# An Ontology-based Approach for Analyzing Emotions in Software Developers' Mailing Lists

Huma Tabassum and Sohaib Ahmed

***Abstract* — Emotions are the feelings one has toward various entities. These have always intrigued scholars since early days. With the advancement of information and communication technologies, automated emotion analysis has been in the focus of research community since last decade. This is because people are extensively using online communications for different purposes such as social networking, writing blogs, tweets and product reviews. These online comments are growing enormously due to increasing number of users daily. Therefore, a concern raised by different communities including government, organizations and customers to analyze and explore these online comments for opinion mining and/or emotion analysis purposes. In software industry, software developers generally use forums, mailing lists and discussion groups in order to collaborate among themselves while developing software projects. However, developers may experience challenges such as less effective communications and conflicts during collaborative activities. Hence, this paper addresses to explore these challenges by identifying whether software developers may possess emotions while communicating in discussions. In the previous literature, ontology-based approach has been sparsely explored for emotion analysis, specifically for software developers' collaborations. For this purpose, an ontology called EmotiOn, is used in order to perform emotion analysis on software developers' mailing lists. Further, an analyzer is implemented that processes the design ontology. In this study, emails of two projects from archived Apache Software Foundation (ASF) mailing lists were used for analysis purposes. The results showed that 63% of those emails revealed various emotions. This indicates that software developers indeed express emotions through online communications. The analyzer was able to recognize correct emotions with a reasonable accuracy of 61.3%. The precision and recall measures for each of the emotions were recorded and presented in this paper.**

***Index Terms*—emotions, emotion analysis, ontology, software developers, mailing lists, analyzer**

## I. INTRODUCTION

In recent years, the need of emotion analysis has been prevalent in academia and industry because of the rapid increase in online communications amongst users [1]. These include emails, forums and social media. Such a rise has opened doors to many opportunities for studying emotions. There are many areas where emotions have been analyzed.

This includes customer feedbacks [1], e-learning environments [2], current trends and product reviews [3] and collaboration in software development teams [4].

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The collaboration in software development teams is one of the challenges in software industry because in open source projects, team members are dispersed in different geographical locations. Due to that one-to-one meeting with each team member is not possible. This may produce oblivious emotions and feelings amongst each other while they collaborate. This result in lack of effective communication and conflict resolution and may deteriorate developers' team performance [5]. Many studies have shown that productivity and job satisfaction among teams is directly dependent how team members feel about their work in an organization [4, 6]. Therefore, there is a need to explore emotions between team members while collaborating in software projects.

Ontological approach is one of efficient ways to perform emotion analysis [7]. For any domain under consideration, it allows for the specification of the concepts along with the relationships involving these concepts. Ontology is described in a formal, structured representation. This makes it understandable to humans as well as machines (computers) [8]. There are many uses of ontologies while applying in any domain such as reusability of information in an efficient way, better understating of domain knowledge and easily extendibility of domain model [9]. In the literature related to emotion analysis, ontology-based approach has been used for different purposes including online user feedback [10], opinion mining and emotion analysis [7]. However, such approach has been sparsely explored regarding emotion analysis amongst software team developers. Thus, there is an opportunity for us to address this issue. For this purpose, an analyzer is designed that processes an ontology, EmotiOn [11] for analyzing emotions of software developers. This ontology was based on Plutchik's wheel of emotions model [12] which is one of the most prominent and influential models of classification of emotions.

The organization of rest of the paper is as follows. Section II discusses existing knowledge about emotion analysis and use of ontology-based approach in emotion analysis. In section III, the design methodology for constructing an ontology is described along with the evaluation methodology for an analyzer. Section IV gives an overview of the ontology EmotiOn, while technical architecture of the entire system that processes EmotiOn is given in section V. The results and analyses are discussed in section VI, and section VII concludes this paper and highlights some future directions of this research.

## II. BACKGROUND

This section provides an overview on emotion analysis and its types. It also discusses exiting ontological approaches for performing emotion analysis.

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### A. Emotion Analysis and Types of Emotion Analysis

As mentioned earlier, emotion analysis is the study of investigating emotions, generated by human beings. It allows extraction of emotional content from a wide variety of sources. These include facial expressions [13], speech or voice [14], and text [15]. Text has always been one of the most widely available and common, sources of data. Emails represent the broadest formal online textual communication. Emotion analysis has been performed by few studies over textual data.

These studies may be categorized into appraisal-based [16], corpus-based and knowledge-based methods [17]. The basis of appraisal-based method lies in appraisal theory that defines the reaction of humans in response to some event or situation determines the emotion experienced [16]. In corpus-based method, dictionary or lexicon annotated with emotions are used. There are general-purpose corpora available for English language, which include WordNet [18], Linguistic Inquiry and Word Count (LIWC) [19], British National Corpus (BNC) [20], to name a few. These, however, are not specific to any domain. Corpus-based approach usually involves methods such as keyword spotting, lexical affinity, and statistical natural language processing [16].

Keyword spotting is a simple and commonly used technique which determines emotions on the basis of certain emotive words present in the text. For example, happy, sad, etc. However, the absence of such words significantly reduces the performance of the method [16]. Lexical affinity associates certain probabilities to each word for different emotions. This probability determines the affinity of each word to have a certain emotion. For example, the word 'mad' would have higher probabilistic affinity towards the emotion 'anger', than that towards the word 'fear'. However, this method does not perform well when rhetorical sentences are involved, or when the sentence structure is complex [16]. Also, a consensus is required for the corpus used in terms of association of affinities, which is difficult to achieve. Statistical natural language processing involves machine learning methods for emotion classification. This includes determining frequencies for co-occurrence of words, learning emotion affinities, etc. This technique has also become popular, but requires large datasets for training purposes. This method also comprises efficiency when there is lack of structure in sentences, and when short informal text such as comments or tweets [7].

On the other hand, knowledge-based methods are the best described in terms of semantic web technologies; among which, ontologies are most popular [9]. These can easily be applied to small sets of textual data, in contrast to statistical natural language processing methods. The requirement for annotated corpora is also not a necessity. Ontology provides a formal representation, which is consistent with structured emotion models [9]. This is why an ontological approach is employed in this study.

### B. Ontology-based Approach for Emotion Analysis

Ontology is a term which originated in philosophical studies, and began to be used in computer science in 1980s. It has become a popular model to describe the concepts of a domain and their relationships. Ontology is most commonly defined as "explicit specification of a conceptualization" [8].

Ontologies work well with text. The analogy between humans using natural language to communicate, and ontology using formal language to represent a domain, describes this relationship well. As discussed earlier, there are several advantages of using ontology as a model. One of the major benefits is its cost effectiveness. It can mature with time, and can be gradually incremented to add new concepts and introduce further relationships between the new and old concepts. Thus, it saves time by avoiding construction from scratch every time, unless required [9].

There are a few studies which have used ontologies for emotion analysis, but those based on a standard psychological emotion model, are rare. In a study by Borth et al. [21], an ontology was built on Plutchik's wheel of emotions [12], similar to EmotiOn [11] used in this study. However, it constructed in such a way so as to capture sentiments rather than emotions. Sentiment analysis is coarse-granular. This means that it characterizes feelings in a broad, abstract manner as positive and negative [7]. In contrast, emotion analysis categorizes feelings at a fine granularity [4]. What sentiment analysis captures as negative; emotion analysis describes it as sadness, anger, etc. The ontology given by Borth et al. was a visual one; which means it specifically targeted images, and tried to assign emotions using adjective-noun pairs only [21]. The use of just adjective-noun pairs, however, does not solely represent emotions. Other parts of speech such as verbs and adverbs are known to carry emotional nuances. For example, 'rejoice' is a verb, which symbolizes emotion 'joy'. The ontology, also, did not cover the entire Plutchik's wheel as EmotiOn does.

In another study, Francisco et al. [15] developed an ontology, called OntoEmotion for performing emotion analysis. The basic emotions were categorized into happiness, sadness, surprise, anger, and fear. They concluded that use of ontology improves detection of emotions. However, their ontology did not conform to a single standard emotion model. Instead, they tried to incorporate several theories and models into one. This has the potential to cause conflict, since the emotion categories across all the frameworks are not same. One model may define an emotion as basic, while other may regard it as not basic. This creates confusion. For example, their application, EmoTag, recognized 'terror' as having emotion 'panic', rather than the emotion 'fright', down in the hierarchy, which may raise doubts. However, Kontopoulus et al. [7] presented an ontology based approach for sentiment analysis in order to analyze twitter posts. In this study, authors used formal concept analysis method for such analyses [7]. Most of these works has been used for different domains but none of them have targeted to software team developers' collaborations.

## III. METHODOLOGY

This section discusses the design methodology of EmotiOn, as well as the methodology used for evaluating the analyzer discussed this study.


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*C. Ontology Development Model*

EmotiOn was developed using the design methodology given by Uschold and King [22]. It was one of the initial approaches for ontology construction, and is known for its simple, yet comprehensive design. The major benefit of this methodology is that it is application-independent [22]. It also resembles design of knowledge-based systems. The four-stage process is shown in Figure 1, and is described as follows.

The first stage was Identifying Purpose, in which the need for building a new ontology was established. The expected outcomes and intended purpose of EmotiOn were identified. Building the Ontology was the second stage in the model, which was further broken down into three steps; ontology capture, coding and integrating existing ontologies.

Ontology Capture was the most important phase in the development. A thorough knowledge and understanding of the domain was obtained via different sources. The scope of the ontology, the various concepts of the domain, and the relationships among these were recognized. Proper terminologies and their definitions were identified as well.

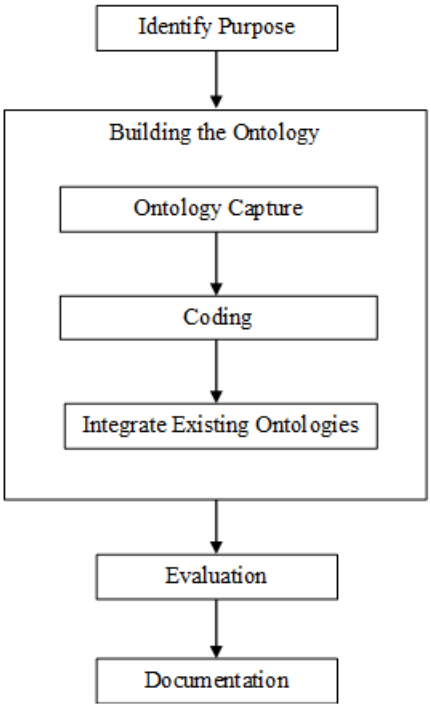


Fig. 1 Methodology for the development of EmotiOn [22]

In the second step of building ontology, Coding, the ontology was then represented in the formal language OWL2 (Web Ontology Language). It is currently the standard and recommended language by W3C (World Wide Web Consortium). It is a very expressive language that represents concepts of the domain in a comprehensive manner. It is an extension of original OWL, and provides thorough expressivity and good reasoning capabilities, without complicating the semantics. Protégé 4.3 (https://protege.stanford.edu/ ) is used as an ontology editor for building EmotiOn. This ontology follows Plutchik's wheel of emotions [12] that comprised of eight classes of emotions; Joy, Sadness, Anticipation, Surprise, Anger, Fear, Trust and Disgust. Further, these classes are inter-related to each other as shown in Figure 2.

Integrating Existing Ontologies was the last phase of building the ontology. The terminologies for software development are only available in the form of glossaries, and not available in structured format. It is, therefore, difficult to query and use with ontologies. Hence, in order to maintain homogeneity, and as a step towards creating a formal domain knowledge for software development, a very basic ontology consisting of only certain concepts was developed. This ontology was integrated with EmotiOn [11].

The third stage for development of EmotiOn was Evaluation. In this stage, the ontology was evaluated against its intended purposes and goals as determined in the early stages. For this purpose, a built-in reasoner in Protégé was used to check for any inconsistency. This was achieved through various Description Logic queries that were carefully formulated for this purpose. The results indicated correct inference for all relationships and constraints for each concept, and no error or incorrect result was obtained.

Documentation was the last stage of design methodology. Since there is no guideline available for any formal documentation of ontology, however, a brief set of information was compiled for quick personal reference. A formal approach may be taken up in future.

*D. Evaluation Methodology*

The dataset for this study comprised of emails, obtained from archived developer mailing lists of two popular, open-source Apache Software Foundation (ASF) projects, HBase and Jena (http://mail-archives.apache.org/mod_mbox/). These mailing lists are publically available and comprise purely on communication of developers working on a project across the globe. For each project, the emails are archived on a monthly basis for every year since the start of the project.

This study took a reasonable amount of emails, pertaining to a 30 month period from January 2013 to June 2015. Even for this limited period, the number of emails is far too many to be practically evaluated. Therefore, the emails were sampled using proportionate stratified sampling technique, with a confidence level of 95%. Stratified sampling ensures balanced representation of each group (month, in case of this study, for each project) in the final sample. The analysis was performed on the sampled emails.

The results were compiled with respect to emotions detected in developer emails. The primary emotion categories of Plutchik's wheel, joy, sadness, anger, fear, anticipation, surprise, trust, and disgust, along with an addition neutral category, were used to record emotions. These emotions were compared against EmoLex [23], the emotion lexicon developed by National Research Council (NRC), Canada. It was chosen as the benchmark for several reasons. It is the only available lexicon which has words, annotated with emotions, according to Plutchik's primary emotions. It is a rich populated source of English words, and was created over a number of years through crowdsourcing. This ensures reliable


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and unbiased annotation as annotators proficient in English language, contributed independently from all over the world. The performance of results was evaluated using following metrics, inspired from the work by Maynard et al. [24].

*a) Accuracy*

Accuracy measures the degree of correctness of the outcomes of an experiment with respect to the actual true outcomes.

$$\text{Accuracy} = \frac{\text{Total Number of Correct Outcomes}}{\text{Total Number of Outcomes}} \quad (1)$$

*b) Precision*

Precision measures the degree of exactness of each category in the outcomes of an experiment with respect to the actual outcomes for that category. It is calculated separately for each category.

$$\text{Precision}_{\text{cat.}} = \frac{\text{Total no.of correct outcomes for a category}}{\text{Total no.of outcomes for a category}} \quad (2)$$

*c) Recall*

Recall measures the degree of completeness, or sensitivity for each category in the outcomes of an experiment with respect to its actual outcomes. It is also calculated separately for each category.

$$\text{Recall}_{\text{cat.}} = \frac{\text{Total no.of resulting correct outcomes for a cat.}}{\text{Total no.of actual outcomes for a cat.}} \quad (3)$$

## IV. EMOTION: ONTOLOGY FOR EMOTION ANALYSIS

The ontology EmotiOn, extensively described in [11], captures the entire Plutchik's wheel of emotions [12]. It was designed with three varying intensities of emotions, mild, basic, and intense, according to the wheel. Each category included eight emotions; that is, a basic emotion 'anger' has a milder level 'annoyance', and an intense level 'rage'. Thus, each intensity of emotion was created as a separate class, with its eight types as the subclasses. A discrete class Neutral was also included cater for the absence of emotions. The varying degrees of emotions were captured by Intensity class which had three members; Mild, Normal, and High.

Each of these classes had various instances, or individuals, in terms of ontology, in order to cover the domain knowledge as much as possible. However, there is still room for enrichment, and addition of similar knowledge will mature the ontology with time. The relationships and constraints among the concepts of EmotiOn were defined with the help of certain properties.

This study deals with just the basic emotions. At present, the analyzer does not consider the varying degrees of intensities. The emotions occurring in the emails are recognized in terms of the basic emotions only.

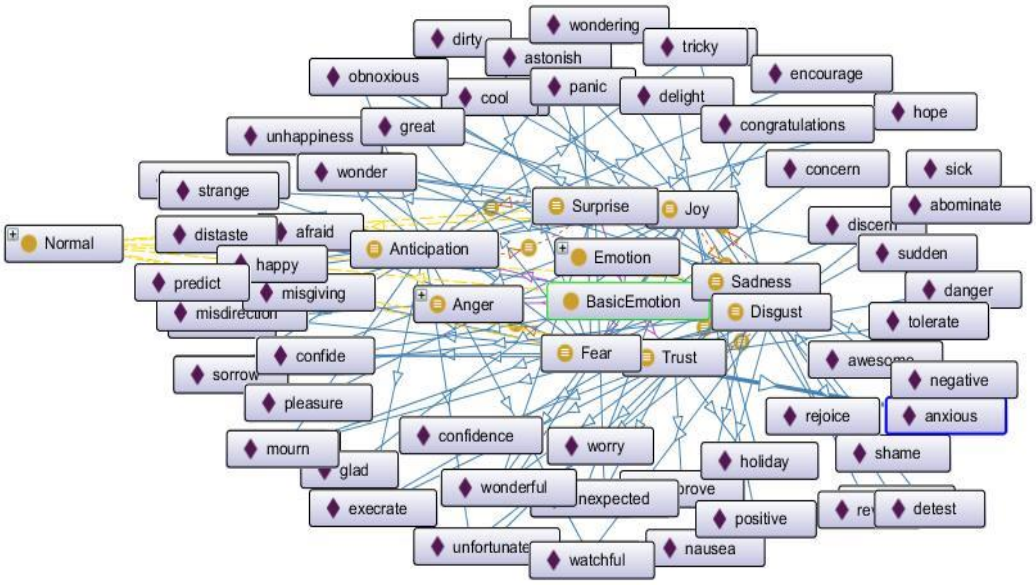


Fig. 2 The Basic Emotion class with its subclasses, individuals, and properties [11]

There are eight classes of emotions namely, Joy, Sadness, Anticipation, Surprise, Anger, Fear, Trust, and Disgust. Each class has certain associated individuals, which are visible as well. All the classes have 'Normal' intensity, as shown in the figure by Normal class with yellow dashed arrows connected with emotions. These arrows represent the 'hasIntensity' property of in the ontology. The contrasting emotions are also linked through the 'isOppositeOf' property. This can also be observed in the figure due to the presence of smaller dashed arrows of brown color.


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## V. TECHNICAL ARCHITECTURE

The technical architecture of the overall system is shown in Figure 3. It comprises of two major parts; the ontology developed in Protégé, and the analyzer developed using Java.

When the use submits a request by selecting an email from the web browser, it is handled by the servlet container. The email, in the form of HTML file, is then retrieved from the archives and passed over to the Java module for processing. First, the text from the body of the email is extracted with the help of JSoup API (http://jsoup.org ), by stripping off all HTML tags. This text is then tokenized and Parts Of Speech (POS)-tagged using RiTa API (Available at http://rednoise.org/rita ). These tokens are then checked, one by one, in the already loaded ontology model, for any emotional concept. The ontology model is created in the analyzer through Jena API (http://jena.apache.org ) over the reasoning capabilities of Pellet (https://www.w3.org/2001/sw/wiki/Pellet). If the token does not match any class or individual, its synset is retrieved through WordNet with the help of JAWS (https://lyle.smu.edu/~tspell/jaws/), and checked in the ontology again. If no match is found, neutral is assigned to that word. Otherwise, a resulting basic emotion is assigned, in accordance with the ontology. Additional notions were also incorporated in the ontology apart from the emotion word of Plutchik's wheel and the synsets. For example, the word 'vacation' does not, in itself, carry emotion; but it implies the feeling of 'joy'. Such notions are also a part of emotion.

WordNet [18] is a renowned lexical database, which is used as standard in many language based applications. It organizes words according to various taxonomies such as hyponyms and synsets (synonym sets). These sets are compiled on the basis of four parts of speech; noun, verb, adjective, and adverb. The final resulting emotion of the email is obtained cumulatively from all the emotional words in email. The most occurring emotion and contrasting emotions are taken into account for the final assignment of emotion. It is then returned to user in the web browser via the servlet.

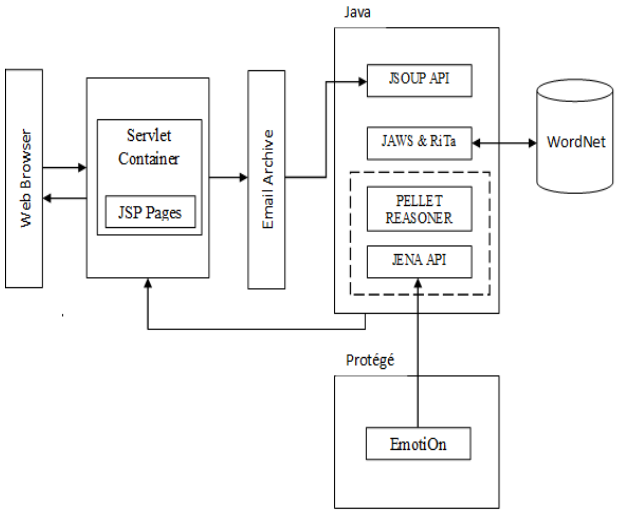


Fig. 3 Technical architecture of the analyzer

## VI. RESULTS AND ANALYSES

After the generation of results by the analyzer, the emotion for each email was recorded and compiled. The distribution of results is shown in Figure 4. This chart presents an overview of the emotions for both the projects within the duration specified. It can be observed that approximately 64% of the emails contain some emotion, while the remaining 36% are neutral. Among the emails carrying emotions, joy, sadness, and anticipation, were the most occurring categories. It is interesting to note that five out of the eight basic emotions of Plutchik, were minimally expressed by the developers.

These results are not surprising. A good amount of emails bearing neutral (no emotion) are fairly common in software development environment. Many of these emails contain a single link such as: https://builds.apache.org/job/HBase-0.94/691/changes

A large number of emails primarily contain announcements or long error logs for discussing issues and bugs in the code. Furthermore, if we consider English language in its normal and general daily use, most of the words do not carry any emotion. As an example, consider this sentence: 'I'm feeling good today after getting up early in the morning'. In this sentence, only one word 'good' carries nuance for emotion 'joy', while the rest do not contain emotion. Thus, the detection of 64% emails with emotion seems a fine result.

The overall accuracy of the analyzer was determined to be 61.3%. It is a reasonable value, considering that it is an initial attempt. Most studies have not performed such kind of analysis. It can be improved as ontology is matured. A combined plot of precision and recall measures for each of the emotion category, along with neutral is given in Figure 5. This plot shows varying precision and recall values for the emotions. As evident from Figure 4, some emotions were scarcely expressed by the developers. Therefore, limited number of emails having these emotions was presented in the data. Thus, these emotions exhibit the most fluctuation in values. Hence, these values cannot be taken as representative of these emotions due to inadequate amount. Most of the frequently occurring emotions have closer precision and recall values.

The high recall values indicate the correctly identified emotion from those emails which actually contained that emotion. Conversely, low recall values indicate that the analyzer was unable to correctly identify the emotion. The high precision values indicate the actual emails containing the emotion, which the analyzer identified. Low values mean that the analyzer incorrectly predicted that the email presented some other emotion.

Consider the example of emotion 'joy'. Its precision and recall values were determined to be 78.5% and 86.8% respectively. These are fairly good results. From the eight basic emotions, joy was the most commonly expressed emotion in the emails. Sufficient data, along with the fact that English language has a wide selection of words with resemblance to joy, are the major reasons for good results.


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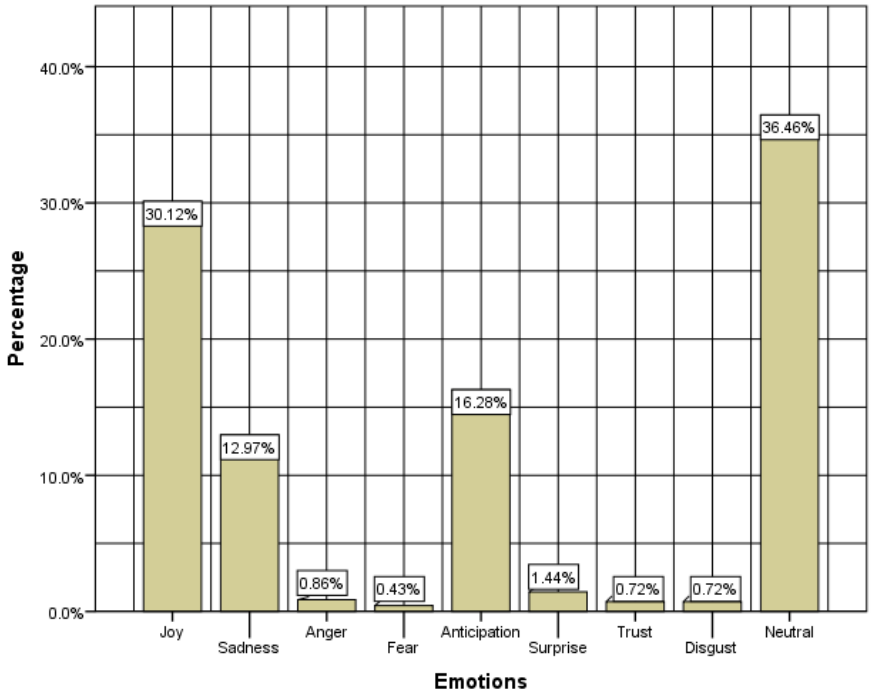


Fig. 4 Distribution of emotions expressed in emails

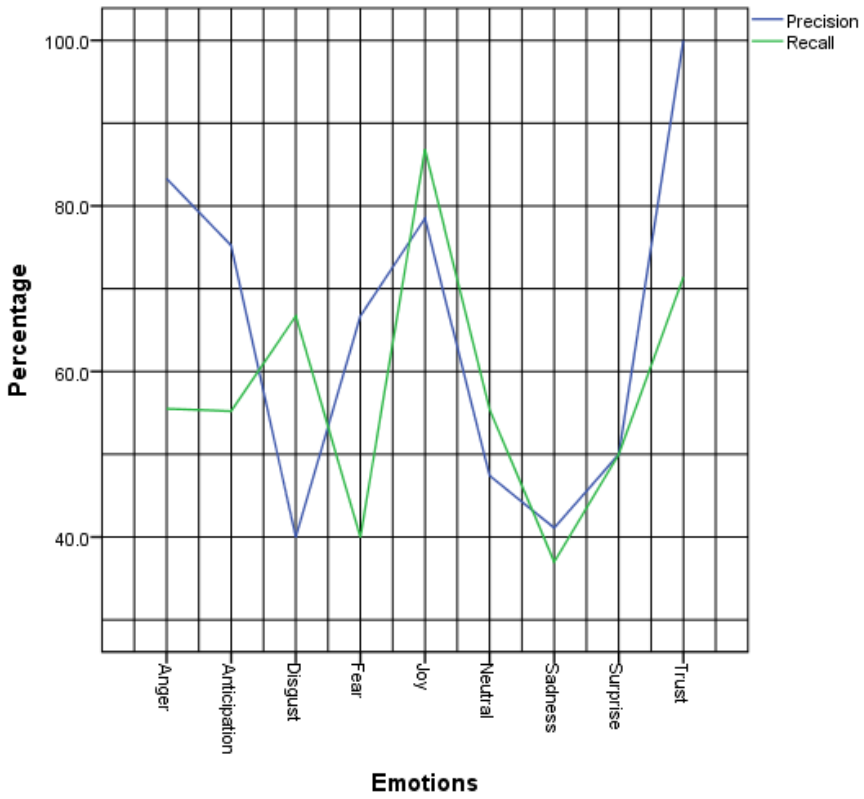


Fig. 5 Precision and Recall measures for all emotions

In contrast, 'anticipation', which the second most frequently occurring emotion from the basic eight, has very different precision and recall values of 75.2% and 55.2%. Although the difference is not very huge, it reveals the significance of domain vocabulary.The domain for this study includes emotions, and software development. However,


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there are currently no benchmarks available, especially for the latter. Hence, the available standard lexical sources for general English had to be used. In order to understand this better, consider this example. The word 'bug', generally, in daily use, may entice the emotion 'fear'; however, in software development environment, it is a common term that occurs frequently indicating some error, and does not carry the emotion 'fear'. Similarly, for 'anticipation', certain routine announcements and suggestive emails, which are considered 'neutral' in the community, were identified as anticipatory by EmoLex [23]. This is the reason behind varying precision and recall results.

## VII. CONCLUSION AND FUTURE WORK

This paper discussed the use of ontology-based approach for emotion analysis amongst software team developers. Further, an analyzer is designed to process the designed ontology, EmotiOn, for such analyses. Archived mailing lists of developers of open source projects were considered for this purpose. The results indicate that software developers indeed express emotions. A highly significant percentage of approximately 63% emails were found to contain emotions. The most frequently expressed emotion by the developers was 'joy'. Other emotions such as 'anticipation' and 'sadness' were also expressed in the results. The precision and recall values for these emotions were also recorded and discussed accordingly.

This study provides various opportunities for future enhancements. EmotiOn can be matured by enriching it with related concepts. This will make it even more comprehensive and shared amongst research community. The ontology for software development and maintenance terminologies may be pursued as a separate study. This will capture the software development domain in structured, machine-readable format. Also, more functionality, such as recognition association of the software developer expressing the emotions, may be introduced.

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