FVA: Financial Virtual Assistant

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Abstract— **Getting information about the current and past financial situation of a company is important before investing in this company. Extracting this information from an information system that uses taxonomy recognized by the financial markets using natural language, is a facility for the investor who has no knowledge and no expertise in computer science. The virtual assistance software are alternatives to help people in an area of knowledge. However, it is observed that there is no information system that interacts with the user through natural language to answer questions about financial information of companies, based on data available in electronic financial disclosures. This paper presents a computational system of virtual assistance, named Financial Virtual Assistant (FVA), which recognizes user questions relating to financial situation of companies, through text, or voice, in natural language. This system provides answers based on available information in electronic financial statements represented in eXtensible Business Reporting Language (XBRL) technology. The system's implementation is based on a proposed architecture for specific purpose virtual assistants that uses a Natural Language Processor (NLP) and the domain information services. Details of this architecture, the system's implementation and the used natural language processing configuration are presented. During testing, the Assistant correctly answered all financial questions about certain companies in a compatible average period with available generic virtual assistants in the market. Besides that, the Assistant could to talk to the user, simulating a conversation between people.**

Keywords-Financial Virtual Assistant; FVA; Virtual Assistants Architecture; Specific Purpose Assistant; XBRL US-GAAP.

I. INTRODUCTION

Usually, financial consulting services provided by an assistant or a financial advisor are very expensive. For a small investor with limited resources to hire a financial professional, a computer system that provides service virtually through answers to questions using natural language can be an alternative to this kind of financial advice. However, the virtual assistant software, usually embedded in smartphones, e.g., Siri [1], Cortana [2] and Google Now [3], provides inaccurate responses to the questions about companies' financial information. Normally, these answers correspond to a list of links to financial sites.

Actually, the available financial information to investors on the market are disclosure by the technology XBRL [4] that is derived from XML and it was created to facilitate the exchange data and financial information. Most of the world's major stock exchanges operate with this technology, e.g., US-SEC (U.S. Securities and Exchange Commission), the European market, Tokyo. Therefore, extracting information represented by XBRL technology is an important source to support the financial questions for decision-making on investments.

After conducting a literature review, we did not find any academic paper, or market solution, related to the financial virtual assistants of question and answers type. However, proposed frameworks and architectures for building virtual assistants have been found. To fill this gap, this paper presents the FVA, based on XBRL technology, that answers financial questions using natural language, in different languages, e.g., English and Portuguese. Therefore, the aim of this paper is to present the architecture and implementation of a computer system of virtual assistance question/answer type that interacts with the costumer using natural language to answer questions about financial state of companies that provide their financial statements on the market. This system supports a conversation with the user too. This paper is organized as follows: Section II discusses some related works; in Section III, the architecture of the FVA is proposed; the presentation of FVA implementation is presented in Section IV; in Section V, the results of the FVA tests are evaluated and in Section VI the conclusion is presented.

II. RELATED WORKS

The architecture for creating specific purpose assistants in [5] allows the expansion of knowledge and behavior of an assistant by adding new services. This architecture predicts the interaction with the user through natural language and supports the dialog management. However, it was designed for agents' technology in [6], which is in disuse. One of the agents' disadvantages is the need for a specific environment for the agents, and many of these environments were discontinued.

The architecture reference for a specific purpose assistants in [7] was designed to build assistants that help the user to explore a specific Web site. So, the created assistants based on this architecture, do not provide precise and complete answers. The architecture in [8], which allows the creation of assistants that may have their expanded knowledge by third-party services, does not provide resources for user interactions in natural language, in

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addition to the dialogue management being restricted by user interface applications.

The architecture of the Virtual Assistant [9] allows users to enlarge your knowledge by adding new plugins. This feature enables the creation and addition of a financial knowledge module. This architecture is implemented by Syn Engine platform [10]. Their drawbacks are it supports only one language (English), and it is available only for two software environments that limits the number of users. For the Assistant.ai assistant [11], only part of its architecture is available. This part is the area responsible for conversation maintenance with the user and is based on a NLP. One of the disadvantages of using this architecture is that it is not complete, i.e., some sections are not available, e.g., the area responsible for the selection and extraction of information domain, the area responsible for the construction of the answers to the user. Architectures of market assistants, e.g., Siri, Google Now and Cortana, are not available.

After the literature review, it is concluded that these architectures and frameworks do not support the creation of a FVA based on XBRL technology that answers financial questions using natural language, in different languages, simulating a conversation between people.

III. FVA ARHITECTURE

The proposed architecture for the FVA is designed to create assistants, question/answer type, to distributed and service-oriented environment. This architecture is an extension of the architecture we presented in [12]. One of the reasons for this architecture design be service-oriented is to facilitate the expansion of behaviors and knowledge of the assistant, through adding new services. This architecture consists of four layers categorized by their functions: Presentation, Orchestration, Understanding / Knowledge and Data, as illustrated in Figure 1.

The Presentation layer is the user interface layer. It is responsible for interaction with the user and forwarding the user requests to the Orchestration layer and presenting the replies that were sent by the Orchestration, to the user in the proper format, i.e., text or voice. The assistant usability depends directly on the Presentation layer. The Orchestration layer is the layer that coordinates the Assistant, manages the knowledge assistant and manages the dialog with the user. It is responsible for making the decision of what should be done in response to the stimuli provided by the Presentation and Understanding / Knowledge layers, also it is responsible for the treatment of any services and / or components failure. In addition to triggering the services of Understanding / Knowledge Layer and forwarding the responses to the Presentation Layer, it also verifies whether the information passed by the user is complete for obtaining an answer or some additional information is still needed. The Assistant robustness depends directly on this layer. The Understanding / Knowledge Layer is the assistant cognitive center. It interprets the user information, it provides the recognized information to decision-making process and it provides the specialized information services in the financial field to Orchestration Layer.

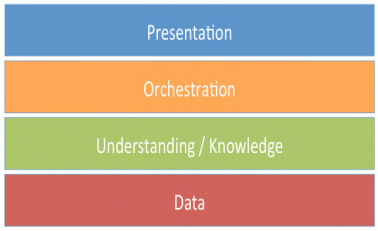

Figure 1. Architecture in layers of the FVA

The Understanding / Knowledge Layer corresponds to the knowledge domain of the Assistant. The greater the knowledge represented by this Layer, the more intelligent and knowledgeable in the financial field is the assistant. The Data layer is responsible for providing the data to the Understanding / Knowledge layer. The reliability of assistant answers is proportional directly for the reliability of the data provided by this layer. The amount of information provided by the assistant is directly influenced by the data amount that this layer has access to.

Although the architecture is designed for the financial sector, it can be used for another domain. The organization of its components is such that it allows the incorporation of multidisciplinary, multilingual and user interaction features. Figure 2 shows the details of each layer that are discussed in the next section.

A. *Details of architecture components*

The Speech To Text (STT), which is a speech to text converter, and The Text To Speech (TTS), which is a text to speech converter, allow interaction by voice between the Assistant and the user. These components access the dictionaries that are databases responsible for supporting the conversions speech to text, and vice versa, for different languages. The User Interface Manager (UIM) is responsible for user interaction, it collects user questions and forwards to the Orchestration layer and waits for the response to present to the user. It also, with the help of STT and TTS, interacts with the user using voice. The presentation of the answer to the user is also the responsibility of the UIM.

The Coordinator is responsible for controlling the life cycle of each question session initiated by the user and for managing the assistant's information flow. The Coordinator is responsible for collecting user requests sent by UIM, and forwarding the question text to the NLP, and getting the NLP answer that is the identification of the user's intention and the parameters that have been recognized in the user question. In addition, the Coordinator is responsible for interacting with Dialog and Knowledge Manager (DKM) for getting the answer to the user, and forwarding it to the UIM, besides its responsibility to treat the failures of the layers with which it interacts. The DKM is the manager of the dialogue with the user and knowledge manager of the Assistant. The DKM uses the context information for supportting the maintenance of the dialogue with the user, simulating a conversation between people. The knowledge management that is its other responsability, is the configuration and maintenance of services belonging to the financial domain in Understanding / Knowledge Layer (UK). The NLP has the responsibility to

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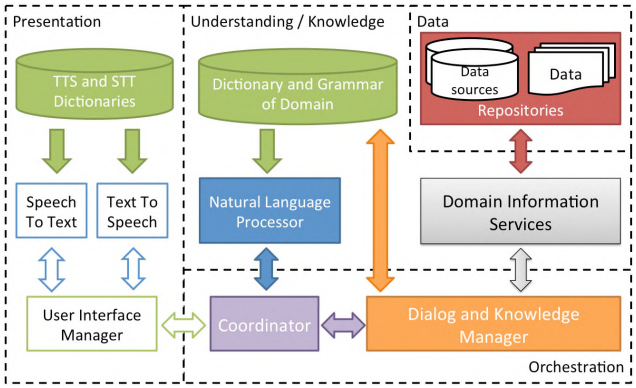

Figure 2. Architecture in layers of the FVA

recognize the user question, made in natural language, and extract parameterized information that is processable for a computer system. For manipulating the knowledge, the NLP needs the dictionary and grammar of the domain, i.e., after receiving a sentence, it queries the domain's dictionary and grammar in order to understand the sentence. Assistants based on this architecture will recognize requests that contain terms of this dictionary that correspond to the standard questions that were previously defined in the grammar. For the FVA, the dictionary and grammar domain of the NLP is financial. However, other domains, with related and proper dictionary and grammar, may be incorporated. The Domain Information Services are responsible for handling the available data in the Data layer and provide domain information requested by the Orchestration layer. These services represent the knowledge domain of the assistant, i.e., the greater scope of the domain information services available, the greater is the representation of knowledge in the assistant. For the FVA, they are called the Financial Information Services. Its ability to answer complex questions, e.g., financial analyzes and comparisons, depends on the availability of these services. The services of Data Layer correspond to repositories that provide data, e.g., a relational database, a data service delivery on the Web. For the FVA, the use of XBRL Repositories for providing financial data, was planned. This repositories can be composed of XBRL documents in XBRL databases or financial information services based on XBRL data. The taxonomy used by XBRL repository is also an item that interferes with the responses relevance of the FVA in relation to the financial area, because this taxonomy has to have representation in the financial domain.

One of the main advantages of the presented architecture is the prediction of the use of a natural language processing service, allowing substitution of NLP service for another, or even to use more than one service of this kind. This feature facilitates the implementation of multi-language virtual assistants of specific purpose, or assistants that recognize the vocabulary of different domains. This feature also facilitates the use of different natural language processing services that are available in the market or in the academic community. The architecture also provides for the dynamic update of the terms and grammar of domain. The isolation of the layers responsible for the knowledge domain and cognition of the assistant, and the voice converter services in the presentation layer, are characterized as another advantage, because it allows the maintenance of knowledge domain in a single layer and also the creation of virtual assistants that interact with the users exclusively through voice, without requiring complex coding in the user interface.

One of the limitations of this architecture is that it does not support the implementation of any specific purpose assistants, i.e., it is designed to build virtual assistants of question/answer type. The autonomous virtual assistants that autonomously perform a task, or a sequence of tasks, according to the context, are not supported by this architecture.

IV. Implementation Of The FVA

The implementation of the layers occurred almost entirely in a server environment, except for the Presentation layer that had one of its components implemented in the customer environment. The UIM was the only implemented component of the Presentation layer, because it is specific for the FVA. An Android application that supports voice recognition using TTS and STT services (provided by the Google), was coded, and a page javascript / html was coded too. The Orchestration Layer components were implemented with Java technology to run on a Web server that allows the Web client requests to be treated by the Assistant. Several Java classes were implemented, whose main classes for this layer are shown in class diagram in Figure 3.

The Coordinator class that was implemented as a Java Servlet, has the function of controlling the flow of information and trigger the basic components and services of

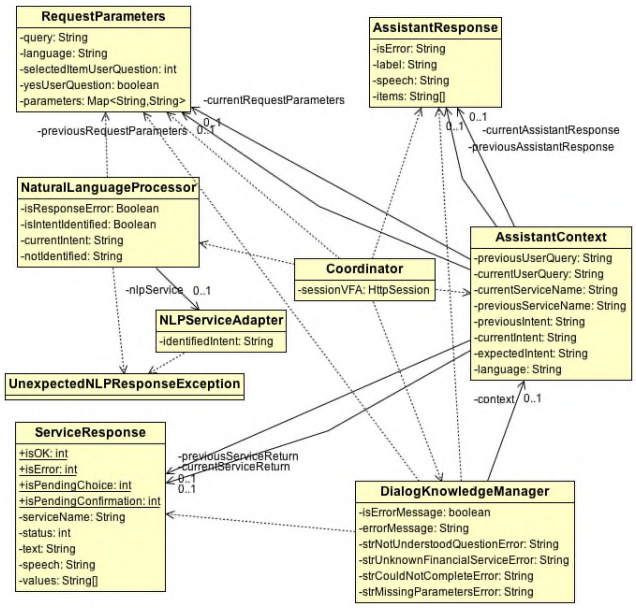

Figure 3. Class Diagram of implementation of The Orchestration Layer

the Assistant. The Coordinator class does not handle any information related to the financial domain; the AssistantContext class corresponds to the context of the

information about the dialogue session with the user; the RequestParameters class stores all the information related to the user's query parameters; the NaturalLanguageProcessor and NLPServiceAdapter classes are the representatives of the NLP. To replace the NLP by another, just change the NLPServiceAdapter class; the AssistantResponse class corresponds to the Assistant answer for the user's question; the DialogKnowledgeManager class represents the Dialog and Knowledge Manager component, whose responsibility is to manage the knowledge of the Assistant and the dialogue between the Assistant and the user; the ServiceResponse class corresponds to the response of the service information to query submitted.

The Understanding / Knownledge Layer was implemented through Web Services. For the NLP, a conversational platform was used. This platform, named Api.ai [13], provides an NLP service for recognizing user expressions in different languages, e.g., English, Spanish and Portuguese. This platform enables the creation of services or components that can be configured to recognize expressions made in natural language related to different knowledge domains. The Financial Information Services have been implemented specifically for the FVA. Two pairs of dictionary of terms / grammar, one for the Portuguese language and other for English language, were built to represent the financial domain. The dictionary of terms is a database where the synonyms of domain concepts, names, keywords and the definition of a corresponding default value are registered. Many groupings of terms, whose denomination is entity, have been created. These entities have been divided into financial and generic types. They are used in grammar rules to indicate, for the NLP, which position in the user's expression the terms are expected. The configuration of the grammar rules was according to grammars' rules setting of the Api.ai NLP, e.g., for English version grammar, the question "What are the current liabilities of Petrobras in 2015" is captured by NLP according to the following rule:

[@greeting] [@CommandExpressions]
@USGAAP_BalanceSheet:financialConcept [of]
@Company:companyData [company] [in,on]
@YearPeriod:yearPeriod [at, in, on fiscal year, in fiscal year, of fiscal year, of year, year] @sys.number:year

In this example, the subsequent expressions to @ symbol correspond to entities of dictionary of terms.

The words or phrases between brackets, inform that the occurrence of them is optional. To identify the user's intention, the grouping of grammatical rules has been used. The performed configuration identifies at least 14 intentions, e.g., "What is the Financial Concept of Company"; "What is the Variation of Financial Ratio of Company in the last period of time"; "Change the company". To represent the organization of the Financial Information Services, a Web Service compatible with the SOAP protocol was implemented. This Web Service has a method that requires two input parameters: a string that corresponds to the name of the service and the second string that corresponds to an instance of the RequestParameters class encapsulated in JSON format [14]. The answer of this Web Service corresponds to an instance of ServiceResponse class that is encapsulated in JSON format. The main function of this Web Service is to trigger the corresponding financial information service. One of the services, triggered by this Web Service, was implemented by CompanyRatioInformationService class, which provides text responses in natural language contains the value of index, or concept, of a financial company in a specified period.

The CompanyRatioInformationService class constructs messages with the answer of the Assistant, in Portuguese or English, and for that, it consumes data from another Web Service that represents the Data layer and it was implemented by XbrlUsgaapWebService class. This Web Service provides data from the US-SEC [15] through the SOAP protocol, and supports the following input parameters: USGAAPElementName that corresponds to the compatible XBRL element name with the US GAAP taxonomy [16]; cik, which is the CIK code of the company; year that corresponds to the year of the financial period; period, which corresponds to the part of year of the financial period. The result is a text provided in XML with structured financial data. The data source of the XbrlUsgaapWebService is the service of XBRL-US that provides the extracted data of the financial statements of companies provided by US-SEC. These statements are in XBRL format, in accordance with US-GAAP taxonomy. For the use of other XBRL taxonomy, e.g., IFRS, GRI, another configuration of this layer is necessary.

One of the advantages of the uncoupling, through the implementation of services, is the ease of maintenance of each component or service and the independence of the technology on which the service was implemented. One of the disadvantages of the implementation by services is the risk of delay in the construction of responses caused by each service involved. Figure 4 shows the corresponding sequence diagram used to build the answer of the Assistant, in response to the user question "Give me the Current Assets of Petrobras in 2009".

V. TESTS AND EVALUATION OF FVA

For testing the FVA efficiency, the financial domain questions were performed to evaluate the Assistant in relation to the question understanding, the speed of response and its accuracy. Another objective was to evaluate the impact of services in the responses overall time. To standardize the results and facilitate measurements and calculations, a javascript script was created, embedded in a Web page client. This script has submitted a series of 43 questions written in natural language and in English language to the FVA.

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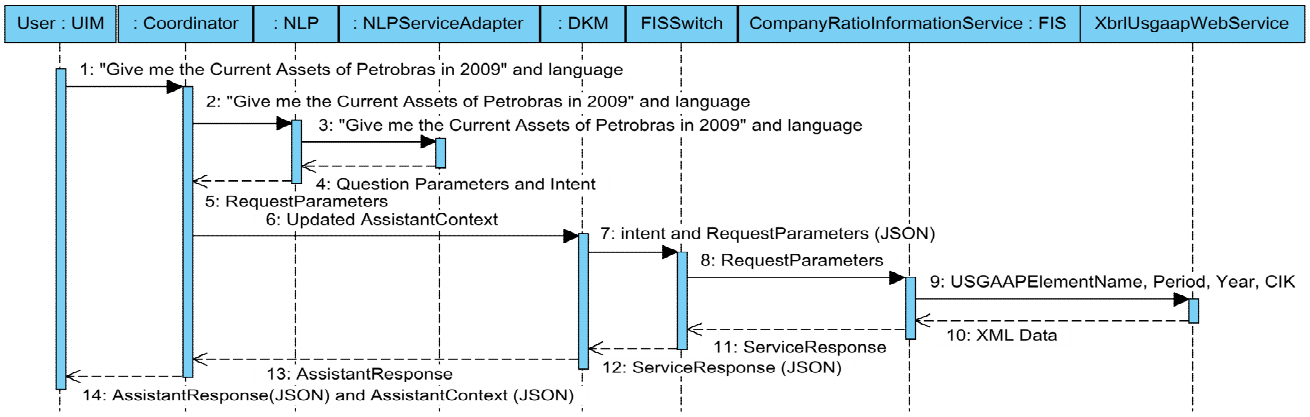

Figure 4. Sequence Diagram of a succesful transaction

As a premise, the key words embedded in the questions of the sequences have been previously registered in the dictionaries of terms and all questions followed the patterns recorded in the NLP grammar. The responses execution times were measured with the same group of questions on different days and at different part of day in order to decrease the impact of the momentary effects caused by network congestion, services overload or processing delay on client computers and/or servers. The tests were performed between June 7th and August 16th 2016 at different times and resulted in 16 samples. For each sample, were measured the individual performance times of the used services and the overall performance of FVA, as shown below: a) total time of Assistant response; b) the response time of Api.ai NLP; c) response time of data service of XBRL-US [17].

The test results showed an average response time equal to 2 seconds, shown in Table 1. These results are compatible with the assistants more used on the market, e.g., Siri, Google Now. The impact of NLP and data services on the average total time Assistant response corresponded to approximately 97%. Any decrease in response times of these services has a directly and significantly impact to the global time, which was evidenced by lower response times recorded for the repeated questions. This decrease is attributed to the use of cache on the data service, which provided a reduction of more than 700 milliseconds on average total time of Assistant. The submitted questions were understood and correctly answered by FVA, in contrast to what happened to the virtual assistants available on the market, which for most of the answers provided it was only a list of links for financial Web sites. Something justifiable, as both Siri and Google Now, do not include the financial domain yet.

To evaluate the management of dialogue with user, a series of four questions was analyzed, three of them are short that were submitted in English language to the Siri, Google Now and FVA. Thus, they were understood and correctly answered by FVA as follows:

1) Submitted question: “Show me the current liabilities of Microsoft in 2014”;

2) FVA response: “The Current Liabilities of MICROSOFT CORPORATION Company in 2014 is US$45,625.00”;

3) Submitted question: “and 2014”;

4) FVA response: “The Current Liabilities of MICROSOFT CORPORATION Company in 2014 is US$45,625.00”;

5) Submitted question: “and 2015”;

6) FVA response: “The Current Liabilities of MICROSOFT CORPORATION Company in 2015 is US$49,647.00”;

7) Submitted question: “and the assets”;

8) FVA response: “The Assets of MICROSOFT CORPORATION Company in 2015 is US$174,472.00”.

However, the other two assistants understood the following short questions as new questions, as was the case with Siri, illustrated in Figure 5.

The FVA was better than the other two assistants, because it was the only assistant that made the connection between the questions in sequence and managed the dialog. The evaluation of dialog management of the FVA was also considered positive.

VI. CONCLUSION

The positive evaluations of the performance, accuracy tests and dialogue maintaining test, confirmed the viability of the FVA that helps users using natural language, with optional voice support, to obtain information about financial indexes or financial concepts of companies. The proposed architecture for Virtual Assistants can be used to build multilingual virtual assistants for a specific domain that answers user questions through natural language is a contribution of this work; the alternative of consulting financial data that is in electronic reports in XBRL technology and US-GAAP taxonomy, through by natural language, is another contribution.

The US-GAAP taxonomy was used on the FVA implementation, but, with minor changes in the Data layer and changes in the dictionaries and grammar of NLP, it is possible to use others XBRL taxonomies.

Despite the positive results, the FVA has some limitations, e.g., FVA does not recognize any financial questions that are not configured on the NLP. The questions used in the tests were compulsorily chosen according to the

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TABLE I. RESPONSE TIMES OF THE FINANCIAL VIRTUAL ASSISTANT

Scope of Measurement	***Global Average of Assistant (ms)***	***Api.ai NLP Average* (ms)**	***XBRL US Service Average* (ms)**	***Api.ai NLP %***	***XBRL US Service %***	***Sum of Serviços (Api.ai, XBRL US)* (ms)**	***Sum of Serviços %***
All 43 questions	2011,15	848,29	1115,21	42,18	55,45	1963,50	97,63
Repeated Questions Only	1291,35	833,20	412,83	64,53	31,97	1246,13	96,50
Diference	719,79	14,99	702,38	-22,35	23,48	717,37	1,13

settings made in the grammars and dictionaries of NLP. Any question that is not expected by the Assistant does not bring any relevant information to the user, only a warning that the Assistant did not understand the question.

As future work to improve the FVA we suggest the study of implementation of a component that allows to configure the grammar of the Assistant through a standard language for construction of grammars, e.g., JSpeech Grammar Format [18], and convert this configuration into a proprietary configuration used in NLP. Another suggestion is the creation of an NLP to recognize the financial questions and extract the financial parameters without the need to configure question standards and thus facilitate the expansion of knowledge of the Assistant.

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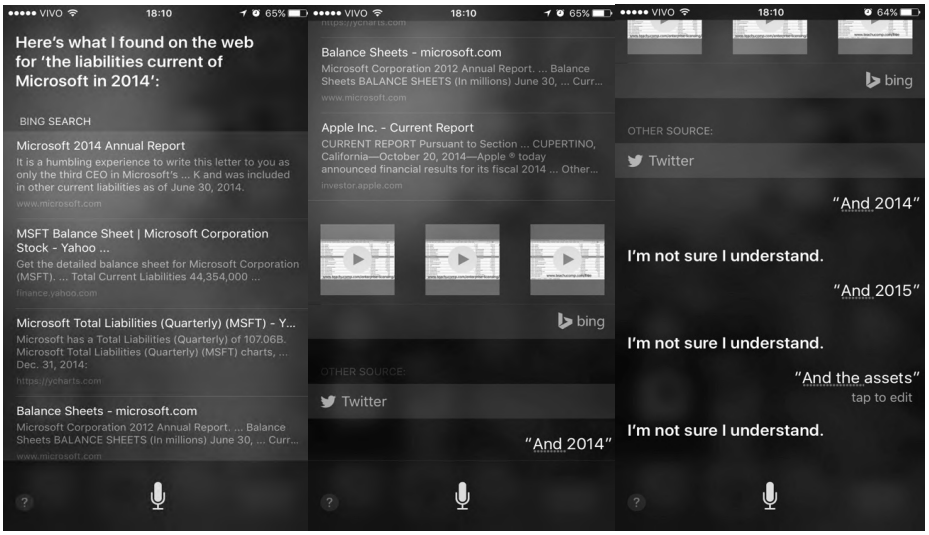

Figure 5. Siri's response to subsequent short questions.