IBM's Watson Analytics for Health Care:

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2 authors:

Mayank Aggarwal
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IBM'S Watson Analytics for Health Care: A Miracle made true

Dr.Mayank Aggarwal,
Assistant Professor, FET, GKV, Haridwar
Mr.Mani Madhukar,
Cloud Partner Lead, South, IBM.

ABSTRACT

With the advent of Internet and Computers, Information Technology (IT) has become a major tool to aid medical issues. IBM Watson is one such initiative by IBM, which provides integration with any application to built Internet of Things (IoT), based health applications and also assists by its existing services. The strength of Watson is its data analytics and Artificial Intelligence. The four variants of Watsons are Watson Discovery Advisor, Oncology, Clinical Trial Matching and Curam. It is based on Open Source Apache UIMA, Apache Lucene. Its integration with IBM Bluemix Cloud, Platform as a Service (PaaS) makes it easily available to users.

KEYWORDS

Watson, Bluemix, Open Source, Health Cloud, Mobile Application, Apache UIMA, Apache Lucene, Watson Clinical Trial.

INTRODUCTION

The use of IT for health care is no longer a new concept. Use of computers and IT in every filed has become a common practice. Recording of patient histories, details, billing and other information in computers has become a common practice everywhere.

But the actual use needed is still missing in India.

According to an expert "75 % of treatment are done on Trial Basis with not exact dosage of medicines and actual number of tests prescribed" such things result in millions of deaths per year in India. If we can have a collection of all records of patient histories countrywide and some way to predict on this basis it would be miracle.

IBM's Watson is one such miracle.

HISTORY

In 2011, in a TV show "Jeopardy" IBM's Watson defeated the Jeopardy's champion Ken Jennings and Brad Rutter. This gave birth to IBM's super computer Watson called after its founder Thomas J Watson. (Jo Best,2011)

When the duel was finished, Watson had $77,147 resulting in loss of $21,600 and $24,000 to Rutter and Jennings respectively.

This was the victory of a machine over two humans and a birth of Artificial Intelligence with learning capacity in real sense.

David Ferrucci, principal investigator of Watson DeepQA technology, said Watson could conduct self-assessments and learn.

JOURNEY TOWARDS MEDICAL SCIENCE

The Jeopardy game was over but IBMers were not out to rest. The mission to make it the best doctor in world continued. This gave birth to IBM Watson Health Cloud. The team added the required information, checked for the results and modified it to give the best performance. Thousands of questions were asked and results checked if anything went wrong then it was corrected afterwards answers were given for which Watson has to ask the questions.Machine Learning enables questioning and answering model and also algorithms can be modified for better results.

In 2013 Watson used many textbooks, like PubMed and Medline and large number of records of different patients from Memorial Sloan Kettering. According to Forbes, 2013 605,000 medical symptoms, 25,000 training cases, 2 million notes have been analyzed and assistance of 14,700 clinician hours for its accuracy in generating the hypothesis.

IBM Watson Health Cloud for Life Sciences Compliance and IBM Watson Care Manager was launched in 2015. It has mergers with Columbia University, Boston Children's Hospital, ICON plc, Teva Pharmaceuticals and Sage Bionetworks

In 2015 acquisition of Merge Healthcare Inc. a leading company helping doctors to store and access medical images, gives a major breakthrough for Watson Health Cloud. (Macmillan & Dowskin,2015).

Important organizations in health-care already working with IBM Watson are Mayo Clinic, Memorial Sloan Kettering Cancer Center, Cleveland Clinic, New York Genome Center and the University of Texas MD Anderson Cancer Center. It has recently made its foray into Indian Medical scene.

Manipal Hospitals' have adopted Watson for Oncology, a cognitive computing platform trained by Memorial Sloan-Kettering Cancer Center, which uses records to give symptoms, based treatment options, it enables the doctors to give personalized attention to cancer patients on individual basis. (Debroha, 2015).

The IBM Watson Health Cloud for Life Sciences Compliance can make medical science to do innovations in much simple and effective way, also deploy GxP compliant infrastructure keeping security, regulation of data in mind.

IBM Watson Care Manager is a population health solution that uniquely combines features of Apple's Health-Kit, Watson Health and Research-Kit, which enables iPhone users to study and research. It allows doctors to generate a broad range of determinants as per their patient’s data to have good knowledge of the treatment and its outcome.

IN DEPTH

Watson is the pioneer to provide cognitive computing capability system available commercially giving rise to new era. The system uses cloud computing, collects high volume of data, analyze it, understands complicated and difficult questions asked in natural language, and gives proof based results.

At first system is told about the symptoms to the system, details like family history, undergoing treatment, duration of illness etc are undertaken and analyzed. Using this information along with the findings from tests along with different types of treatment guidelines, digital record of medical cases and prescriptions of physicians, as well as peer-reviewed research and clinical studies. Then, Watson can gives different options for treatement and its confidence rating for each option. It uses the power of unstructured data. (Feldmen & Hanover, 2012)

VARIANTS

Currently Watson Health Cloud provides various variants for different purposes as follow:

1. Watson Discovery Advisor for Life Sciences

   It makes solutions easier by connecting and drawing relationships between different data sources so it can find something new.

2. Watson for Oncology

   Trained by Memorial Sloan Kettering (MSK) it collaborates the patient's medical report with huge database along with current expert training from MSK physicians, histories of other cancer cases and more, which results in evidence based treatment options.

3. Watson for Clinical Trial Matching

   It facilitates doctors to reduce all possible cancer trials and faster matching of appropriate trials, resulting in better and new treatment options for the patients.

4. Curam

   By designing around the client, Cúram solutions empower organizations to collaborate around client needs and offer more effective ways to achieve desired health and social goals

WORKING OF WATSON

So the first question arises is how does Watson work and its use in health-care.

Watson makes use of Natural Language capabilities; Hypothesis generation and finally evidence based learning to learn from literature and case studies available. It then helps medical professionals in making their decision.

Watson can now assist a surgeon in diagnosing a disease or making subscription of medicines/surgery to the patient based on various parameters it takes into account while making the suggestion.

The process of getting a Watson recommendation for health-care professional can be explained in the following steps for more clarity-

1. It starts with the medical professional putting a question to the Watson system giving details of the symptoms and other relevant information that can make an impact.
2. Watson system starts parsing the inputs provided to identify important details. Watson has acquired skills on understanding medical terms and has Natural Language processing capabilities.
3. Watson mines the data of the patient to identify relevant information about the family of the patient, current treatments undertaken and other relevant data about the patient.
4. As a next step Watson, puts this information in a perspective to form Hypothesis, putting together information from patient history, medical tests etc.
5. Watson has capabilities to integrate electronic medical records of the patient, clinical studies, medical publications, guidelines for prognosis etc. with the patient data and analyze them together in one perspective gaining insights from the latest medical findings and how they can be useful in patient's diagnosis.

Armed with all the information, Watson now creates a list of potential diagnosis's mapping each with the information it had collected and collaborated. Each line item in the list of potential diagnosis has a score, which indicates the correctness of hypothesis.

This ability to gather all the related information and generate scores during the hypothesis generation makes Watson useful to solve the complex problems, also assists doctors to make accurate decisions and well informed.

The Watson engine workflow for analyzing the interpretation process of Watson can be explained with the help of figure 1. below. The workflow explains the various stages that Watson undergoes to interpret, reason and find answers to any query being analyzed by Watson.

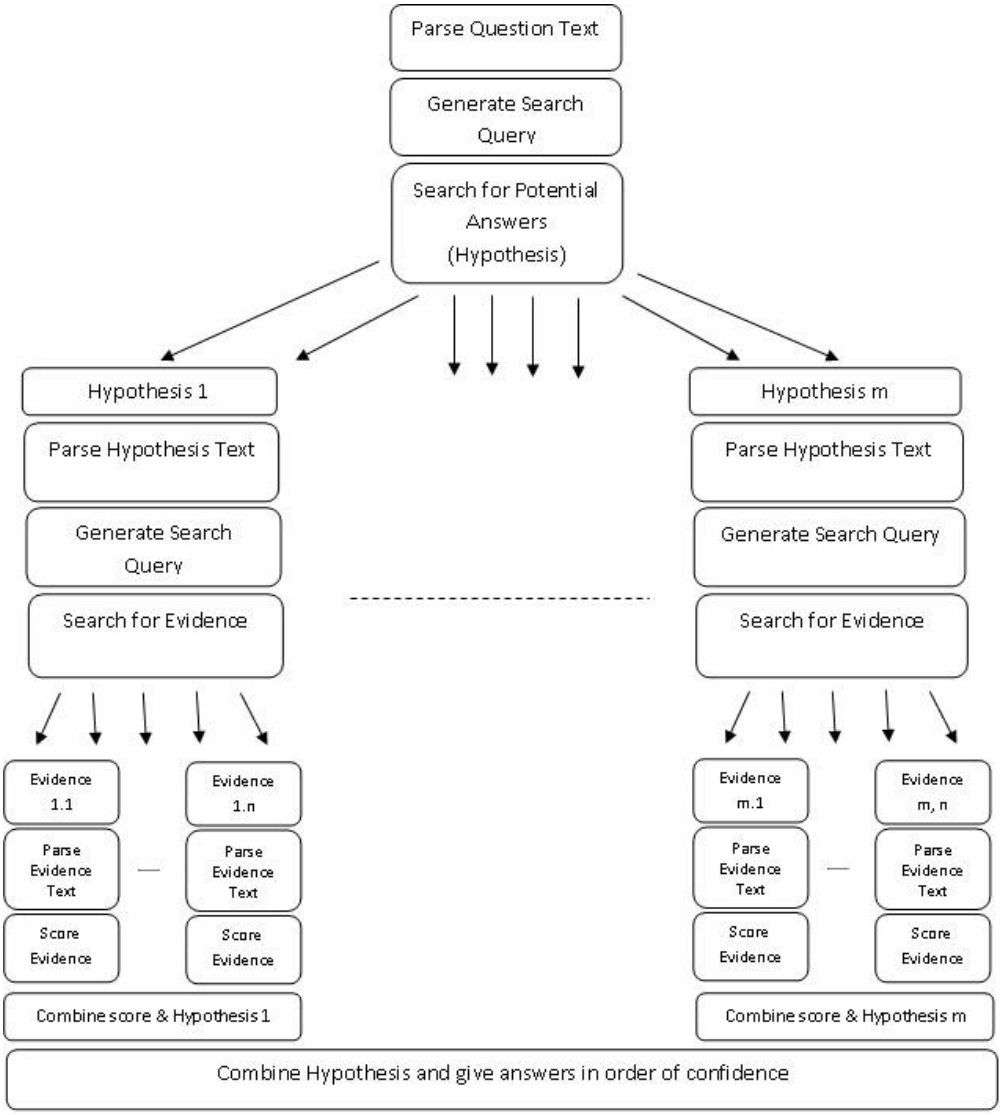

Figure 1. The workflow Watson goes through to answer a question

Source: (http://www.ibm.com/developerworks/library/os-ind-watson/#fig1)

1. It generates a search query after parsing natural language question.
2. It gives all related information notes by its inbuilt search engine searching the vast amount of records.
3. It generates appropriate results (the hypotheses) by parsing the natural language based search results.
    a. In support of the generated hypothesis it collects evidences by constructing and initiating another search.
    b. Evidence to support each hypothesis is searched by inbuilt search engine.
    c. Evidences searched are again parsed and strength of each evidence is calculated.
    d. Based on the strength of the evidence all the hypotheses are given a score.
4. Users are now apprised with the solutions in the form of Hypotheses as a list.

Basically, parsing of natural language and scoring of evidence results in evaluating the unstructured text records. Apache UIMA (Unstructured Information Management Architecture) based software components perform those tasks. For each question many search queries are generated, and many

different search techniques are used to give the evidence and hypotheses. Different search technologies used are Apache Lucene (term frequency to rank results), Indri (Bayesian network to rank results), and SPARQL (search relationships between terms and documents).

Let's consider a case of an ailment with multiple treatments that can be offered, the Watson service can help patient in deciding the course of treatment to undertake based on the various parameters including chances of success of the treatment, Adverse effects of the treatment opted, planned treatment duration and chances of success to name a few.

The list of options to analyze:

Id	Name	Planned treatment duration (months)	Adverse effects (1 to 5)	Chance of success (%)	Duration of effectiveness (years)	Out of pocket expenses ($)
0	BTC	12	5	50	10	8500
1	BIC followed by weekly syntinene	10	3	70	6.5	11000
2	EG followed by syntinene every 2 weeks	7	4	70	15	8750
3	FEG followed by weekly syntinene	7	4	85	14.75	8750
4	EG followed by weekly syntinene	3	1	65	5	8000
5	AG followed by donatel every 3 weeks	10	3	90	6	11000
6	Dose-dense AG followed by donatel	8	5	67	13	7900
7	FEG followed by N	13	2	84	10	10500
8	NBT	13	5	45	10	8500
9	NBT followed by weekly syntinene	11	3	50	6.5	11000
10	ST followed by syntinene every 2 weeks	10	5	60	8	9000
11	GEG followed by weekly syntinene	9	4	60	14.75	8750

Figure 2. Choice of treatments suggested by Watson

IBM Watson provides for an interactive engine to the user for making an optimum choice based on parameters of patient's choice, the same can be ascertained from the figure below.

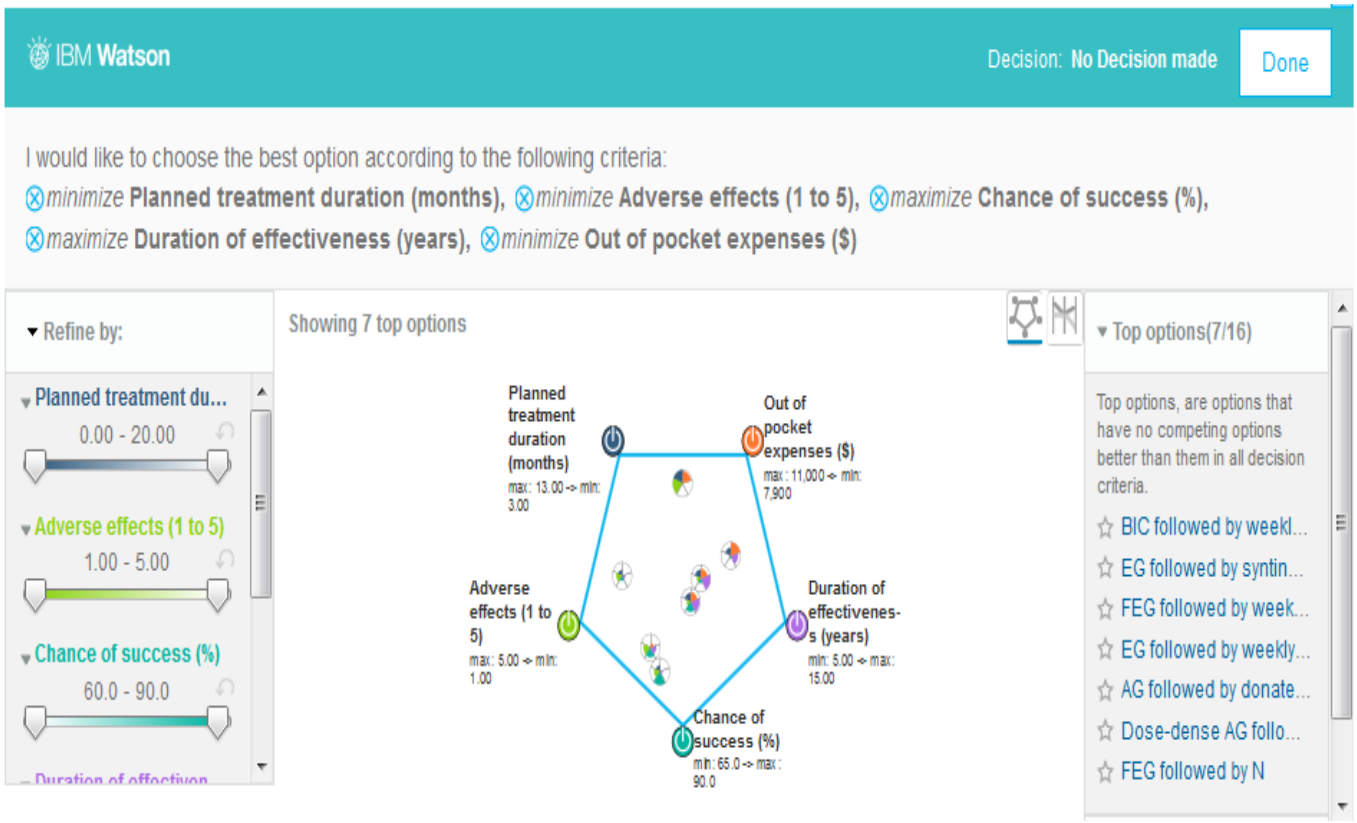

Figure 3. Interactive view of Treatment selection using Watson

The figure 2 gives a snapshot of the possible medications to a certain ailment, detailing each treatment with information on duration of treatment, Adverse affects, Chances of success, Duration of effectiveness of treatment and cost of the treatment. The patient can now make an informed decision taking into account the various parameters for an effective and suitable treatment.

The figure 3 provides a visual tool offering interactivity to make suitable choices from the various offered parameters.

Let's consider another example of selection of drug for a certain treatment, Watson would pull out all the possible drugs that can be administered along with details of probability on intestinal absorption, Blood barrier penetration, Non-carcinogenic probability along with other parameters.

The figure. 4. give a snapshot of the various choices of drugs by Watson with relevant details about the performance of each drug.

The figure 5 details the choice of the drug using an interactive tool provided by Watson.

The list of options to analyze:

Id	Name	↑ Human Intestinal Absorption (probability)	↑ Blood Brain Barrier Penetration (probability)	↑ Non-carcinogenic (probability)	↓ Rat acute toxicity (LD50, mol/kg)	↑ Not an hERG inhibitor (probability)
0	Blanfilast	0.991	0.9446	0.875	2.9547	0.7501
1	Prembelol	0.9484	0.8631	0.5199	2.3882	0.8546
2	Glucofilon	0.8589	0.9143	0.9716	3.3039	0.969
3	Thamiphoride	0.9775	0.9382	0.9378	1.2287	0.8735
4	Pseudonarine	0.9645	0.5638	0.7739	2.6024	0.9277
5	Eriladrine	0.9934	0.966	0.9322	2.9371	0.7961
6	Chlorogaline	0.9939	0.7421	0.8374	2.2158	0.8293
7	Eurolone	0.9522	0.9525	0.9116	2.3715	0.7418
8	Tranfilast	0.981	0.9346	0.775	3.2158	0.7501
9	Premvinol	0.9184	0.7631	0.5	3.024	0.8546
10	Glutofilon	0.766	0.8143	0.716	3.4287	0.969
11	Thaminorphoride	0.9375	0.8382	0.9	3.3039	0.735
12	Pseudocitarine	0.6645	0.538	0.5739	2.9882	0.917
13	Xiladrine	0.7934	0.766	0.9322	2.5715	0.7961
14	Ciprogaline	0.8139	0.5421	0.75	2.9547	0.8293
15	Monolone	0.9122	0.9425	0.9	3.0371	0.7418

Pre-selected objectives that the service will compare upon clicking Analyze.
An objective that will be maximized.
An objective that will be minimized.

Figure 4. Snapshot of Drug choices offered by Watson

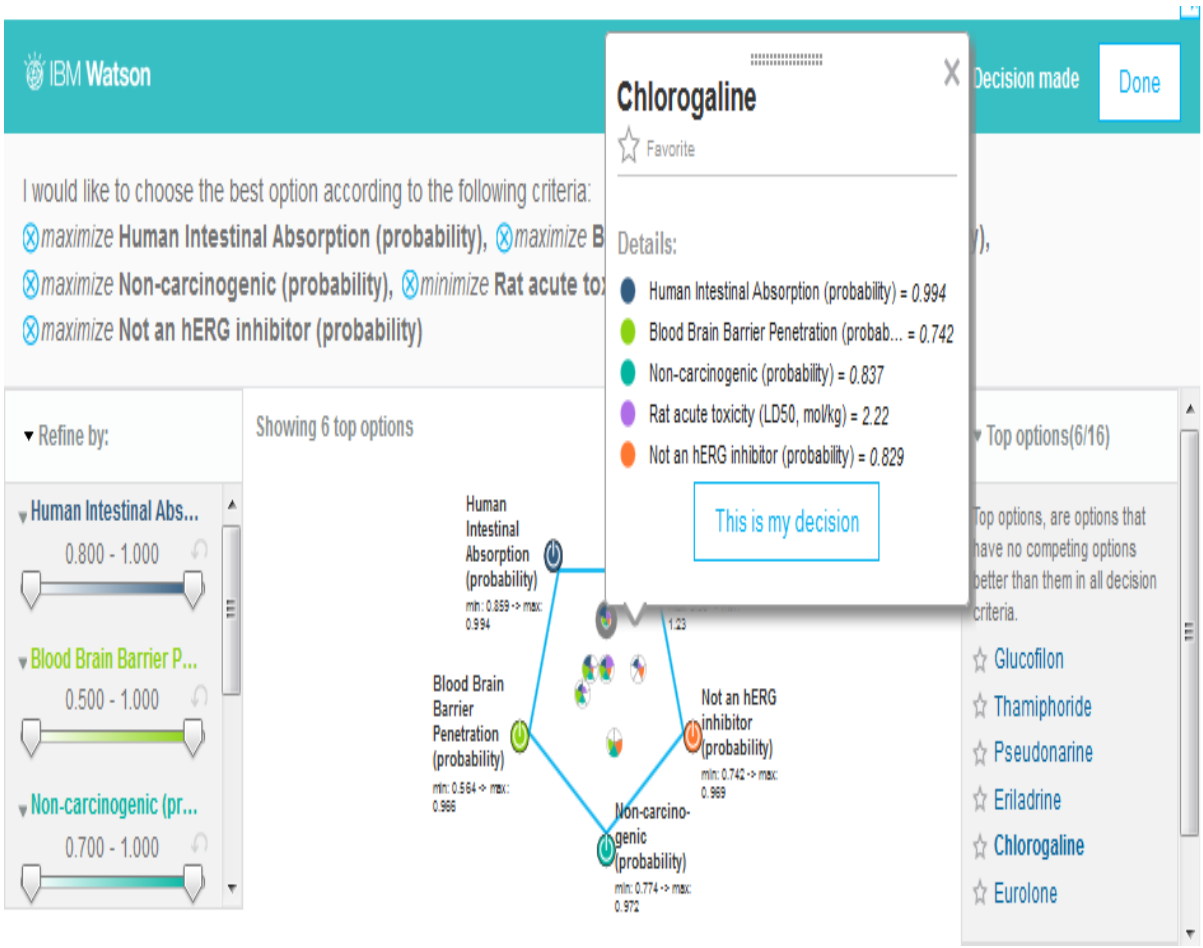

Figure 5. Interactive tool to make selection of drug by Watson

TECHNICAL SPECIFICATIONS

Watson is build using Open Source software, mainly. It uses Apache UIMA, Apache Lucene, Indrim and SPARQL. Though built on open software but makes use of its own algorithms.

Apache UIMA

To execute the text-process applications like Watson, OASIS UIMA is a useful framework. Apache UIMA is an open source outcome of the OASIS UIMA

It works by creating a link like structure of different applications (called components) in a chain. The results of text processing of one application are passed to the next linked in the chain for further processing.

UIMA-AS is a parallel processing framework, which allows parallel executions of different applications (components). For developing in Java UIMA-AS uses Apache open source framework, ActiveMQ, which uses Java Messaging Services to allow communication between tasks asynchronously.

In Watson, we have already seen after the hypothesis is generated scoring is done.

UIMA-AS made 2880 CPUs to come up with *Jeopardy!* answers within 3 seconds. If so much of resources are not needed then the system can scale down also. As in the case of "physician assistant" application need not to be too fast, which will require lesser amount of resources as compared to Watson.

The unstructured text document if given as input to an annotator (UIMA application) coded in Java or C++ which gives structured information as an output. In order to write these annotators UIMA documentation can be used which hosts a large piece of information having examples also using regular-expressions etc.

In NLP not only extracting of information with regular-expressions is required but large number of algorithms to find, generate tokens, tag, distinguish, and parsing of characters, letters and sentences from the input paragraph to extract its meaning based on the problem is used.

AS UIMA is an open source framework, other developers are encouraged to write their own algorithms and use them. Developers to create the annotators also use many known algorithms; the open source makes it easier to be used by new users. Huge amount of repositories of annotators like OpenNLP (Open Natural Language Processing) and IBM Semantic Search annotators can be downloaded from UIMA website.

To search by a specific name in document repository The IBM Semantic Search annotators is used.

Apache Lucene

We have already seen; to get hypotheses and their supporting evidence a large amount of database is searched. Indexing and searching of the unstructured documents Apache Lucene is used.

It is written in Java with full power of indexing and searching, along with APIs, which allow developers to use it in their own applications. It allows personalization of indexing and scoring as per developer's choice. It also enables to use a high end query language similar to Google search engine query language

Large documentation repositories: a trivial database and Wikipedia articles for *Jeopardy!* and medical publications for the health-care application are indexed by Lucene. During questions and answering session UIMA annotators whenever required to search database invoke Lucene. Peer reviewed medical journals like Medline and official guidelines like from Agency for Healthcare Research and Quality makes the examples of database for Lucene.

It stores the structured information generated by UIMA and also indexes the unstructured data based on count of words. Structured data results in a specific format and it enables searching through column fields (metadata). The structured information is stored in Common Analysis Structure (CAS). The Lucene CAS indexer (Lucas) is a standard annotator, which comes along with UIMA. Lucas saves CAS information into Lucene index files.

UIMA and Lucene work together to form the analytics and knowledge engine for Watson.

MOBILE APPLICATIONS

Watson can be used for building health based mobile applications. The cloud API of Watson can be used to develop these mobile applications. The mobile applications make the use very easy by integrating the power of Watson in mobile. User can get the updates on his mobile for all his health related queries. It serves as a full time nurse for the user. We can say it is a digital nurse for the users.

WATSON AND BLUEMIX

Watson services are available on IBM cloud Bluemix. Bluemix is a Platform as a Service (PaaS) from IBM where user can make and deploy applications of various types. With the integration of Watson with Bluemix to develop user based health applications using power of Watson Healthcare has become easier. Watson Application Program Interface (APIs) can be integrated with user's application in a very easy way.

WATSON CLINICAL TRIAL

Clinical trials are the methods to find whether new medical approaches will work fine on people or not.(“Mediline Plus.”, n.d) It finds the solutions for diseases and also enables to prevent from diagnosis by answering the questions. It may also analyze a treatment by comparing it with already available treatment.

Watson Clinical Trial is a huge machine learning experience with large amount of data. Here we describe a step-by-step procedure for using clinical trial service of Watson.

Step 1: Register at Watson Clinical Trial
(https://apps.admin.ibmcloud.com/account/public/trial/signup?partNumber=CTM_Trial)

This will allow 30-day free trial.

Step 2:

Once you login you will get a screen as below:

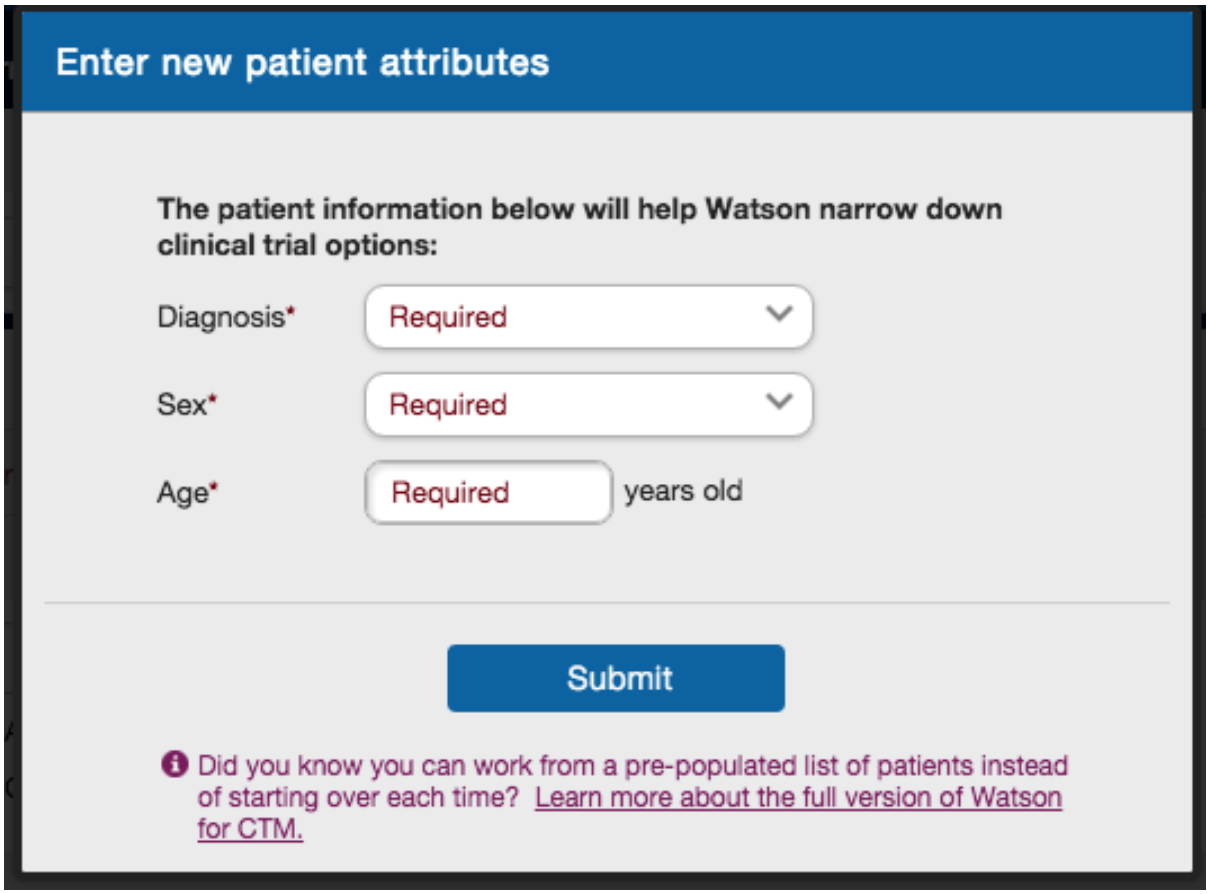

Figure 6. Screen Shot for New patient entry

The diagnosis gives options for five types of Cancer ; Colon ,Breast, Rectal, Colorectal and Lung Cancer. Choose the required option and fill other details.

Step 3:

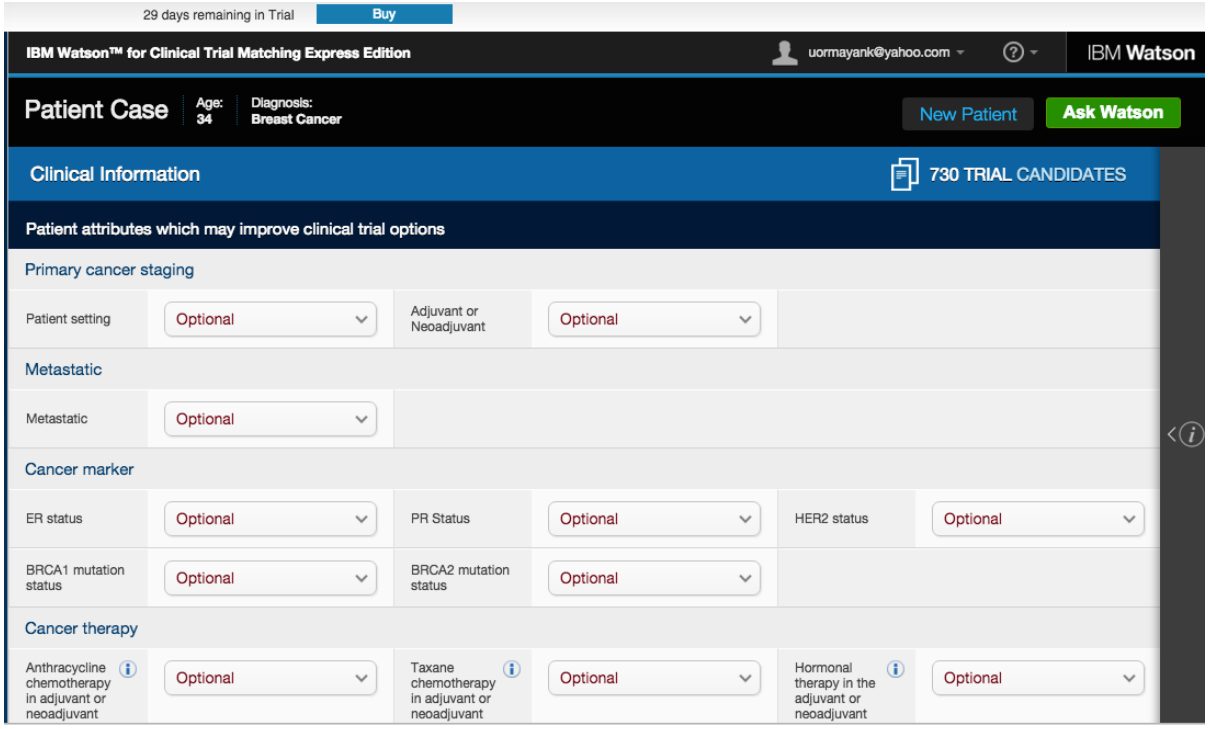

Figure 7. Screen Shot for details of patients

Once you submit the details as in step 2, the next page opens as shown in Figure. …After filling the required details on this screen press on ASK WATSON tab shown in green. Try to enter optional patient data details also, as it would give results that are closer to the concerned patient. Entering the location/zip code also facilitates in the same manner.

Step 4:

After entering all the required details. Watson processes the information and gives the results as shown:

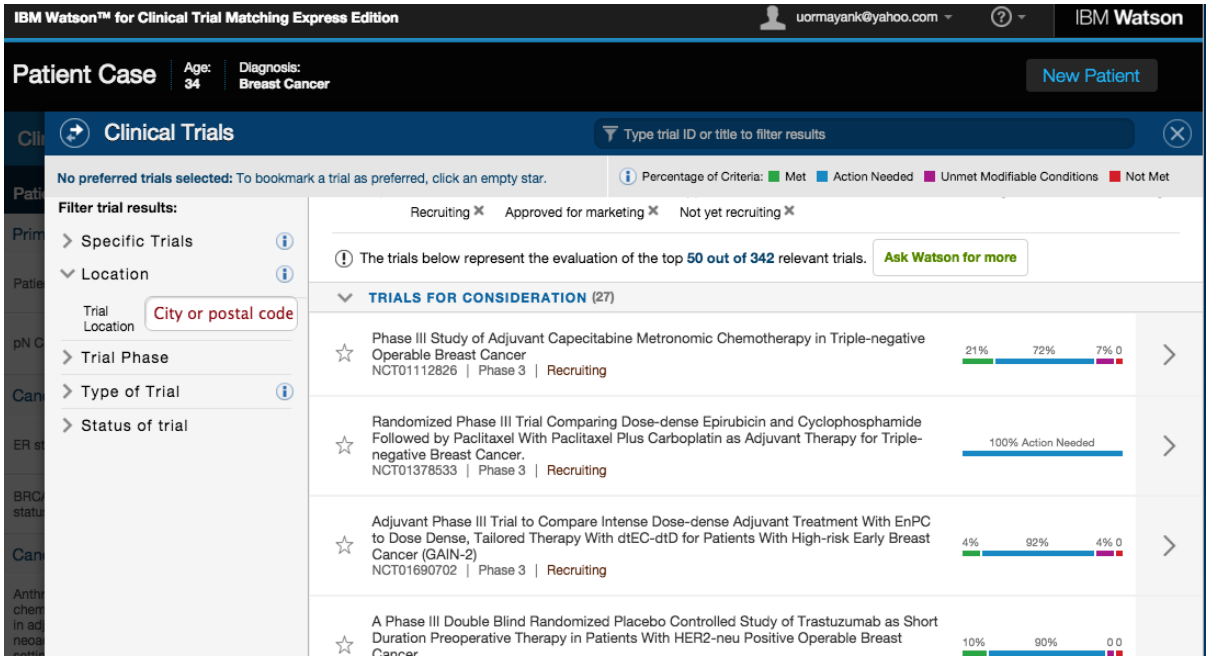

Figure 8. Screen Shot of resuls

The results (Trials) are divided in two categories Trials for consideration and Ineligible Trials.

Trials for Consideration:

This section refers to the trials, which matches with the patient's data and can be considered for further diagnosis. The trials show 4 variations:

- Met: In this clinical trial data matches with patient data.
- Action Needed: In it Watson requires more input from the patient, to know exactly about suitable clinical trial.
- Unmet Modifiable Conditions: In it are the trials which are not met currently with the patient but which might modify at later stage and be useful for the patient.
- Not Met: In it are the trials, which are of no use for the patient.

Ineligible Trials:

These are the trials for which the patient is not eligible. They have Not Met trials at a higher range.

Step 5

After getting the trials, you can Filter them by clicking on them. You can choose by checking the Action Needed check box and unchecking others to gather all action needed trials. Further on expanding the trials feed additional information to get more results by clicking on Ask Watson tab.

WATSON AND WEARABLE DEVICES

Wearable devices are small devices, which we can wear, and they give us data for different purposes. Mostly wearable devices are used for lifestyle and health related data for egg. Fit bit. The data fetched from these devices are not used up-to the level it can be used because of complex programming and machine learning required in analyzing that data. Watson API gives a way in which this data can be used for much better information and results.

Lack of Information

These wearable's gives lots of data but actual information is still lacking. For example consider the case of Fit bit which tells you how much calories you have burnt today by walking but it does not cover whether this is good for your health or not depending on your age, and other characteristics and condition.

Bridging the Gap

Watson API helps in bridging these gaps. The data collected from wearable devices is easily integrated with other data and records to give a much clear and better analysis of the data. Currently no such tool is available which allows you to do so with very little programming efforts and without building your own system, Watson is one, which provides you such opportunity.

Watson APIs

Watson has got some few APIs, which are available in Watson Service Catalog.(Sen,2015). The APIs are:

- Concept Expansion
- Concept Insights
- Language Identification
- Machine Translation
- Message Resonance
- Natural Language Classifier
- Personality Insights
- Question and Answer
- Relationship Extraction
- Speech to Text and Text to Speech
- Tradeoff Analytics
- Visual Recognition

- Visualization Rendering

  To make this service more accessible and easier Watson is integrated with Bluemix the IBM cloud (PaaS). Users can make their applications and integrate Watson services as per their requirements directly in Bluemix. These facilitate them to work on any simple machine connected with Internet and choose the programming language of their choice.

HOW TO USE WATSON API

In this section we consider to use Watson Trade of Analytics APIs. For it we need the following:

- A Bluemix account
- The Cloud Foundry CLI tool
- Basic understanding of JavaScript
- Basic understanding of Node.js

Step-by-Step method to deploy the application using CLI tool is explained below:

1.Get the Tradeoff Analytics Node.js application from GitHub (https://github.com/watson- developer-cloud/tradeoff-analytics-nodejs) in one of these ways:

- Download the .zip file and unpack it to a directory called Try
- If you are using Git, clone the repo to the Try directory

2. Navigate to the Try directory, and then edit the manifest.yml file.

3. Log in to IBM Bluemix by entering the following command from the Try directory where you downloaded the source code:

cf login -a https://api.ng.bluemix.net.

4. Provide your login credentials, and if you have more than one workspace, select a workspace.

5. Push the code up to IBM Bluemix by entering the following command:

cf push Try -no-start

6.Create an instance of the Tradeoff Analytics service by entering the following command:

cf create-service tradeoff_analytics standard tradeoff_analytics_node.js.

7.Bind the service instance to the Try application instance by entering the following command:

cf bind-service Try.tradeoff_analytics_nodejs

8. Restage the application by entering the following command:

cf restage Try

9.Log in to your Bluemix account.

10.Open the user interface for your Try application by using one of these methods:

• Copy the route or URL that displays under the application name.

• Click the **open website** button, under your Try application, which is next to the running text.

FUTURE OF NATURAL LANGUAGE PROCESSING IN HEALTHCARE

Natural language processing in health-care is much more that doubts and solutions. In 2008, the Nature journal published a issue indicating on how big data can be used for medical purposes. The medical science is moving towards data mining for conclusions rather than theoretical and hypothetical views. Genomic data is used big data mining in Nature but natural language text data is can also be used, ant it opens a research front using text data.

We can take the digital records of doctor's notes as input for big data mining to give treatment options, symptom based diagnosis, reductions in medical errors etc. Mayo Clinic has already tied up with IBM to give its records to be used and searched by using Watson and integrate it with UIMA annotators.

Not only the doctor's data but feedback from patients, their blogs, emails can also be used for data mining to help in medical analysis. Communities like Patients LikeMe and Association of Cancer Online Resources have large amount of this type of data. The reports of patients telling about adverse effects of medicines not covered by FDA and also sometimes the solutions given be patients can be mined for better treatments. Natural language tools, can take medical Sciecne to new heights.

By Open-Source and Cloud based hardware, Watson shows what can be done. The open source and easy deployable efforts by R&D team of Watson has given an opportunity to the developer community to write innovative applications to take advantage of these capabilities!

FUTURE RESEARCH DIRECTIONS

IBM Watson can be integrated with any medical issues, the user can built his own IoT applications for any illness he wishes to, as there are no restrictions from Watson. Recently IBM tied with Apple and Apple watch intenerated with Watson to predict the health status in depending on sleeping habit.

CONCLUSION

The average life span in 2014 is reported to be 64 years, in 1869 it was 26 years, in 1800 it was 23 years, with the advent of antibiotics the life span increased 3 times in 150 years and with the advent of IT and cloud computing with the help of Watson we can expect life span of 90 years within short span of time. Think is it possible for a doctor to record details of $5 * 10^{30}$ bacteria moving in the atmosphere. But with Watson it is possible.

Watson's way of reasoning is to generate hypotheses (that is, candidate answers) from a large body of documents, as opposed to from pre-conceived theories as humans typically do. In fact, a major trend in scientific research is to "mine" discoveries from data. While Watson is trying to emulate human intelligence, humans seem to think more like Watson too!

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ADDITIONAL READINGS

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http://www.ibm.com/smarterplanet/us/en/ibmwatson/what-is-watson.html

http://www.ibm.com/smarterplanet/us/en/ibmwatson/health/

KEY TERMS AND DEFINITIONS

Cloud: It is a model that provides access/compute/storage to users any time any place and on any device connected by Internet.

Mobile Applications: Applications, which are made for, and run on mobile devices are called mobile applications.

IoT: A device connected and controlled through Internet irrespective of the location.

Bluemix : A PaaS by IBM.

Responses to Comments and Review

1. Word Count: Increased to 4400 from 3300.
2. Key Terms and Definitions: Added Key Terms and Definitions
3. References: Added References
4. Additional Readings: Added Additional readings
5. Key Words: Increased number of Keywords from 4 to 8
6. Abstract: Re-written keeping the word limits
7. Future Research Directions : Added Future Research Directions
8. Language and Acronym : Revised