTIONALITY ANALYSIS

	FUNDA	JAAP	HUIZENZOEKER	NIKI
Main categories				
buying	yes	yes	yes	yes
selling	yes	yes	no	no
renting	no	no	no	yes
future	no	no	no	yes
mortgages	no	yes	no	no
statistics	no	yes	yes	no
moving	no	yes	no	no
blog	no	yes	no	no
forum	no	yes	no	no
shop	no	yes	no	no
realtors	yes	no	yes	no
profile	yes	yes	yes	yes
Subcategories				
buying	yes	yes	yes	no
renting	yes	yes	yes	no
new built	yes	no	no	yes
information own house	no	yes	no	no
business	yes	no	no	no
recreation	yes	no	no	no
Europe	yes	no	no	no
agriculture	yes	no	no	no
Searching				
provence	no	no	no	yes
city	yes	yes	yes	yes
postal code	yes	yes	yes	no
radius	yes	yes	yes	no

Fig. 8. Content- and functionality analysis (1/4)

B. CONTENT- AND FUNCTIONALITY ANALYSIS

	FUNDA	JAAP	HUIZENZOEKER	NIKI
Searching				
price range	yes	yes	yes	yes
specific address	yes	yes	yes	yes
multiple cities	yes	no	yes	yes
map	yes	no	yes	no
browsing	yes	no	yes	yes
advanced	yes	no	yes	yes
↳ projectname	no	no	no	yes
Profile				
account	yes	yes	yes	yes
picture	yes	no	no	no
details	yes	yes	yes	yes
search query	yes	yes	yes	yes
favorites	yes	yes	yes	no
my house	no	yes	no	no
neighborhood mail	no	yes	no	no
selling	yes	yes	no	no
dreamhouse (alert)	no	no	yes	no
recently viewed	yes	no	yes	no
delete account	yes	no	yes	yes
Results				
total number of houses	yes	yes	yes	yes
top houses	yes	yes	no	no
price	yes	yes	yes	yes
realtor	yes	no	no	no
advertisement	yes	yes	yes	no
map	yes	yes	yes	no

Fig. 9. Content- and functionality analysis (2/4)

C. CONTENT- AND FUNCTIONALITY ANALYSIS

	FUNDA	JAAP	HUIZENZOEKER	NIKI
Results				
filters	yes	yes	yes	no
listview	yes	yes	yes	yes
gallery view	yes	no	no	no
Sorting				
address	yes	yes	no	no
postal code	yes	yes	no	no
city	yes	no	no	yes
type of house	no	no	no	yes
living m2	yes	no	yes	no
land m2	yes	no	yes	no
rooms	yes	no	no	no
date	yes	yes	no	no
(asking) price	yes	yes	yes	yes
price change	yes	yes	no	no
realtor	yes	yes	no	no
mortgages	no	yes	no	no
statistics	no	yes	yes	no
moving	no	yes	no	no
Sorting				
blog	no	yes	no	no
forum	no	yes	no	no
shop	no	yes	no	no
realtors	yes	no	yes	no
profile	yes	yes	yes	yes

Fig. 10. Content- and functionality analysis (3/4)

D. CONTENT- AND FUNCTIONALITY ANALYSIS

	FUNDA	JAAP	HUIZENZOEKER	NIKI
Filters				
price from	yes	yes	yes	no
price to	yes	yes	yes	no
price inquiry	no	yes	no	no
value indication	no	yes	no	no
auctions	yes	no	no	no
neighborhood	yes	yes	yes	no
postal code	no	no	yes	no
street	no	no	yes	no
radius	no	yes	no	no
status	no	no	yes	no
type of object	yes	yes	yes	no
type of built	yes	no	yes	no
rooms	yes	yes	yes	no
living m2	yes	yes	yes	no
land m2	yes	yes	yes	no
features	yes	yes	no	no
↳ multiple	yes	yes	no	no
year of built	yes	yes	yes	no
type of area	yes	no	no	no
extra's	yes	yes	no	no
recently added	yes	yes	yes	no
price changed	no	no	yes	no

Fig. 11. Content- and functionality analysis (4/4)

E. ONLINE SURVEY RESULTS

1. What is your gender?	Count	Percentage
male	28	56%
female	22	44%

2. How old are you?	Count	Percentage
17 - 25	8	16%
26 - 34	23	46%
35 - 44	8	16%
45 - 55	7	14%
55+	4	8%

3. What are your computer skills?	Count	Percentage
very inexperienced	1	2%
inexperienced	2	4%
fairly experienced	14	28%
experienced	17	34%
very experienced	16	32%

4. Have you ever bought a house?	Count	Percentage
yes	41	82%
no	9	18%

5. How long ago did you buy a house?	Count	Percentage
less than 1 year ago	9	22%
between 1 and 3 years ago	10	24%
between 4 and 6 years ago	9	22%
more than 6 years ago	13	32%

6. Have you ever visited a housing website?	Count	Percentage
yes	50	100%
no	0	0%

Fig. 12. Survey results (1/8)

F. ONLINE SURVEY RESULTS

7. Which of the following websites have you visited at least once?	Count	Percentage
Funda.nl	49	98%
Jaap.nl	23	46%
Huizenzoeker.nl	7	14%
Woningennet.nl	2	4%
Zuka.nl	1	2%
Marktplaats.nl	15	30%
Other	7	14%

8. Did you contact a real estate agency to acquire a property?	Count	Percentage
yes	10	30%
no	23	70%

9. “The price is the most important factor while searching for housing.”	Count	Percentage
strongly disagree	3	6%
disagree	7	14%
neither agree nor disagree	11	22%
agree	15	30%
strongly agree	14	28%

Sum: 180.0
Average: 3.6
Standard deviation: 1.2
Maximum: 5.0

10. “When searching for houses online, I want to specific mortgage offers.”	Count	Percentage
strongly disagree	15	30%
disagree	12	24%
neither agree nor disagree	8	16%
agree	9	18%
strongly agree	6	12%

Sum: 129.0
Average: 2.6
Standard deviation: 1.39
Maximum: 5.0

Fig. 13. Survey results (2/8)

G. ONLINE SURVEY RESULTS

11. "When searching for houses online, it would be important to see houses plotted on a map."	Count	Percentage
strongly disagree	1	2%
disagree	3	6%
neither agree nor disagree	2	4%
agree	18	36%
strongly agree	26	52%

Sum: 215.0
Average: 4.3
Standard deviation: 0.94
Maximum: 5.0

12. "I would find it important to search in multiple cities at once."	Count	Percentage
strongly disagree	11	22%
disagree	18	36%
neither agree nor disagree	6	12%
agree	10	20%
strongly agree	5	10%

Sum: 130.0
Average: 2.6
Standard deviation: 1.30
Maximum: 5.0

13. "I would find it important to search by postal code."	Count	Percentage
strongly disagree	14	8%
disagree	14	28%
neither agree nor disagree	16	32%
agree	8	16%
strongly agree	8	16%

Sum: 152.0
Average: 3.0
Standard deviation: 1.18
Maximum: 5.0

Fig. 14. Survey results (3/8)

H. ONLINE SURVEY RESULTS

14. "I would find it important to see the estimated monthly costs for a house."	Count	Percentage
strongly disagree	10	20,4%
disagree	13	26,5%
neither agree nor disagree	8	16,3%
agree	11	22,4%
strongly agree	7	14,3%

Sum: 139
Average: 2.8
Standard deviation: 1.36
Maximum: 5.0

15. "I would find it important to search within a radius of specific city of postal code."	Count	Percentage
strongly disagree	3	6%
disagree	7	14%
neither agree nor disagree	9	18%
agree	17	34%
strongly agree	14	28%

Sum: 182.0
Average: 3.6
Standard deviation: 1.20
Maximum: 5.0

16. "I would find it important to see sponsored houses on top of the result list."	Count	Percentage
strongly disagree	36	72,0%
disagree	11	22,0%
neither agree nor disagree	2	4,0%
agree	1	2,0%
strongly agree	0	0,0%

Sum: 68.0
Average: 1.4
Standard deviation: 0.66
Maximum: 5.0

Fig. 15. Survey results (4/8)

I. ONLINE SURVEY RESULTS

17. "An offered house is not interesting without pictures."	Count	Percentage
strongly disagree	0	0,0%
disagree	0	0,0%
neither agree nor disagree	4	8,0%
agree	13	26,0%
strongly agree	33	66,0%

Sum: 234.0
Average: 4.7
Standard deviation: 0.55
Maximum: 5.0

18. "I would find it important if the houses that do not completely match my criteria, are shown nonetheless."	Count	Percentage
strongly disagree	2	4,0%
disagree	1	2,0%
neither agree nor disagree	10	20,0%
agree	25	50,0%
strongly agree	12	24,0%

Sum: 194.0
Average: 3.9
Standard deviation: 0.93
Maximum: 5.0

19. "I would find it important that for sale is separated from for rent."	Count	Percentage
strongly disagree	0	0,0%
disagree	0	0,0%
neither agree nor disagree	4	8,0%
agree	13	26,0%
strongly agree	33	66,0%

Sum: 229.0
Average: 4.6
Standard deviation: 0.64
Maximum: 5.0

Fig. 16. Survey results (5/8)

J. ONLINE SURVEY RESULTS

20. "The price is the most important factor while searching for housing."	Count	Percentage
strongly disagree	3	6%
disagree	7	14%
neither agree nor disagree	11	22%
agree	15	30%
strongly agree	14	28%

Sum: 180.0
Average: 3.6
Standard deviation: 1.2
Maximum: 5.0

21. "When searching for houses online, I want to specific mortgage offers."	Count	Percentage
strongly disagree	15	30%
disagree	12	24%
neither agree nor disagree	8	16%
agree	9	18%
strongly agree	6	12%

Sum: 129.0
Average: 2.6
Standard deviation: 1.39
Maximum: 5.0

22. How important do you rate the following filtering options?	Average rank	σ
filtering by year of construction	2.71	1.39
filtering by number of rooms	3.82	1.06
filtering by neighborhood in a city	3.86	1.05
filtering by special features (balcony, swimming pool, etc)	3.78	1.13
filtering by type of house	3.90	0.97
filtering by living area in square meters	4.04	0.92
filtering by recent items	3.35	1.25

Fig. 17. Survey results (6/8)

K. ONLINE SURVEY RESULTS

23. Which of the following functionalities would you consider important?	Count	Percentage
Googling the street name	24	49,0%
compare houses in a table	34	69,4%
visualization of the rank (based on match)	21	42,9%
previous prices for similar houses	35	71,4%
asking questions about an item	14	28,6%
Other	3	6,1%

24. How important do you rate the following features shown per items?	Average rank	σ
the name of the street	4.47	0.84
the postal code	3.06	1.46
the city	4.71	0.53
the asking price	4.82	0.44
the name of real estate agency	2.73	1.31
estimated monthly costs	2.67	1.39
energy label	2.39	1.32
living area in square meters	4.27	0.90
ground area in square meters	3.88	1.17
special features	3.67	1.17
public right of way	3.31	1.28
number of rooms	4.16	1.09
map of the building	3.98	1.00
information about the neighborhood	3.41	1.07
map of the neighborhood	3.45	1.14
similar houses in the neighborhood	3.80	0.95
year of construction	3.98	1.13

Fig. 18. Survey results (7/8)

L. ONLINE SURVEY RESULTS

25. How important do you rate the following search options?	Average rank	σ
formulate personal search terms	3.40	1.33
search for facilities nearby	2.78	1.22
searching for city	4.63	0.63
searching for postal code	3.00	1.36
searching for street-name	3.04	1.18
searching on a map	3.84	1.11
searching in multiple cities	2.29	1.25
searching for number of rooms	3.73	1.06
searching for energy label	2.20	1.19
searching for specific real estate agency	1.51	0.84

26. How important do you rate the following sorting options?	Average rank	σ
sorting by price	4.63	0.60
sorting by number of rooms	3.90	1.05
sorting by year of construction	2.88	1.24
sorting by street name (alphabetical)	2.14	1.26
sorting by postal code	2.53	1.34
sorting by living area in square meters	3.82	1.12

Fig. 19. Survey results (8/8)

M. INTERFACE SCREEN 1

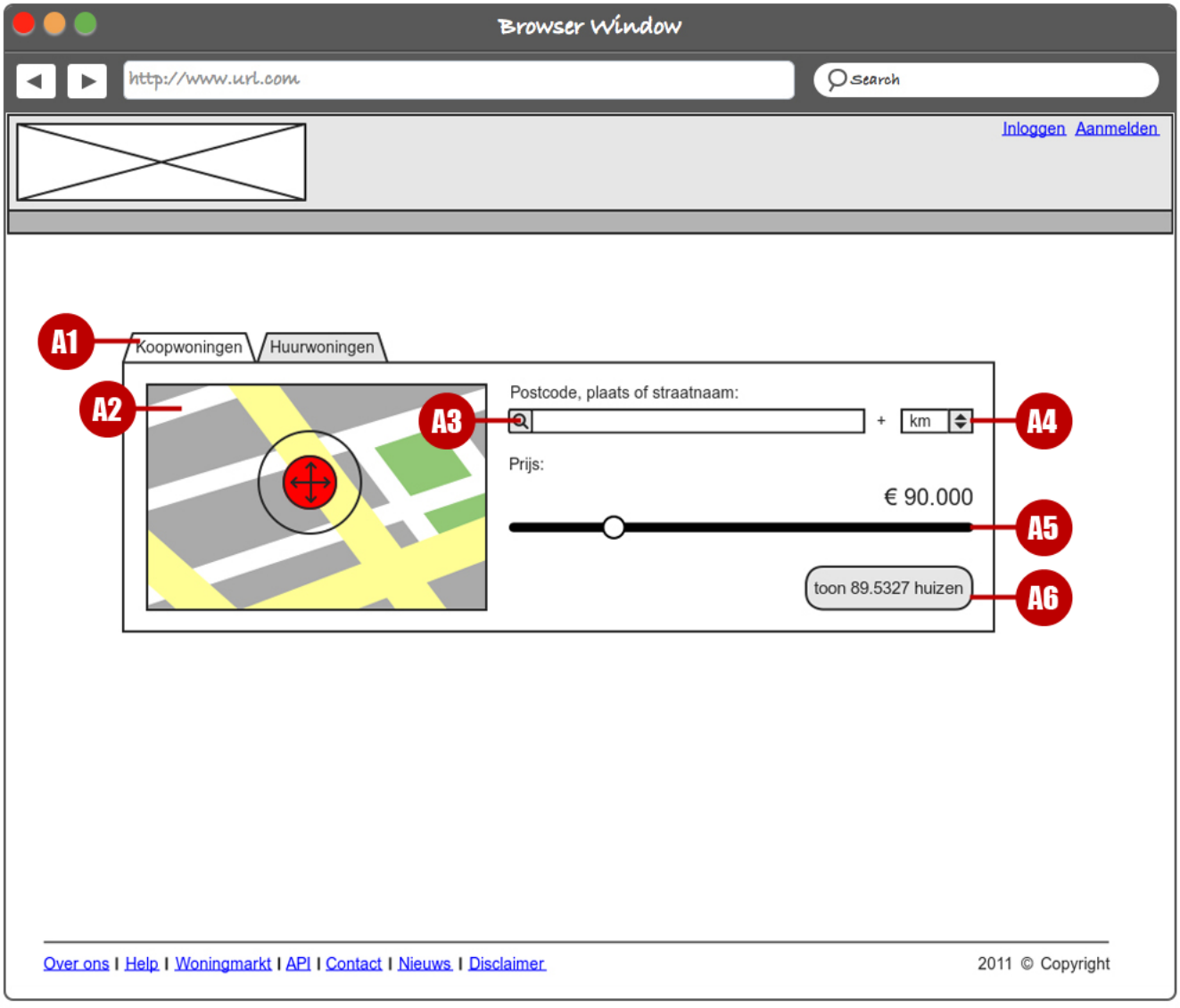

Fig. 20. A1: *tabs to switch between for sale and for rent* A2: *Google Maps*^{TM}*integration* A3: *input field for search query* A4: *dropdown to define radius in km* A5: *slider to define price* A6: *button to show found houses*

N. INTERFACE SCREEN 2

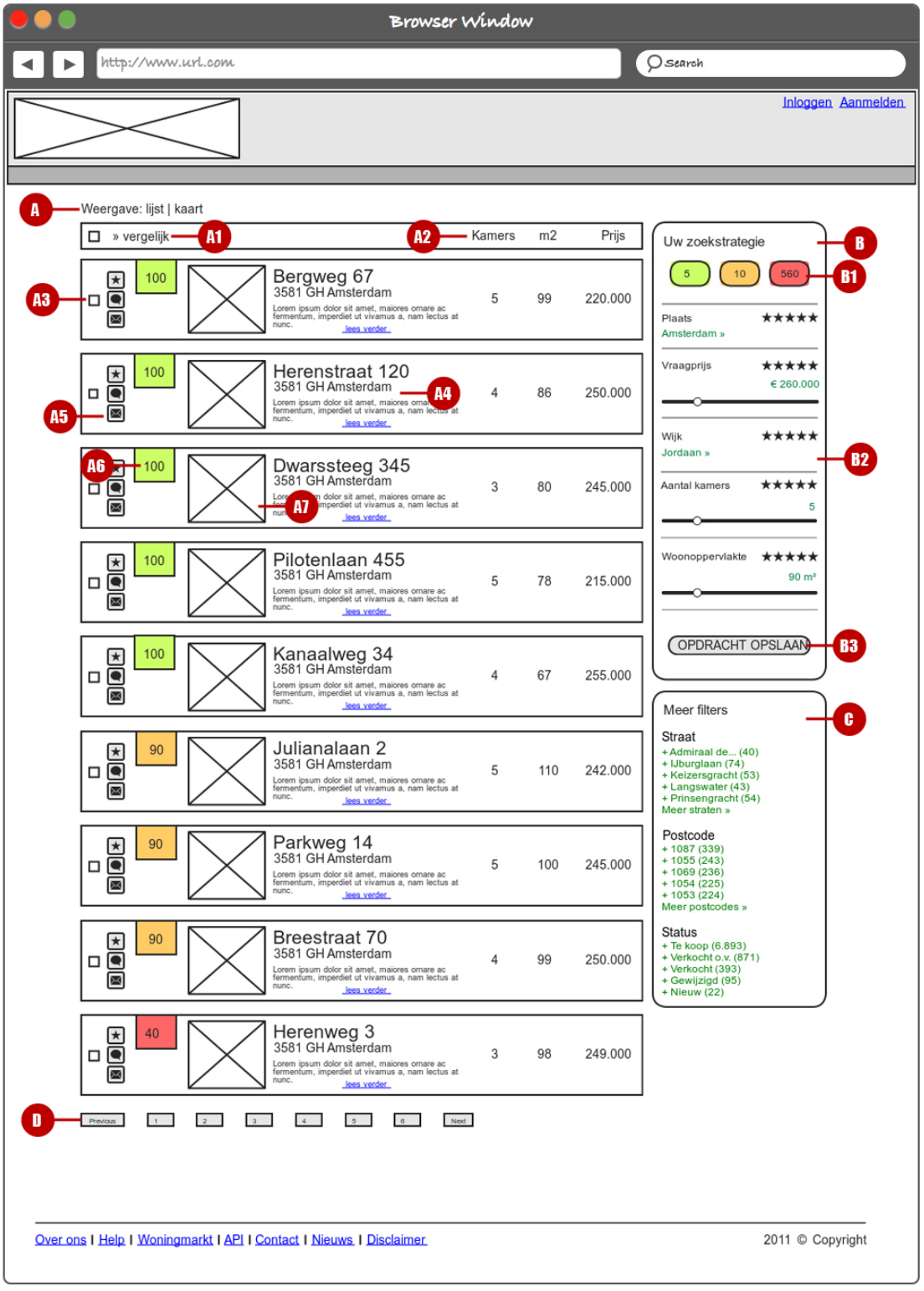

Fig. 21. A: *switch to change from list-view to map-view* A1: *button to compare selection* A2: *option to sort by number of rooms, living area and price* A3: *checkbox to select specific item* A4: *description of the item* A5: *buttons to (top) add to favorites (middle) contact real estate agency and (bottom) send email with item* A6: *relevance label, green: full match, orange: semi-match and red: no match* A7: *picture of the item* B: *personal search strategy* B1: *number of houses; green: full match, orange: partial match and red: no match* B2: *list of chosen filters, with 5-star ranking* B3: *button to save search strategy to account* C: *list of inactive - but available - filters* D: *navigation for multiple pages of results*

O. INTERFACE SCREEN 3

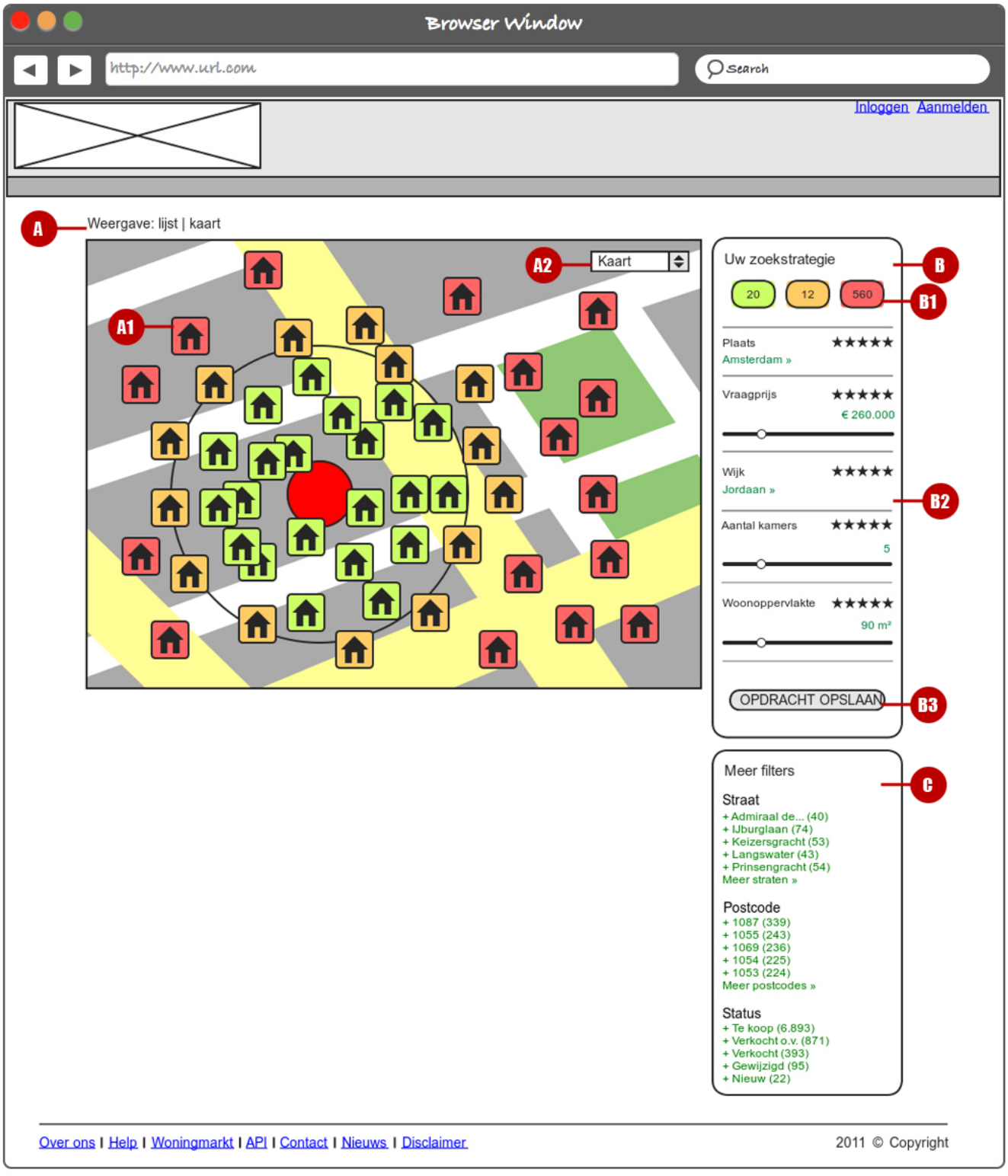

Fig. 22. A: *switch to change from list-view to map-view* A1: *green: full match, orange: partial match and red: no match* A2: *switch to change Google Maps™ from map to satellite* B: *personal search strategy* B1: *number of houses; green: full match, orange: partial match and red: no match* B2: *list of chosen filters, with 5-star ranking* B3: *button to save search strategy to account* C: *list of inactive - but available - filters*

P. INTERFACE SCREEN 4

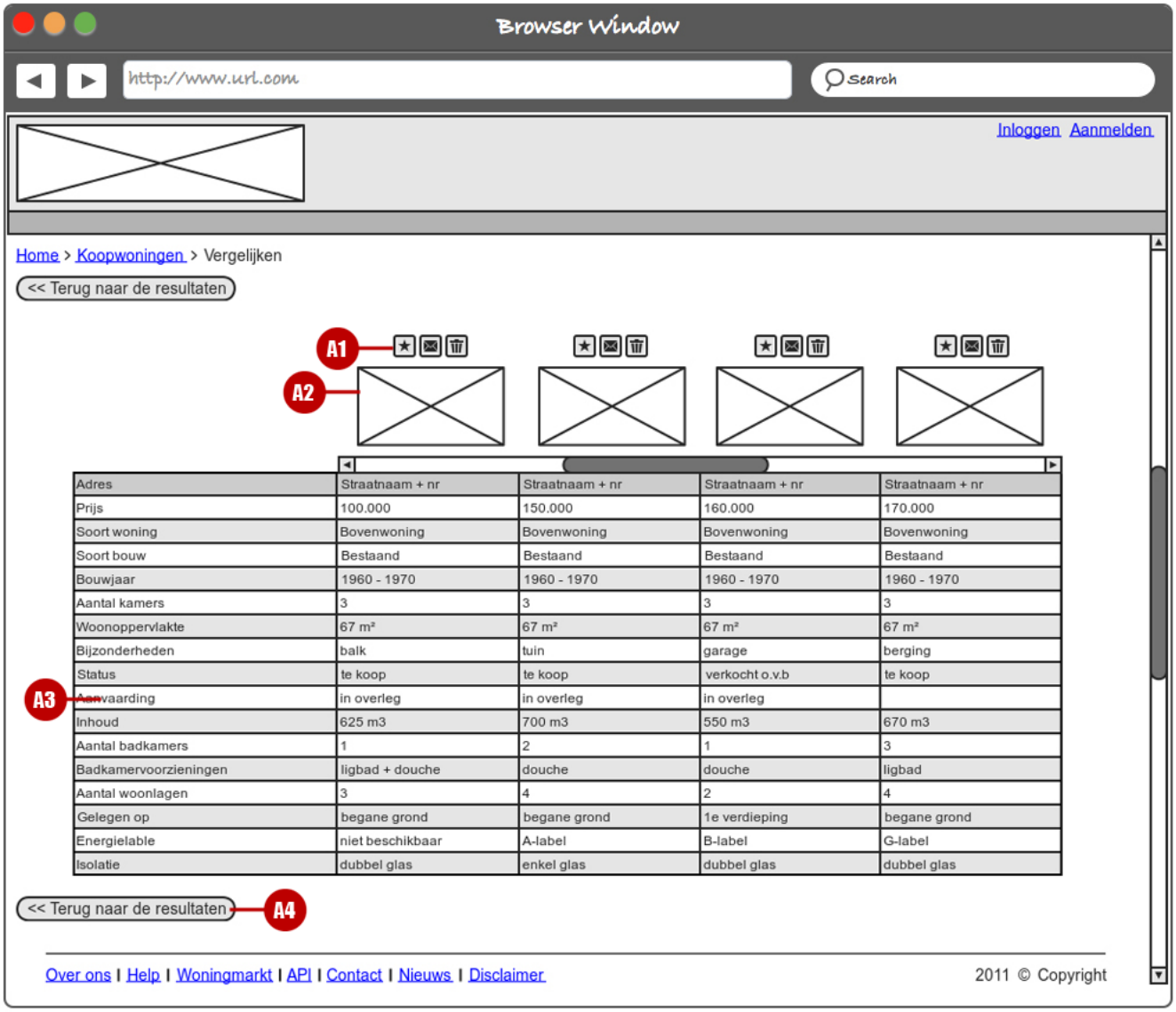

Fig. 23. A1: controls to (left) *add to favorites*, (center) *send email with item* and (right) *delete house* A2: picture of the house A3: *list of features* A4: *back button to return to result-list*