

# User Customized Temporal Content Recommendations for StackOverflow

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## ABSTRACT

We present a survey of 150+ StackOverflow users, which motivates the use of StackOverflow as a corpus for delivering temporally relevant, personalized content recommendations to specific users based on their stated interests. We demonstrate, through our survey, the inability of the existing StackOverflow newsletter to provide this function. We propose a user adaptive recommendation system to address the problem, and present it in context of related work. Finally, we present a brief statement of our start up exercise with a simulated system output.

## Keywords

customization, stack overflow, recommendation, ranking, filtering, temporal data

## 1. INTRODUCTION

*"Search is what you do when you're looking for something. Discovery is when something wonderful that you didn't know existed, finds you."*

- CNN Money, "The race to create a 'smart' Google

Recommendation systems have attracted considerable interest from both the academic and industrial research communities since their conception in the 1990's [11, 15, 18], and continue to represent an area of active research today.

The commercial value of recommendation engines has proven to be immense: for instance, 67% of movies watched on Netflix[6] are recommended. Amazon generates 35% [13] of it's

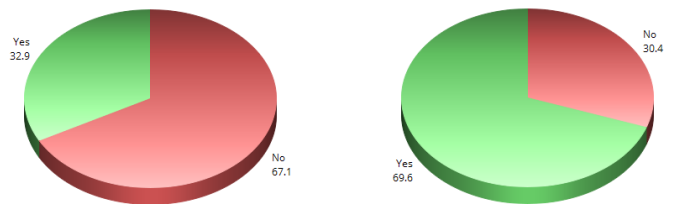


Figure 1: The case for our proposed system, from a survey of 154 users(see Sec 3). Left: Are you satisfied with the StackOverflow newsletter? Right: Would you like customizable content recommendations from StackOverflow?

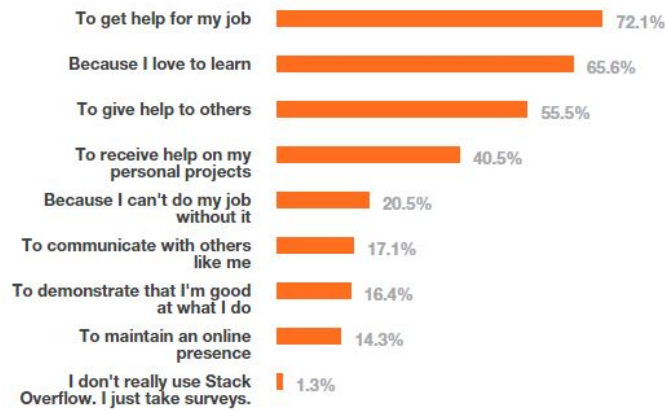
total sales from recommendations to users, and Google News recommendations[10] generate 38% more clickthrough.

This commercial success notwithstanding, there has been surprisingly little penetration of recommendation systems into more general areas of society, such as education. Despite the impetus provided by online tutoring platforms such as Coursera and Khan Academy, the problem of recommending temporally relevant instructional material in a truly customizable form remains academic[20, 16].

Probably the closest existing systems are the academia.edu[1] newsletter and the Mendeley[4] suggestion system, which circulate most highly cited research papers within a chosen area(s) of interest to users. However, research papers correspond only to a minority of the larger education community, which remains an open opportunity for research and development in this area.

In this project, we extend the focus to the popular Question-and-Answer platform StackOverflow[5]. StackOverflow features a large corpus of knowledge and content covering many areas of Computer Science and Software development in particular. Further, content on StackOverflow is inherently temporal, and thus presents users with the opportunity to stay updated with current trends in their areas of interest.

However, our survey (see Sec 3) revealed that existing StackOverflow tools present two obstacles to achieving this:



**Figure 2: 72% of StackOverflow users report that it helps with their job. 66% use it as a resource for learning.**

firstly, no user customizable recommendation system exists for the platform. Secondly, the existing newsletter chooses content from all areas on the website, and hence only a very small subset of it is relevant to a given user.

We therefore propose in this work to develop a personalizable content recommendation system for StackOverflow users. The remainder of this paper is organised as follows. Firstly, our introduction concludes with a formal description of our user group, it's software tool, it's goal and the intervening problem. Section 2 details our literature study. In Section 3, we present the results of our user survey. Section 4 presents a brief discussion of our start up exercise statement. Finally, we conclude the paper.

## 1.1 Formal Definition

### 1.1.1 Problem

- StackExchange offers a rudimentary newsletter. It includes top weekly questions and new unanswered questions.<sup>1</sup>
- The service is common to all users and cannot be customized according to specific user preference.
- This makes it difficult for users to receive content relevant to them, and thus stay up-to-date with the latest developments in their specific areas of interest.

### 1.1.2 User Group

32 million users visit Stack Overflow every month[3]. From the StackOverflow developer survey[3], 66% of respondents reported that they use StackOverflow to learn and keep abreast of developments in their areas of interest. Also, 63% of respondents report that they visit StackOverflow multiple times a day.

<sup>1</sup>The newsletter does provide an option to follow a specific topic over a brief period (3-8 hours). However, all content corresponding to the given topic is presented and the request must be resubmitted every 8 hours.

76% of the users from our survey wanted to hear from StackOverflow. Of these, 67% of respondents (see Sec 3) report dissatisfaction with the existing StackOverflow newsletter and nearly as large a percentage (63%) report that they would like customizable content recommendations. These represent our user group.

### 1.1.3 Software Tool

The tool in question is StackOverflow, a sub site of StackExchange meant for programming and software engineering related QnA. It is a community moderated platform created by Jeff Atwood and Joel Spolsky in 2008. One can ask questions, answer questions, upvote questions or answers, reply to answers for specific queries among other things. Users of StackOverflow earn reputation points and badges if the community deems their contributions valuable in the form of upvotes. All content is licensed under the Creative Commons Attribute-ShareAlike license.

Stack Overflow is written in C# using the ASP.NET MVC (Model-View-Controller) framework, and Microsoft SQL Server for the database and the Dapper object-relational mapper used for data access. To build a customizable system for this platform, we will create a website scraper to pick up data. We will then categorize it according to various parameters including tags, timestamps, upvote count etc.

### 1.1.4 Goal

Our user group's goal is to stay updated with the latest news and developments in their stated areas of interest. Note that this goal is inherently user specific, and therefore cannot be accomplished simply by reading the StackOverflow newsletter(see Sec 1.1.1). It is also pertinent to point out that a search based on tags, such as 'python' (526584 results) or 'prefix trees' (20083 results) would yield large masses of content, unfiltered by popularity, relevance, or temporality.

## 1.2 The Gulf of Evaluation

While Section 1.1 defines our problem in a software engineering sense, the question of how to arrive at a quantitative evaluation of our proposed system remains to be addressed.

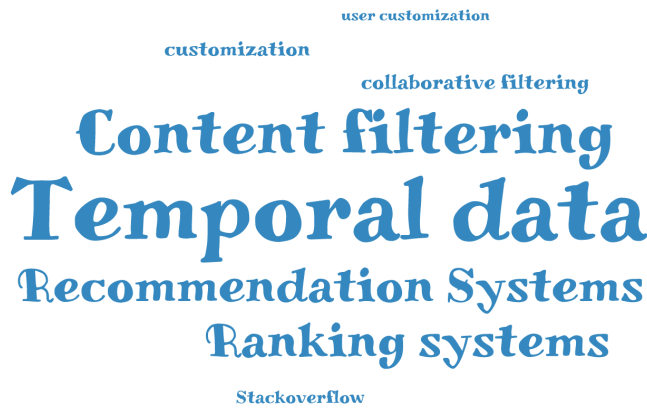
Our stated problem is defined on two key counts:(i) personalize to a specific user (ii) keeping "up to date" with latest developments in a stated area. Arriving at a quantitative evaluation of such a system is less straightforward than, say, evaluating a modification to a text editor environment, in which case simply measuring average user error rate with and without the modification would suffice. We will carry out the following assessments to address this gulf:

### 1.2.1 User Satisfaction Survey

Similar in spirit to the survey we conducted to define our problem, we will carry out a user survey of our system in the final two to three weeks of the semester. Users will input stated areas of interest and report their levels of satisfaction with the system versus the StackOverflow newsletter. While we will not have a ground truth to measure against in this case, we remain hopeful that the survey will still provide value to our evaluation.

### 1.2.2 Sanity Checks

We will manually identify ground truth content in specific areas (for instance, fixes to a well known bug in Python),



**Figure 3: Our initial search terms. Size depicts number of results.**

and examine whether such content is recommended by our system.

### 1.2.3 Statistical *p* value testing

As part of our user survey, we will ask participants to identify the number of articles from our system that they found relevant and useful, over and above the StackOverflow newsletter. This measure will serve as an (approximate) Gaussian distribution from which we will calculate a *p* value to evaluate the statistical probability that our system has a positive effect.

## 2. LITERATURE STUDY

### 2.1 Methodology

Our search was primarily conducted on Google Scholar, since it is a library that includes publications from most organisations such as IEEE, ACM, and so on. We initially conducted a search for the keywords listed in Fig. 3, which visualizes each according to the number of results it returned on Google Scholar. The initial search unsurprisingly returned an intractably large number of articles in each category; for instance, 380000 results for content filtering, 250000 results for recommendation systems, and so on.

Our initial preprocessing strategy was simple: we argue that any article relevant to our particular problem must contain ALL the essential terms that define the problem. Our initial attempt at pruning the result set was thus defined by the following search:

**recommendation OR ranking AND filtering AND temporal data.**

This search pruned our result space to a cardinality of approximately 27000 articles. Then, we utilized the fact that the first recommendation systems began to appear in the mid to late 90's, which refined our search to the period between 1995 and the present (2016). This further scoped our results to a cardinality of 18000 Google Scholar entries.

To motivate our next search filter, we introduce a generic binary classification of recommendation systems according to their differing reliance on training data: collaborative versus content based filtering systems[2]. Collaborative filtering methods are based on collecting and analyzing a large amount of information on users behaviors, activities or pref-

erences and predicting what users will like based on their similarity to other users.

While we do not dispute that collaborative approaches in general yield consistently good results, we do not seek to implement such an approach in our project for the following reason: Collaborative approaches rely on the availability of large corpuses of user data and preferences, which are usually generated over years of recorded data. The constraints imposed by utilization of simple user surveys make it impossible for us to generate such a corpus within the time constraints of a semester project.

Instead, we adopt a content based filtering approach[2], which are based on a description of the item and a profile of the user's preference.[28] In a content-based recommender system, keywords are used to describe the items and a user profile is built to indicate the type of item this user likes. In other words, these algorithms try to recommend items that are similar to those that a user liked in the past (or is examining in the present). In particular, various candidate items are compared with items previously rated by the user and the best-matching items are recommended. Such an approach fits well into the data provided by a user survey, into which users may enter specific areas of interest based on which our system can recommend content.

Thence, we now restrict our search to content based filtering systems, while continuing to incorporate the search parameters described earlier. This now prunes our search space to a cardinality of 700 articles.

We now proceed to manually select individual articles. Our selection criteria are as follows. We firstly look for relevance to our proposed problem, disqualifying articles that are clearly unrelated or address irrelevant research questions not connected to our chosen problem.

Then, we apply a simple heuristic filter for the number of citations. We exclude any article cited less than 20 times, excepting those articles that appeared after 2014. Our literature survey hence **maintains a H index of 18**.

It is pertinent to point out here that our filtered search does identify well known research in the field[17, 7].

### 2.2 Summary of selected papers

We now summarise the content of our chosen subset of literature, and point out the salient contribution and relevance of each article for our specific application. We begin with reference[17], a seminal survey paper in the area of recommender systems. The article presents a general taxonomy for recommendation systems, which informed our search. Within the taxonomy, we identify our system as a Keyword based Item to User correlation technique, that outputs predictions featuring a persistent level of user personalization.

In 2009, Chu and Park[9], proposed a predictive bi-linear model that evaluates content using a combination of user profile, feature responses of content, and timestamp. While the technique presented in the paper is primarily a collaborative one and therefore beyond our ability to reproduce (see Sec 2.1), the paper remains an important one to point out the role of temporality in determining user preference.

This tradition is again observable in[19], which introduces a personalised context aware system for TV content recommendation. The system proved to have industrial success after being commercialized, underlining the relevance of user customized recommendation.

Reference[7] presents a comprehensive survey of the state

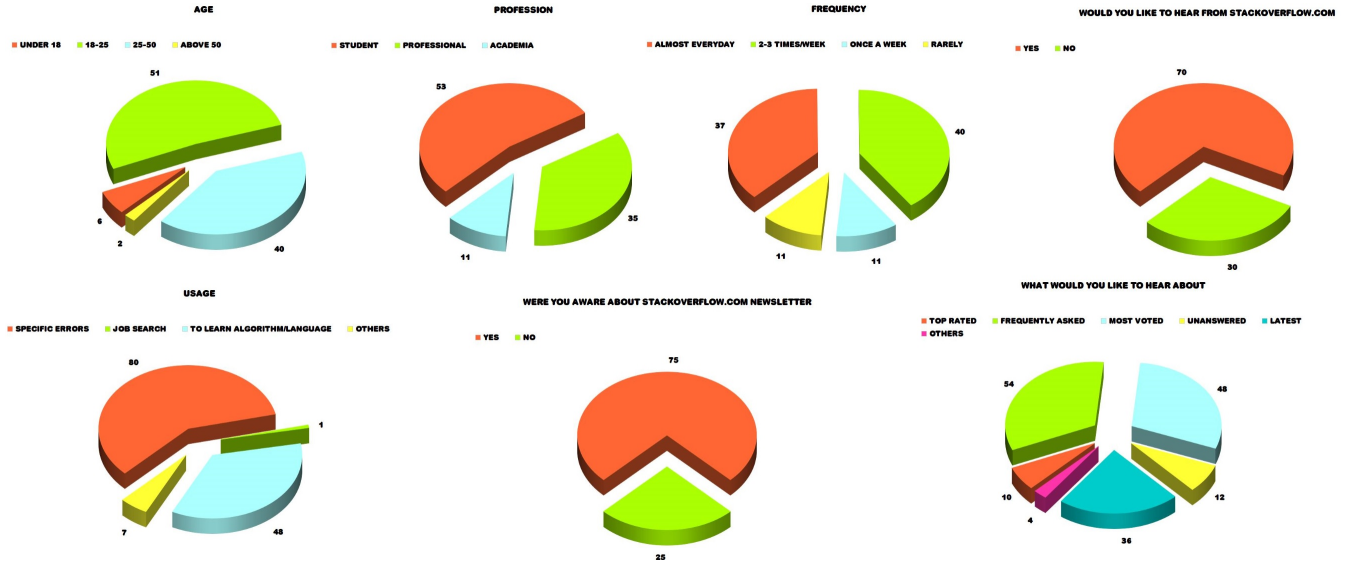


Figure 4: Sample statistics from our user survey.

of the art in the recommender systems of 2012. It is interesting to contrast the contributions of this survey with the original one conducted in 2001. The primary additions to traditional recommendation systems take two forms: firstly, social context is used to enhance recommendation results in a manner similar to that described in [19]. Secondly, and more importantly from the point of view of our project, the 2012 survey article stresses the importance of user personalization in the form of highly sophisticated and frequently updated user models.

[12] presents a study of the impact of various factors on the commercial success of a recommendation system. The study found that the participant was a significant factor in determining persuasiveness, and that there should be more factors related to the participants that could affect the recommendation persuasiveness. The article received 233 citations in a ten year period, which serves as an additional confirmation of the importance of user personalization.

Chicaiza et al [8] developed an education specific taxonomy of user profiles to aid in the personalization profiles for educational recommendation systems. While the established classification corresponds to the collaborative paradigm (see Sec 2.1) would take too long for us to implement, the paper does serve to motivate our approach to personalization.

Reference [14] presents a user adaptive music recommendation system that takes into account changing user interests with time. While this approach is again difficult to replicate, it serves as a motivator for adaptivity to temporal user interests.

In addition to these, we briefly discuss additional relevant work in the introduction section, and do not repeat those here.

### 3. USER SURVEY

Our survey form is listed in Appendix A. We begin by collecting demographical information about the participant, such as age group and profession.

We then solicit information about the participant's trends of usage on StackOverflow. Questions include the user's

areas of interest, their frequency of use of the website, and what they use it for.

Having collected this generic information, we then proceed to more specific queries about our proposed area of work. We ask if the user is aware of the existing StackOverflow newsletter, and if so whether it keeps her adequately informed on topics of her interest. Finally, we ask if she would like a customized newsletter from the website, the parameters of which she may modify.

#### 3.1 Results

The survey was conducted on a user base of 150+ people. We estimate that users on average spent  $\approx 5$  minutes to read the description, understand the purpose of the survey and answer the questions. We summarise the results below :

- Students and professionals comprised  $\approx 80\%$  of the participants. Only 11% of our survey participants were from academia.
- Almost 90% of the respondents were in the age range 18-25 or 25-50. This reaffirms our initial observation that most users of the website are either students or professionals.
- Our respondents listed many areas of interest including programming languages (Java, Python, C/C++), databases, networking, operating systems etc. took the survey. This indicates the diversity of areas that StackOverflow provides knowledge in, and the breadth of users who consider it a reliable source of information.
- The respondents who used stackoverflow everyday or at least 2-3 time a week formed 77% of the user base with everyday users comprising 37%. This speaks to the credibility of our user pool, since the most frequent users of the website would be the best informed as to how StackOverflow's corpus of knowledge may be leveraged.

- 80% of our survey audience used stackoverflow for specific programming errors and 48% use it to learn languages and algorithms. It is noteworthy that despite the proliferation of online tutoring portals such as Coursera and Khan Academy, almost half our respondents still utilize stackoverflow.com to learn new things. The fact that 80% of respondents use StackOverflow for programming errors is overwhelming evidence that the platform is the best available choice for information on debugging in general.
- 75% of the respondents reported that they would like to hear from StackOverflow. This result reaffirms our motivation to provide a content recommendation system for the site.
- 60% of our user pool reported that they were dissatisfied with the existing StackOverflow newsletter. Indeed, 80% wanted the newsletter to be customizable.
- Our survey had a total of  $\frac{154}{12} \approx 13$  people hours.

#### 4. STATEMENT OF START UP EXERCISE

As described earlier (see Sec 1.1), StackOverflow runs on C# using the ASP.net MVC controller framework. All four members of our project team have a working knowledge of C# and have used it previously. Our start up exercise involves **implementing a website scraper in C#**. This corresponds to the logical first step in the development of our system. We will then use our scraper to create a representative dataset, which will serve as a test bench for our recommendation system.

#### 5. CONCLUSIONS

Surveying a sample of our user group, the users of StackOverflow.com, we documented one of their goals of using the site as that of looking for current content in their area(s) of interest. We observed, given the existing tools of the website, problems of content relevance ranking and user customization. Motivated by our findings, we proposed a content based filtering system to recommend customized content to users based on their stated interests.

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#### APPENDIX

##### A. OUR SURVEY FORM

# User Review Form - StackOverflow

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Form Description

**Name\***

**Age Group**

**Profession\***

**Area of Interests\***

Your areas of interest separated by commas

**How often do you use StackOverflow?\***

**I mainly use StackOverflow for\***

- ☐ Specific programming errors
- ☐ Job searches
- ☐ To learn languages/algorithms
- ☐ Other:

**Would you like to hear from StackOverflow?\***



## User Review Form - StackOverflow

Are you aware of the Stack Overflow newsletter?\*

Does it keep you adequately updated on topics of your interest?\*

Would you like a customized content from Stack Overflow?\*

- ☐ Yes
- ☐ No

What would you like to hear about?\*

- ☐ Frequently Asked Questions
- ☐ Top Rated Questions
- ☐ Most Voted Answers
- ☐ Unanswered Questions
- ☐ Latest Questions

☐ Other: