intel® Saffron™

INTEL® SAFFRON™ COGNITIVE SOLUTIONS

Technical White Paper

SYNOPSIS

The rise the Internet of Things provides an opportunity to gain new insights from growing volumes and sources of data not previously available. Up until now, most organizations focused on capturing and filtering the data. The capacity and ability to truly exploit the Internet of Things to create personalized customer experiences, to learn of emerging business threats and opportunities across myriad and disparate data sources, to simply connect the dots, or to find networks or similarity patterns across massive amounts of data has remained elusive. Traditional analytics such as Artificial Intelligence applications or business intelligence solutions continue to offer rule-based systems which require complex engineering knowledge including rule engines, relational databases, statistical probability and search indexes. The Saffron Cognitive Solutions group believes that there is a better way, and it begins with Natural Intelligence.

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EXECUTIVE SUMMARY

The ability to see, analyze and understand the world in real time is a uniquely human capability. They assimilate countless facts, ideas and events, and make sense of the world by associating these inputs in memory. The brain finds similarities between people, places and things, using reasoning from the past to understand the present and to anticipate the future. In the business world, these abilities let people prepare for future outcomes to maximize profit while minimizing costs. Until now, such capabilities were limited to human beings, but the power of cognitive computing platforms is bringing computers closer to learning and reasoning like people.

Intel® Saffron™ Cognitive Solutions bring to the Internet of Things the incredible ability of the brain to find meaning in data, but at a scale that far exceeds human capabilities. With each new experience, the solution continuously builds memories, incrementally learns from outcomes and makes new connections. Saffron Cognitive Solutions help businesses benefit from the knowledge in their data by shortening the time to insight for faster and more comprehensive decision making.

This paper, organized in four sections, explains how the Saffron Cognitive Solutions' works and describes the methods to change the signal-to-noise ratio in the analysis process including:

1. The Principles of Natural Intelligence

If technology is to assist in transforming data into information, and information into actionable knowledge, then it needs to be intuitive.

2. Associative Memory and Cognitive Distance

Saffron Cognitive Solutions unify data points in its associative memory and finds patterns in the data using similarity analysis.

3. Entities and Networks

Saffron Cognitive Solutions' network of networks are more natural, like independent agents that hold their own memories and express certain links to each other, depending on context.

4. Conclusion

The Intel® Saffron team has developed the technology of natural intelligence. Today, Saffron Cognitive Solutions are applied to address serious problems for government and corporate enterprises. However, this is only the beginning of what is possible.

1. THE PRINCIPLES OF NATURAL INTELLIGENCE

The Genius of the Human Brain

The Saffron Cognitive Solutions group develops software founded on principles of memory-based representation and reasoning to make applications mimic the human brain. Saffron Cognitive Solutions offer a revolutionary approach, inspired by human reasoning, to help transform data into intelligence.

Humans use associative memory to identify people from various parts of everyday life. The associations contained in these relationships matter: What interests or friends are shared? From when or where do they know each other? Relational databases lose much of this valuable information a priori, as the restrictions of columns and fields are rigid, predefined, often due to the constraints on size, structure and management of computer maintenance.

Saffron Cognitive Solutions read free text to identify relationships, then analyzes the strength of relationships based on correlation, count, context and closeness.

Models Limit Information

Non-cognitive computers index and retrieve documents and records according to their content. Using these traditional designs, representing and remembering how every "thing" potentially relates to every "thing" else is not scalable.

Traditional methods address this scaling challenge by reducing the information residing in a population of data into an abstract model or set of rules. Rules place specific constraints on the data, the data structures or the relationships within the data. Rules by their nature demand reduction of available information for the sake of simplicity and in doing so also lose the actual relationships and exceptions within the data.

These models may be representative of yesterday's normal cases and approaches, but today's problems require knowledge of the exceptions – whether the problem is predicting an adverse event before it happens or providing enhanced diagnostic capabilities through pattern recognition. Rich and detailed information about each entity or individual is what matters and requires a more intelligent approach.

MAKE COMPUTERS WORK LIKE A BRAIN TO BETTER ASSIST PEOPLE

As We May Think

Dr. Vannevar Bush was the first to articulate the idea of a human-like associative memory for computers[1]. "The human mind operates by association," Bush suggested. "Selection by association, rather than indexing, may yet be mechanized." Dr. Bush was familiar with the development of computing during and after World War II. The view of computing during this timeframe focused on indexing rather than associating, a view and process still in place today, almost 70 years later.

Memories Between Data and Models

The foundation of Saffron Cognitive Solutions' approach is patented associative memory technology, which uniquely addresses the problems unresolved by traditional methods.

Searching through massive data sets and reading large volumes of documents to make sense of it is challenging for humans. Intel® SaffronMemoryBase™ stores information as associations between data points and recalls all relevant associations from experiences and evidence – as they relate to a specific situation.

2. ASSOCIATIVE MEMORY & COGNITIVE COMPUTING

Humans learn how to relate things when they are seen together or in sequence. The brain makes sense of new situations because they trigger memories of prior familiarities. It recalls what each have in common, and then imagine what is missing or what is new and different.

Memories: Representation of Coincidence Matrices

Saffron Cognitive Solutions define memory as association frequencies represented in an associative matrix. An association represents an observed coincidence between any two things.

The software counts each observed coincidence and represents an association frequency.

An associative matrix is a representation of many association frequencies, called the Intel® Saffron Memory Base.

Figure 1 shows how a simple data table represents an associative memory. Rather than recording raw data, such as records or documents, the associative matrix represents the cross-record and cross-document information about all the things within the data.

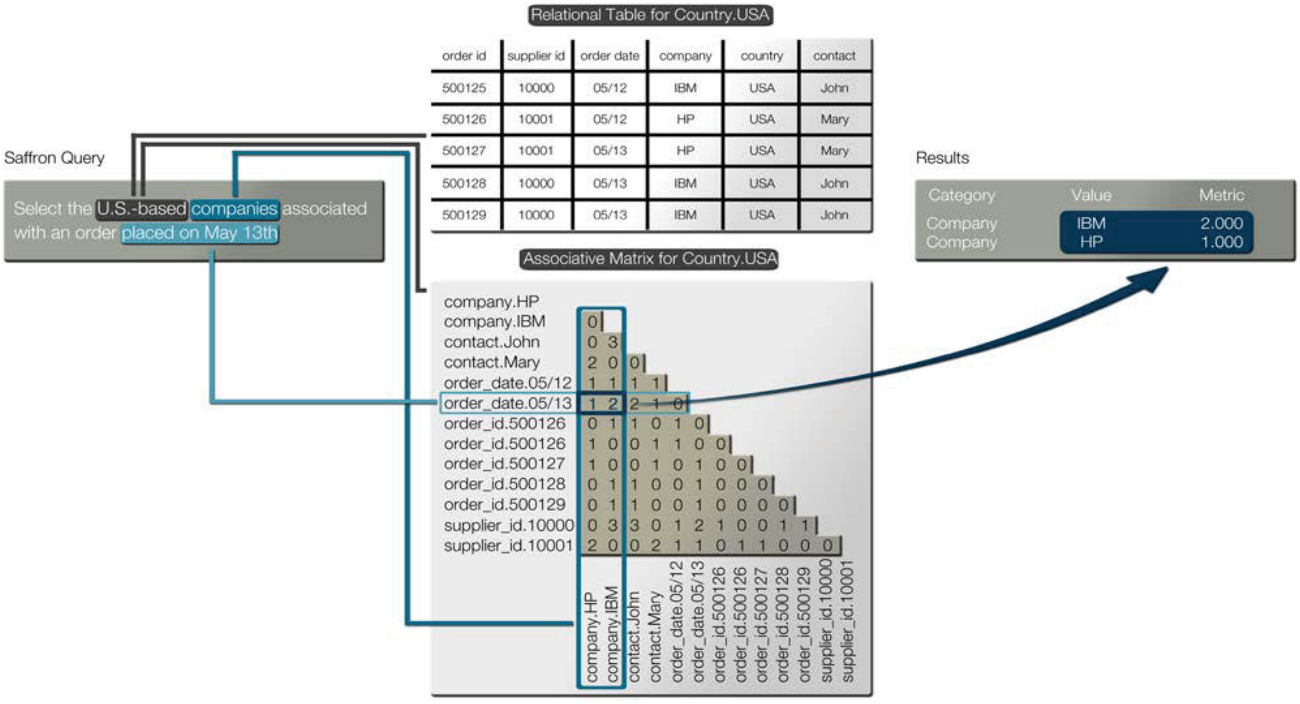


Figure 1. Comparison of an Associative Matrix with a Data Table

Saffron Cognitive Solutions show equivalent associative memory representing the frequencies of association across all the data elements. It can easily see that on May 13 there was one order placed to HP and two orders placed to IBM. Additionally, it can easily discern the relative number of orders placed to each company in relation to the other orders. While these can be counted from the table, it is much easier to look at the matrix to find useful information, instead of just raw data.

Memories Are Faster to Exploit

While both the data table and the associative memory can answer this simple query, note how little work is required to recall results with the associative memory vs. pulling data from the table. Memories do not "search" for answers; they simply lookup and recall the answers from everything they have already memorized. When the time comes to exploit data, an associative memory requires less computation and less input/output access to the total data store – rendering the data volume stored as less relevant.

Businesses need to be able to exploit data rapidly to understand a situation. Questions such as "Who is related to whom?" and "Who is similar to whom?" are quickly answered when information is represented in an associative memory base.

Reasoning by Memory

Memories also provide better answers to other types of queries, such as "what is it?". Although the example given in Figure 2 is simple, Saffron Cognitive Solutions focus in more challenging areas where associative richness and detail make all the difference when the nonlinear combinations of attributes define the class. Think about applying this to personalization where a consumer might like to wear the color red, but only red ties and not red shoes. In most domains, humans think in patterns of attributes and how they occur together, reminding them of past cases and their categorizations.

Memories Learn Autonomously

Traditionally, the accomplishment of data categorization is by the modeling of rules or statistics. Knowledge engineering, also called "data mining," includes the authoring of rule bases or the parameterization and training of statistical models. Despite the approach taken, the resulting static models require significant time and effort to develop, deploy, and maintain. As the environment constantly changes, the rules and models quickly become out of date, which in turn requires yet more time and effort to reconfigure, test and re-deploy. Associative memories are autonomous, non-parametric and learn incrementally, like the brain.

Memories Learn Quickly

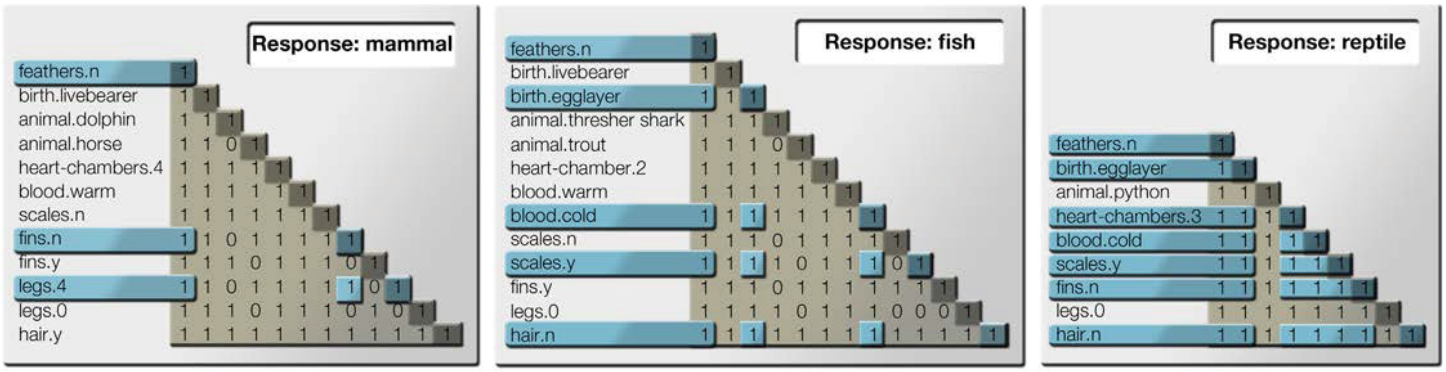
The example in Figure 2 also shows how memorybased reasoning is not data hungry, which is a problem with data mining and the probabilistic assumptions.

> ASSOCIATIVE MEMORIES ARE AUTONOMOUS, NON-PARAMETRIC, INCREMENTAL LEARNERS, SIMILAR TO THE BRAIN

Statisticians might argue that so few examples do not provide enough statistical confidence, but increasingly, the assumptions of statistics are failing. In contrast, memory-based reasoning provides effective accuracy with few training examples. Using similarity analysis, a single observation of a reptile, for example, is enough to estimate that the new case is most likely a reptile based on all the information available to date.

Figure 2. Categories of Associative Memories for Multiple Animal Types

The associative memories represent a set of observed classes for different types of animals. The memories have observed examples of mammals (a dolphin and a horse), examples of fish (a trout and a shark), and an example of a reptile (a python). The memories represent the nonlinear coincidence structure of how the attributes of each animal occur in relation with each other. The table shows a new set of attributes for a reptile, and each memory is asked to imagine how well the pattern "belongs" to its class. Reasoning from memory, this cold-blooded, egg-layer with scales is most likely some sort of a lizard.



3. ENTITIES AND NETWORKS

The previous examples are illustrative of associative memories, but Saffron Cognitive Solutions' memory-based reasoning are much more elegant than described here and it addresses the scale of data far beyond these simple illustrations. Imagine an army of personal assistants—each assistant contains at least one associative memory that learns everything about an entity whenever it appears, whether in structured data or unstructured text. Each assistant reads, remembers and recalls all its associations to other entities (people, places, things and events) in the context of other attributes, which are not first-class entities.

In Figure 3, each memory represents a network of connections within its entity's perspective, and the collection of networks is yet another level of connectivity. Other graph-based representations of entity networks are too atomic. In these atomic representations, each entity is an abstract node, and connections are context-free links with only one characteristic. Saffron Cognitive Solutions' network of networks are more natural, like independent agents that hold their own memories and express certain links to each other depending on context.

Observe Associations in Context

Rather than searching for and reading one document at a time while building a matrix and collecting evidence, Saffron Cognitive Solutions reads all the documents and connects all the entities automatically. With Saffron Cognitive Solutions, less time is spent searching and more time analyzing. This makes it possible to understand associations between people, places and things more quickly and visualize these associations in a variety of ways. The result is faster access to a complete picture of the available knowledge in your data, enabling quicker and more well-informed decisions.

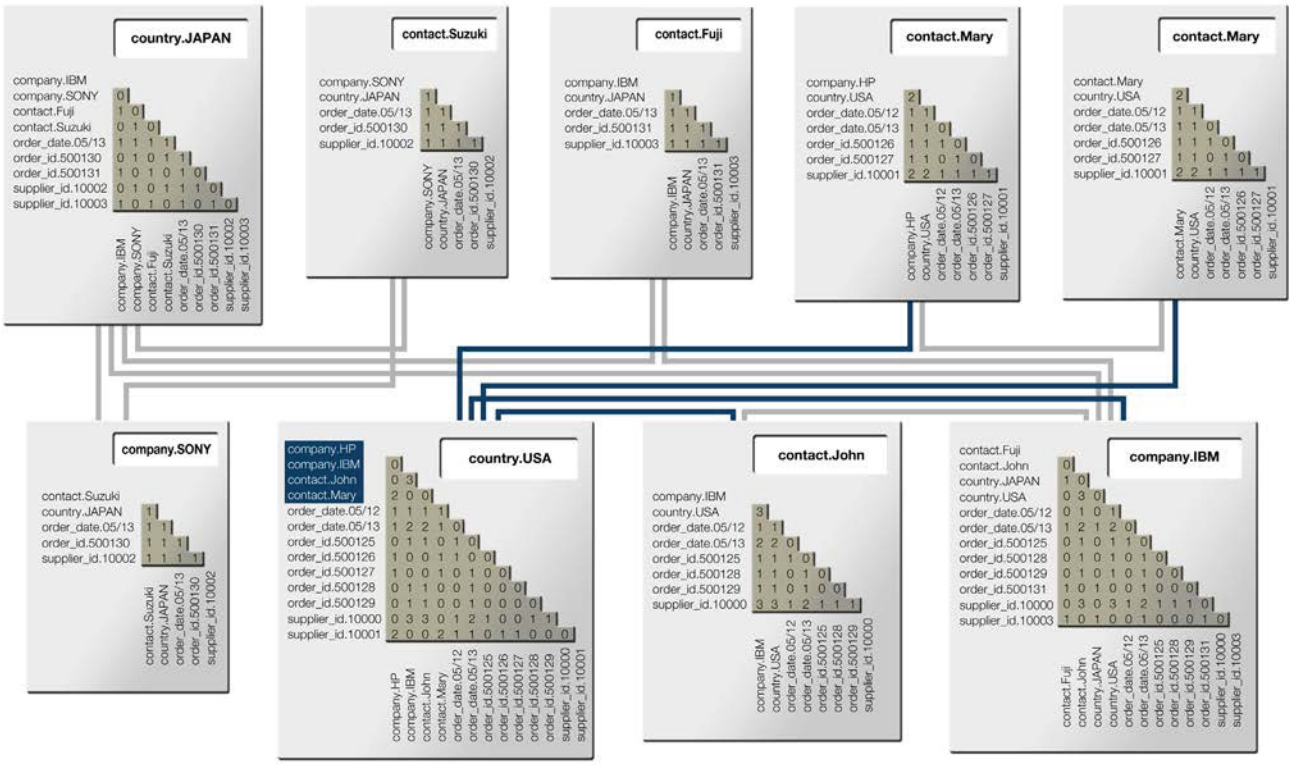


Figure 3. Memory Base of Associative Memories Within an Entity Network

The blue outlined box within the USA memory illustrates that USA is associated to Mary when the context is HP, and that USA is associated to John when the context is IBM. John's memory knows the association to IBM when the context is USA. Given any starting point, the memory network can recall the other associated entities, in context.

Saffron Cognitive Solutions unify massive data sources — structured and unstructured — at the entity level. All unstructured data pass through entity extractors to mark the people, places and things that define the entities. Saffron Cognitive Solutions build an associative memory for each one, remembering the links, context of links, and snippets of evidence, to warrant each link across all the source data. Rather than spend time in researching, collecting, and reading, businesses can more quickly find and make sense of contextually relevant entity networks, and publish reports, thereby accelerating the production of intelligence decisions and possible action.

Massive Network Scalability

Intel® Saffron Memory Base can contain millions of memories, which can contain many more millions of coincident attributes. Each memory represents many billions of associative "triples." A triple is composed of three elements: the name of the entity (also called primary key), the memory of the entity and another entity or attribute paired within it.

In an implementation of this size, Intel® Saffron Memory Base requires only three 32-bit general-purpose computers. Saffron Cognitive Solutions have solved the associative "crossbar" problem using various patented methods for compression and partitioning. Real-time memory allows random access to the representation, both to incrementally write new observations and quickly read the memory to answer any question. At the system level, Saffron Cognitive Solutions uniquely provide near-linear, infinite scalability across multi-processor systems.

Context Matters

Perhaps the all-time classic tabular database is the old telephone book. It's easy to use if looking up a known person. However, imagine if the person was someone met someone at a party who was looking for a new bassist for her band, but they didn't give their name. Saffron Cognitive Solutions would reveal not only who was at the party, but also their names, the band's name, and where they were playing next. It would also show who the last bass player was and where he was playing now. Saffron Cognitive Solutions could also find in what bands this person has played and whether there are other bass players attending the party. Saffron Cognitive Solutions capture the context of association automatically within its network of network and uses it to exploit social information effectively. The more the network increases in size, the more this context dependency is required to find the right links among billions and trillions of links.

Knowing Who is Who

Saffron Cognitive Solutions' memory-based approach address both major aspects of entity analytics: "Who is associated to whom?" and "Who is similar to whom?" the solution uses virtually all the information about an entity to lookup other similar entities. Rather than rely on assumptions of rules to select and match on only a few variables, Saffron Cognitive Solutions estimate the matching value of all the attributes in the data, whatever they might be. Furthermore, the matching value based on the entropy of the attribute is a measure of a frequency distribution. By definition of a memory, Saffron Cognitive Solutions' memories store such frequency distributions. In Saffron Cognitive Solutions, all information for all attributes is available and exploited to answer similarity-based questions more quickly and with higher accuracy.

The Future is About Anticipation

Anticipatory analytics is also part of data mining, dominated by traditional statistical methods, but these reductionist models tend to find a few terms that capture the most variance. When the goal is to capture as much variance as possible in the fewest terms, most information is lost. Saffron Cognitive Solutions' memories do not rely on attribute subset selection of the most informative terms. Instead, a memory retains all the attributes to select and "shrinks" them, depending on the desired context. A particular attribute may be of little value in most situations yet under another construct, it may become the most critical to inform.

Cognitive Distance and Kolmogorov Complexity

Associative memories can be divided into autoassociative and hetero-associative memories. Autoassociative memories find patterns to answer questions like, "who is similar to whom?" using entities. Hetero-associative memories recall data from distributed graphs to find patterns, and make predictions. Saffron Cognitive Solutions connect and illuminate the dots that matter using reasoning by similarity to discern the signal from the noise. This method is powered by cognitive distance, based on Kolmogorov complexity.

To learn more, to read "Reasoning by Cognitive Distance on an Associative Memory Fabric" white paper, explaining how Saffron Cognitive Solutions combine the power of associative memories with cognitive distance in order to anticipate outcomes.

CONCLUSION

New technologies are required to address the explosive growth of the Internet of Things. Rule-based systems require much time and effort to define, test, and maintain, yet remain highly inaccurate in a dynamic world.

It is time for a different approach.

Saffron Cognitive Solutions support decision making with a level of information and knowledge far beyond what raw data can produce. Saffron Cognitive Solutions are schema free and can read everything. It connects all the data points regardless of source or structure, and returns analytic results by entity rank rather than search results by document rank. Today, many diverse organizations from both government and corporate enterprises apply Saffron Cognitive Solutions to address and solve challenging problems. However, this is only the beginning of what is possible. The Saffron Cognitive Solutions group is working to understand new requirements for prediction and the power of memories for patterns to help solve a new generation of difficult problems with memory-based technology and similarity analysis.

REFERENCES

[1] “As we May Think” - Vannevar Bush, The Atlantic, July 2008 http://www.theatlantic.com/doc/194507/bush

[2] The Law of Large Numbers says that in repeated, independent trials with the same probability of success ineach trial, the chance that the percentage of successesdiffers from the probability ‘p’ by more than a fixed amount,‘e’ > 0, converges to zero as the number of trials goes toinfinity for every positive ‘e’ - 12 July 2008

http://www.stat.berkeley.edu/~stark/Java/Html/lln.htm10

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