International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

F.746.3

(11/2015)

SERIES F: NON-TELEPHONE TELECOMMUNICATION SERVICES

Audiovisual services

Intelligent question answering service framework

Recommendation ITU-T F.746.3

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Recommendation ITU-T F.746.3

Intelligent question answering service framework

Summary

Recommendation ITU-T F.746.3 defines the intelligent question answering service (IQAS) framework as well as the features, requirements and the functionality to support the intelligent question answering (QA) service. The intelligent QA system is an advanced function to generate answers to a user's questions in a natural language. More and more systems in the future are expected to be equipped with QA functions for an advanced user experience.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T F.746.3	2015-11-29	16	11.1002/1000/12619

Keywords

Intelligent system, natural language processing, QA, question answering.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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1 Scope

This Recommendation provides an overview of the intelligent question answering service (IQAS) framework and describes the features, general requirements and functionality which form a framework to support the intelligent question answering (QA) service. The scope of this Recommendation focuses on QA architecture, devices, servers, interfaces and communication protocols among QA servers and clients in a high-level approach.

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.101]: A structured set of capabilities, which provide value-added functionality supported by one or more services.

3.1.2 content [b-ITU-T H.780]: A combination of audio, still image, graphic, video, or data.

NOTE – Variety of formats is classified as the "data" (e.g., text, encoded values, multimedia description language introduced by [b-ITU-T H.760]).

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 co-reference resolution: A function that detects the preceding referents of the pronouns which replace the noun phrases of the input sentences.

3.2.2 CV_occupation: A named entity tag that belongs to the civilization (CV) category that indicates a person's occupation (e.g., scientist).

3.2.3 CV_prize: A named entity tag that belongs to the civilization (CV) category that indicates a prize (e.g., the Nobel prize).

3.2.4 IsA relation: A hierarchical relation between two words in such a way that the meaning of one word includes that of the other word.

3.2.5 knowledge base: A collection of knowledge resources that consist of structured and unstructured data. The knowledge base is used to provide information to the various applications that are related to information provision such as the QA system and search system.

3.2.6 named entity recognition: A function that recognizes named entities such as PLO entities which are people, locations and organizations from the sentences. The PLO can be decomposed into more specific named entities depending on the applications.

3.2.7 natural language processing: A method that analyses text in natural languages through several processes such as part-of-speech recognition, syntactic analysis and semantic analysis.

3.2.8 part-of-speech recognition: A function that recognizes parts of speech (POS) in the sentences and assigns relevant POS tags considering contextual meaning of the target sentences.

3.2.9 question answering: A system that provides answers in natural language to questions which are in natural language form by analysing the questions and all the knowledge resources that are available to the system.

3.2.10 semantic analysis: A function that recognizes the semantic relations among the words around predicates that exist in the same sentence. The semantic analysis function then generates a semantic predicate-argument structure (PAS).

3.2.11 syntactic analysis: A function that analyses sentence structures and generates dependency relations among words based on dependency grammars.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ARG	Argument
CV	Civilization
DB	Database
DS	Digital Signage
ID	Identifier
IQAS	Intelligent Question Answering Service
KB	Knowledge Base
NLP	Natural Language Processing
NLU	Natural Language Understanding
NNG	Noun General
NNP	Proper Noun
NP_OBJ	Noun Phrase Objective
NP_SBJ	Noun Phrase Subjective
PAS	Predicate-Argument Structure
PLO	People, Locations and Organizations
POS	Parts Of Speech
QA	Question Answering
SL	Sub Language
SPARQL	SPARQL protocol and RDF Query Language
SQL	Structured Query Language
VP_MOD	Verb Phrase Modal
VV	Verb
XSNG	Auxiliary Suffix from Noun General
XSV	Auxiliary Suffix from Verb

5 Conventions

The following conventions are used in this Recommendation:

– The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

– The keywords "is prohibited from" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

– The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

– The keywords "is not recommended" indicate a requirement which is not recommended but which is not specifically prohibited. Thus, conformance with this Recommendation can still be claimed even if this requirement is present.

– The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with this Recommendation.

6 Introduction

The intelligent question answering (QA) system is an advanced function to generate answers to a user's question in a natural language. More and more systems in the future are expected to be equipped with QA functions for an advanced user experience. Currently, the most widely recognized QA system is an intelligent agent which is provided in smart phones. Although not a completely intelligent agent able to answer all questions that users may ask, a QA service would be useful for a defined environment. A QA service would be useful if a standardized QA service framework existed which could be applied to various domains such as TV-related services, digital signage (DS) and e-health services. A QA service would also be useful in terms of accessibility because natural languages are used to request and provide information conveniently with a speech interface. Figure 1 illustrates the concept of a QA system in the DS domain, where a user requests information about shoe stores from the QA system at a shopping mall.

– Scenario of an intelligent question answering service (IQAS) system: An IQAS system at a shopping mall.

  Michelle visits a shopping mall in Seattle. There is a DS helper which displays information about the various shops at the mall. It also answers customers' questions about the shops. Michelle wants to buy a pair of shoes and asks the DS helper "Where can I find some nice shoes?" The DS helper answers "Go to the third floor". Michelle goes to the third floor where she can find some shoe stores. The answer can also be shown in text form on the screen or can be provided by speech synthesis in a spoken form according to the needs of the user.

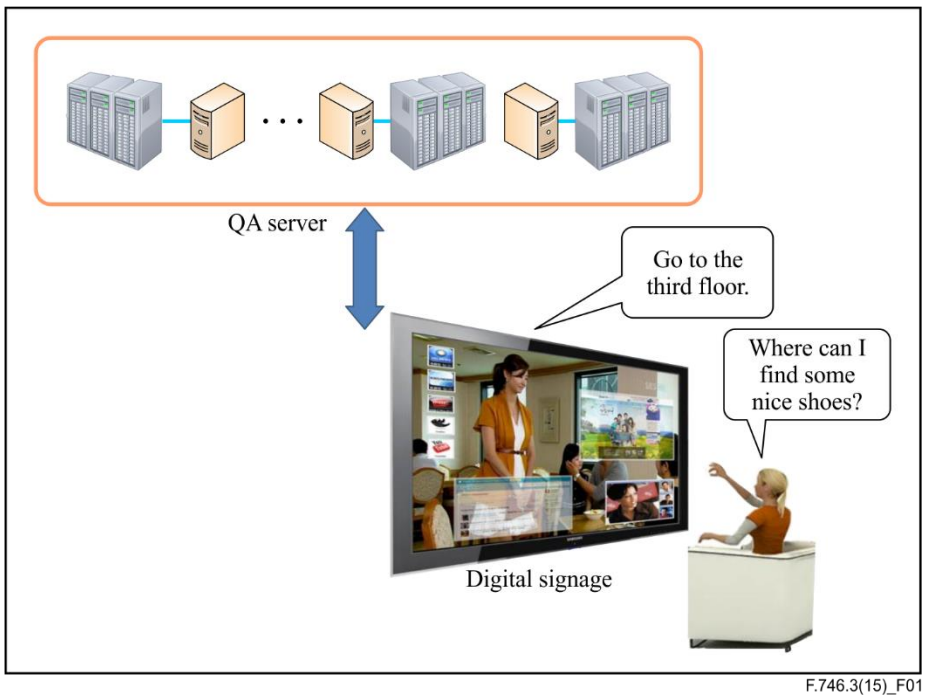

Figure 1 – Digital signage with a QA function: At the mall

Figure 2 presents an example of functional blocks in QA architecture. The QA system consists of several functional blocks: natural language processing (NLP), question analysis, candidate answer generation, answer inference and answer generation.

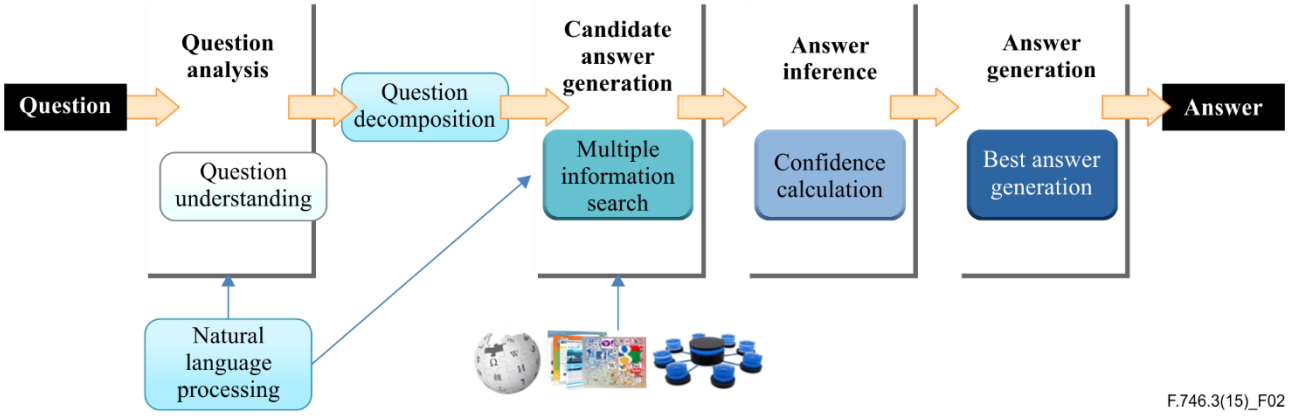

Figure 2 – Example of functional blocks in QA architecture

7 Requirements

7.1 General requirements for IQAS and the system to support the QA service

– The IQAS is required to provide answers to the user's various questions considering the user's intention.

– The IQAS is recommended to provide answers in natural language, whether it is in text or in spoken form depending on the user's environment.

– The IQAS is recommended to provide answers in natural language from multiple information sources.

– The IQAS is recommended to provide accessibility for different user needs.

– The IQAS is recommended to provide answers to the user's questions within a proper time span.
– It is recommended to provide an input editor for the user's question whether it consists of a single sentence or multiple sentences.
– It is recommended that the user's question is input in voice or text form depending on the user's device.
– The IQAS is recommended to provide example questions for the user's convenience.
– The IQAS is recommended to provide a manual on the use of the system for the user.
– The IQAS is recommended to provide a human intervention mechanism where the reliability of the answer is below a predefined threshold value.
– The IQAS is recommended to be able to save and update profile information such as the history of users' questions and answers.
– The IQAS is recommended to be able to provide answers appropriate to the user's level of knowledge.

7.2 Natural language processing requirements

The following requirements relate to NLP in an IQAS and the system to support the IQAS:

– The IQAS system is recommended to include a NLP module that analyses natural language sources at a deep level.
– The NLP module is recommended to include a pre-processing block that filters non-essential text to better understand the text and increase the speed of the IQAS.
– The NLP module is recommended to include a part of speech processing block that analyses the natural language text and assigns the correct part of speech tag to the output.
– The NLP module is recommended to include a named entity processing block that analyses the natural language text and assigns the correct named entity tag to the output for language understanding.
– The NLP module is recommended to include a syntactic analysis processing block that analyses the structure of the natural language sentences to help understand the information sources.
– The NLP module is recommended to include a semantic analysis processing block that analyses the meaning and the role of each semantic part of the natural language sentences to help understand the information sources.
– The NLP module is recommended to include a co-reference resolution processing block that relates nouns with the pronouns that refer to the nouns to help understand the information sources.
– The NLP module is recommended to continuously update all the language analysis results and extract time/location information and semantic relation information among words based on the continuous update for the IQAS.

7.3 Question analysis requirements

The following requirements relate to question analysis in an IQAS and the system to support the IQAS:

– The question analysis module is recommended to analyse the user's question and understand the intention of the user.
– The question analysis module is recommended to process the user's question, whether it comprises of a single sentence, complex clauses or multiple sentences.

– The question analysis module is recommended to find relevant information on the type of candidate answers.
– The question analysis module is recommended to decide the best strategy to find evidence for the correct answer and to present it to the user.
– The question analysis module is recommended to include the functions of question classification, answer type recognition, dictionary title recognition, question decomposition and semantic information analysis for the better understanding of the user's question.
– It is recommended that the question decomposition results be presented as an intermediate analysis result.
– It is recommended that the final question analysis results be presented to the user.
– It is recommended that the question paraphrases or question hypotheses which have the same meaning as the user's question be provided with reliability information.
– The question analysis module is recommended to be able to make inferences on the user's level of knowledge.

7.4 Candidate answer generation requirements

The following requirements relate to candidate answer generation in an IQAS and the system to support the IQAS:

– The candidate answer generation module is recommended to provide related language knowledge that is the basis for answer candidates to the user's question.
– The candidate answer generation module is recommended to use the existing knowledge bases for the candidate answer generation.
– The candidate answer generation module is recommended to add new language knowledge increasingly to the existing knowledge bases.
– The candidate answer generation module is recommended to provide the interface to retrieve taxonomy from the knowledge bases.
– It is recommended that the candidate answer generation module provides the ranking of the information that it finds.
– The IQAS system is required to search for the candidate answers from multiple information sources.
– The IQAS system is recommended to have various indexed databases of all different informal documents
– The IQAS system, based on the question analysis results, is recommended to provide the search results, answer rankings and weight information extracted from each of the informal indexed databases.

7.5 Answer inference and generation requirements

The following requirements relate to answer inference and generation in an IQAS and the system to support the IQAS:

– The IQAS system is recommended to calculate the reliability score for each candidate answer based on multiple proofs to support the candidate answers.
– The information sources are recommended to include big data such as web data, Wikipedia and different knowledge bases that are publically available.
– It is recommended to provide the source of the extracted documents, paragraphs and sentences to be able to confirm the reasons for the searched candidate answers.

– The IQAS system is required to provide the best answers and their ranks to the user from among the candidate answers based on the confidence scores.

– It is recommended to provide the information on the reliability of the best answer.

– It is recommended to provide the best answer from among multiple candidate answers.

– When the answer is presented by real-time answer generation, the documents and paragraphs from which the answer is extracted are recommended to be presented along with the answer.

– When the answer is presented based on the knowledge base (KB), the information on the KB is recommended to be provided accordingly.

8 Functional components and interfaces for intelligent question answering service

IQAS functional components are basically composed of natural language processing, question analysis, candidate answer generation, answer inference and answer generation functional blocks as follows:

– **Natural language processing functional block:** supports natural language processing on the QA server;

– **Question analysis functional block:** supports question analysis on the terminal;

– **Candidate answer generation functional block**: supports candidate answer generation by searching information in various databases (DBs);

– **Answer inference/generation functional block:** supports answer inference based on feature normalization and ranking of candidate answers and best answer generation on the terminal.

Functional blocks of the intelligent question answering service are shown in Figure 3.

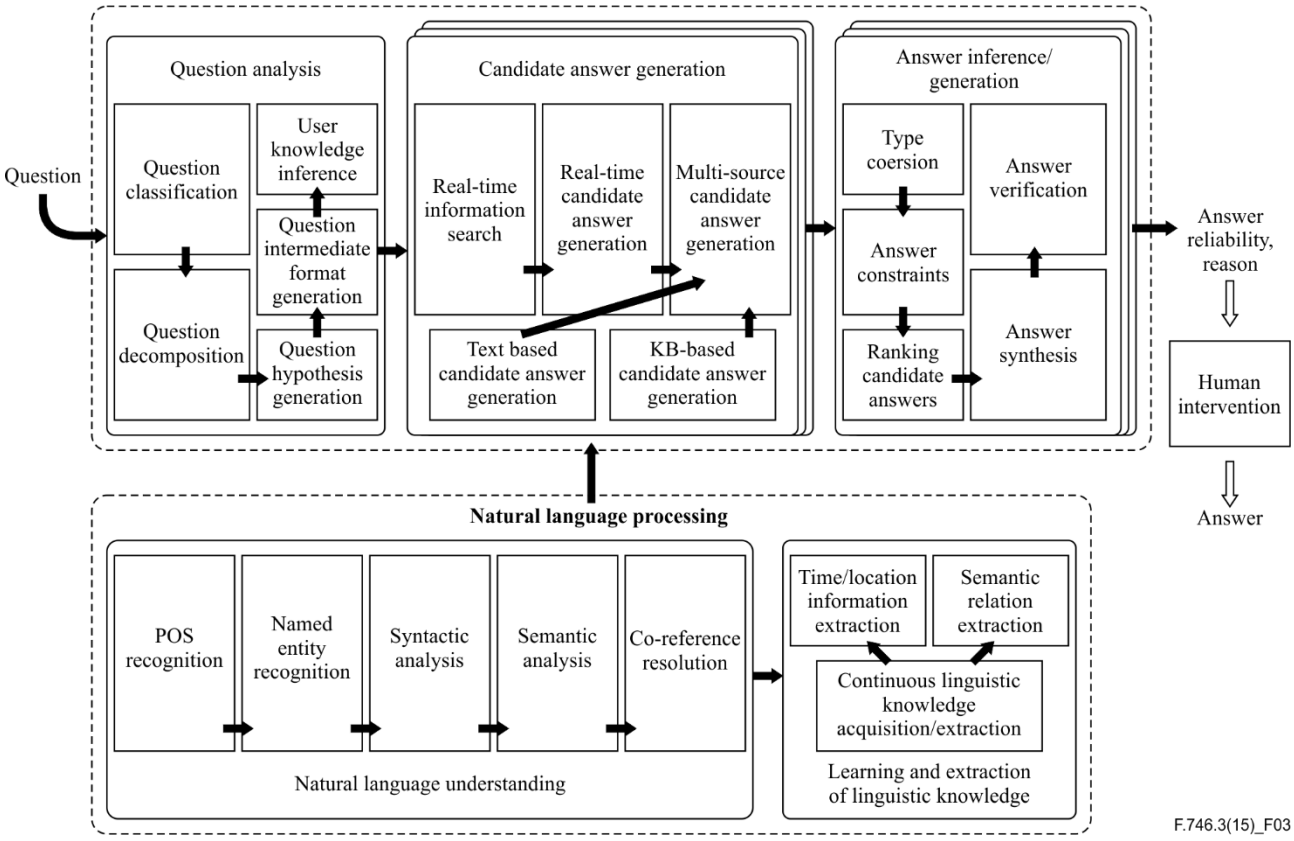

Figure 3 – Logical functional block diagram of an IQAS

8.1 Natural language processing

The NLP functional block consists of the natural language understanding function and the linguistic knowledge learning and extraction function. The natural language understanding function analyses the user's questions as well as target documents for knowledge extraction using the technologies of semantic level analysis such as semantic entity recognition and co-reference resolution in addition to the well-known parts of speech (POS) recognition, named entity recognition and syntactic analysis for sentence structures. The linguistic knowledge learning and extraction function shown in Figure 4, extracts semantic relations among words and time/location information in the documents and provides the framework to continuously acquire linguistic knowledge and to extend it to deal with new knowledge.

– Natural language understanding function consists of: the POS recognition sub-function, named entity recognition sub-function, syntactic analysis sub-function, semantic entity recognition sub-function and the co-reference resolution sub-function.

  • Part of speech recognition:

    The POS recognition sub-function analyses sentences by tagging POS tags to the minimum semantic unit which has the meaning. The POS analysis technology recognizes parts of speech in the sentences and documents and assigns relevant POS tags considering contextual meaning of the target sentences. The technology to analyse POS includes rule-based methods and statistical recognition methods.

  • Named entity recognition:

    The named entity recognition sub-function recognizes named entities such as people, locations and organizations (PLO) from the sentences. The PLO can be decomposed to more detailed named entities depending on the applications. Both the rule-based method and the statistical method are used to analyse named entities.

  • Syntactic analysis:

    The syntactic analysis sub-function analyses sentence structures that are input to the module and generates dependency relations among words based on dependency grammars. It performs the functions of head-dependant recognition function, labelling of sentence structure for the dependency relations recognized and storing the recognized dependency and labels to the predefined data structures.

  • Semantic analysis:

    The function of the semantic analysis sub-functional block is to recognize the semantic relations among the words around predicates that exist in the same sentence. It then generates the semantic predicate-argument structure (PAS). For the semantic entity recognition, semantic frames, such as FrameNet, are required that define the semantic roles of the arguments for each predicate. Because it is expensive to manually build all of the different frames one by one, it is required to extend and validate the semantic frames automatically based on a large collection of text.

    NOTE – FrameNet is a free downloadable lexical database of English that is both human- and machine-readable, based on annotating examples of how words are used in actual texts. More details can be found at [b-FrameNet].

  • Co-reference resolution:

    The function of the co-reference resolution sub-functional block is to detect the preceding referents of the pronouns which replace the noun phrases of the input sentences.

– Learning and extraction function of linguistic knowledge

  • Semantic relation extraction:

The function of the semantic relation extraction sub-functional block is to find the IsA relation among two words based on the deep natural language understanding analysis and to extract the word pair of the IsA relation. The extracted pairs of IsA relations are then stored in the pre-defined data structures.

- Time/location information extraction:

  The function of the time/location information extraction sub-functional block is to extract the information related with time/location from the sentences and documents that are necessary to generate answers in the QA system. Time information is the relative, absolute, or abstract time expressions that are present in the sentences. The purpose of the function is to extract the relevant time expressions from the natural sentences and find the relations among them. Location information is the absolute geological location or relative geological location of the words that are present in the natural sentences. The function of the location extraction is to extract the location information and understand the relation of the location expressions in the sentences.

- Continuous linguistic knowledge acquisition and extension:

  The function of the continuous linguistic knowledge acquisition and extension sub-functional block is to provide the functionality for the IQAS to be able to answer to the user's questions reflecting continuously changing real-world environments. This functionality is composed of two functions: the updating function of natural language understanding (NLU) analysis results and the framework function to learn and extend language knowledge based on the continuous updates. The updating function of NLU results includes a metadata saving sub-module which saves intermediate results to produce language analysis results. Another sub-module of the updating function of NLU, the updating sub-module analyses the saved metadata again based on the new language knowledge and then updates the existing language analysis results based on the re-analysed results of the metadata.

  The framework function to learn and extend language knowledge based on the continuous updates includes the sub-modules such as the plug-in function for the continuous learning, the workflow function, the document collecting function, the continuous engine function, the monitoring function for the system learning process and the workbench for learning verification function.

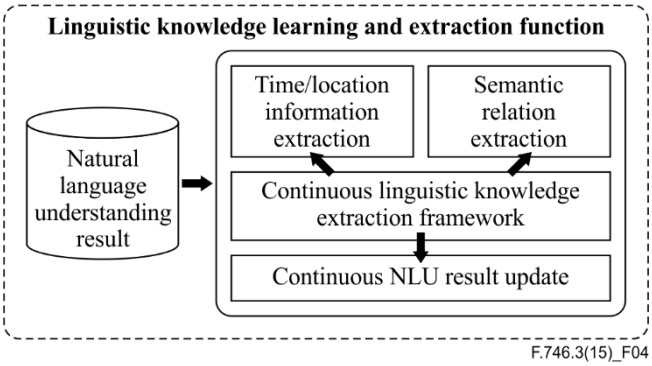

Figure 4 – Logical block diagram of the linguistic knowledge learning and extraction function

8.2 Question analysis

The question analysis functional block analyses questions which are input in a natural language by a user; it understands the user's intention and recognizes various information on the answers that should be presented as the output of the IQAS system. The question analysis functional block consists of the following functional sub-blocks:

– **Question classification**: defines question types based on the question answering strategy and classifies questions.

– **Question decomposition**: decomposes the question based on structural and semantic information and recognizes question types of sub-questions and the relations among them.

– **Question hypothesis generation**: generates multiple paraphrased questions with the same meaning of the user's question. The generated paraphrased questions are input to the QA engine and candidate answers are extracted. After integrated ranking of the candidate answers, the final answer is presented to the user. The ranking of the paraphrased question hypotheses are decided by evaluating meaning preservation, grammar preservation and the general expressiveness of the questions.

– **Question focus and answer type recognition**: recognizes the words or phrases that can replace the candidate answer as a question focus and answer type. The answer types are of lexical answer type and semantic answer type.

– **Keyword extraction**: recognizes the salient keywords which match with the title of the encyclopaedia. If any ambiguity occurs in matching them, it is resolved by comparing similarities.

– **Generation of question intermediate format:** generates intermediate question formats which are intermediate forms between the user's natural language questions and formal knowledge base queries such as SPARQL and structured query language (SQL). Question intermediate formats are represented as a logical equation with answer variables and answer restrictions extracted from the natural language question.

– The user's knowledge level is inferred by analysing the user's question sentence, domain-specific vocabularies in use and the individualized language usage of the user.

The workflow of question analysis is shown in Figure 5.

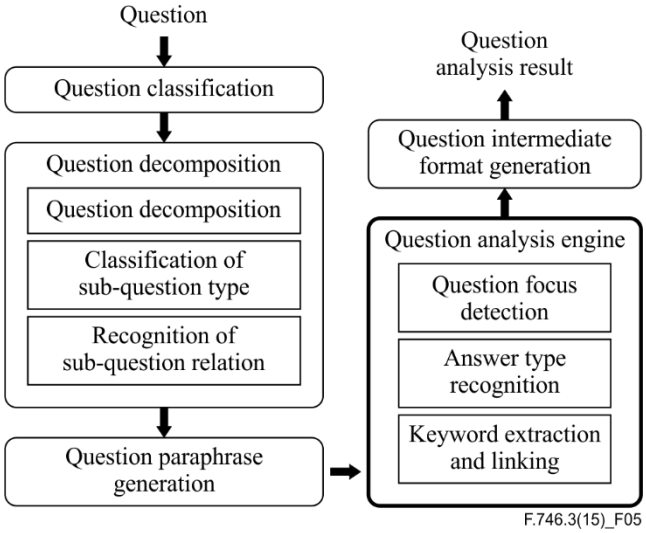

Figure 5 – Workflow of question analysis

In Figure 6, an example of an intermediate question format is presented with a natural language question in Korean "X-seon ul balgyeon han yi saram-un bangsanung sidae-lul yeoreotda. Nobel Mulihak Sang-ul batun yi Gwahakja-nun nuguinka? (The X-rays that this person discovered opened up the era of radiology. Who is this scientist who received the Nobel prize in physics?)"

In Table 1, the interfaces among sub-blocks of the question analysis functional block are defined.

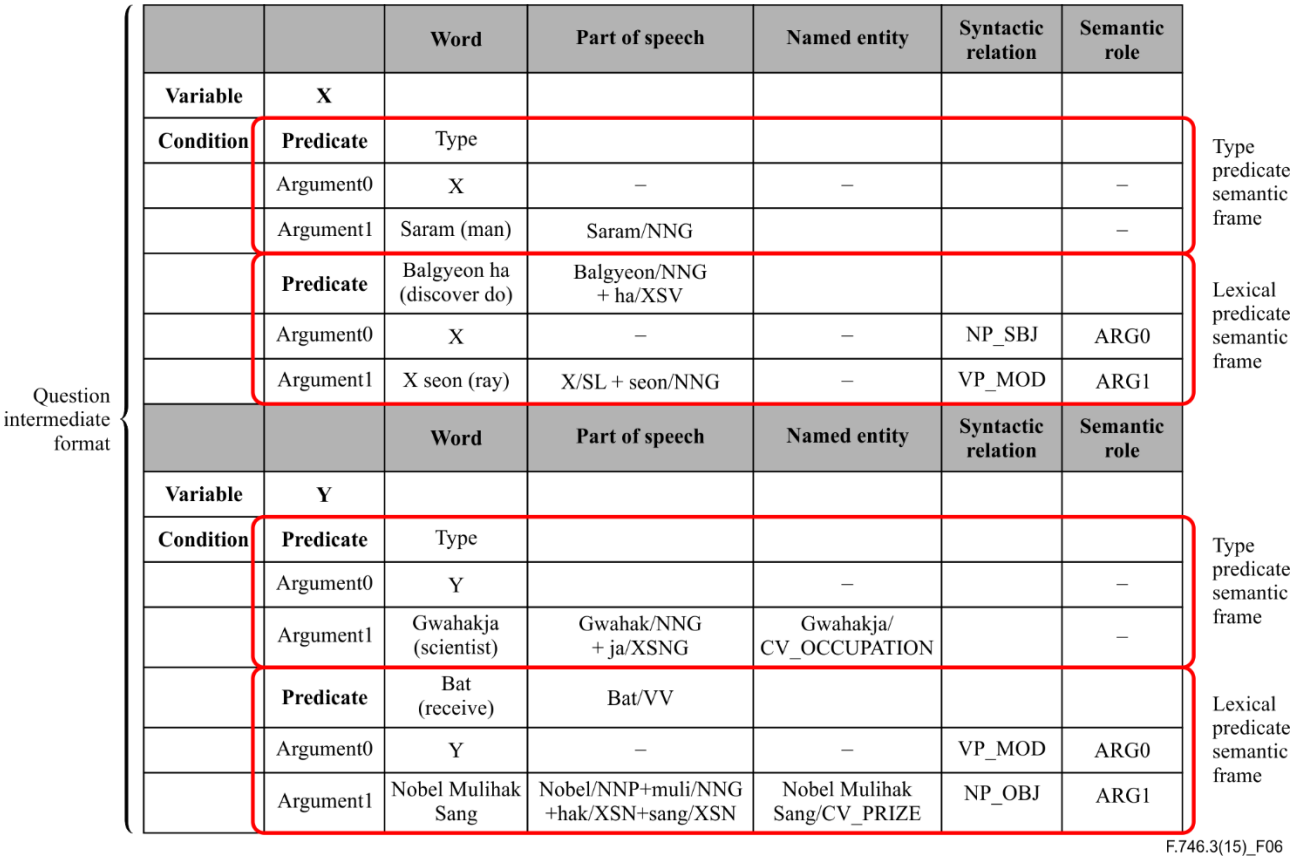

Figure 6 – Example of an intermediate question format

Table 1 – Interface of question analysis functional sub-blocks

Functions	Input	Output
Question classification	Questions	Question type
Question decomposition	Question with question type attached	Sub-question and relations among sub-questions
Question hypothesis generation	Question, decomposed sub-questions	Question hypothesis with reliability
Question focus and answer type recognition	Question, answer type dictionary	Question focus and answer type
Keyword extraction	Question, title lists of encyclopaedia	Title, title identifier (ID) of encyclopaedia
Generation of intermediate question format	NLP analysed question, information extracted, answer types, question focus	Question semantic frame list representing answer constraints in logical form

8.3 Candidate answer generation

The candidate answer generation module performs the index and search functions on the document collections and generates candidate answers using search results and various databases. The module then determines the ranking of the candidate answers by using methods such as type coercion, time/location inferences and calculation of similarities among sentences. The candidate answer generation functions involve sub-functions such as real-time information search, real-time candidate answer generation and multi-source/text-based/KB-based candidate answer generation.

– **Real-time information search**: The target of the real-time information search includes the general document collections, as well as the open user-created encyclopaedia such as Wikipedia. When searching for the information in the open user-created encyclopaedia, the IQAS also uses the unstructured and semi-structured information. In the open user-created encyclopaedia, the main text and definitions are unstructured information and section title document, category document and info-box document are semi-structured information. The information search module consists of an indexing stage and a searching stage. The indexing function takes the unstructured text as input and generates multiple indexed databases. The searching function searches for similar documents from the indexed databases based on the question analysis results. It provides as a result document contents, rankings and weights.

– **KB-based answer generation**: This sub-function generates KB questions which are specified by each KB based on the question intermediate format produced during the question analysis stage. It then searches each KB and generates candidate answers. The KB-specific questions are generated by the following steps: The arguments of the question intermediate format are mapped onto the classes or instances defined in the specific KB; The predicate of the question intermediate format is mapped to the property defined in the specific KB; The KB-specific questions are searched for and generated in the specific KB, and finally the candidate answers are generated.

8.4 Answer inference and generation

The function of the answer inference and generation module is to decide upon and generate the best answer from among the candidate answers by measuring reliabilities based on multiple knowledge sources of different types. The inference and generation module performs feature normalization and ranking of the candidate answers by learning the reliability thresholds according to the question types. The best answer is synthesized and finally presented to the user as the output of the question answering service.

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<https://framenet.icsi.berkeley.edu/fndrupal/about>

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Printed in Switzerland
Geneva, 2016