

Browse the Book

These chapters discuss two of the core technologies of SAP Leonardo: big data and machine learning. Each chapter provides a general overview of the technology before diving into the specific solutions SAP provides in these areas.



"Big Data"



"Machine Learning"



Table of Contents



Index

The Authors

Pierre Erasmus, Vivek Vinayak Rao, Amit Sinha, Ganesh Wadawadigi

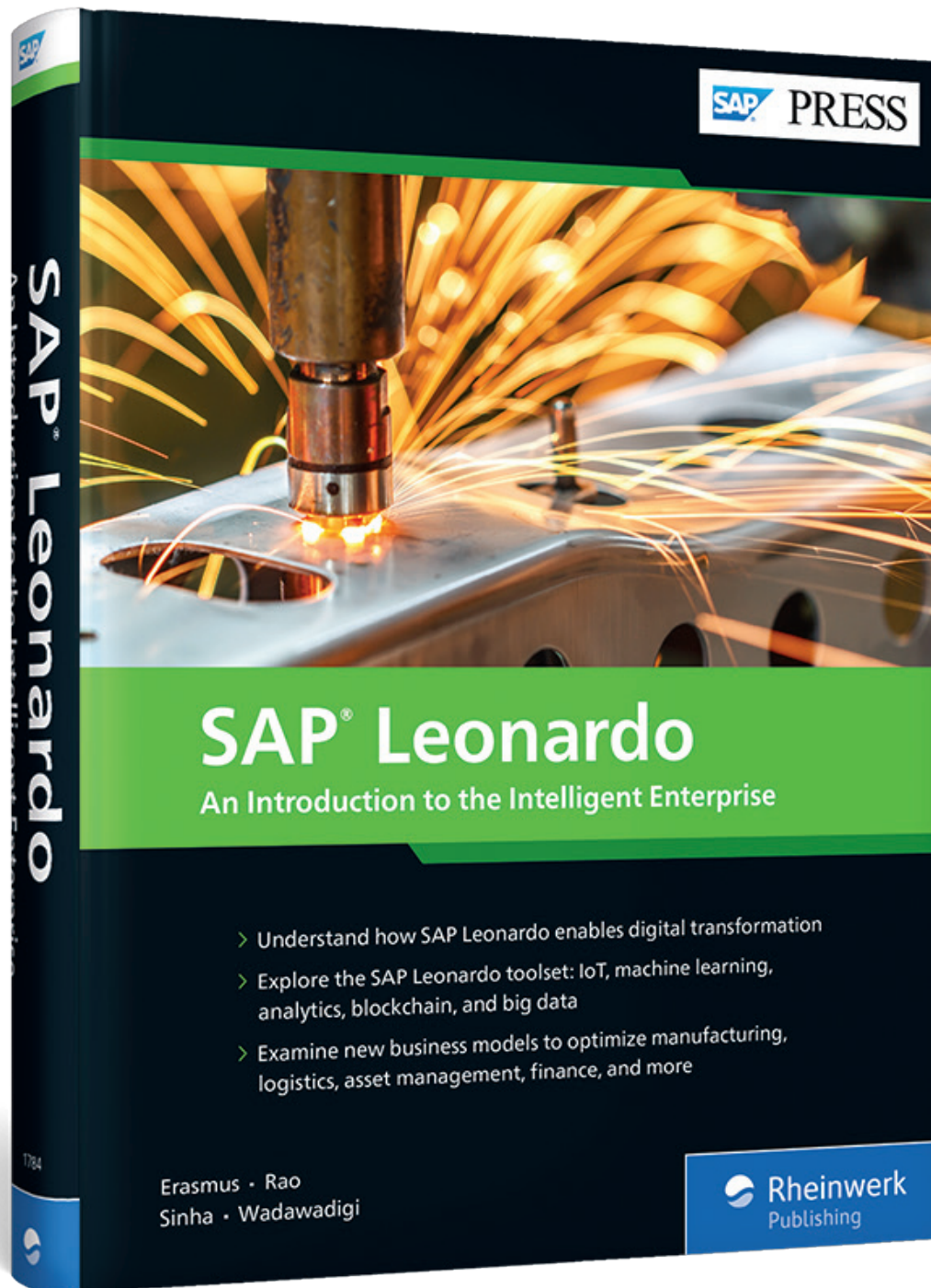
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Chapter 3

Big Data

Data is the currency of today's digital enterprise. Essential to your digital transformation journey is the ability to move, transform, integrate, and improve data quality—any type of data, from any source, at any frequency. You need an enterprise-ready, distributed computing solution to help uncover actionable insights from big data.

Big data is identified with the characteristics of 3Vs: volume, velocity, and variety. Volume refers to the large scale of data, running into multiple terabytes and petabytes; velocity refers to the speed at which the data is generated especially streaming data from sources like Internet of Things (IoT) sensors; and variety refers to the different types of data: structured, unstructured, and semi-structured. Companies now collect data along all these dimensions. Unlike in the past, when most of the data was largely transactional in nature, using a relational database paradigm to store, process, and consume data can't keep up with today's reality of big data.

Your IT strategy must keep up with the latest technological advances to reduce and bridge data silos, manage cloud as well as hybrid deployment strategies, leverage new data architectures like “data lakes” of unstructured data, and handle new types of data such as spatial and streaming IoT data.

In this chapter, we'll first introduce you to big data in general, looking at what big data is and why you need it. Then, we'll introduce the tools and products SAP offers to support this technology, while describing some industry-specific and line of business (LOB) use cases supported by these tools and products.

3.1 What Is Big Data?

Data has become central to any business, especially with the advent of big data from the influx of new sources like streaming data, social media data, and other types of unstructured data. While you may still rely on transactional databases that underpin

your core business processes, new sources of data play an increasingly important role in your business in an unprecedented way. A universal data fabric is an architectural approach and set of data services to provide consistent capabilities and services that spans on-premise and multi-cloud environments and helps simplify the management of data integration and enable digital transformation for your organization. This universal data fabric answers questions that arise in the process, such as the following:

- Should I have different specialty databases for different types of data?
- Should each database operate in its own environment?
- How do I eliminate lag times arising from integrating these different environments?

Such an architecture also addresses the following requirements:

- **Performance**
An infrastructure that delivers data at the speed your users and processes require and your business demands.
- **Freedom**
As data is generated by your users, systems (both in the cloud and on-premise) and a variety of third parties, you need the data to flow unconstrained and seamlessly.
- **Data models**
You'll need to model the data to your specific business goals. With big data, data discovery is critical for finding relationships and unearthing hidden insights.
- **Independence**
You'll need to be able to scale; your computing power should not limit your data, and your data should not limit your computing power.
- **Low latency**
Though data is being generated at an unprecedented rate, to keep up with the needs of your business, this data needs to be available for incorporation into transactions, automated processes, and analytics as soon as the data is created.
- **Governance**
While ensuring data availability and usability needs, data integrity and security cannot be compromised.
- **Frictionless**
Ensure seamless interoperability to combine structured data and new data sources as data is created without exposing the underlying complexity of the various data types.

In addition, a typical company's data management landscape will have evolved over the years to address the following individual business needs:

- **Enterprise data warehouses**
Generally a single data warehouse to support the entire enterprise; this need arises from the requirement to connect processes across transactional applications and subsequently integrate the transactional processes with enterprise business intelligence.
- **Data marts**
Allows you to draw data from multiple sources to optimize and support a business application or business needs. A data mart is often optimized to function operationally to answer business questions that need to be answered right away to take action.
- **Data lakes**
Generally on a big data platform like Hadoop or Spark with the intent to store and mine all IoT data streaming from sensors across numerous locations, both within and outside your company, in its raw form. The data is then transferred from the data lake to a data warehouse or a data mart to organize and refine it, so it can be used for decision-making at all levels of an organization.

The SAP HANA Data Management Suite addresses these needs by enabling you to collect and combine all types of data, in real time, on a single platform. The SAP HANA Data Management Suite allows you to reduce data sprawl, analyze data in an instant, and solve previously unsolvable business problems, greatly simplifying your transition to an intelligent enterprise. As shown in Figure 3.1, the SAP HANA Data Management Suite enables secure, governed, enterprise-class applications and analytics by providing an open, hybrid, and multicloud-enabled solution suite that can orchestrate all your data in a trusted, unified landscape.

The SAP HANA Data Management Suite enables you to manage your data end-to-end, from capturing the data; to ingesting and processing the data; and, finally, to orchestrating, computing, and consuming the data. In the process, SAP HANA Data Management Suite can act as your decision factory by taking raw data, cleaning, and bringing it into a trusted format that can be used by applications, analytics, machine learning or a range of other uses. It acts as a development platform for your applications that need analytics on real-time transactions; for data governance, anonymization, and pipeline flow to protect and refine data across the landscape; for modeling across lines of business; for handling different data types and technology architectures; and for providing in-memory, multimodel analytics and data processing on a distributed computing framework.

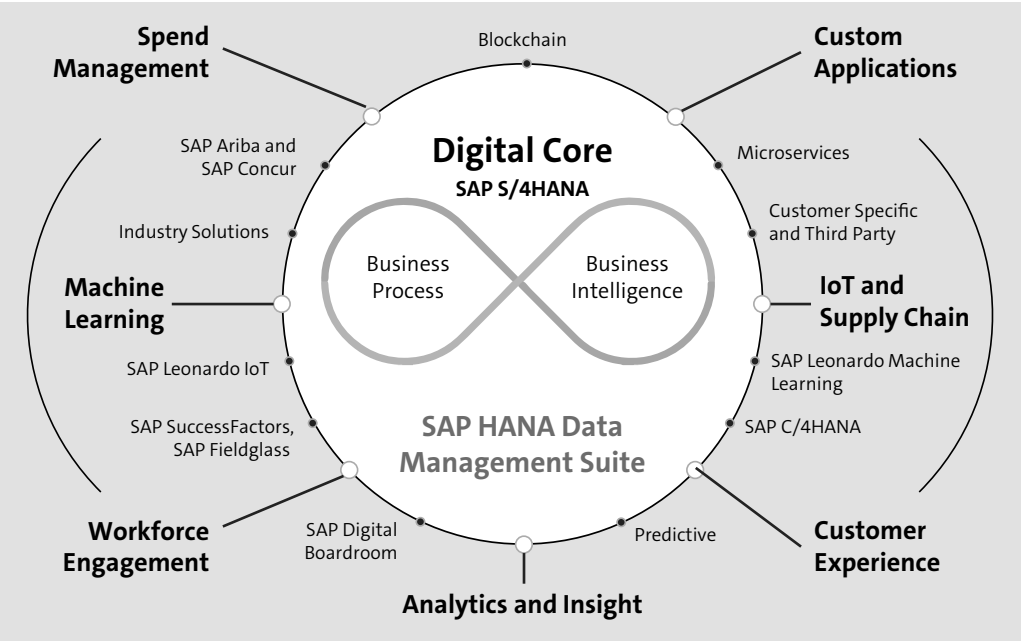


Figure 3.1 SAP HANA Data Management Suite for Intelligent Enterprises

As shown in Figure 3.2, SAP HANA, SAP Data Hub, and SAP Cloud Platform Big Data Services are key tools in the SAP HANA Data Management Suite for addressing big data needs, which we’ll cover in the following sections.

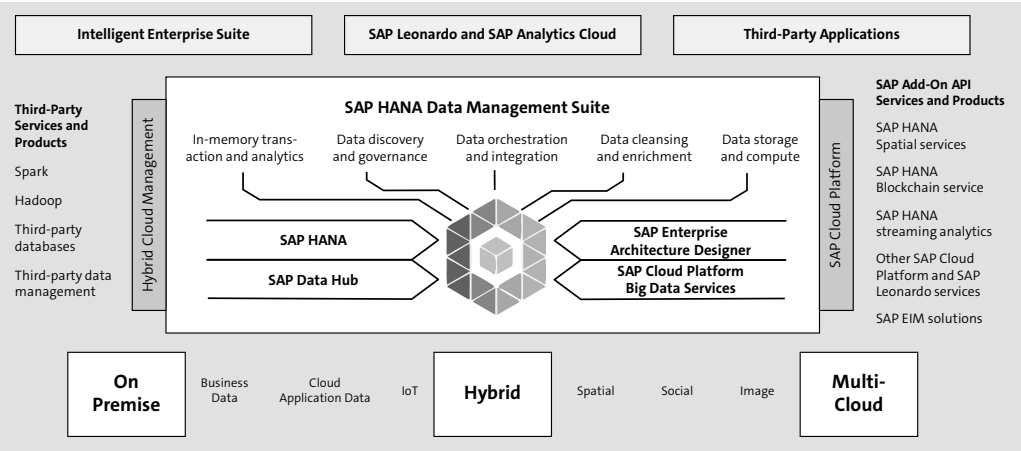


Figure 3.2 SAP HANA Data Management Suite

3.2 Universal Data Management Platform

SAP HANA, shown in Figure 3.3, provides you with a data processing architecture purposely designed to address today’s data explosion so you can easily take advantage of new technology breakthroughs. You can run real-time analytics on live transactions without data replication by virtually or physically connecting to all data from any source. In fact, SAP HANA goes a step further and provides next-generation hybrid transactional/analytical processing (HTAP), with its unique ability not only to process operational analytics on structured data, such as business transactions, but also to apply advanced analytics processing, such as predictive machine learning or natural language processing on structured and unstructured data, for example, graph data, spatial data, text, document store, searches, and live data streams.

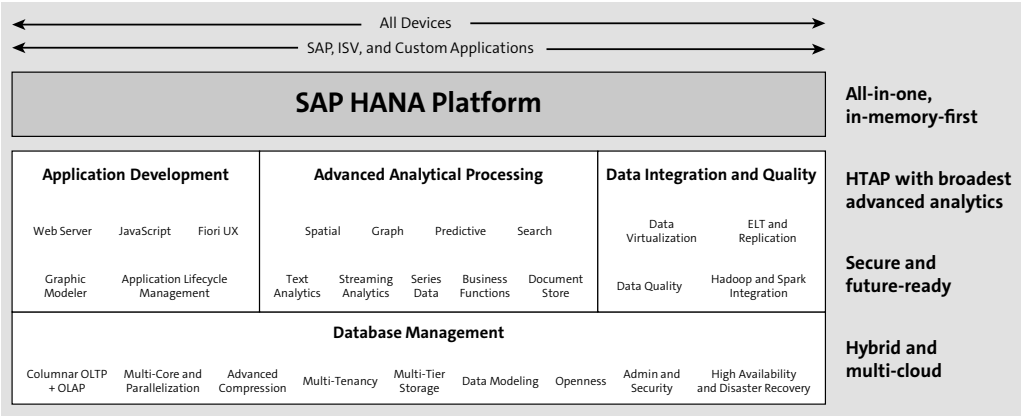


Figure 3.3 SAP HANA as a Business Data Platform for All Applications

SAP HANA also has built-in predictive libraries (SAP Leonardo Machine Learning Foundation) and integration to major machine learning frameworks such R, Tensor-Flow, etc. SAP HANA provides fast machine learning training, validation, and scoring as well as an automated framework to embed machine learning models into applications allowing developers and data scientists to move away from batch machine learning to real-time machine learning.

With built-in advanced analytics and multimodel processing, your application development architectures and IT landscapes will be radically simplified with SAP HANA. Logical data modeling eliminates the need for data stores and data marts, and you won’t have to create separate data subsets and special purpose data repositories anymore. Instead, you can create virtual tables on the fly by pulling data from wherever it resides, and you can change virtual tables in response to changing business or

technical requirements. As you develop applications, whether on-premise or in the cloud, openness is essential for fast innovation. SAP HANA supports both open and industry standards such as network protocols (OData); containerization (Cloud Foundry, Docket); security (SAML, LDAP, Kerberos); machine learning (TensorFlow, R); app servers (J2EE, Hibernate); and programming languages (Java, Node.js, Python), to name a few. Such capabilities help you achieve faster time to value and achieve immediate business results by allowing you to act on live intelligence from all your data.

SAP HANA’s columnar, in-memory storage provides you the ability to achieve massive compression and computing performance. You’ll get real-time performance metrics for analytics and transactions without complex tuning while avoiding data latency. You won’t need to create and maintain indexes and aggregates anymore, as you would in relational databases, to fine-tune query and report generation response times. As a result, the time and effort needed to prepare the data for analysis will be greatly reduced, all while flexibility is enhanced for analysis.

SAP HANA offers advanced data security, including a privacy protection framework that supports data masking, encryption, anonymization, and authorization. Given compliance requirements like General Data Protection Regulation (GDPR) and the increasing threat of data breaches, anonymization is becoming increasingly necessary. SAP HANA provides sophisticated algorithms to anonymize data on the fly without altering the original data to ensure specific data points cannot be traced back to specific people. If you plan to share data from your SAP S/4HANA system with new applications you build on SAP HANA, you can automatically take advantage of SAP S/4HANA’s authorization settings as already implemented, thus saving you time and effort. These features are key for preserving your customers’ trust and for monetizing your data assets.

Finally, SAP HANA allows you to choose your own cloud provider, since SAP HANA is designed to run on major cloud platforms in addition to on-premise.

3.3 Big Data Operations Management

With a deluge of data, as shown in Figure 3.4, data often ends up in silos across the enterprise, resulting in distributed landscapes and manual, siloed data operations. Meeting the data access needs of the various LOBs can be a challenge. Lack of data transparency due to difficulties in managing and orchestrating data across distributed data landscapes and the risk and burden of enforcing compliance across a multitude of corporate and regulatory data policies can make innovating with big data a daunting task.

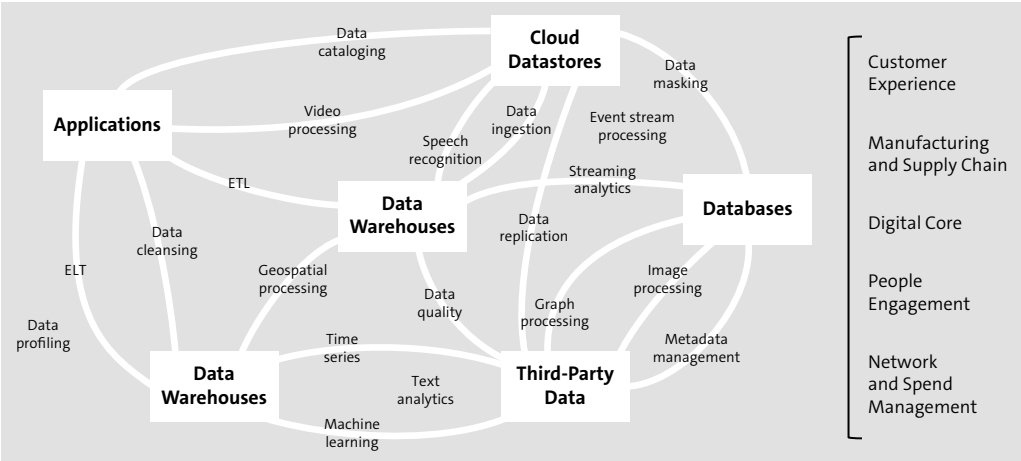


Figure 3.4 Data Deluge Makes Delivering Actionable Information Challenging

A streamlined approach to big data operations is needed to bridge the gap between disparate data sources and the consumption of this data by business processes in your digital core as well as all LOBs. As shown in Figure 3.5, regardless of where the data resides or where it originated, you’ll need the ability to centrally orchestrate data and automate the end-to-end process of data discovery, refinement, enrichment, and governance so that you can deliver reliable and trusted data to different users and parts of your organization.

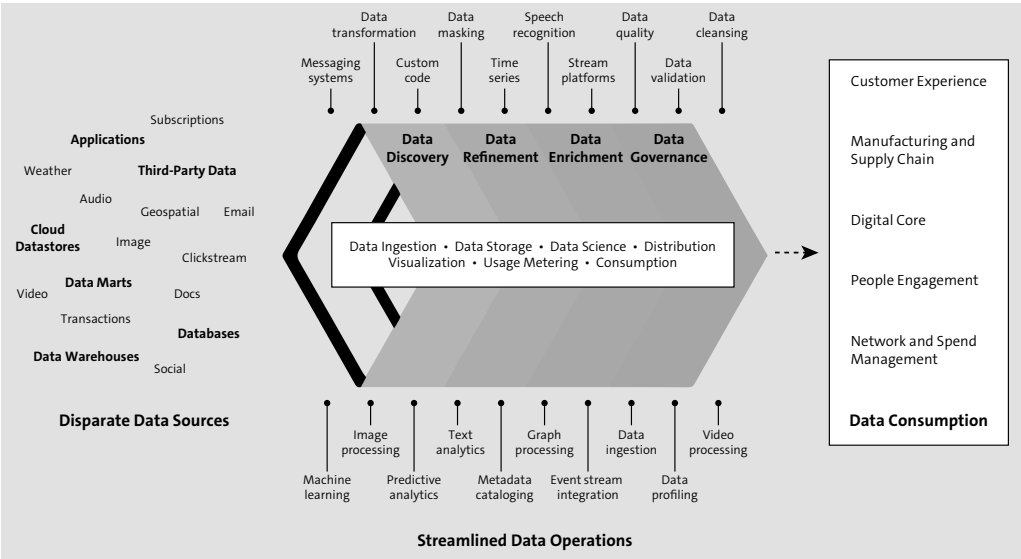


Figure 3.5 Streamlining Data Operations

SAP Data Hub, shown in Figure 3.6, is a multifaceted data operations solution designed to manage the ever-increasing distributed data landscape resulting from big data. SAP Data Hub helps you flexibly scale to orchestrate and automate the flow and refinement process of big data (structured, unstructured, streaming, bulk transfers, etc.), all in a single environment.

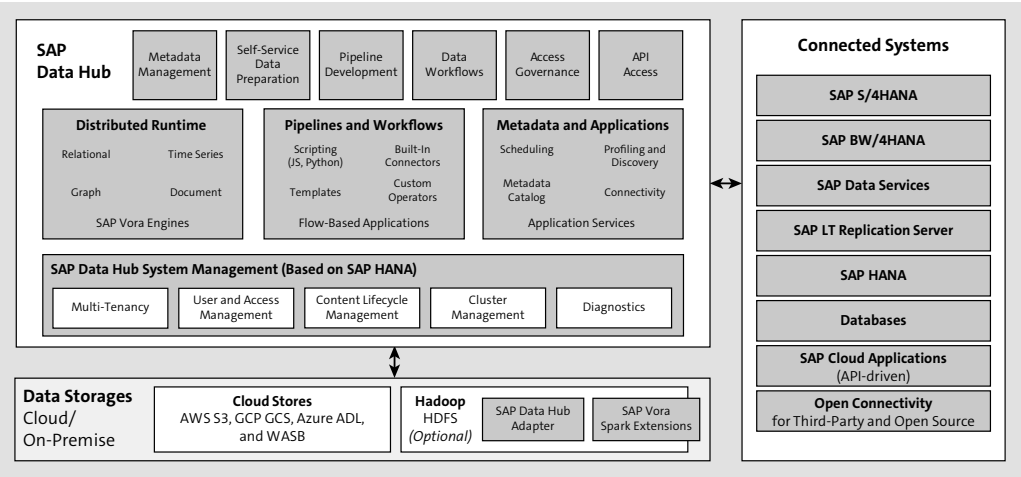


Figure 3.6 SAP Data Hub

To deliver intelligent data with the right context at the right time to the various users in your organization like IT administrators, data administrators, data stewards, data scientists, and business analysts, SAP Data Hub provides the following three building blocks, as shown in Figure 3.7:

■ Data landscape management

SAP Data Hub provides open and flexible end-to-end data landscape management. With a full view of your data landscape, you'll be able to orchestrate all data movements and understand their impact on data models. Data could reside on-premise, in the cloud, in various applications, in data warehouses, in data lakes, and in both SAP or non-SAP sources. Your data won't need to be physically centralized; instead, the orchestration of the data is centralized. You can leverage existing connections and integration tools as well as add new connections easily and flexibly. You can manage security settings for data access and enforce data policies to ensure appropriate data governance and security. A comprehensive view of systems and assets across the entire landscape helps you monitor your data.

■ Data pipelining

You can create, automate, and reuse powerful data pipelines to cleanse, conform, transform, ingest, refine, orchestrate, prepare, and enrich information from a variety of sources across your organization, all while leaving the data where it resides. You can define data operations processes by reusing existing code and libraries consisting of several predefined and customizable operations. You can understand the impact of quality problems on all downstream systems and applications to drive efficient and speedy innovations through the consumption of big data.

■ Data governance

Given the characteristics of the 3Vs of big data, delivering the right data to the right users with the right context at the right time is vitally important. Data profiling helps you analyze data to clarify its structure, uncover its relationships, determine deviation rules, and understand anomalies. Data profiling helps in data discovery so you can evolve data models more quickly. Metadata cataloging helps define, govern, and manage your metadata assets across enterprise systems with disparate sources.

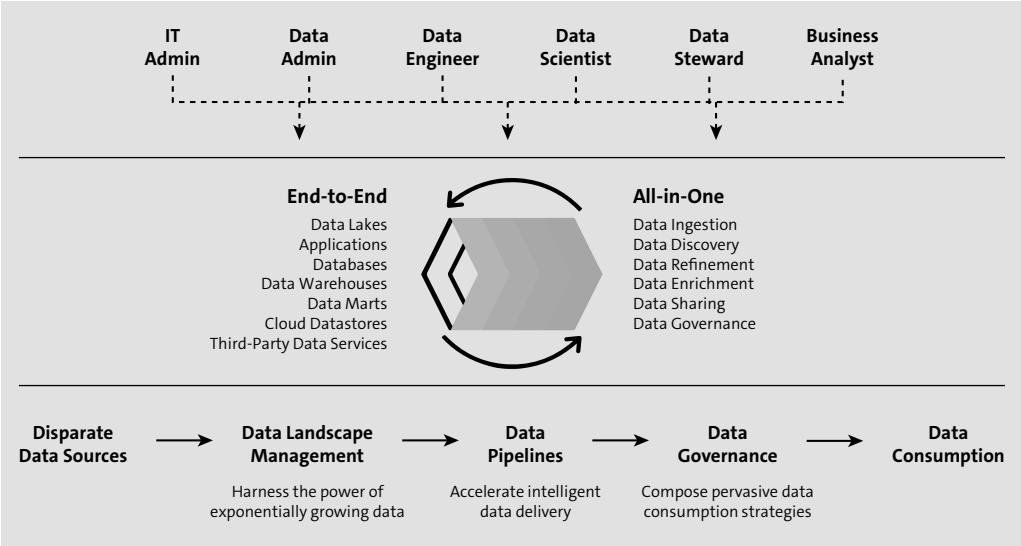


Figure 3.7 SAP Data Hub for Intelligent Data

SAP Data Hub has a cloud-native architecture and is designed to run in any environment—on-premise, cloud, or hybrid. SAP Data Hub can be installed on Kubernetes clusters provided by Google (Google Kubernetes Engine), on Microsoft Azure (Azure

Container Service), and Amazon Web Services (AWS). Apache Hadoop and embedded Apache Spark are optional components.

SAP Data Hub supports numerous data sources, for example, SAP HANA, SAP Vora, SAP Business Warehouse (SAP BW), Hadoop Distributed File System (HDFS), native cloud storage like Amazon S3, Google Cloud Platform, Google Cloud Storage, Microsoft Azure, ADL, and WASB. SAP Data Hub also supports several messaging systems like Kafka, Message Queuing Telemetry Transport (MQTT), NATS, and WAMP. Additional data sources can be connected via SAP Data Services.

With these capabilities, SAP Data Hub can help create value from your various big data initiatives at scale by supporting agile, data-driven applications and processes, for example:

- **Data science and machine learning data management**

The use of machine learning on big data has vast applications across all industries, for instance, risk profiling in insurance, credit analysis and generating automated scoring models, predicting failures for automated preventive maintenance of assets, and fraud detection, to name a few. Typically, these applications start as data science projects where data scientists spend considerable time collecting, cleansing, and organizing data from various sources (structured, unstructured, streaming, etc.).

SAP Data Hub can help you move from the prototype stage to production by identifying and refining all relevant data in a reliable and cost-efficient way. SAP Data Hub provides you with a single solution to process machine learning and advanced analytics algorithms using both SAP engines (SAP HANA Predictive Analysis Library, SAP Leonardo Machine Learning Foundation) as well as non-SAP engines (Python, R, SparkML, TensorFlow, etc.) to quickly operationalize machine learning outcomes back into enterprise processes to democratize their usage beyond your data science team. In addition, SAP Data Hub provides extensive data wrangling capabilities out of the box so that your data science team can spend less time collecting and cleansing the data and more time analyzing the data to create algorithms that help you rapidly innovate.

- **IoT data ingestion and orchestration**

IoT-enabled devices provide you with real-world performance information that you can use to optimize your supply chain and logistics applications. You can perform on-the-fly, context-aware rerouting and replanning to adjust to changing business conditions, by using the concept of a digital twin to test outcomes and impacts of potential actions. As a result, you could provide better customer

service, create new revenue-generating business models, and/or initiate smart manufacturing by establishing predictive maintenance for your shop floor assets, etc. The challenge you'll need to overcome is integrating and analyzing vast amounts of raw data streams and events from disparate sources with low-level semantics and little or no business context. You must integrate IoT data with enterprise data stored in data warehouses, data marts, enterprise applications, etc. and be able to handle high volumes of data and complex computations. SAP Data Hub helps you meet the challenges of point-to-point integration and allows you to process disparate data from messaging systems, high-volume cloud storage, and enterprise applications with event-based pipelines and can execute thousands of pipelines in parallel at any time across highly distributed landscapes.

- **Intelligent data warehousing**

As your business grows, you'll need to rapidly integrate and leverage new data sources with your existing traditional data warehouses, data marts, big data stores, and enterprise applications. Such situations can arise when you acquire or merge with companies or start big data projects like Hadoop. SAP Data Hub's capabilities can help you with these goals.

- **Governance and data cataloging**

SAP Data Hub's centralized metadata catalog helps you effectively secure and govern an ever-increasing number of disparate data sources. This solution can crawl through your connected sources automatically to discover entities and their relationships. All the valuable metadata can be gathered and stored in a centralized information catalog so that you can search common data definitions and business rules in a seamless fashion regardless of how diverse and distributed your data source landscape is. The profiling capability helps you gain a deeper understanding of the source data so you can create meaningful pipelines.

- **SAP HANA cold data tiering**

SAP Data Hub reduces total storage cost by optimizing integration from SAP HANA into various object storages like HDFS, Amazon S3, ADL/WASB, GSC, etc. You'll be able to offload older, less frequently accessed data to a much lower-cost storage options while still making this data accessible and usable whenever needed.

3.4 Big Data Services

Companies tend to start experimenting with leveraging big data by dipping their toes into Hadoop pilot projects. Soon, they realize the enormous benefits of big data,

and these one-off pilots become larger-scale projects with large Hadoop and Spark big data clusters with multiple compute and storage nodes.

Since Hadoop runs in a distributed manner on multiple nodes, a host of complexities in this process often arise, including hundreds of Hadoop and Spark parameters to configure, troubleshoot, maintain, and upgrade; cluster parameters to fine-tune; and queries to modify to boost performance, among other things. In an on-premise approach, you'll need to consider the cost and lead time required to procure hardware; the effort required to manage the data center daily; the need to keep up with hardware and software installations and upgrades; the need to hire and train staff; and the burden of dealing with evolving computing and storage needs (e.g. data aging, training machine learning models, etc.).

Cloud-based big data platforms help you overcome all these challenges. These platforms help you future-proof your investment in a scalable data platform, allowing you to start small and grow your storage and computing resources over time by leveraging elastic computing and storage capabilities. You can easily onboard new big data sources like IoT, social media, mobile, etc. and quickly transition your proofs of concepts (POCs) to proofs of value at production scale. Last, but not the least, flexible, consumption-based pricing models allow you to efficiently allocate your capital.

SAP Cloud Platform Big Data Services, shown in Figure 3.8, provides all these benefits in a one-stop solution that includes hardware, software, data center operations, and support as well as integration with your SAP landscape. As a result, you can focus your efforts on building big data-driven applications to achieve the desired business outcomes and to reap the benefits of mining big data at petabyte scale.

SAP Cloud Platform Big Data Services run on infrastructure in data centers optimized for big data. These servers provide the right balance of computing power, memory, and disk storage for Hadoop and Spark workloads. The network provides bisectional bandwidth to support high volumes of interserver traffic while lightweight containers avoid the performance penalty common in virtual machines. SAP provides 24/7 operational support to keep your clusters healthy and running. The management tools found in the Unified Control Panel can provision your clusters, grow/shrink them as needed, and monitor them on an ongoing basis.

At the core of SAP Cloud Platform Big Data Services is Apache Hadoop and Spark, which can serve as a platform for you to build applications and run big data workloads. You can run your choice of big data tools on Hadoop like analytics, data exploration, custom applications, etc. Finally, the workbench is a server that acts as an edge or gateway node to access the cluster. SAP provides tools for data transfer

from common data stores like local file systems or Amazon S3. A web-based portal can serve as a central access point for your administrators to manage users and view cluster usage.

Security is an integral part of the SAP Cloud Platform Big Data Services, which is SOC 2 Type II and HIPAA compliant. SAP enables Kerberos on the environment for distributed network authentication if needed.

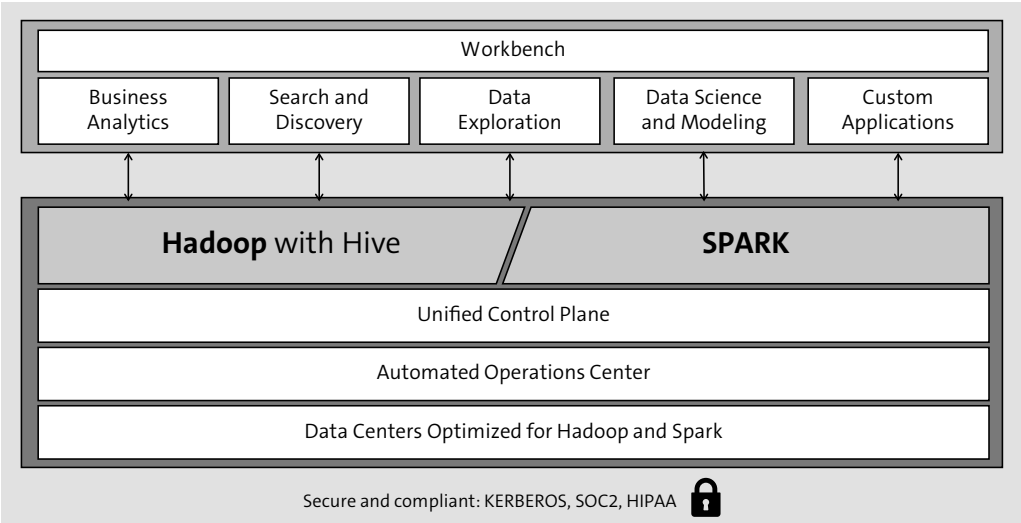


Figure 3.8 SAP Cloud Platform Data Services

With SAP Cloud Platform Big Data Services, you'll have access to fully managed and optimized big data operations for storing and processing structured and unstructured data, for training and scoring machine learning models, for running analytics, and for building IoT use cases, thus allowing you to minimize development and maintenance effort even while engaging in rapid innovation cycles.

3.5 Summary

Regardless of your industry, big data is a treasure trove of information, not only so you can intimately understand your customers' needs and behaviors, but also so you can innovate new business models and outflank your competition. As you embark on your big data journey, you'll need a sound technology strategy for storing, processing, and scaling your operations with big data as well as for helping your business

users leverage big data to make well-informed decisions in real time. Both hardware and software considerations as well as integration tools for your enterprise data and analytics will need to be considered, as will data privacy and security, which are of utmost importance. Taking a cloud approach has numerous advantages, both from a cost perspective and from a scalability perspective, since big data has the power to radically transform your business.

Chapter 5

Machine Learning

Machine learning is a component of artificial intelligence (AI) that provides systems the ability to automatically and continuously learn to improve business understanding with the purpose of driving better outcomes.

Machine learning enables computers to complete operational tasks by learning from large sets of operational data, outcomes, or historical data rather than just being explicitly programmed to perform repeatable tasks. Machine learning often uses a library of complex algorithms to learn from large sets of big data derived from multiple sources. The general rule is that the more comprehensive the data available (for example, larger sets of historical data dating back further in time, more seasons), the more intelligent algorithms become (with better results and more accurate anomaly detection).

This chapter begins by introducing machine learning in general, explaining what the technology is and how it works. We'll then focus on the use of machine learning in the context of enterprise applications. Next, we'll look at SAP Leonardo Machine Learning Foundation, before moving on to the application of machine learning within existing SAP tools and products. In this section, we won't go into depth about each product in which machine learning can be embedded but rather, we'll elaborate on how machine learning can enrich these solutions. Finally, we'll end the chapter with a look at a brand-new offering from SAP: SAP Intelligent Robotic Process Automation.

5.1 What Is Machine Learning?

Data scientists use machine learning to explore, discover, and train algorithms to detect patterns in big data. The goal is to use machine learning to derive new insights and deliver new outcomes, through two categories of algorithms: supervised learning algorithms and unsupervised learning algorithms.

Supervised machine learning is often the starting point for beginners and more commonly used when the context, processes, or outcome are more descriptive or better known by humans. Examples of algorithms used by supervised learning are linear and logistic regression, multiclass classification, and support vector machines. In supervised machine learning, a data scientist takes the lead to decide the inputs and desired outputs to program the algorithm with an end design and expected descriptive result in mind. Therefore, with supervised learning, the algorithm's outputs are already known and require that the input data used to train the algorithm is already labeled. In this case, supervised learning can improve existing processes in terms of performance or efficiency with a focus on automation.

Unsupervised machine learning is closer to what we define as artificial intelligence and emphasizes the exploration of data through continuous learning. In this case, algorithms learn to identify anomalies and patterns in data without human intervention and train themselves through continuous data exploration. Today, we've only just started exploring the possibilities with unsupervised learning, which is often used for simpler use cases. However, this area shows much promise, and unsupervised machine learning may lend itself to solving much more complex problems that humans normally lack the capacity to solve.

In unsupervised learning, new data inputs are identified and relabeled with new categories. For example, IoT sensor data like friction, vibration, and temperature could all be identified as triggers/symptoms related to malfunctioning or incorrectly installed spare parts in machinery. Often, the inputs and outputs are unexpected and have changed over time as the algorithm learns or accesses more relevant inputs and delivers more valuable results. The outcome of unsupervised learning can result in creating new business processes and/or inspire a process change. In reality, a combination of both supervised and unsupervised learning is used for executing machine learning principles.

At a broad level, the output of a machine learning algorithm is based on the algorithm used with the training data. Typical modeling categories include the following:

■ **Regression**

Regression analysis is based on statistical modeling and is used for causal inferences. Regressions are performed through the usage of independent and dependent variables. Regression analysis determines the correlation between the outcomes by predicting the dependent variable based on the value of independent variables. For training data, values for both variables are provided. The model fits

a regression line, which can be used to predict the value on the test data. Figure 5.1 shows an example of a regression analysis where a regression line is fit for the dependent variable of sales revenue based on the independent variable values of the sales promotion budget and the new product research budget. This regression line can be used to predict future sales revenue based on the sales promotion and product research budget. SAP Leonardo Machine Learning Foundation and solutions like demand sensing include various sophisticated regression models for predictive analytics.

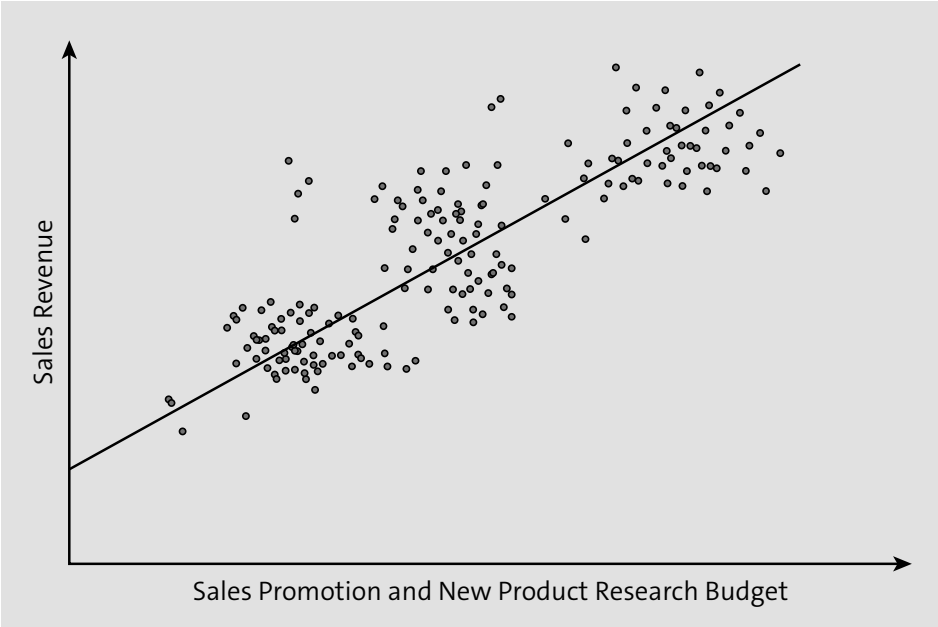


Figure 5.1 Machine Learning Regression Example

■ **Classification**

The goal of a classification model is categorizing an object into a group of predefined categories based on its attributes. Thousands of fraudulent credit card transactions are now checked through machine learning classification models, where, based on attributes of the transaction, fraudulent transactions are flagged from thousands of transactions in real time. Another example, shown in Figure 5.2, is based on image recognition to identify a product. In this example, the asset maintenance team takes a picture of a worn-out part and feeds the image into the SAP Leonardo system.

Using the classification algorithm, machine learning can identify the critical part and monitors its current inventory in the plant from among thousands of the other parts. Then, through the integrated enterprise system, machine learning can offer the option to order additional quantities from inventory at the warehouse or to create a purchase order to procure from a supplier so that no production stoppages occur due to the part not being available in a timely manner. This example demonstrates the huge transformative potential of machine learning in inventory management for maintenance parts and the associated process efficiency gains.

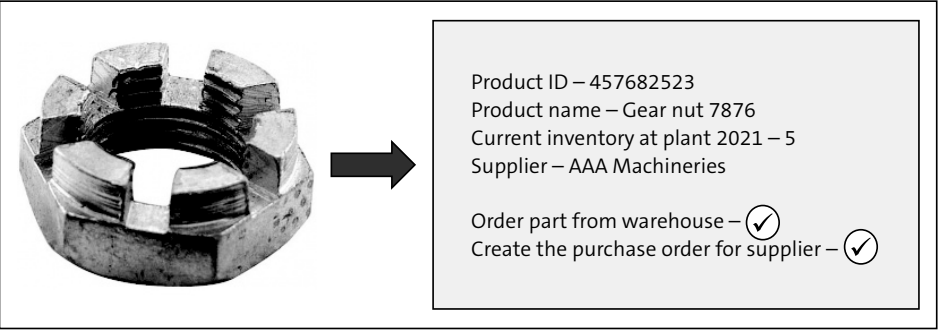


Figure 5.2 Machine Learning Classification Example

■ Clustering

Clustering is an example of unsupervised learning aimed at grouping a population into meaningful clusters relevant for business actions and decision-making. The expectation is that members of the same cluster or group will share more similarities than members of the other clusters. The number of clusters for a population size can be either provided to the algorithm or can be calculated by the machine learning cluster modeling algorithm. Figure 5.3 shows the example of a cluster algorithm output by SAP Leonardo in which for an online retail company, customers are grouped based on their yearly income and the yearly purchase amount. As shown in Figure 5.3, customers can be grouped into three separate identifiable clusters; these clusters can be used for targeted sales promotion programs, focused advertising, or creating upsell opportunities. Such intelligence enhances the effectiveness of sales and marketing budgets, creates revenue, generates opportunities, lowers the revenue-to-cost ratio for each customer, and generates long-term customer loyalty.



Figure 5.3 Machine Learning Cluster Example

Two types of machine learning approaches exist, as follows:

■ Embedded machine learning

This approach is appropriate for simple cases like trending or forecasting or for algorithms with low CPU/RAM/data demands. Data located in S/4HANA is sufficient for model training—no need for massive amounts of external data for training. The required algorithms are provided by SAP HANA (e.g. the Predictive Analysis Library, the Automated Predictive Library (APL), text analysis) and handled by the SAP Predictive Analytics integrator in terms of machine learning model lifecycle management.

■ Side-by-side machine learning

This approach is appropriate for deep learning cases like image or language processing or neural networks with high CPU/RAM/data demands. The machine learning logic resides in the SAP Cloud Platform while the business logic can be based on SAP S/4HANA or SAP Cloud Platform. Huge volumes of external data are required for model training, with a focus on processing unstructured data.

Figure 5.4 shows the architecture involved in machine learning; on the center left, you'll see an example of embedded machine learning used within SAP S/4HANA or applications whereby machine learning runs side-by-side, such as the case in the upper right corner where SAP S/4HANA machine learning applications use SAP Leonardo Machine Learning Foundation's business and technical services.

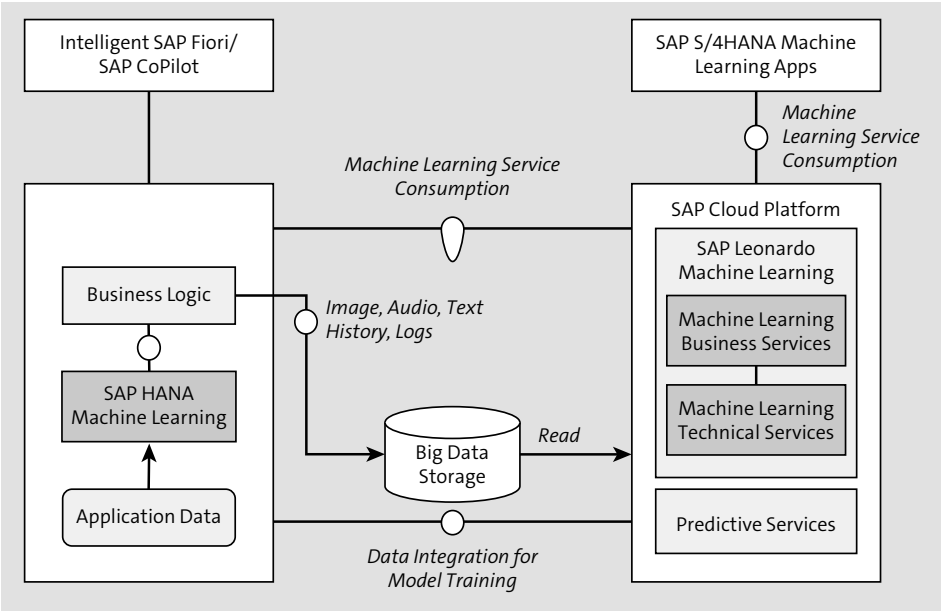


Figure 5.4 Machine Learning Architecture

5.2 Machine Learning Foundation

The solution of choice for building, creating, and testing machine learning algorithms for applications is SAP Leonardo Machine Learning Foundation, which provides users and companies the ability to build, test, execute, modify, and maintain algorithms.

SAP Leonardo Machine Learning Foundation is used for creating customized machine learning applications. Users of all levels, including novice beginners with no data-science skills, can use the toolset and library of existing templates and algorithms to experiment, edit, modify, and test, while advanced users can use the platform to create sophisticated algorithms. SAP Leonardo Machine Learning

Foundation can also connect multiple stakeholders, including developers, partners, and customers, to share machine learning technologies through the SAP Cloud Platform.

SAP Leonardo Machine Learning Foundation is a cloud-based product with a ready-to-use services library with prebuilt algorithms to train, test, and execute algorithms using custom data sources or multiple data sources. The ability to integrate third-party solutions and data sources for data flow streams, such as Google TensorFlow models, is also possible. The solution can help you easily develop and improve customized applications processes with machine learning rules and provides the option of using different data types with algorithms specializing in image, speech, text, and time-series data.

As shown in Figure 5.5, SAP Leonardo Machine Learning Foundation empowers end users to execute machine learning processes embedded through applications. Some capabilities are as follows:

- Developers can use reusable machine learning services to build into their applications.
- Data scientists can perform the training of models as a service by implementing their own models.

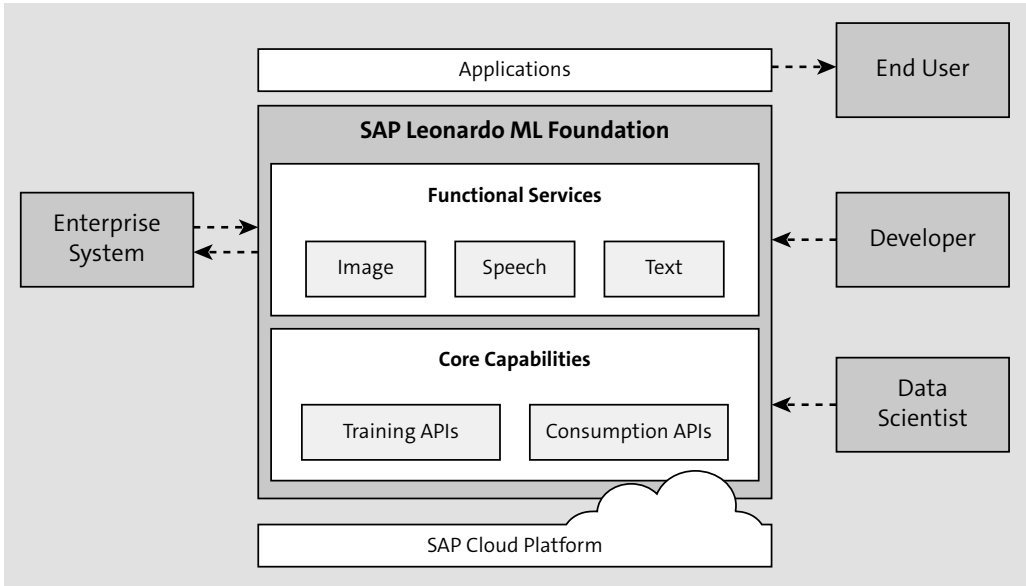


Figure 5.5 SAP Leonardo Machine Learning Foundation

- Retraining as a service can be used to customize or modify existing machine learning models.
- You can bring your own model and deploy existing results as a service.
- Services can be embedded into business applications.

Enterprise systems can serve as data sources via the cloud connector in SAP Cloud Platform Connectivity, or you can use SAP Data Hub to connect to an SAP S/4HANA or SAP HANA database system.

The main functional services in SAP Leonardo Machine Learning Foundation include algorithms for image, text, and speech processing. Customized machine learning services can be used with your own data using training APIs and custom models. You can also consume the services via REST APIs using the consumption APIs.

SAP Leonardo Machine Learning Foundation’s image processing capabilities include the following functionalities:

- **Image classification**
Classifies an image into generic categories, such as attribute types, color, size, image theme, etc.
- **Customizable image classification**
Create a custom image classification service with your own data to recognize your own classification types.
- **Customizable image object detection**
Create a service that localizes and recognizes custom objects in images.
- **Image feature extraction**
Represents the content of an image as a vector, which can be used for search or finding pictures with similar content.
- **Optical character recognition (OCR) and scene text recognition**
Processes document scans or images containing text and extracts texts and numbers.
- **Human detection and face detection**
Detect pictures that show humans or human faces.
- **Face feature extraction**
Represents a picture of a face as a vector, which can be used to find pictures with matching faces.

- **Multi-instance image segmentor**
Partitions an image into multiple segments, typically used to detect boundaries or locate objects.

Figure 5.6 shows SAP Leonardo Machine Learning Foundation’s image processing capabilities and examples of image processing microservices.

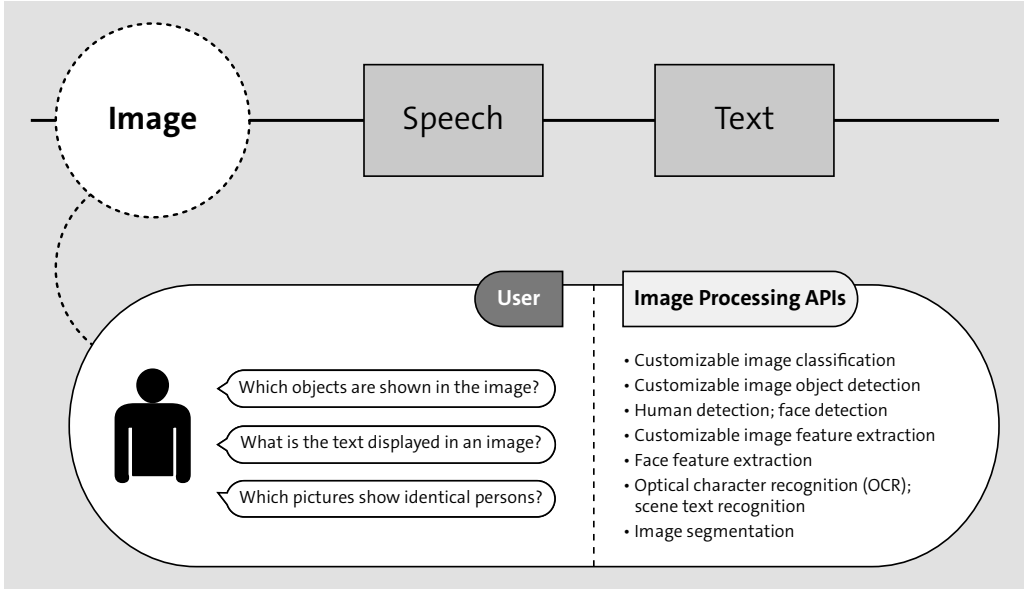


Figure 5.6 Machine Learning Image Classification

SAP Conversational AI is a platform to include capabilities for natural language processing technology. This platform can be used to create custom bots that can understand and communicate with customers and automate repeatable tasks efficiently. Industry-specific, off-the-shelf customer support bots make for quick and easy implementation. Speech capabilities include the following:

- Speech-to-text processing: Converting speech into text.
- Text-to-speech processing: Converting text into speech.

Figure 5.7 shows SAP Leonardo Machine Learning Foundation’s speech processing capability and example microservices.

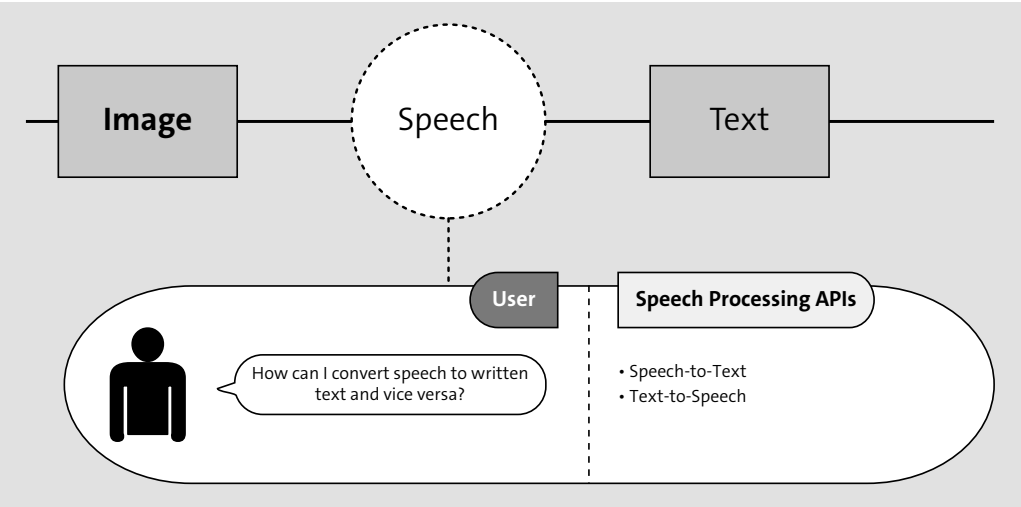


Figure 5.7 SAP Leonardo Machine Learning Foundation Speech Processing

Finally, text processing services include the following:

- **Topic detection services**
Extracts topics and keywords from documents and assigns the documents to the most relevant topics.
- **Customizable text classification**
Use custom text data to create your own text classification service.
- **Text feature extraction**
Represent the content of a text document as vector, which you can be used for retrieving similar documents.
- **Language detection**
Detects the language of a given text.
- **Translation**
Translate texts into different languages, specifically suited for SAP-related content to provide accurate terminology.

Figure 5.8 shows SAP Leonardo Machine Learning Foundation’s text processing capabilities and its related microservices.

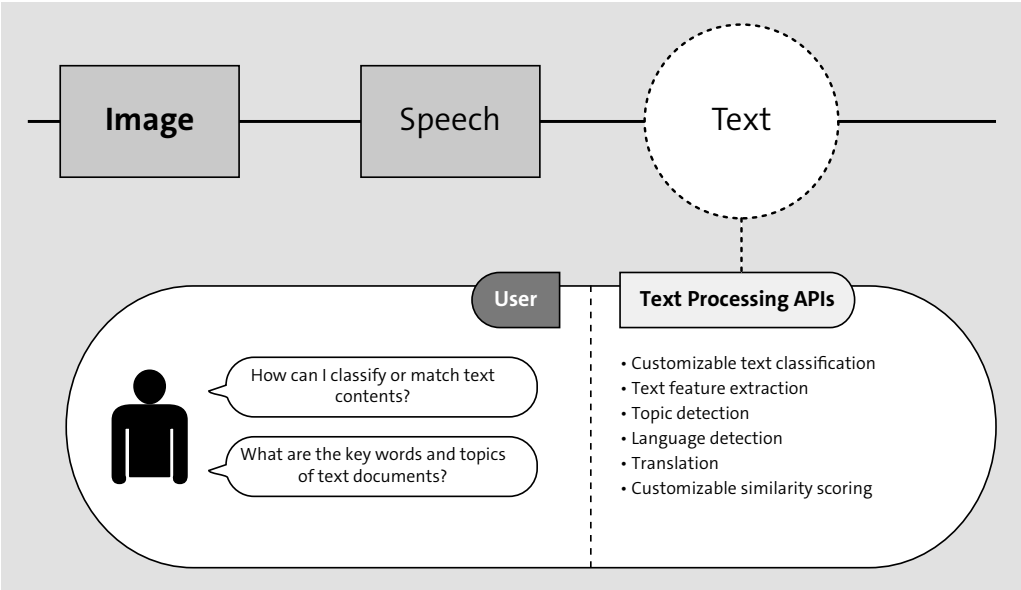


Figure 5.8 SAP Leonardo Machine Learning Foundation Text

5.3 Embedded Machine Learning

Machine learning technology is currently embedded in several SAP solutions, from the digital core to planning, execution, and innovation platforms, and will be embedded in additional solutions in the future. Figure 5.9 shows some areas where machine learning is planned to be embedded into existing solutions.

SAP Leonardo Machine Learning Foundation as a technology is presented as a toolkit to create applications or services or to be embedded into existing products. The three main categories are:

- Conversational experience, through SAP Conversational AI
- Intelligent applications and embedded solutions
- Machine learning and data science platform (SAP Leonardo Machine Learning Foundation)

In the following sections, we’ll walk through a nonexhaustive sample of products and new capabilities derived from machine learning. Figure 5.10 shows a summary of machine learning process improvements by product.

SAP Leonardo Machine Learning		Solution		Machine Learning Emended in SAP Products
Conversational Experience	SAP Conversational AI			
Intelligent Apps	Intelligent Finance	SAP Cash Application Intelligent GR/IR Account Reconciliation	SAP S/4HANA SAP S/4HANA	
	Intelligent People	Job Standardization Resume Matching Item Recommendation	Embedded in: SAP Fieldglass SAP Ariba	
	Intelligent Customer Experience	SAP Service Ticket Intelligence Lead intelligence SAP Brand Impact Product and Offer Recommend	Embedded in: SAP C/4HANA	
ML and Data Science Platform	SAP Leonardo Machine Learning Foundation			
On SAP Cloud Platform and SAP HANA				

Figure 5.9 SAP Leonardo Machine Learning Foundation Solutions

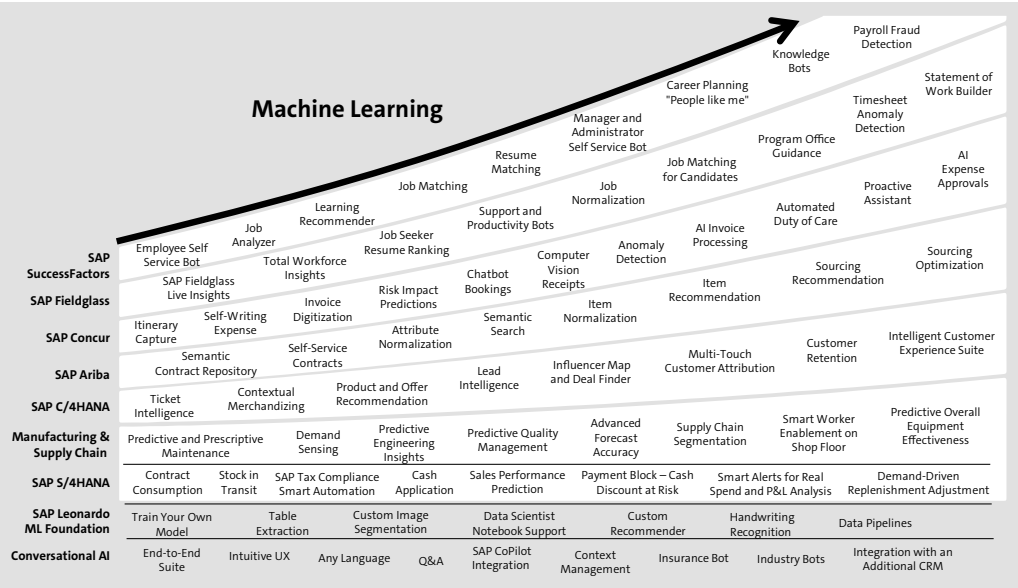


Figure 5.10 SAP Machine Learning Roadmap

5.3.1 Machine Learning with SAP Concur

SAP Concur has continuously looked for opportunities to reduce manual processes via machine learning and intelligence. The SAP Concur team started with eliminating the manual processes associated with expense reports. Using SAP Leonardo Machine Learning Foundation’s image processing services, a user can take a picture of a receipt, and the service will automatically add the receipt to an expense report with the right amount, description, and expense classifications. The same capabilities were also used for other expense processes, invoice processing, and travel expenses. These processes now recognize receipt images and automatically create expense report entries via machine learning.

Expense processes automatically sense and process the text of a receipt, deriving currency, amount, dates, supplier, location, and the type of receipt to be included in your expense report. Some additional areas where SAP Concur is using machine learning are as follows:

- Concur Expense uses machine learning technologies in conjunction with Office 365 to enable users to create expense report entries directly from emailed receipts.
- Concur Detect uses machine learning to uncover expense fraud, errors, and compliance issues in real time, therefore auditing 100% of your expense reports.
- Concur Locate builds on machine learning to predict where employees are located through credit card data, itineraries, and other sources, enabling companies to help keep their employees safe in the event of an emergency.
- Hipmunk’s Natural Language Processing (NLP) uses AI-powered travel search and travel bots to integrate with your calendar and provide travel advice and recommendations.
- TripIt leverages machine learning to give users a mobile interface experience by automatically integrating emails from travel bookings, Airbnb, Uber, flights, and hotel data.
- Concur Slack Beta allows users to type natural language commands into Slack, like “expense \$5 to Uber” and populate expense reports in near real time.
- Concur Invoice uses machine learning to extract data from invoices and scale their managed invoice capture service. An area experiencing growth, higher-volume OCR extraction can be accomplished with lower technology and operational costs.

Figure 5.11 show the main capabilities for invoicing, expense, and travel associated with SAP Leonardo Machine Learning Foundation.

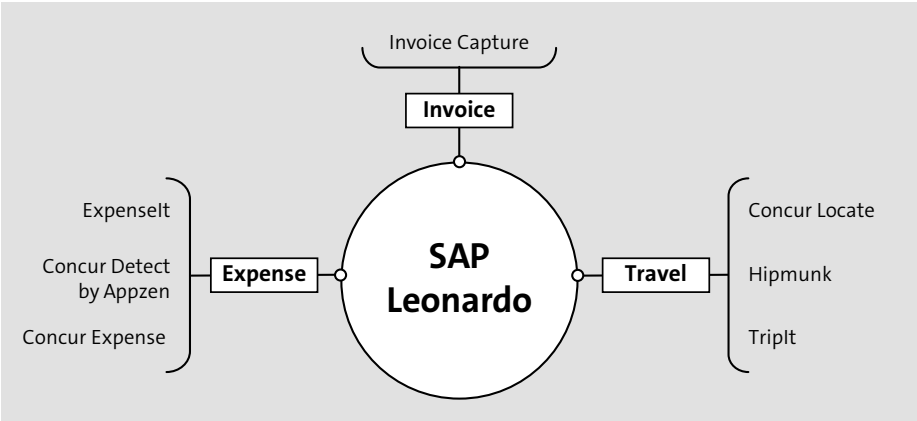


Figure 5.11 SAP Concur with Embedded Machine Learning Capabilities

5.3.2 Machine Learning with SAP SuccessFactors

SAP SuccessFactors is a cloud-based human resource (HR) management solution that covers multiple features, from payroll to employee engagement, scorecards, and performance management.

With SAP Leonardo Machine Learning Foundation embedded into SAP SuccessFactors, the following functional improvements were made:

- **People insights**
The ability to use historical data provides the ability to simulate and predict what could happen next. Better understand your people, the organization, and how they behave and evolve. HR and management can analyze the effects of, for example, organizational change and determine what positive or negative effects certain actions have on employees, including providing flight risk predictions and influencer analysis.
- **Learning**
Personalized learning recommendations can assist individual employees with a focused development path. In this case, all new personalized learning recommendations are powered by machine learning capabilities with SAP Leonardo. These targeted recommendations are based on taking what an organization knows about an employee, such as their learning history, and apply machine learning algorithms. Employees can maximize relevance by indicating topics of interest, which helps to focus the recommendation engine on delivering the best courses that match their preferences.

- **Service ticket intelligence**
SAP SuccessFactors can now provide HR services with intelligent, automated processes which include capabilities to read, categorize, solve, route, and propose solutions for HR ticketing tasks. The SAP SuccessFactors digital assistant is a personalized HR resource for all employees, which enables instant access to information and actions across a broad range of HR activities through a conversational interface. In this case, machine learning speech services can be used to retrieve Q&A information via speech-to-text user interactions on mobile or desktop devices. These capabilities are now accessible through the SAP SuccessFactors solution as well as through other solutions like Slack and Microsoft Teams.
- **Recruiting**
An intelligent job analyzer reviews and recommends the proper length of job descriptions and scans for gender bias to identify and recommend replacements for unconscious bias. Other suggested recommendations, such as salary band recommendations, can be based on a machine learning analysis of salary data by comparing salary to job difficulty.
- **Resume matching**
Resume matching capabilities compare and pick appropriate applicants' resumes with open positions, based on skills, location, and experience. SAP Leonardo Machine Learning Foundation provides capabilities for finding suitable candidates based on job requirements for open positions. Scoring metrics and quantification scores with matching visualization assist managers to filter to a shortlist of suitable candidates.

5.3.3 Machine Learning with SAP Fieldglass

SAP Fieldglass Live Insights is a new machine learning-based solution to use data-driven insights and services to help decision-makers benchmark, plan, predict, and simulate talent processing.

The solution focuses on a recruiter's skills and soft skills, not just their previous job titles, by using machine learning algorithms. SAP Fieldglass is one of the world's largest source of transactional workforce data, which makes it ideal for machine learning services to derive new insights. These machine learning services now simulate primary and alternative suggested job locations and predict alternative roles based on the ideal talent you're looking to hire.

These machine learning services provide skills-matching algorithms provided by a rule-based engine that allows you to define which skills are most critical versus skills

that are optional for the role. The machine learning service can then source millions of records to display alternative roles that best match the ideal skillset, using analytics. With this new insight, decision-makers can determine which skills are in short supply and determine a competitive salary for a job vacancy, including time to fill and candidates per role, for both permanent and talent options.

Executives can strategize by simulating and predicting in real time. SAP Data Network can assist with data-driven hiring decisions and help determine a corrective placement approach. Within a single view, decision-makers can see:

- Total cash to acquire a new hire
- Time required to fill a position
- Your successful hiring rates
- Alternative roles and locations for lowest total cash and shortest time-to-fill values

Machine learning can provide decision-makers with certainty and factual insights to make informative decisions, therefore enhancing confidence in their business case. SAP Data Network, live insights for workforce, is integrated with hiring processes running in the SAP Fieldglass solution, so once an decision-maker decides on an approach for hiring, the necessary workflows are triggered.

5.3.4 Machine Learning for Enterprise Applications

SAP delivers enhancements that enable companies to act on live data by integrating new intelligent applications using SAP Leonardo Machine Learning Foundation and predictive capabilities directly into the digital core. In this section, we'll only showcase a few, select examples of new enterprise applications created through the use of machine learning:

- **SAP Cash Application**
You can consult the SAP Cash Application to see the number of invoices to be processed. This application uses machine learning to automatically clear matching payments with invoices. If the payments cannot clear automatically, the algorithm suggests the best-fitting invoices.
- **SAP Brand Impact**
SAP Brand Impact is a product that uses machine learning image recognition services to analyze brand logos within videos to determine their exposure in terms of time and the position they appear on the screen, like upper right or lower left.

- **Digital sales and after sales services**
The next enterprise machine learning application is designed to replace spare parts and broken products. You can upload a photo of the broken product and use the machine learning image feature extraction algorithm to determine a similarity score. Also, the image feature extraction algorithm can be used to analyze product catalog images using the feature vectors database to derive similarity scores. You'll then be presented with several materials or products with the highest similarity scores. The product can then be selected and ordered.

- **Legal document classification**
This application can identify and rate legal documents relevant for product design and development. Typically, legal documents are available on the publicly accessible servers of governments with over 1,000 legal changes at any given moment. This feature can determine if a new legal change is relevant or important. Missing a legal change can have severe impact on your company.

The solution leverages several SAP Leonardo Machine Learning Foundation text analysis services: language detection, text classification, similarities coding, and text feature abstraction. With integration of these services, new laws and regulations can be immediately detected once documents are published and determined to be relevant. The overview page shows a quick preview of all the legal documents with an assessment of their relevance appearing on the top to the left of the document.

The details of the document show relevance and similar documents while highlighting the importance of the paragraph. The machine learning algorithm's confidence in detecting relevant changes is shown in the intensity of the highlighting. Darker blue indicates more relevant. The machine learning text processing services used in this case are the text feature extraction and text feature classification algorithms. Finally, the solution provides users with a reduction in time, effort, and risk.

5.4 Robotic Process Automation

Robotic process automation (RPA) accelerates the digital transformation of business processes by automatically replicating tedious actions that have no added value. RPA is available in two main types:

■ **Unattended**

Fully automated process, where robots are working autonomously with human supervision only

■ **Attended**

Partially automated process, where robots are coworking with human beings, also called robotic desktop automation

RPA solutions automate repetitive tasks traditionally performed by humans without modifying existing business systems. Some typical RPA activities include the following:

- Extract data through various connectors, for example, Excel files, PDFs, external apps, websites, third-party apps, and enter this data into a finance system
- Log on to enterprise instances, collect purchase requisitions, and distribute to shared service center (SSC) teams
- Download various reports, which can be collated and saved in shared drive
- Check ticket inboxes in a Shared Service Center and route tickets to bots
- Search invoices by reference number in various ERP instances

RPA can impact almost any line of business in just about any industry. Think of situations where someone must access multiple systems or manually process artifacts according to a set of rules. Let's look at a few examples:

■ **Procure-to-pay**

Many procure-to-pay processes (P2P) span multiple systems including ERPs, CRMs, banks, and logistics companies—systems not easily integrated. You can process invoices with computing power and connect to multiple backend systems while saving time, improving accuracy, enforcing policies, and allocating resources to high-value activities. With RPA, invoices from third parties can be processed with computer vision and connected to multiple backend systems, which saves time, improves accuracy, and easily allows the enforcement of procurement policies.

■ **Insurance claims processing**

Insurance claims processing is another example of too many manual steps. You can access a dozen or more disparate systems, process unstructured data, interpret text, make decisions, offer suggestions, and track progress in real time.

■ **Access and bring data together**

RPA can automatically connect to disparate systems, interpret text, make decisions, and track progress in real time. You're creating more data than ever, all spread across many systems, and bringing that data together for reporting can be

time-consuming. RPA can automatically access these systems; get the data (whether via an API or a manual extraction, for older systems); bring the data together; and based on an understanding of the data, decide how to disseminate the report. RPA can be set up to know that, if certain data sources contain too many error log entries, the report must go to a different distribution list. The options for access and bringing data together include the following:

- Access legacy systems, Excel files, third-party portals, websites, etc.
- Bring together data from disparate systems and generate regular reporting
- Intelligently determine dissemination based on content status

Current RPA systems in the market interact with systems like a user. You're replacing the person using a laptop with a bot, and many times, this bot is interacting with other bots. These bots use the same UI as a person, but you'll need to ask some of the following questions:

- What happens if the UI changes?
- What happens when the system is updated? System maintenance becomes a risk.
- A person can easily relearn, but what about an RPA bot?

These bots typically scrape the UI of systems, like a web crawler looking at webpages. This approach may reduce the manual nature of the previous process, but now, the process is far more complex. That complexity means that an inherent risk exists even updating or upgrading your systems. If one piece changes, the entire thing could break.

When SAP automates systems, the actual APIs behind the UI are being used. Updating the system and breaking the UI has no risk to the bot because the APIs stay stable.

SAP's intent is to deliver an intelligent, integrated automation suite so that you don't spend time and effort resolving deployment/tool issues rather than leveraging the potential of RPA. If the basic expectations of RPA are fulfilled as promised, great opportunities can be opened up for analyzing the process-level data that a process is executed on and for formulating a suggestive/prescriptive mode of process modeling, with self-driving robots unleashing the complete potential of RPA. In this scenario is where SAP's strength of integration and the significance of SAP Leonardo Machine Learning Foundation are more relevant than ever.

SAP has launched the SAP Intelligent Robotic Process Automation solution where RPA is the "hands" and the "legs" of the robot, whereas SAP Leonardo Machine Learning Foundation acts as the "brain" that makes decisions, and where conversational AI

can play an interfacing role to receive and disseminate instructions digitally. Figure 5.12 shows the three groups of capabilities: interact, execute, and optimize.

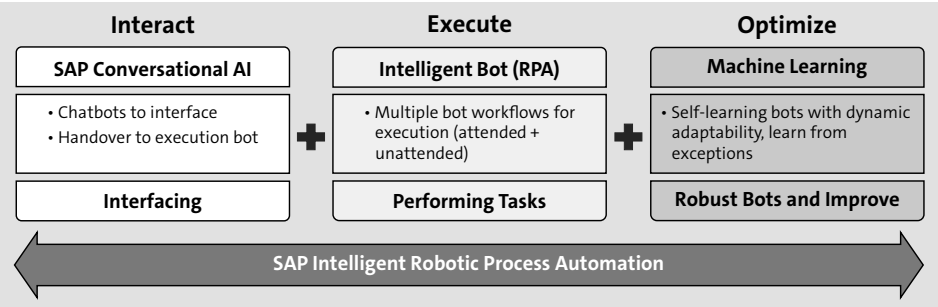


Figure 5.12 SAP Intelligent Robotic Process Automation Scope

The solution has the following key modules:

- Modeler for graphically designing bot workflows
- Repository for storing individual process steps as well as for reusing steps during the design phase
- Runtime environment for managing robot deployments in various virtual/on-premise/hybrid environments
- Monitoring tool for an overview of the robots in action, including work completed, progress, service-level agreement fulfillment, risk mitigation, etc.

Figure 5.13 shows the key modules found in SAP Intelligent Robotic Process Automation.

	Design Environment	Central Repository	Runtime Environment	Control/Monitoring Tool
Purpose	Flexibly design robot workflows, record screens	Store atomic steps for full workflow, configuration info	Execution engine for running bot scripts across deployments	Process monitoring, analytics for robot performance/SLAs
Key Capabilities	<ul style="list-style-type: none">• End user friendly workflow designer• Automation methods:<ul style="list-style-type: none">– API interfaces– OCR/NLP– Screen scraping– Computer vision• Connectors for MS office tools, third-party apps, legacy systems• Predefined robot templates	<ul style="list-style-type: none">• Multi-tenancy• Security• Bot version control• Marketplace for third party/ecosystem bots	<ul style="list-style-type: none">• Scaling/load balancing• Public cloud deployment-orchestrating desktop RPA and cloud runtime• WF management machine/human• Bot scheduler and time zone manager• Bot failsafe engine• Multiple channels support such as SAP Conversational AI (chatbots)• SAP Leonardo ML Foundation	<ul style="list-style-type: none">• UX, mobile access• Audit trails• Process insights• Logging and Monitoring cockpit

Figure 5.13 Key Modules

SAP aims to realize their vision for SAP Intelligent Robotic Process Automation in multiple phases. With phase 1, SAP intends to deliver the core solution with four critical components: design, repository, runtime, and monitor. This SAP S/4HANA-focused release will include SAP S/4HANA-specific preconfigured content out of the box and will include the ability to integrate with SAP S/4HANA APIs, machine learning services, and SAP Conversational AI. In phase 2, SAP intends to extend SAP Intelligent Robotic Process Automation for the wider SAP portfolio, including SAP SuccessFactors, SAP Concur, etc., depending upon how use cases are prioritized. Phase 3 move towards cognitive modes after gaining some experience through multiple robot deployments. Thus, SAP can make robots more and more AI enabled with a prescriptive mode that can remodel processes and can self-correct.

5.5 Summary

Machine learning technologies enable computers to complete operational tasks by learning from large sets of operational data, outcomes, or historical data. Machine learning opens up a dialogue around using automated machine-driven to repurpose human effort to more high-value tasks, while automation focuses on areas characterized by a high degree of repetition.

SAP Leonardo Machine Learning Foundation as technology is present as a toolkit to create new applications, services or embedding machine learning into existing products. SAP Leonardo Machine Learning Foundation is used for building, creating, and testing machine learning algorithms for applications. Machine learning in enterprise applications delivers enhancements that make have made it easier than ever for companies to run on live insights by integrating new, intelligent applications using SAP Leonardo Machine Learning Foundation and predictive capabilities directly into the digital core.

Contents

Foreword by Hans Thalbauer	17
Foreword by Darwin Deano	19
Preface	21

PART I Digital Transformation and the Intelligent Enterprise

1	Introduction	31
1.1	Introduction to SAP Leonardo	31
1.1.1	Technology and Components	32
1.1.2	Intelligent Enterprise Components	35
1.1.3	Adoption Options	37
1.2	Benefits of SAP Leonardo	38
1.3	Digital Transformation	39
1.3.1	Digital Disruption	39
1.3.2	Business Process Innovation	41
1.3.3	Workplace Innovation	43
1.3.4	Business Usage	47
1.4	SAP Cloud Platform	48
1.4.1	Business Services	50
1.4.2	Platform Services	50
1.4.3	Data and Storage Services	51
1.4.4	SAP Edge Services	53
1.5	Associated Technology	55
1.5.1	Big Data	56
1.5.2	Data Intelligence	58
1.5.3	Data Analysis	59
1.5.4	Machine Learning	60
1.5.5	Blockchain	63
1.5.6	Internet of Things	66
1.6	Summary	72

2	Digital Transformation: Ecosystem and Approach	73
2.1	Intelligently Connected People	73
2.1.1	Collaboration	75
2.1.2	User Interfaces	78
2.1.3	Real-Time Analytics	84
2.2	Intelligently Connected Things	88
2.2.1	Connected Products	89
2.2.2	Connected Assets	90
2.2.3	Connected Fleet	91
2.2.4	Connected Infrastructure	92
2.2.5	Connected Markets	92
2.3	Intelligently Connected Processes	94
2.3.1	Integrated Processes	94
2.3.2	Process Automation	100
2.3.3	Microservices	103
2.4	Design Thinking	104
2.4.1	Design Thinking at SAP	104
2.4.2	Approach	109
2.4.3	Design-Led Development	119
2.5	Summary	121

PART II Technologies

3	Big Data	125
3.1	What Is Big Data?	125
3.2	Universal Data Management Platform	129
3.3	Big Data Operations Management	130
3.4	Big Data Services	135
3.5	Summary	137

4	Analytics	139
4.1	What Is Analytics?	140
4.2	Business Intelligence Portfolio	141
4.3	Planning and Analysis	145
4.3.1	SAP Analytics Cloud	146
4.3.2	SAP Digital Boardroom	147
4.3.3	SAP Business Planning and Consolidation	148
4.3.4	SAP Profitability and Performance Management	148
4.4	Predictive Analytics	149
4.5	Summary	152
5	Machine Learning	153
5.1	What Is Machine Learning?	153
5.2	Machine Learning Foundation	158
5.3	Embedded Machine Learning	163
5.3.1	Machine Learning with SAP Concur	165
5.3.2	Machine Learning with SAP SuccessFactors	166
5.3.3	Machine Learning with SAP Fieldglass	167
5.3.4	Machine Learning for Enterprise Applications	168
5.4	Robotic Process Automation	169
5.5	Summary	173
6	Data Intelligence	175
6.1	What Is Data Intelligence?	176
6.2	Data-Driven Business	177
6.3	Data Monetization Strategies	179
6.4	Data-as-a-Service	180
6.5	Summary	184

7	Blockchain	185
7.1	What Is Blockchain?	185
7.2	Enterprise Blockchain	190
7.2.1	Foundational Services	191
7.2.2	Blockchain Services	192
7.3	Blockchain for Industries	196
7.3.1	Consumer Products, Agribusiness, and Retail	197
7.3.2	High-Tech	198
7.3.3	Utilities and Energy	199
7.3.4	Life Sciences	200
7.4	Blockchain for Lines of Business	201
7.4.1	Procurement	201
7.4.2	Logistics	202
7.4.3	Finance	203
7.5	Summary	205
8	Internet of Things	207
8.1	What Is the Internet of Things?	208
8.2	Reference Architecture	211
8.2.1	Connecting Assets and Processing on the Edge	212
8.2.2	Data Processing and Storage	213
8.2.3	Analytics	214
8.2.4	Reusable Business Services	215
8.3	Applications	215
8.4	Platform and Foundation Services	218
8.5	Edge Computing	220
8.6	Application Enablement	221
8.7	Summary	223

PART III SAP Leonardo Business Processes

9	Products and Inventory	227
9.1	Digital Product Management	229
9.1.1	Compliant Product Lifecycle Management	229
9.1.2	Intelligent Enterprise Portfolio and Project Management	232
9.1.3	Product and Project Insights	236
9.2	Demand Management	242
9.2.1	Consensus Demand Planning	245
9.2.2	Sensing Short-Term Demand Patterns	251
9.2.3	Incorporating Demand Influencing Factors	254
9.3	Inventory Optimization	260
9.3.1	Accounting for Inherent Variabilities in the Supply Chain	261
9.3.2	Establishing Multistage Inventory Targets	263
9.3.3	Meeting Customer Service Levels	263
9.4	Connected Products	266
9.4.1	Network of Digital Twins	266
9.4.2	Connecting IoT Sensors to the Enterprise	267
9.4.3	Operationalizing Sensor Data and Establishing New Business Models	269
9.5	Summary	271
10	Manufacturing and Assets	273
10.1	Smart Manufacturing Optimization	273
10.1.1	Factory Automation	274
10.1.2	Building Blocks of a Smart Factory	276
10.2	Digital Manufacturing and Operations	277
10.2.1	Characteristics of a Smart Factory	278
10.2.2	Smart Shop Floor Overview	279
10.2.3	Shop Floor Control Tower	282

10.2.4	Material Availability	284
10.2.5	Floorplan View	285
10.2.6	Dynamic Routing	288
10.2.7	Production Planning and Detailed Scheduling	291
10.3	Digital Asset Network and Operations	292
10.4	Predictive Maintenance	297
10.4.1	On-Demand Spare Parts through 3D Printing	298
10.4.2	Building Blocks of Predictive Maintenance	299
10.4.3	Digital Dashboard	306
10.4.4	Machine Learning Service	309
10.5	Digital Twins	313
10.5.1	Digital Twins of a Physical Objects	313
10.5.2	Varieties of Digital Twins	315
10.5.3	Digital Twin Integration in SAP Leonardo	316
10.5.4	SAP Leonardo Digital Twin Portfolio	318
10.6	Summary	320

11 Transportation and Warehousing 321

11.1	Transportation Logistics	322
11.1.1	Digitalizing Transportation with Dynamic Planning	323
11.1.2	Logistics 4.0 and the Connected Fleet	325
11.1.3	Inbound Transportation	329
11.1.4	Outbound Transportation	330
11.1.5	SAP Leonardo Integration with SAP S/4HANA	330
11.1.6	SAP Transportation Management	331
11.1.7	SAP Leonardo for Transportation	335
11.2	Intralogistics	343
11.2.1	Digitizing the Yard and Warehouse with Dynamic Planning	343
11.2.2	Inbound and Outbound Processing	344
11.2.3	SAP Warehouse Insights	346
11.2.4	Yard and Hub Logistics	353
11.2.5	SAP Leonardo for Intralogistics	354

11.3	Logistics Network	362
11.3.1	Supply Chain Visibility	362
11.3.2	SAP Global Track and Trace	363
11.3.3	SAP Logistics Business Network	364
11.4	Summary	367

12 Finance 369

12.1	Financial Planning and Analysis	370
12.1.1	Budgeting and Forecasting	371
12.1.2	Planning and Predictive Finance	375
12.1.3	Dynamic Reporting	378
12.2	Financial Accounting	380
12.2.1	Accounts Receivable and Digital Automation	380
12.2.2	Accounts Payable and Digital Automation	384
12.3	Accounting and Financial Close	391
12.3.1	Reconciliation and Year-End Reporting	391
12.3.2	Continuous Soft Close	395
12.4	Financial Controls	397
12.4.1	Audit and Compliance Management	397
12.4.2	Fraud Management	400
12.4.3	Risk Management	402
12.5	Summary	404

13 Assorted Business Processes 405

13.1	Reimagined Solution Architecture	405
13.1.1	Architecting the Digital Core	406
13.1.2	Microservices	416
13.2	Human Resource Management	419
13.2.1	Intelligent HR Solutions	420
13.2.2	Examples and Use Cases	424

13.3	Sourcing and Procurement	427
13.3.1	Cognitive Procurement	428
13.3.2	Examples and Use Cases	432
13.4	Sales and Marketing	436
13.4.1	Sales and E-Commerce	437
13.4.2	Smart Campaigns	438
13.4.3	Examples and Use Cases	440
13.5	Summary	443
 14 Digitization of Industries		445
14.1	Discrete Manufacturing Industry	446
14.1.1	Digital Innovation Use Cases	446
14.1.2	Business Examples	448
14.2	Process Industry	453
14.2.1	Digital Innovation Use Cases	454
14.2.2	Business Examples	455
14.3	Consumer Products and Retail Industries	458
14.3.1	Digital Innovation Uses Cases	459
14.3.2	Business Examples	460
14.4	Other Industries and Sectors	463
14.4.1	Digital Innovation Use Cases	463
14.4.2	Business Examples	465
14.5	Summary	468
 15 Roadmap and Outlook		469
15.1	SAP Leonardo Technological Innovation Roadmap	469
15.2	SAP Leonardo Process Innovation Roadmap	471
15.3	SAP Leonardo IoT Roadmap	472
15.4	Summary	474

Appendices		475
A	Future Cities	475
B	The Authors	507
 Index		509

Index

3D printing	298	Blockchain (Cont.)	
A		<i>finance</i>	203
ABC and XYZ segmentation	246	<i>financial accounting</i>	388
Accounts payable	384	<i>food traceability</i>	197
Accounts Payable service	101	<i>high-tech</i>	198
Accounts receivable	380	<i>industries</i>	196
Advanced variant configuration	231	<i>large-scale</i>	470
Airbnb	177	<i>LOB</i>	201
Analytics	139, 145, 214, 457	<i>logistics</i>	202
<i>maturity curve</i>	140	<i>network extensibility</i>	195
Anomaly detection	286	<i>payments</i>	390
Apache Hadoop	456	<i>pharmaceuticals</i>	399
Application integration services	190	<i>pharmaceuticals and life sciences</i>	200
Application Programming Interfaces (APIs) 33, 61		<i>platforms and protocols</i>	186
Asset central foundation	293, 300	<i>procurement</i>	201
Asset health monitoring	280	<i>retail</i>	198
Asset management	447	<i>RFQ</i>	204
Asset Manager	319	<i>use cases</i>	187
Asset utilization	288, 290	<i>utilities and energy</i>	199
Auditing	397	<i>variations</i>	186
Autonomous assets	360	Bring your own model (BYOL)	469
B		Budgeting	371
Best fit algorithm	248	Buffer levels	262
Big data	56, 125, 132, 182, 222, 457, 464	Building insights	92
3 Vs	57	Business intelligence	176
<i>operations management</i>	130	Business object service	194
<i>overview</i>	125	C	
<i>services</i>	135	Capital expenditure (CapEx)	270, 447
<i>streamlined operations</i>	131	Case management	250
Blockchain	63, 185, 383	Charts	283
<i>accounts receivable factoring</i>	204	Citizen engagement	468
<i>auditing</i>	389, 398	Classification model	155
<i>collections</i>	204	Clean ERP	409
<i>ecosystem</i>	189	Cloud Foundry	51, 104, 194, 419
<i>enterprise</i>	190	Cloud-first approach	412
<i>explanation</i>	185	Cognitive procurement	428
<i>farm-to-consumer POC</i>	198	Cold chain logistics	454
		Cold store	214
		Collaboration	75, 231, 239
		<i>cross-enterprise</i>	43
		<i>types</i>	75

Compliance	219, 397
Concur Detect	165
Concur Expense	165
Concur Invoice	165
Concur Locate	165
Connected assets	90, 212, 215
Connected communities	489
Connected fleet	91, 216, 323, 326, 338
<i>capabilities</i>	327
<i>integration</i>	331
Connected infrastructure	92, 216
Connected markets	92, 216
Connected people	73, 216
Connected processes	94
Connected products	89, 215, 266
Connected things	88
Connected vehicles	68, 96
Connectivity	278
Consensus demand planning	245, 247
Construction	92
Consumables on-demand	451
Consumer products	458
Content management interoperability (CIMS)	239
Continuous soft close	395
Create, read, update, delete (CRUD)	186, 222
Cryptography	186
Customer experience	42
<i>shopping</i>	461
Customer segmentation model	439
Customer service	448
Customer service levels	227, 263
D	
Data analytics	58
Data governance	127, 181
Data intelligence	58, 175, 179
<i>data analysis techniques</i>	176
Data lake	214
Data landscape management	132
Data management	35
Data monetization	130, 179
Data pipelining	133
Data provisioning	258
Data sharing	182
Data transparency	130
Data warehousing	135
Data-as-a-service (DaaS)	176, 180
Data-driven business	177
Days sales outstanding (DSO)	380
Decentralized ledger	196
Decoupling points	262
Delivery logistics	463
Delivery performance	465
Demand	462
Demand management	242
<i>network</i>	243
Demand planning	
<i>big data</i>	255
<i>factors</i>	254
<i>network analytics</i>	258
Demand segmentation	246
Demand sensing	94, 252
<i>example</i>	95
<i>machine learning</i>	252
<i>patterns</i>	252
Demand signals	258
Demand-driven material requirements planning (DDMRP)	262
Design gates	121
Design thinking	34, 94, 104, 458
<i>ideate</i>	106
<i>phases</i>	105
<i>prototype</i>	107
<i>testing</i>	109
Design-led development	34, 119
<i>phases</i>	120
Detailed scheduling board	291
Device management	219
Digital asset network	292
Digital assistant	423
Digital disruption	39
Digital manufacturing	277
Digital sales services	169
Digital transformation	38, 39, 73
<i>business processes</i>	41
<i>readiness</i>	228
Digital twins	266, 296, 313, 451
<i>applications</i>	314
<i>integration</i>	316
<i>model</i>	313
<i>network</i>	266
<i>overview</i>	313
<i>varieties</i>	315

Digital workplace	44, 75
Discrete manufacturing	446
Distributed ledger	63, 185
Document Management System (DMS)	239
Dynamic planning	343
Dynamic planning algorithm	323
Dynamic reference line	379
Dynamic reporting	378
Dynamic route planning	323
Dynamic routing	288, 339
Dynamic time filters	378
E	
Earth mover's distance (EMD)	311
Employee productivity	44
Employee retention	426
Empty travel	348
Energy grids	92
Enterprise asset management (EAM)	292
Enterprise data warehouse (EDW)	127
Entity extraction	426
Equipment health	286
Equipment notifications	283
Event management	341
F	
Factory automation	274
Farmin	452
Finance	369
Financial accounting	380
Financial close	391
Financial controls	397
Financial planning and analysis (FP&A)	370
Fit-to-standard	409
Fixed asset insights	90
Fleet analytics	97
Fleet economics	328
Food manufacturing	461
Forecasting	373
Forecasting algorithms	248
Forklift Analytics app	355
Fraud management	400
Freight costing	333
Freight management	332, 333
Freight request	365

G	
General Data Protection Regulation (GDPR)	190
Geofencing	268
Global accounting hierarchy	394
Global delivery	337
Google TensorFlow	159
Governance, risk, and compliance	45
GR/IR clearing	387
GR/IR monitor	384, 387
Gradient boosting decision tree	248
Graphical scheduling board	280
H	
Hadoop	127, 136, 183
Hash	64
Hipmunk	165
Human resource management (HRM)	419
Hybrid transactional/analytical processing (HTAP)	129
Hyperledger Fabric on SAP Cloud Platform	187, 191, 202
Hyperledger Foundation	188
I	
Image-based requisition	384
Inbound processing	344
Inbound transportation	329
Incremental revenue	275
Industry 4.0	273
Industry case studies	445
Infrastructure management	315
Innovation architecture	414
Insight-to-action	49
Insurance claims processing	170
Intelligent enterprise	35, 414
Intent matching	426
Inter-bank payment processing	466
Internet of Things (IoT)	66, 207, 451
<i>connectivity sensors</i>	280
<i>data ingestion</i>	134
<i>data processing</i>	213
<i>devices</i>	461

Internet of Things (IoT) (Cont.)
 energy usage 70
 example 69
 features 67
 goods and equipment 89
 industries 208
 overview 208
Intralogistics 343
 SAP Leonardo 354
Inventory 227
Inventory optimization 260
Invoice matching 382

K

Key performance indicators (KPIs) 50, 145, 250, 360

L

Legal document classification 169
Live asset tracking 356
Live Product Cockpit 237
Load planning 335, 336
Local delivery 337
Logistic regression (LOR) 312
Logistics 4.0 325
Logistics networks 91, 328, 362
Logistics safety 91

M

Machine learning 60, 61, 62, 134, 150, 153, 235, 247, 250, 269, 309, 385, 430, 438, 461
 algorithms 60, 62, 236, 311
 architecture 158
 embedded 157, 163
 enterprise applications 168
 image processing 160
 overview 153
 pattern recognition-based 254
 SAP Analytics Cloud 374
 SAP Concur 165
 SAP Fieldglass 167
 SAP SuccessFactors 166
 side-by-side 157

Machine learning (Cont.)
 speech processing 161
 text processing 162
 train model 309
Maintenance, repair, and overhaul (MRO) .. 292
Management by exception 250
Manufacturing and assets 273
Manufacturing execution 90
Manufacturing networks 90
Market insights 93
Market opportunities 40
Master data 472
Material availability 284
Material availability checking 280
Means of transport 284
Meat processing industry 310
Microservices 33, 103, 210, 416, 418
Mobile asset insights 91
Monitoring and Tracking app 98
Monolithic architecture 416
Moving assets 355
Multichain blockchain 455
MultiChain on SAP Cloud Platform 187, 191
Multidrop delivery 339
Multistage inventory targets 263
Multivariate autoregression (MAR) 311

N

Network model management 352

O

Operational expenditure (OpEx) 270, 447
Optical character recognition (OCR) 160
Order management 332
Outbound processing 344
Outbound transportation 330
Overall equipment effectiveness (OEE) 450

P

Package building 333
Pay-as-you-drive 466
Pay-for-outcome business model 447
Payment block 150

Permissioned blockchain 64
Persona 110
Physical-digital-physical data
 transfer 276, 277
Planning 145
Platform-as-a-service (PaaS) 35
Platform-first approach 410
 decision tree 412
Portfolio and project management 232
Predict arrival of stock in transit 150
Predictive analytics 328, 375
Predictive insights 42
Predictive maintenance 287, 297
Predictive model 376
Principal component analysis (PCA) 311
Private blockchain 64
Process automation 100, 325
Process industry 453
Process segmentation 407
Procurement 450
Procurement bot 435
Procure-to-pay (P2P) 170, 384, 427
Product and service digitization 40
Product costing 231
Product development
 big data 456
Product lifecycle management 229, 314
 compliant 229
Product management 229
Production Planning and Detailed Scheduling (PP-DS) 291
Production transparency 278
Productivity 275
Products 227
 insights 89
 integrated development 231
 lifecycle 232
 safety 232
Project cost forecasting 151
Project cost prediction 235
Project insights 236
Project types 233
Proof of history service 193
Proof of state service 193
Public blockchain 64
Purchase order management 389

Q

Quality enhancement 456
Quality inspection 433
Quantity contract consumption 150
Quorum on SAP Cloud Platform 187, 192
Quotation conversion probability rate 150
Quotation Conversion Probability Rate
 app 441

R

Real-time business 42
Real-time monitoring 449
Real-time reporting 281
Recipe development 231
Reconciliation 391
Recruitment 424
Regression analysis 154
Reinforcement learning 62
Requirements management 230
Rerouting production order 291
Research and development (R&D) 235
Resource utilization 350
Resume matching 167
Resume Matching service 424
Retail 458
Reusable business services 215
Risk management 402
Risk reduction 275
Robotic process automation (RPA) 102, 169, 422, 433
Root cause analysis 287
Run to failure strategy 297

S

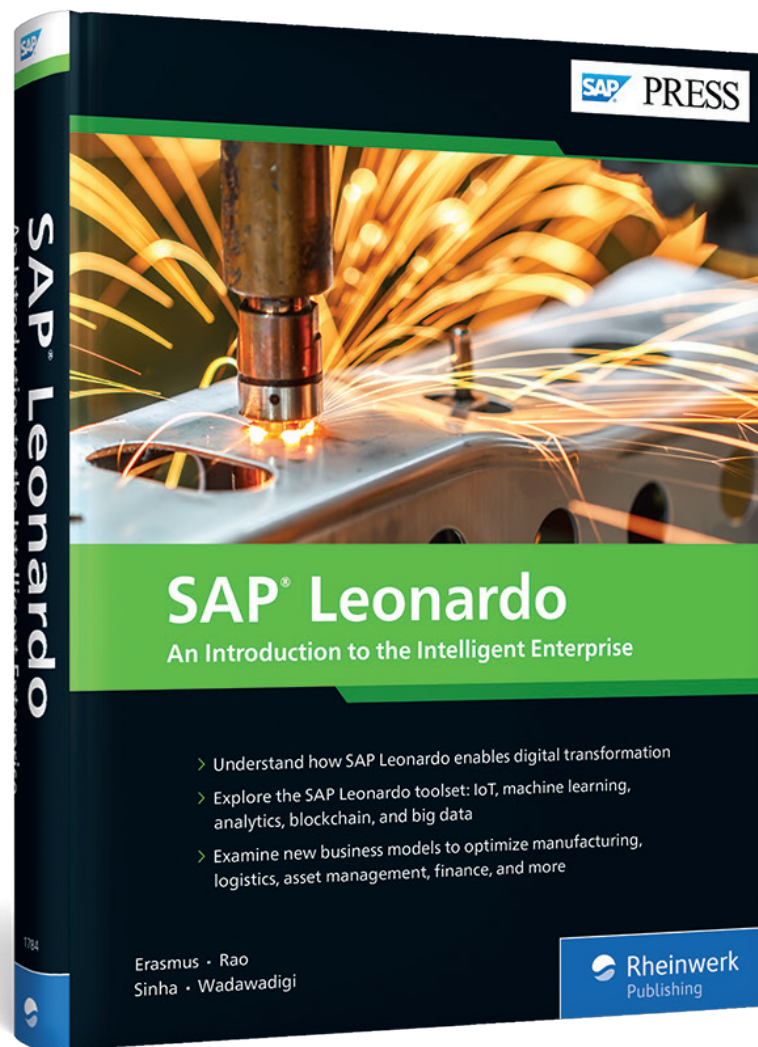
Saleable returns 455
Sales and marketing 436
Sales and operations planning 244
Sales conversions 440
SAP 3D Visual Enterprise 267
SAP Advanced Track and Trace for
 Pharmaceuticals 66, 201, 399, 454
SAP Analysis for Microsoft Office 141, 148
SAP Analytics 141, 143

SAP Analytics Cloud	60, 84, 141, 146, 149, 151, 258, 360, 370, 385, 457, 463, 470
<i>dashboards</i>	386
<i>data sources</i>	143
<i>features</i>	85
<i>forecasting techniques</i>	374
<i>LOB</i>	144
<i>model creation</i>	372
SAP Analytics Hub	143
SAP API Business Hub	178
SAP API Management	180
SAP Ariba	35, 202, 428
SAP Ariba Supplier Risk	430
SAP Asset Intelligence Network	231, 293, 295, 301, 447, 451
<i>dashboard</i>	296
<i>digital twins</i>	296
SAP Asset Strategy and Performance Management	294
SAP Brand Impact	168
SAP Build	109, 112
SAP Business Explorer (SAP BEx)	145
SAP Business Integrity Screening	151, 400
SAP Business Planning and Consolidation (SAP BPC)	148, 457
SAP BusinessObjects Enterprise	143
SAP BW/4HANA	141, 148
SAP C/4HANA	35, 437, 438
SAP Cash Application	101, 168, 381, 471
SAP Cloud Platform	32, 35, 48, 70, 103, 141, 144, 159, 189, 190, 213, 281, 411
<i>business services</i>	50
<i>data and storage services</i>	51
<i>integration</i>	49
<i>platform services</i>	50
SAP Cloud Platform API Management	418
SAP Cloud Platform Big Data Services	51, 58, 128, 136, 137
SAP Cloud Platform Blockchain	191, 388
<i>application enablement services</i>	192
SAP Cloud Platform Blockchain Services	448
SAP Cloud Platform Document service	52
SAP Cloud Platform Internet of Things	220
SAP Cloud Platform Workflow	221, 241
SAP Cloud Platform, SAP HANA service	51
SAP Concur	165
SAP Conversational AI	100, 161, 426, 470
SAP CoPilot	100, 234, 423, 426
<i>UI</i>	234
SAP Customer Business Planning	259
SAP Data Hub	52, 128, 132, 133, 134, 160, 178, 181, 212, 213
<i>architecture</i>	182
<i>capabilities</i>	181
SAP Data Intelligence	183
SAP Data Network	168
SAP Data Network, live customer cloud	179, 180
SAP Data Network, live insights for workforce	179
SAP Data Services	134, 181
SAP Demand Signal Management	95, 255, 258, 259
<i>machine learning</i>	257
SAP Digital Boardroom	47, 60, 85, 147, 148, 370, 403
<i>functionality</i>	86
<i>risk analysis</i>	404
<i>use cases</i>	86
SAP Digital Supply Chain	35
SAP Edge Services	53, 54, 55, 452
SAP EHS Regulatory Documentation OnDemand	232
SAP Enterprise Asset Management (SAP EAM)	309
SAP ERP	416
SAP Extended Warehouse Management (SAP EWM)	346
SAP Fieldglass Live Insights	167
SAP Fiori	78, 219, 237
<i>app recommendations analysis</i>	79
<i>app strategy</i>	79
<i>custom tiles</i>	83
<i>images</i>	82
<i>tiles</i>	81
SAP Fiori launchpad	81
SAP Fraud Management	402
SAP Global Batch Traceability	454
SAP Global Track and Trace	65, 198, 338, 363
SAP Global Trade Services	203
SAP Governance, Risk, and Compliance	403
SAP Guided Outcomes	37

SAP HANA	128, 129, 178, 195
<i>security</i>	130
SAP HANA Automated Predictive Library (APL)	151
SAP HANA Blockchain service	194
SAP HANA cold data tiering	135
SAP HANA Data Management Suite	58, 127
SAP HANA IoT Integrator by OSIsoft	455
SAP IBP for demand	245, 247, 250, 252, 461
SAP IBP for inventory	260, 261, 263, 265
SAP IBP for response and supply	461
SAP IBP for sales and operations	262
SAP Information Collaboration Hub for Life Sciences	201
SAP Information Steward	181
SAP Integrated Business Planning (SAP IBP)	56, 245
<i>analytics</i>	264
<i>Excel</i>	247
SAP Intelligent Robotic Process Automation	171, 173, 470
<i>scope</i>	172
SAP IoT Application Enablement	221
<i>capabilities</i>	222
SAP Jam	76
<i>actions</i>	76
<i>example</i>	76
<i>tasks</i>	77
SAP Leonardo	
<i>accelerator packages</i>	33
<i>adoption</i>	37
<i>benefits</i>	38
<i>components</i>	32
<i>engagement track</i>	37
<i>intelligence technologies</i>	34
<i>open innovation</i>	37
<i>overview</i>	31
<i>roadmap</i>	469
<i>smart shop floor</i>	279
<i>technologies</i>	55
<i>use cases</i>	47
SAP Leonardo Analytics	59, 140
SAP Leonardo Big Data	57, 59
SAP Leonardo Blockchain	462, 468
SAP Leonardo Data Intelligence	59
SAP Leonardo IoT	68, 88, 96, 209, 268, 270, 298, 447, 452, 460, 465, 472
<i>applications</i>	216
<i>areas</i>	215
<i>dashboards</i>	219
<i>edge processing</i>	219
<i>inventory monitoring</i>	270
<i>reference architecture</i>	211
<i>security</i>	219
SAP Leonardo IoT Bridge	68, 462
SAP Leonardo IoT Edge	210, 212, 220, 231, 268, 456, 473
SAP Leonardo IoT for SAP Distributed Manufacturing	267, 448
SAP Leonardo IoT Foundation	209, 210, 218
SAP Leonardo Machine Learning	100, 101, 163, 214, 230
SAP Leonardo Machine Learning Foundation	129, 155, 158, 159, 160, 447, 460, 469
SAP Logistics Business Network	364, 365
SAP Marketing Cloud	439, 442, 443
SAP Plant Connectivity	212
SAP Portfolio and Project Management for SAP S/4HANA	234
SAP Predictive Analytics	151, 376, 401, 470
SAP Predictive Analytics integrator	149, 157
SAP Predictive Engineering Insights	267, 294
SAP Predictive Maintenance and Service	267, 280, 283, 285, 294, 318, 434, 447, 451
<i>alerts</i>	307
<i>building blocks</i>	299
<i>classes</i>	301
<i>digital dashboard</i>	306
<i>documentation</i>	303
<i>equipment</i>	304
<i>groups</i>	305
<i>location</i>	305
<i>machine learning</i>	300, 309
<i>machine learning algorithms</i>	311
<i>master data</i>	305
<i>model</i>	302
<i>monitoring</i>	307
<i>notifications</i>	309
<i>predictions</i>	310
<i>spare parts</i>	305

SAP Product Lifecycle Costing	231
SAP Product Stewardships Network	232
SAP Profitability and Performance	
Management	148
SAP S/4HANA	35, 50, 56, 79, 130, 141, 390, 411, 413
<i>procurement</i>	428
SAP S/4HANA Asset Management	331
SAP S/4HANA Cloud	381, 413, 417, 418
SAP S/4HANA Cloud for intelligent product design	231, 237, 238, 242, 462
<i>collaboration</i>	239
<i>computability checks</i>	241
<i>document sharing</i>	240
<i>systems engineering</i>	241
SAP S/4HANA Cloud, single tenant edition	413
SAP S/4HANA embedded analytics	393
SAP S/4HANA Finance for group reporting	392, 394, 395, 396
SAP S/4HANA Manufacturing	331
SAP S/4HANA Manufacturing for planning and scheduling	291
SAP S/4HANA Supply Chain	331
SAP Smart Business	50
SAP SMS 365	452
SAP SuccessFactors	166, 423, 424, 471
<i>digital assistant</i>	167
<i>intelligent services</i>	420
SAP Tax Compliance	151
SAP Transportation Management	203, 331, 336, 338, 341
SAP Vora	214
SAP Warehouse Insights	346
SAP Web Analytics	52
SAP Web IDE	116, 241
SAP Yard Logistics	353
Semi-finished goods	284
Semi-private blockchain	64
Sensor data	268, 269, 276, 281
Sentiment media analysis	442
Service tickets	449
Shared documents	240
Shared economy	41
Shop floor navigation	280
Shopfloor dashboard	282
Short-term demand	251
Short-term forecasts	254
Smart alerts	150
Smart Assist	151
Smart buildings	498
Smart campaigns	438
Smart cities	476
Smart contracts	186
Smart factory	98, 277
<i>building blocks</i>	276
<i>characteristics</i>	278
<i>processes</i>	99
Smart home	68
Smart manufacturing	273, 274
<i>benefits</i>	275
Smart monitoring	67
Smart plants	449
Smart Predict	151
Smart Shop Floor tool	277, 292
<i>capabilities</i>	280
<i>control tower</i>	282
<i>floorplan</i>	285
<i>overview</i>	279
Solution architecture	405, 406
<i>golden principles</i>	408
Solution map	408, 409
Sourcing and procurement	427
Sourcing intelligence	429
Spare parts	298, 448
Spark	127
Spend analysis	430, 439
Static route plans	323
Statistical forecasts	250
Strategic sourcing	427
Structured data	56
Supervised machine learning	154
Supplier risk	430
Supplier risk management (SRM)	427
Supplier selection	432
Supply chain	260, 471
<i>stages</i>	261
<i>transparency</i>	462
<i>variability</i>	261
<i>visibility</i>	362
Supply networks	89
Support vector machines (SVM)	312
Systems of record	36

T	
Telematics	329
Three-way invoice matching	384
Time series analysis	246
Time series management	473
Time stamp service	192
Time-series chart	375
Transportation and logistics	66
Transportation Cockpit	331
Transportation logistics	322
Tree ensemble classifier (TEC)	312
Triplt	165
U	
Universal Journal	393
Unstructured data	56
Unsupervised machine learning	154
Usage-based billing	324
User experience (UX)	78, 109
<i>enterprise architecture</i>	406
<i>strategy</i>	78
User interface (UI)	78
V	
Vehicle diagnostics	327
Vehicle maintenance	328
Virtual fencing	329
VR technology	336
W	
Warehouse layout	348
Warehouse management	
<i>heat maps</i>	351
<i>live optimization</i>	353
Warehouse optimization	357
Waste minimization	460
Weibull algorithm	311
What-if scenarios	265
Workforce data	179
Workforce dynamics	45
Workplace innovation	43



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Pierre Erasmus is a specialist in the Internet of Things. He is an expert in SAP Leonardo supply chain and logistics technologies like network logistics, vehicle insights, and moving assets. He has led organizations in IoT go-to-market and SAP solution strategy.



Vivek Vinayak Rao is a consulting managing director and SAP digital transformation leader at Deloitte Consulting, LLP. He has extensive experience in developing IT optimization strategies, providing both advisory and implementation services. Vivek has over 18 years of global technology consulting experience and has presented on topics ranging from traditional SAP technologies to the latest trends such as SAP S/4HANA, cloud, and SAP Leonardo.



Amit Sinha is a leader in SAP supply chain practices at Deloitte Consulting, LLP. He has over 14 years of experience in supply chain planning and business transformation projects. He has worked extensively with different industry sectors across the globe in the areas of sales and operations planning, demand planning, supply planning, inventory optimization, and supply chain analytics. He is an expert in SAP IBP and other SAP supply chain applications.



Ganesh Wadawadigi is a chief demand insight expert for IoT and digital supply chain solutions at SAP, responsible for the global roll-out of solutions that help companies derive actionable insight from demand signals. He has over two decades of experience in the areas of supply chain management and manufacturing.

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