KONICA MINOLTA

Understanding the workplace of the future

Artificial Intelligence series

Giving Shape to Ideas

Cognitive Hub and the Semantic Platform

Within today's 'digital workplace', there is a growing need for different tools and technologies that support individuals and even more so, supports teams in the achievement of their business goals. These objectives are so frequently reliant upon the interaction and collaboration within the user's own and external work groups, that seamless management of the communication, exchange, and more importantly obtaining insight from data and information must be facilitated by an organisation's technology.

In any working day hundreds or even thousands of pieces of information or documents are moved around, changing hands between colleague, teams, databases and applications, and flowing in and out to the external world across a myriad of systems and networks. Each piece of data or each document is an element that contributes to the completion of a given task, often within a certain activity or workflow that has to be executed by an employee as one of their daily goals.

To effectively manage this growing complexity in the everyday workplace, Konica Minolta's Cognitive Hub provides a federated system that is capable to orchestrate AI services and agents. Cognitive Hub is a system of systems that manages other intelligent platforms providing services in data analytics, environment sensing, semantic understanding of data, distributed robotics management and advanced human computer interaction.

As an evolution of Konica Minolta's Workplace Hub, Cognitive Hub exploits the interactions between collections of intelligent edge devices and comprises a programme of features, applications and services that are implemented on several different platforms. One of these platforms, the Semantic Platform is a complex ecosystem of machine learning and Natural Language Processing functions that supports users to manage information collected from all the unstructured data and systems of records they interact with in their digital workplaces. This paper describes the capabilities of the Semantic Platform, the technology behind it, and shows how it can be used to help the everyday user conquer the challenges of the digital workplace and turn them into opportunities.

Architecture and technology highlights

Cognitive Hub is designed as a set of Machine Learning and Natural Language Processing components in form of microservices. It is highly distributed, scalable and utilises a Docker environment to achieve high service availability and reliability. Components of the system communicate with each other using REST API and asynchronous messaging.

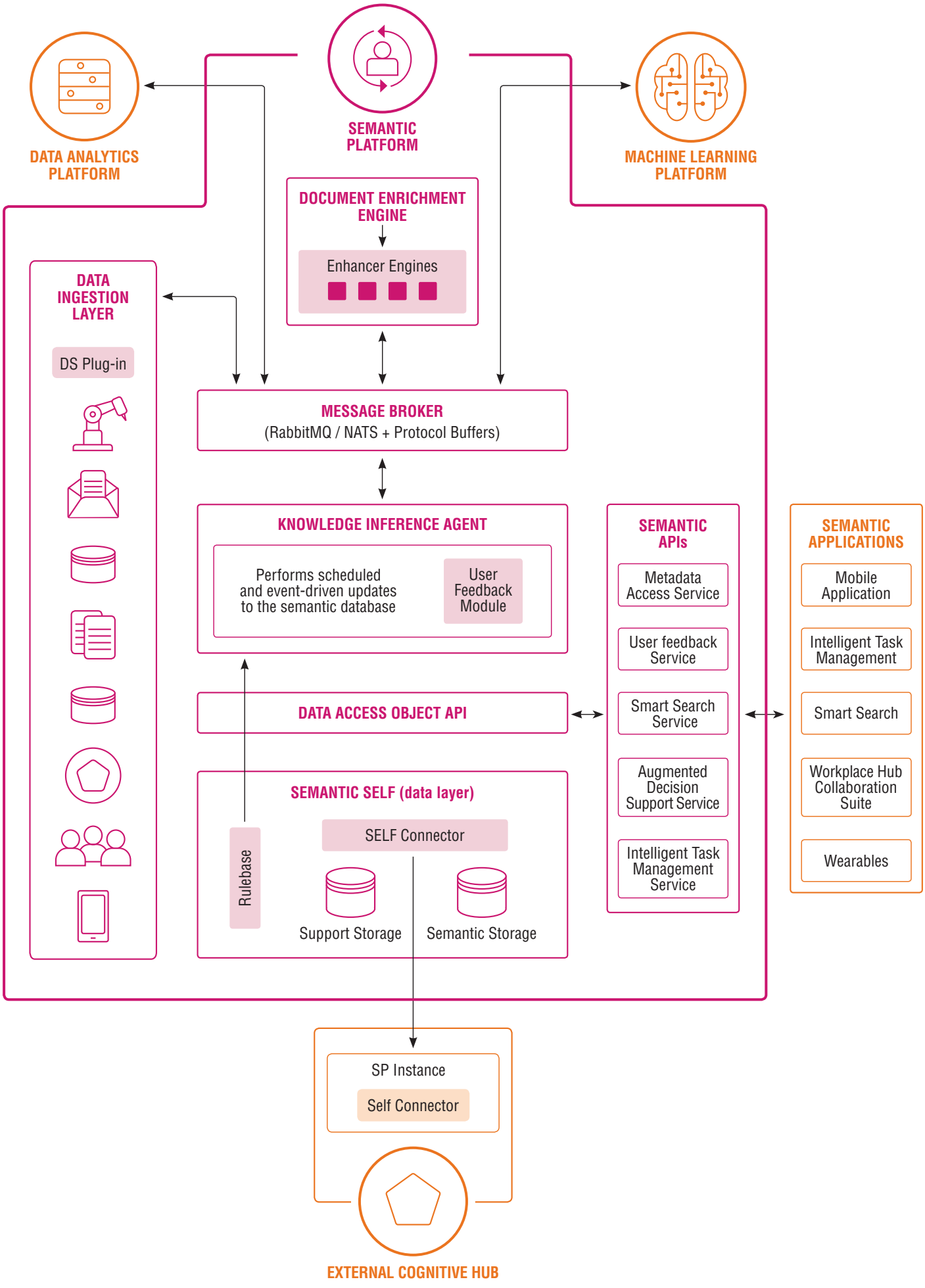
What is the Semantic Platform?

The Semantic Platform comprises a rich ecosystem of semantic applications for the digital workplace. Exploiting the integration of several state-of-the-art semantic-inspired technologies such as Natural Language Processing (NLP) and dialogue systems present through the workflow automation, it delivers smart services devoted to help individuals and especially teams to be more productive and avoid wasting time in the organisation, retrieval, and usage of digital documentation.

The Semantic Platform leverages information from various unstructured data sources to understand the user's and the team's work preferences, and the forecasting of their needs, to derive an interpretation of this information in the context of the digital and physical working environment. Within this framework, the Semantic Platform exploits innovative intelligent and adaptive user interfaces that support users and groups in taking informed decisions.

The main research and development focus areas within the Semantic Platform are:

- **Extraction of information** from **unstructured data sources** (textual documents, images, multimedia, sensors) - understanding documents and other data
- **Semantic Enrichment and Linking Framework (SELF)** - knowledge representation and reasoning, interpretation of information in the context of the digital workplace, understanding of the user and their operations in the physical and digital working environment
- **Artificial intelligence for coordination of team interactions** - navigating users through information overload, document management and search, automation of routine back office operation tasks such as task management, travel planning, goal management and information search. It deals with user specific virtual assistants
- **Adaptive virtual agents** - understanding user preferences, feedback and learning systems, scaling solutions for automation.


SEMANTIC PLATFORM
DATA ANALYTICS PLATFORM
MACHINE LEARNING PLATFORM
DOCUMENT ENRICHMENT ENGINE
Enhancer Engines
DATA INGESTION LAYER
DS Plug-in
MESSAGE BROKER
(RabbitMQ / NATS + Protocol Buffers)
KNOWLEDGE INFERENCE AGENT
Performs scheduled and event-driven updates to the semantic database
User Feedback Module
DATA ACCESS OBJECT API
SEMANTIC SELF (data layer)
Rulebase
SELF Connector
Support Storage
Semantic Storage
SEMANTIC APIs
Metadata Access Service
User feedback Service
Smart Search Service
Augmented Decision Support Service
Intelligent Task Management Service
SEMANTIC APPLICATIONS
Mobile Application
Intelligent Task Management
Smart Search
Workplace Hub Collaboration Suite
Wearables
SP Instance
Self Connector
EXTERNAL COGNITIVE HUB

The Semantic Platform and its subsystems

The Semantic Platform keeps track of all the sources of information related with users and groups (tasks, activities, calendar, social network and their data and documents) to predict their interests, provides them with the right information at the right time, automates routine tasks, and offers them automated and adaptive assistance.

To accomplish these functionalities, the Semantic Platform (SP) is based on an event-driven microservices architecture, represented in the graphic, and it has the following key attributes:

- **Open**: as the result of the use of widely supported and consensus-based standards in its key interfaces, the SP accepts inputs from external sources and produces outputs that are 'understandable' by external systems. Adding, upgrading or swapping (between systems or services) components does not have any impact on the SP's architecture.
- **Interoperable**: the SP offers an extensible modular framework for incorporation of data connectors, called a Data Ingestion Layer, through which interoperability is achieved with appropriate plugins.
- **Heterogeneous**: In order to provide different functionalities, the SP is able to integrate various algorithmic components and particular machine learning models that are able to work together (interoperability). Different components and models can represent a variety of programming languages, ML model types, database systems and support components from broad range of tool and components providers.
- **Pervasive**: the SP acquires data and information at different levels of granularity (e.g., raw data from sensors and log files, through to user-related events and actions) in order to deliver predictions, inferred knowledge and a holistic understanding of user in digital and physical workplace.

The Semantic Platform and its subsystems

- **Modular**: each of the components in the SP or its modules is responsible for only a specific feature or functionality, or an aggregation of cohesive functionality. The SP minimises the number of interaction points amongst its components to achieve low complexity.

- **Scalable**: the SP handles increases in load (e.g., number or frequency of the requests, new sources of inputs, etc.) without impact on the performance. This is possible mainly thanks to the distributed microservices of Cognitive Hub.

- **Extensible**: the SP may be extended in terms of delivered functionalities. Each new functionality does not affect its internal structure and the data flows.

- **Secure**: Since the SP manages a great amount of private data and behaviours (explicit or inferred) of the end-users and also the private data of the company, the platform is GDPR compliant. It is able to prevent not only malicious or accidental actions beyond the designated usage, but also disclosure or loss of information by utilising techniques such as automatic anomaly detection.

Within the Semantic Platform, information is acquired from multiple data streams, processed through variety of enhancer engines of Document Enrichment Engine, and within the architecture, it is stored in a **graph structure** (in **Semantic Storage**) to capture the semantics of the data - the objects and their semantic relations. The knowledge base holding this information represents the “semantic repository” collecting explicit and inferred knowledge about the user, the group, the company and the managed documentation and data.

The machine-understandable knowledge base enables the provisioning of the semantic services that are exploited by the Semantic Applications. Within the process of data acquisition and creation of the knowledge base, the Document Enrichment Engine (DEE) and the Semantic Enrichment and Linking Framework (SELF) are two of the fundamental steps forming the base function of the Semantic Platform. The **Knowledge Inference Engine** processes available data sources and it is inferring additional information using Machine Learning models to extend the graph data structure in the Metadata Storage.

The Semantic Platform and its subsystems

Document Enrichment Engine

Analysis of information collected from unstructured data, such as textual documents, images, webpages, or multimedia recordings, is usually a difficult task with a high computational load. Moreover, many low-level data processing steps are common to a variety of applications (e.g., text extraction, language detection, document categorisation, etc.) and also dependent on each other. The Document Enrichment Engine (DEE) is a software service that allows the creation of document processing pipelines. It takes as its input any unstructured document and enriches (annotates) it with relevant structured and semi-structured data from multiple connected information sources. The purpose of the annotation is to enable further processing of the document by higher-level Semantic Platform components.

Additionally, the platform provides clients applications with convenient programming interfaces (APIs) for common data understanding functionality.

The key concept in the Semantic Platform is the document (data), the unit that encapsulates the bulk of the information about the external world; it is the main input stream to the system. A document can represent any physical or virtual objects, such as digital documents, persons, activities, events, etc. Unstructured documents (textual documents, image and multimedia documents, data streams from sensors) are examples that have great importance for the system since they represent the biggest challenge: in these kinds of data, the information is hidden as a signal in many different ways. Unstructured documents do not have explicit semantics pre-assigned semantics, and therefore require complex processing to extract and interpret the valuable information that they represent.

The Document Enrichment Engine is the core architectural component of the Semantic Platform to interpret the document. The DEE is a flexible, extensible, and scalable framework that defines and executes the document processing pipelines. The pipelines, called enhancement chains, specify the elementary processors, or enhancers, and the dependencies between them, as the outputs of some engines become the inputs to the others. Such a design allows for the isolation of atomic processing functionality and the correct sequencing of their execution, whilst ensuring maintainability, flexibility in deployment, and scalability.

The Semantic Platform and its subsystems

At the core of DEE: implementation

Within the current development, the DEE is implemented in Java and our system uses Apache Camel[1] as a routing system. It integrates various other open source libraries for its specific processing capabilities, such as Apache Tika for plaintext extraction from office suite document formats, or Apache Open NLP for text processing. Notably, the system also leverages proprietary technology of Konica Minolta for processing of document formatting, as well as for advanced Optical Character Recognition (OCR) and vectorisation of rasterised (scanned) graphics[2] .

The output of the Document Enrichment Engine is a set of explicit and structured concepts that are stored as a graph structure in the Semantic Storage and its supporting storage (e.g., indexes), enabling further high-level processing, such as reasoning and retrieval.

[1] The Apache Software Foundation, http://camel.apache.org/

[2] Konica Minolta Laboratory USA, http://research.konicaminolta.us/

The Semantic Platform and its subsystems

Semantic Enrichment and Linking Framework

The Semantic Enrichment and Linking Framework (SELF) represents all the information about users and groups, as well as their digital and physical working environment and devices being used by the user or the space in which the user resides, that are to be leveraged by the Semantic Applications. SELF represents the user-centric view of the digital workplace where each delivered service is 'tuned' according to the inferred needs and the explicit or implicit preferences that have been identified from analysis of the user's behaviour and their use of the digital systems. Information about how the user manages documents (data), achieves assigned goals, organises their daily work and interacts with other colleagues and groups are all key elements to determining the context of the user. Considering the wider working environment, the Semantic Platform also builds connections with IoT sensors and other Cyber Physical Systems (CPS) to enable the digitisation of the workplace. The SP is connecting data and spaces to bring a holistic understanding of both the content and its context.

Within the Semantic Platform, the links between documents (data) managed by users and groups, and their working behaviours are identified, thus creating the users' context. The intelligence to achieve this is provided by semantic technologies that are able to map the users' context through the identification of the relationships between data (and metadata) and the users' actions; it is a layer of descriptive information connecting the way the users work, communicate and organise their personal digital environment.

The SELF contributes to the automatic tuning of the semantic services by sharing the inferred knowledge about the users' behaviours and needs. By defining a specific user context, the SELF enables the building of context-aware applications and services; it interprets the contextual information based on changes in the users' environments to provide particular services to the user.

At the core of SELF: Semantic Storage

To support the storage of the semantic relationships among the concepts of the SELF Knowledge Base, Blazegraph technology is currently used: Blazegraph is an ultra-scalable, high-performance graph database with support for RDF/SPARQL APIs and the Apache TinkerPop™ stack.
Written entirely in Java, the platform supports the SPARQL 1.1 family of specifications, including Query, Update, Basic Federated Query, and Service Description. Blazegraph supports novel extensions for durable named solution sets, efficient storage and querying of reified statement models, and scalable graph analytics.

Real life application: benefits and use cases

The main benefit of the Semantic Platform is its adaption of all of its functions to the needs of the user or group, whether it is a regular employee, a C-level executive, a department or even the whole organisation. Through the Semantic SELF, tailoring of the functions will continuously improve with use, over time as the system gathers more and more data and better understand the users' behaviours and interactions.
This level of personalisation and adaptiveness means that the Semantic Platform can help people and organisations to optimise:

1. **Content Management**: Processing structured and unstructured data in the company to enable intelligent search, discovery of duplicate information, similarities, or providing intelligent information summaries for particular employee.

2. **Task and time management**: Optimises how people and teams conduct tasks. It enables tasks to be discovered in any communication media, including email, chat, and meeting minutes, and aggregates them in one place. In addition, it allows for intelligent prioritisation of tasks based on importance and time criteria, that may be unseen to the specific individual.

3. **Decision making:** Augmented decision-making is enabled via providing tailored decision cues which differ amongst different users based on their personal characteristics, role, position, knowledge, skillset, or their business unit in the organisation.

4. **Collaboration**: Semantic platform enabled team collaboration connects people in the organisation based on similar projects, technology interests, roles, positions, or processes. It will make organisation structures, goals, projects and connections more transparent.

The Semantic Platform offers value through many different areas across an organisation, covering the following use cases.

Task Discovery

Exploiting NLP techniques, Task Discovery detects the assignment of a task to a person, by analysing the body text of an email or an instant message sent in a chat.

This can be further extended to detect missing information in the task assignment, for example the task's deadline or the related reporting person. In this extended scenario, in the case of the email application, this functionality is delivered as a plug-in of the email client that is invoked just before the email is sent. If the SP's service (termed as the Broken Task Notifier) detects a 'broken' task in the email body text (e.g., information is missing in the description of the task), this event is notified to the email client in order to suggest to the user how to modify the email's content to better describe the task.

Once a task is detected and its related information has been processed by the DEE component, its metadata (e.g., title, deadline, assignee, reporter, etc.) that is represented as elements in the graph structure are stored in the metadata storage system (i.e., the Knowledge Base). This 'update' event is notified to the Message Broker component to 'inform' all the subscribers (e.g., relevant third party applications) that need to perform specific actions. The Knowledge Inference Engine (KIE) can be directly invoked by the Semantic Storage or activated by the event notified by the new source data creation or delivery to the platform. This engine will perform 'reasoning' on the Knowledge Base in order to infer new axioms (i.e., to generate new knowledge). This is mainly possible thanks to the inference of new data form data sources and its linkage to existing graph data in the Metadata Storage.

Real life application: benefits and use cases

Semantic Search

The Semantic Platform supports the implementation of a semantic search engine that is capable of using the 'meaning' of analysed documents (e.g., invoice, contract, academic paper, picture, video, etc.) to improve the accuracy of user searches. A higher accuracy result is achieved by an improved understanding of the context defined by the user's query. Use of the Semantic Search Engine (seen as a plug-in within the SP architecture) ensures more relevant results from the ability to understand the definition of the word or the term that is being searched for. This use case considers two separated phases: knowledge extraction and knowledge retrieval.

In the knowledge extraction phase a document item (e.g., an email, an audio file, etc.) is acquired from a document source through the Data Ingestion Layer or the related Data Source plug-in (DS Plug-in). It is then processed by the DEE component through use of a specific elaboration chain. The output is a graph of enriched metadata that is semantically interconnected by means of semantic relationships that are stored in the Knowledge Base (metadata storage).

In the knowledge retrieval phase the user submits a query through a dashboard application and then the search engine will identify the intended context defined through the query's terms. The semantic search engine retrieves all the relevant and semantically related results (e.g., documents) even if these items do not contain terms that are explicitly specified in the query. During the information retrieval process a graph traversal algorithm is used to 'visit' the nodes (vertices) and links (edges).

Knowledge Discovery

Knowledge discovery describes a set of features that give the user the possibility to increase their understanding of:

- the current status of their work;
- completed and in-progress activities in projects and categorise these activities according to the inferred scope or to related topics;
- documents potentially relevant for the project activities or matching some criteria that is automatically defined/inferred through the understanding of the user's interests, fields of expertise, user's role(s), social relationships, etc.;
- the identities of the people (colleagues or external collaborators) or companies that could be involved in a project or in a specific user's activity connected with achieving the desired result;
- actions that are needed to accomplish a specific activity (explicitly stated by the user or inferred by the system through its semantic reasoning) and the related resources that they require.

The system's applications push suggestions to the user on the basis of the knowledge currently stored in the platform; a feedback mechanism is delivered to the user (User Feedback Module as part of the SP Core) to update the Knowledge Base with the user-provisioned inputs. This information is used by the inference engine when new facts are identified and then determines if these facts should, or should not, be added into the Knowledge Base. Of course, the inference engine, through the user's explicit feedback, can also remove existing facts from the Knowledge Base.
The dashboard application, or third party applications, discover relevant information that is to be provided to the user: each of them communicates with the User Feedback Module when a new user's feedback has to be stored, and information about user-provided feedback has to be used by a specific application logic. For example, to adjust the ranking or order of the suggestions, or filter out some suggestions about the proposed inferred data.

Partnership opportunities

We are building the Semantic Platform as an open platform for partner's solutions and applications where partnership opportunities are available within two domains:

- Partnerships in intelligent application development
- Partnerships in core platform technological components

Partnerships in intelligent application development are targeted for providers of third party application solutions. Utilising the platform's potential and the wide group of more than two million customers of Konica Minolta and a rich set of APIs providing inferred insights into digital workplace actors, our partners can use their skills to deliver specific solutions for customers from a variety of business verticals and with varied needs. Within this partnership model Konica Minolta will provide a variety of Software as a Service (SaaS) share business models. Through the concept of the Konica Minolta Marketplace, an application store available from the first version of Workplace Hub[3] platform and also utilised in the Cognitive Hub platform, we will establish multiple levels of support, access to APIs and advanced features, development tools and even application-marketing support.

Partnerships in core platform technological components are focused on the development and enhancement of the platform capabilities itself. In this area, we welcome cooperation, as well as academic and open source community contributions, in terms of algorithms, specific Document Enrichment Engine modules, Machine Learning models and expertise in areas of NLP, Ontology Engineering and Machine Learning. This business model is open for cooperation ranging from subcontracting, components licensing, joint R&D projects (under the umbrella of a flexible framework) or open source project participation. This area is full of opportunities for your contribution and ideas.

[3] Workplace Hub, http://workplacehub.konicaminolta.com/

Talk to us

We look forward to discuss with you and work with you on making the Semantic Platform of the Konica Minolta Cognitive Hub, a comprehensive Digital Workplace Platform.

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