A Review on Natural Language Processing based Automatic Question Generation

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Abstract— The advent of the Internet resulted in availability of e-content in huge quantities; this e-content includes information in different domains. This information is being exploited for various reasons and applications. As the formal evaluation and assessment techniques are undergoing transformations, there is also a need for a voluminous Question Bank (QB). The manual creation of questions is a time-consuming and expensive task as it requires domain experts and there is a growing trend towards question bank based question paper generation for assessment. Hence the problem of automatic question generation has attracted attention of the Natural Language Processing (NLP) research community; this problem can be handled by NLP. Automatic generation of high-quality questions is the long-term goal of the Question Generation (QG) research community. The automatic question generation aims to generate all possible questions from the input text or document. This survey article presents the issues, challenges and approaches as well as reviews the reported research work in the context of automatic question generation for different languages at national and international level.

Keywords - Question Generation, Question, Natural Language Processing, Parts of Speech tagging(POS), Named Entity Recognition.

I. Introduction

The Automatic Question Generation (AQG) generates all possible questions from the input text, paragraph or document. The text can be a word, sentence or a paragraph. Question generation is used in question bank based question paper generation, dialogue systems, instructional games and natural language summarization systems. This problem of question generation can be automated using Natural Language Processing (NLP). NLP is one of the subfields of artificial intelligence (AI). NLP deals with how computers can understand and process the language spoken or written by humans. Questions are used from the early childhood stage of learning up to the higher research level. Humans are inquisitive by nature. They ask questions to satiate their never-ending quest for knowledge. For instance, students ask questions to learn more from their teachers, teachers ask questions to help themselves evaluate the performance of the students, and our day-to-day lives involve asking questions in conversations, dialogues to render a meaningful co-operative society. Questions are important for a teacher to analyze the learner's understanding and also it will help the learner to understand the topic he learns [3].

Now a--day's e-contents are available in huge quantities; this e-content includes information in different domains. This information is being exploited for various reasons and applications. As the formal evaluation and assessment techniques are undergoing transformations, there is also a need for a voluminous question bank (QB). The manual creation of questions is a time-consuming and expensive task as it requires domain experts. As there is, for formal assessment, it becomes difficult to do this task manually.

Hence there is a need for technology intervention to handle this problem and there is a growing trend towards question bank based question paper generation for assessment. Automatic question generation systems can address this issue and reduce the efforts, time required to generate the question papers.

This article discusses aspects related to questions and their automatic generation as well as reviews reported research work. Section II describes definitions of questions and their types. In section III taxonomy of questions is described. Question generation process is described in section IV. Section V and VI describes applications of automatic question generation and review of related work.

II. Question

The meaning of the word 'question' is asking something; or requesting or obtaining information about something through interrogation. Question is an interrogative statement to request for information; which itself can be the single word, line, paragraph or a document.

A. Question Types

There are many ways to classify the questions. Like depending on the length of the answer, depending on the type of the answer (true/false/yes/no/one word), depending on the learner's learning level etc. Questions are also classified depending upon the length of the answer as short answer questions and long answer (subjective) questions. Long answer questions can be generated at the paragraph level, while short answer questions can be generated at the sentence level.
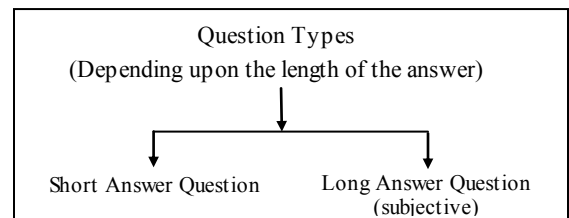

Fig.1. Question types

'Factoid questions' have fact based answers. Factoid Questions begin with a wh-phrase, i.e. what, who, which, why, when, where, whose, whom, how etc. Automatic generation of these questions will be possible at sentence level.

Example: What is a factoid question?

'List questions' have a set of answer terms and they will generally start with the question word which or enlist.

Example: Enlist the types of questions?

'Multiple Choice Questions' (MCQ) will have a 'wh' question which comes with four options generally called as distractors as an answer, out of which one is the correct

answer term. MCQ generation process has three steps Sentence selection, key selection and distractors selection.

Example: Select the correct type of factoid question?

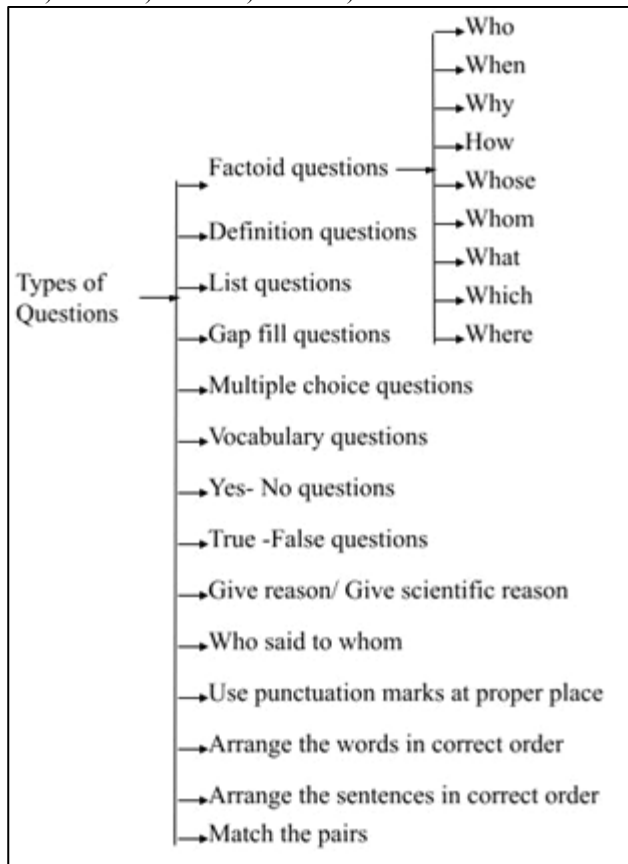a)Who   b) when   c) what   d) all of these

Fig.2. Question types

'Gap fill questions' have a sentence with one or more blanks in it. Preparing these questions manually will take a lot of time and effort. They are also called fill in the blank questions. Sumita et.al. have generated fill in the blank questions to test English knowledge of the learner using correct verbs [11]. To extract the more suitable answer phrase from the sentence to generate a fill in the blank question researchers have used POS categories like verb, noun chunks.

Example   'Gap fill questions' have a sentence with one or more ------------- in it.

'Yes-no questions' are known as polar questions in linguistics. These types of questions are either affirmative or negative, they have answers in yes or no words. Bernhard (2012) generated yes-no questions[15].
Example: Is the Sun rising in the east?

'Vocabulary questions' types like definition, antonym, synonym, hypernym, hyponym: these question generation systems will use wordnet.
Example: Write synonyms and antonyms for 'good'.

'True or False questions' are questions whose answer is either true or false. Zou et. al. have generated true/false questions using a masking and infilling strategy[23].

'Arrange the words in proper order' Here the words in a sentence have been jumbled, the learner has to arrange the words so that the sentence should have proper meaning. Example summer ice cream John only eats in the. Arrange the words in proper order.

'Arrange the sentences in correct order' Here, a number of phrases are offered in a random order, all of which depict a series of actions or occurrences. Lerner must determine the right arrangement of the sentences and rearrange them accordingly.

There are different kinds of long answer questions as follows.

'Describe' type questions will involve description of given things or statements in a few lines.

'Write a short note on' type questions will also expect answers in a few lines that will explain given terminology, statements or it can be anything related to the given subject.

'Distinguish / compare'   here two terms are given for which the learner has to write comparative features of both the terms.

'Match the pairs' This type of question has two columns the learner has to match the correct pair from the left column and right column.

III.   Taxonomy of Questions

The taxonomy was proposed in 1956 by Benjamin Bloom, an educational psychologist at the University of Chicago. He has defined six levels of questions as knowledge, comprehension, application, analysis, synthesis and evaluation [10] as shown in Fig. 3.
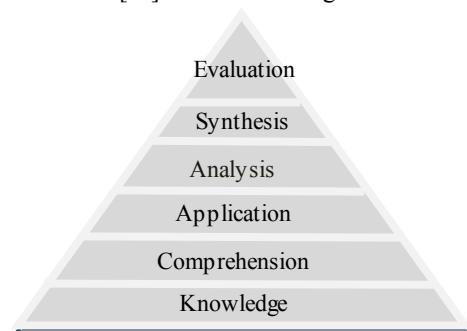

Fig.3. Bloom's taxonomy of questions.

Bloom's taxonomy is a powerful tool to develop learning objectives. The advantage of generating questions based on Bloom's taxonomy enables them to generate the questions that help to assess the learning ability of the students. Most of the automatic question generation systems have generated questions for Bloom's level 1 i.e. 'knowledge level' only [2][4][5][6][7][8]. It will involve questions which will test the learner's recalling of basic facts. Blooms level 1 i.e. Knowledge level will involve questions like What _? When _? Where_?List,Define__. e.g. Who were the illiterates? What is the name of the capital of India? Who said to whom, "————————-"? This level of questioning ensures that students retain particular material   from   the   course. The level 2 i.e. 'comprehension' will involve questions which will test the learner's understanding of facts. The level 2 questions are about causes and effects [17]. Stasaski et al used the causal relationships from the input text, to generate cause and effect based questions [16].

Example Why can't rough surfaces easily rub against each other? _ State the important points.

The level 3 i.e. 'application' will involve questions like whether the learner can apply the acquired knowledge in a new situation.

Example: How   would   you   present----? Level 4 is the "analysis" level, which consists of more difficult problems that require the learner to do more than just recall, comprehend, and apply. Analysis level questions are as follows.

Example: What is the main idea of the story? What are the consequences of __? Why do you think ___?

Why do we call these animals' omnivores? The learner has to determine reasons and causes in order to analyze something.

Level 5 is the 'synthesis level' i.e. Organize ideas into a new whole or propose alternative solutions. It will include the following questions.
What would happen if___? Can you predict___? Combine these words to make a complete sentence.
Problems where analysis and synthesis is required are more difficult than problems that require comprehension. The highest level i.e. Level 6 is 'evaluation'. How one can make a judgment based on some evidence. Students are encouraged to form opinions by using evaluation questions. It will involve questions like What would you choose? Why was it better than _?

Most of the AQG systems have generated questions having Bloom's level 1 only. When AQG systems have been used in education then they should generate questions having higher Bloom's level. It is one of the challenges for the NLP research community to generate questions above Bloom's level 1. Bloom's taxonomy was revised by his student Lorin Anderson in 2001; they changed all the six categories from verb to noun and according to them creation is the highest level[17].

IV. Automatic Question Generation Process

The AQG aims to generate all possible questions from the input text or document. AQG can be viewed as both natural language understanding (NLU) and natural language generation (NLG) application areas of NLP as shown in the Fig. 4. NLU is concerned with comprehending the input text (content) while NLG helps in question formation.
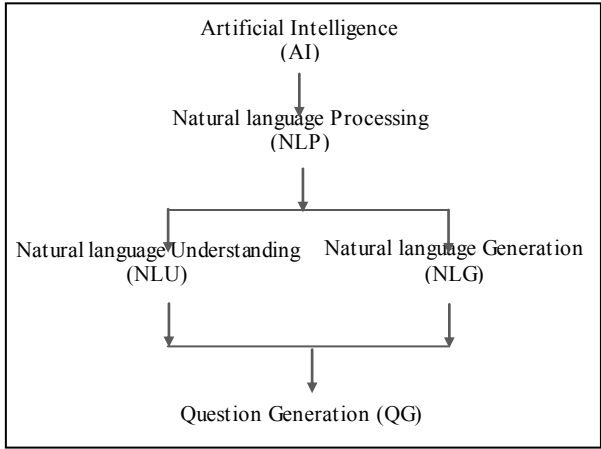

Fig. 4 Question Generation

The basic block diagram of the AQG is depicted in following fig 5.
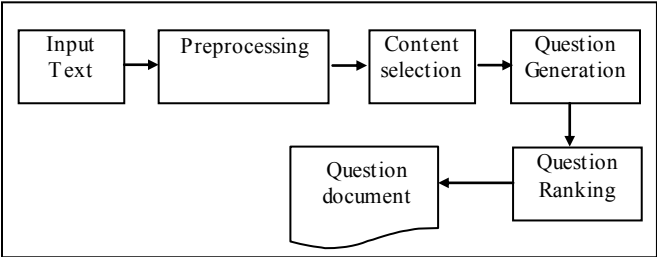

Fig.5 Basic block diagram of AQG

The input text can be a word, sentence, paragraph or a document. The AQG process involves various phases as shown in Fig. 5; Prior to sentence preprocessing, researchers may have simplified the sentences [15][18][20], selected informative sentences manually or chosen the most instructive sentences from the paragraph using summarizer [01].

A. Preprocessing

For any NLP work sentence preprocessing is a crucial work step. Sentence preprocessing has been used in various ways by different scholars. Depending on the type of answer phrase, several preprocessing steps will be required. Like any other NLP applications the first step does perform various NLP tasks such as; tokenization [19], Chunking, POS tagging, Named Entity Tagging, dependency parsing, semantic role labeling etc. Various researchers have utilized one or more tasks from the NLP stack to generate questions automatically, including POS, named entity recognition (NER), chunking, semantic role labeling (SRL)[01][13], and dependency parsing. NER tools are used to identify the named entities from the input text and depending on the type of entity questions will be generated [6][7][21]. Relations between different words of a sentence will be identified using dependency parsing and depending on these relations questions will be formed [12]. The grammatical analysis of the sentence fragments is the outcome of the sentence preprocessing.

The preprocessing tools used for various NLP tasks by various researchers are summarized here.

TABLE I : Existing NLP tools used by various researchers

Author (Year)	Existing NLP tools	Purpose
Narendra, A., (2013) [1]	Stanford Core NLP tool kit TopicS tool	Tokenization, POS tagging, NER, Parsing, co-reference resolution.
Husam Ali (2010)[2]	Oak system	for tokenization and POS tagging
	Charniak Syntactic parser	Parsing sentence
Hussein, H.(2014) [4]	OpenNLP	Parsing
Mannem, P(2010)[13]	BART	Sentence splitter
	The MorphAdorner	Lemmatizer
	Bidirectional	POS tagger
	Illinois	Named Entity Tagger
	Bidirectional LTAG	Dependency parser
	ASSERT toolkit	Semantic role labeler
Michael Heilman (2009)[5]	Stanford Phrase Structure Parser, Tregex	Tree Searching Language and Tool
Khullar, P.(2018) [12]	Spacy parser	Dependency parsing
S.Sowmya (2013)[7]	Tamil POS tagger and chunking tool	POS tagging and chunking

B. Content Selection

1.Answer Phrase Selection

This step involves selection of the answer phrase which is an important part of the question generation. The answer phrases can be named entities [1][6][07], verb words, adverb words, relative adverb words, adjectives, relative pronoun words[12], constituents[1], noun chunks[22], clauses or discourse connective words [08]. Answer phrases can be a single word or a phrase. Researchers have generated questions from complex sentences; in which an answer phrase can be a main clause or a subordinate clause [23]. Dependency parsed relations, subject, object [20], semantic roles [13][20] are used as an answer phrase. An input sentence might have more than one answer phrase. All these answer phrases will not be used for question generation. More suitable answer phrase depends on the position of the sentence in a document/paragraph, length of the sentence, syntactic and semantic properties of the answer phrase.

2.Determination of question type

After selecting the answer phrase the next step is to decide what type of question can be phrased. Questions were

generated from the named entities. The type of entity must be known in order to determine the question word. This is accomplished using the NER tools. If the named entity is a person then who type question, if location then where type question, if time then when type question will be formed.

Illustration: Sentence:- John lives in Mumbai. Here John is named entity with the type person while Mumbai is a named entity with the type location. So we can ask who question to the person named entity and where question to the location noun entity because it indicates the place. The type of entity will determine the question word.

Who lives in Mumbai? Where does John live? If the input sentence is a complex sentence then the question word is determined by the subordinate conjunction. If 'because' is a conjunction in a complex sentence, a why type or cause and effect based question can be generated. Following table summarizes the answer phrase type and the type of question generated from it.

TABLE II : Answer phrase and type of questions.

Answer Phrase	Type of question
Named entity Person Location Time Number	 Who Where When How many
Dependency relation subject object	 who what
Semantic role labels	who, what, where, when
Subordinate conjunction	what, when, why, what will happen if, what is the result of

C. Question Generation

This is the last step of AQG which is responsible for constructing question sentences automatically. It involves framing a proper question from the answer phrase and preprocessed sentences from previous phases. Natural language generation rules and predefined templates are used for constructing the questions. Mannem et. al. were applied syntactic transformation rules for question construction [13].

D. Question Ranking

The questions generated by AQG systems were ranked to find the best questions. The following is a list of the criteria that will influence the question rank.

1) The question's grammatical correctness.

Illustration: Why is the sky blue? This is a grammatically incorrect question.

2) The question's semantic accuracy.

3) Clauses: main clause or subordinate clause[13].

The questions generated from the main clause of the input sentence will be more accurate than the ones generated by the subordinate clause.

4) The number of pronouns in the question [13]: The presence of the pronoun in the question lowers its rank.

Illustration: Why is he late today? This question is semantically incorrect.

5) The length of the input text and the resulting question

6) The input text and the generated questions' lexical, semantic and conceptual relevance. [23]

After ranking the generated questions, the high rank questions will be stored in a question document.

V. Applications of automatic question generation

Due to its relevance, AQG has its application primarily in the education field. Besides this, it has applications in

1. Question bank based question paper generation.

2. Question generation is used in dialogue systems.

3. The natural language summarization systems will use the answers of the generated question for creating a summary.

4. Pre-questions can help focus learners' attention on the learning material targeted by the questions. Giving questions before learning can improve future memory for that topic [3].

5. Automatic question generation is also helpful in medicine by generating suggested questions for patients and caretakers.

6. Pre questions can be used for a game based learning environment.

VI. Review of related work

Automatic question generation is a very popular and challenging research area. Many researchers are working on question generation systems for different languages with different issues and challenges. The research work in the field of AQG has been presented in many surveys. A question can be an inquiry or it can be an interrogative sentence or is a request for information. G. Kurdi et al assessed the AQG work solely for educational purposes from 2014 to 2019[9]. They discovered the necessity for improved evaluation metrics and the creation of automated question templates.

Narendra, A. et al used semi-structured approach to generate MCQs using named entities, adjectives, pronoun or a constituent[1].Ali et al. have generated questions using subject, verb, object and prepositions for QGSTEC (Question Generation Shared Task Evaluation Challenge) 2010 development data [2].Hussein et al. have used templates to generate wh questions type questions [4]. Heilman et al. have used a rule based approach to simplify the sentences and also to generate questions by decomposing the main verb into subject and auxiliary verb [5]. Kaur and Bathla (2015) have used hybrid approach for Hindi MCQ generation. They have combined rule based, dictionary look up and example based approach [6]. Vignesh and Sowmya have designed rules to replace the specific POS tags by question words [07]. Discourse connectives will connect the two sentences. Between these two sentences one is used to create a question [08]. Deepali K. have generated questions using rule based stemmer for Marathi. They have generated only wh type questions[14]. The problem with this approach is that questions are generated using single answer words only. Questions can be generated by combining different approaches called hybrid approaches [21]. Khullar et al. generated questions using structural relationship between relative adverbs and relative pronouns [12] using custom rules. Bernhard (2012) has designed rules for sentence simplification, then generated questions using syntactic parsing and (Singh 2014) 'Named Entity Recognition' [15]. Also they have created multiple questions from one generated question through the use of variations in question word and nominalization of the main verb [15]. Mannem et al. (2010) proposed semantic role labeling and predicate argument structure based approach to generate questions from paragraphs [13]. Stasaski et. al. have generated questions using causal relationships from the passages [16]. Woo, S. et.al. have generated personalized authentication questions by utilizing the

dependency relations and the semantic role labels to identify the subject and generated who and what type questions[20].

TABLE III. Summary of question generation techniques used for different languages

Author (Year)	Language	Evaluation Datasets	Approach	Answer phrase	Types of Question
Narendra, A., (2013)	English	Cricket sport domain	semi-structured approach	Pronoun, Named entity	Multiple choice questions
Husam Ali(2010)	English	TREC-2007 (Question Answering Track) 1 dataset	Rule based approach	Prepositions, Named Entity	Factoid questions(what, who, whom, where, which, when, how many)
Hussein, H.(2014)	English	--	Syntactic pattern matching approach	Named entity	Wh questions:who, when, where,what, how much
Heilman, M(2009)	English	WIKI-ENG, WIKI-SIMP	Rule based approach	Noun phrase	Wh, where, when, how much
Arvind Joshi (2010)	English	QGSTEC 2010 Wikipedia, Yahoo answers, Open Learn	Predicate Argument Structure, Dependency Parser, Semantic Role Labeling	Copular verbs, semantic arguments	Factoid questions
Agarwal, M (2011)	English	QGSTEC development dataset and Wikipedia dataset.	Syntactic approach	Discourse Connectives (arg1 or agr2)	Why, when, give an example type questions, yes/no
Sumita, E. (2005)	English	ATR's Corpus of the business and travel domain, news site	POS tagging	Verb	Fill in the blanks
Khullar, P.(2018)	English	Wikipedia corpus	Rule based approach	Relative pronouns, adverbs	Wh questions
Mannem, P(2010)	English	Paragraphs taken from Wikipedia, Yahoo answers, Open Learn.	Rule based approach	Semantic roles	How, why, when, where, what, who
Bernhard D. (2012)	French	a corpus of newspaper articles 40 sentences from Wikimini and Vikidia, which are simplified versions of the French Wikipedia targeted at children.	Rule based approach	Noun phrase	factoid questions (what, when, where, who) Yes-No questions
Woo, S.(2016)	English	collected few sentences in a free-form format regarding personal life events from 28 students and 12 Amazon Mechanical Turk workers	Rule based, two phase approach	Named entity, semantic roles ,subject, object	Personalized authentication questions(who, when, what, where)
Agarwal, M.(2011)	English	Two chapters of text book :Campbell Biology, 6th Edition	Syntactic approach	Noun chunks	Fill in the blanks
Zou, B (2022)	English	20 English passages from the quiz materials at a level of elementary education	Template based, Masking and infilling approach.	Subordinate clause, prepositional phrase, semantic roles, adversative clause	True/False questions
Stasaski, K(2021)	English	SQuAD Wikipedia articles and middle school science textbooks	Pattern matching and rule based approach	Causal links(adverbial, prepositional, subordination, clause integrated linkage)	Cause and effect questions
Zheng, H (2018)	Chinese	news data from Netease and Toutiao	rule-based templates	Named entity, adjective	Factoid Questions

TABLE IV. National Languages

Author (Year)	Language	Evaluation Datasets	Approach	Types of Question
Deepali K. (2018)	Marathi	28 sentences	Rule based [Answer phrase:noun]	Factoid Questions
S.Sowmya (2013)	Tamil	--	Rule based approach Tamil POS tagger	Factoid Questions Who, what, where, when,
Nisha Sharma (2015)	Punjabi	500 different sentences	Hybrid approach(Dictonary Look up, Rules and example]	Multiple choice questions
Ashok Kumar Bathla (2015)	Hindi	300 sentences from Hindi websites and Hindi text books.	Hybrid approach(Rule Based, dictionary lookup & example based	Multiple choice Questions

VII. Conclusion

In this survey we have studied the key aspects of the question generation system such as question, question types, taxonomy of questions, AQG process and various approaches used by researchers for generating questions. We have observed that most of the researchers have generated factoid questions i.e. Bloom's level 1. It is one of the challenges for the NLP

research community to generate questions with Bloom's levels 3 and higher. The survey of various automatic question generation systems reveals that most of the work is done in foreign languages. It has been observed that for Indian languages especially Marathi language the reported work appears to be at an elementary stage. Hence our research work will be initiated to develop the automatic question generation system for Marathi language in near future.

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