This sample chapter discusses SAP’s extension strategy for SAP S/4HANA, with coverage of both in-app extensibility and side-by-side extensibility. It also discusses SAP Cloud Platform, IoT, and SAP Leonardo’s machine learning capabilities in terms of extensions.

“Extending SAP S/4HANA”

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Chapter 12

Extending SAP S/4HANA

Customization underpins our world. Everyone has different techniques and preferences, and businesses are no different. The very first IT systems were specifically tailored to how businesses operated, at a high cost and risk. Later came out-of-the-box products to increase success and decrease costs and risk by using best practices to encourage businesses to adopt the standard processes and use customization for unique business processes.

Software as a service (SaaS) encourages best practices even more, providing robust functionality with less customization, which businesses are willing to sacrifice for agility, faster deployments, regular feature updates, and reduced costs. However, the inescapable truth is that customization can’t be removed fully from the technology that supports businesses. Because each business is different, there will always be some custom application code and software parameters configuration. Best practices may enable businesses to upgrade functionality with less prep time, effort, and risk, which is good for software companies that want happy clients, but businesses require technology to enable their uniqueness, too.

The answer to this dilemma lies in a computing concept that’s both logical and old; separate the application from the customization by creating extensions.

In the past, the customization and extension of SAP functionality focused mainly on ABAP application development as part of the SAP ERP solution. Later, Java application development was added with the introduction of SAP NetWeaver and service-oriented architecture to create a composition environment. Building in the runtime environments of SAP NetWeaver AS ABAP or SAP NetWeaver AS Java were the two methods to enhance the SAP ERP core.

With the move to cloud-based “X as a service” solutions, there’s a need for strong governance to maintain the solution and therefore restrict options to extend or customize
SAP S/4HANA. The same is true for other cloud-based line of business (LOB) solutions, such as SAP SuccessFactors, SAP Hybris Cloud for Customer, SAP Ariba, SAP Fieldglass, and Concur.

SAP’s approach for SAP S/4HANA is to keep a stable solution running the business and to use extensions to provide custom functionality without implications for maintenance. The previous methods and tools are still available for SAP S/4HANA, but the recommendation is to adopt the approach and tools available for SAP S/4HANA Cloud to prepare for the future and to leverage their benefits.

Separating all custom development into extensions is a fundamental business architecture and technology architecture decision with an impact on SAP S/4HANA design and implementation, and which will have an impact for the next decade or more. In the following sections, we’ll detail the various extension approaches.

12.1 Extensions for SAP

In the following subsections, we’ll begin with an overview of the two extensibility approaches available for SAP S/4HANA, then we’ll jump in to their specifics.

12.1.1 Overview

SAP has defined two approaches for going forward: in-app extensibility and side-by-side extensibility. These two approaches are illustrated in Figure 12.1.

In the in-app extensibility approach, customization occurs in the SAP S/4HANA ABAP backend, SAP HANA database, and cloud platform. These have been classified into two subtypes:

- Key user in-app extensibility, in which a key user (e.g., a super user or functional consultant) performs configuration changes via SAP Fiori–based tools to customize the SAP S/4HANA ABAP backend and SAPUI5/JavaScript SAP Fiori front end. As a key feature of SAP S/4HANA using SaaS principles, this option is available for all SAP S/4HANA editions.
- Classic in-app extensibility, in which developers have full access to the SAP S/4HANA ABAP backend, SAP HANA database backend, and SAPUI5/JavaScript SAP Fiori front end. This is a continuation of the customization available in previous SAP ERP suites and is only available for on-premise SAP S/4HANA.

In the side-by-side extensibility approach, customization occurs on an adjacent application layer. This approach uses the latest development advantages from cloud technologies and tools to create capabilities on an adjacent application layer with decoupled feature update timelines for parallel delivery. Using side-by-side extensions is the next method to provide the business with a value-add for SAP products. An overview of the differences between the two extensibility approaches and their use is provided in Figure 12.2.
The extensibility approaches available are different from what you may have experienced with SAP, as shown in Figure 12.3, which depicts extensibility approaches for SAP S/4HANA compared to SAP Business Suite (SAP ERP 6.0).

Figure 12.3 Extensibility Approaches for SAP Business Suite versus SAP S/4HANA

The key consideration when comparing in-app extensibility, which is very similar to the approach that's been used for many years, and the cloud computing–based side-by-side extensibility approach is the technologies introduced and therefore the impact on skills availability, best practices, and methodologies. The new approach considerations are discussed in Section 12.1.3.

Figure 12.4 summarizes the key technologies from both approaches for customization, and the following sections will discuss the approaches and their implications in detail.

12.1.2 In-App Extensibility

In the in-app extensibility approach, customization occurs in the SAP application. The following subsections briefly describe the additional knowledge required for SAP S/4HANA, as this approach uses the same methods and tools from past SAP ERP releases.

Key User In-App Extensibility

This approach provides SAP Fiori–based tools to customize SAP S/4HANA and is designed for smaller changes made directly to the application (SAP S/4HANA) or data (SAP HANA database) layer.

The approach is named the key user approach because it relies on a super user or functional consultant who has been empowered to perform these customization changes as part of the design. It’s a key provision of SAP S/4HANA and critical for the
public cloud edition; this feature has been adapted from the principles of other SaaS offerings in the marketplace.

The tools used for key user in-app extensibility in SAP S/4HANA are as follows:
- UI Adaptation Mode
- Custom Analytical Queries app
- Custom Catalog Extensions app
- Custom CDS View app
- Custom Communication Scenarios app
- Custom Fields and Logic app
- Custom Business Objects app
- Adobe Forms Designer and the Maintain Form Template app
- KPI Design app
- Manage Software Collection app
- Cloud ABAP Web Editor (high restrictions)

These SAP Fiori-based tools empower key users with the following tools and advantages:
- UI tools to customize the application simply and within restrictions
- Stable lifecycle due to restricted customizations removing regression impact after product upgrades
- Support for both on-premise and cloud deployment options

An example of a smaller change performed on an SAP Fiori app—the SAP S/4HANA Custom Fields and Logic app—is shown in Figure 12.5.

**Classic In-App Extensibility**
This approach provides preexisting tools for full access to customize all layers; examples of these tools include the ABAP Workbench, ABAP Development Tools (ADT) for Eclipse, and SAP HANA Studio, based on Eclipse.

This approach is called the classic approach because it follows the same principles used in previous SAP ERP suites. The provision is only available in on-premise SAP S/4HANA, and we recommend that this approach only be used with the whitelisted APIs for SAP S/4HANA to ensure greater governance and reduced requirements for regression testing during product upgrades.

**Whitelisted APIs for SAP S/4HANA In-App and Side-by-Side Extensions**
In-app extensions and side-by-side extensions can use the SAP-managed (and thereby regression-controlled) public model APIs for SAP S/4HANA. These APIs are designed for SAP S/4HANA Cloud but are available for on-premise SAP S/4HANA as well. The whitelisted APIs provide a wide variety of functionality, which provides greater governance of changes to the SAP S/4HANA application itself.

For SAP S/4HANA Cloud, this is the only method for in-app extensions and side-by-side extensions; it ensures stable lifecycle management and enables regular product upgrades on the public cloud.

The following types of APIs are available for in-app extensions:
- ABAP classes
- BAdIs for implementable code breakouts of business logic changes
- BAPIs and other function modules
- CDS views

Previously, SAP also defined managed in-app extensibility using the whitelisted APIs. This was a paid service for the enterprise edition of S/4HANA Cloud and has since been removed from documentation.

**12.1.3 Side-by-Side Extensibility**
In the side-by-side extensibility approach, customization occurs on an adjacent application layer. This approach is available for on-premise and cloud editions, using the latest development advantages from cloud technologies and tools to create extensions with development and update timelines decoupled from the SAP applications.
Therefore, side-by-side extensions can be built more quickly and released more frequently without impacting SAP S/4HANA, and these extensions provide the business with value-adds for SAP and early value realization. This approach often uses PaaS provisions, such as SAP Cloud Platform, which is detailed in Section 12.2.

The purpose of the side-by-side extension is to ensure the stability of the core solution while extending the solution. It’s the default option for SAP S/4HANA extension development and can provide the following, for example:

- Unique business processes (e.g., industry solution extensions)
- Specific front-office functionality for business-to-business (B2B)
- Specific front-office functionality for business-to-consumer (B2C)
- Specific back-office functionality
- Integrated custom or partner solutions for SAP S/4HANA
- Integrated open-source developments
- Integrated emerging technology services and solutions
- Integration with social networks
- Event streaming and triggering from IoT devices

Product upgrades and feature updates are the main benefits of this side-by-side extensibility approach; separate lifecycle management enables a stable SAP S/4HANA and stability in other SAP applications for LOBs to provide for business transactions and provide separate customization.

For example, SAP applications such as SAP S/4HANA or SAP Ariba can be upgraded separately from adjacent applications (e.g., a customized SAP Fiori-designed SAPUI5 application for a calendar view of deliveries). Therefore, business operations will continue to meet best practices, and the extensions will enable agility in the business to adapt rapidly to new requirements, market changes, and new technologies.

The side-by-side extensions are usually SAP Fiori-designed, SAPUI5-based server-side applications and are primarily run on a PaaS model; the PaaS offerings can be from different cloud providers and use different services. Businesses are increasingly adopting PaaS as a strategy for agile application development, with PaaS providing centralized and usage-based application hosting that’s scalable and highly technology flexible. The hybrid cloud model, using best-of-breed services, solutions, applications, and “as a service” applications, has wide-ranging architectural implications for the technology landscape.

Critically, the side-by-side extensions should always be delivered through agile application development. When building within a cloud environment, it’s necessary to leverage the best-in-class tools available for automating build, test, and release, as well as open-source frameworks for building the applications; this comes with risks, as we’ll discuss in the following subsections. This approach requires agile methodologies to be used in delivery and a DevOps culture to be instilled in the business and developers. The various scenarios for side-by-side extensions are as follows and are shown in Figure 12.6:

- Scenario S1 is an extension of the frontend server with a custom UI consuming existing OData services.
- Scenario S2 demonstrates the possibility of extending the existing UI via SAP Cloud Platform by calling an existing OData service.
- Scenario S3 has no change in SAP S/4HANA while you build a new data structure, business logic, and OData service with a new UI to develop a complete new solution that extends SAP S/4HANA.
- Scenario S4 shows data replication for analytics on SAP Cloud Platform.
- Scenario S5 is based on a new SAP S/4HANA OData service that is being consumed by a new custom UI on SAP Cloud Platform.
- Scenario S6 shows that SAP S/4HANA is consuming an SAP Cloud Platform service.

![Figure 12.6 Side-by-Side Extension Scenarios](image-url)
To complete the picture, Table 12.1 provides an overview of the programming models, development tools, and SAP S/4HANA APIs available for the different extensibility options.

<table>
<thead>
<tr>
<th>Extension Type</th>
<th>On-Premise or Cloud</th>
<th>Programming Model</th>
<th>Development Tools</th>
<th>SAP S/4HANA APIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side-by-side extensibility with SAP Cloud Platform</td>
<td>Both</td>
<td>SAP Fiori</td>
<td>SAP Web IDE</td>
<td>Remote APIs: web services (OData)</td>
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<tr>
<td></td>
<td></td>
<td>Other web techniques</td>
<td>Related IDEs</td>
<td></td>
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<td></td>
<td></td>
<td>Java</td>
<td>Eclipse</td>
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<td></td>
<td></td>
<td>JavaScript</td>
<td>SAP HANA Studio</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SAP HANA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-app extensibility</td>
<td>Key user</td>
<td>SAP Fiori flexibility</td>
<td>SAP Fiori UX</td>
<td>Public local APIs: CDS views, ABAP class APIs, etc. (restricted key user scope)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Custom fields, logic,</td>
<td>adaption mode</td>
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<td>reports, and so on</td>
<td>SAP Fiori key</td>
<td></td>
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<td></td>
<td></td>
<td>SAP HANA new/ extended CDS</td>
<td>user tools</td>
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<td></td>
<td></td>
<td>views</td>
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</tr>
<tr>
<td>Managed</td>
<td>Both</td>
<td>SAP Fiori</td>
<td>SAP Web IDE</td>
<td>Public local APIs: CDS views, ABAP class APIs, etc. (restricted scope)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ABAP web techniques</td>
<td>Eclipse</td>
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<tr>
<td></td>
<td></td>
<td>(restricted)</td>
<td>ABAP</td>
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<tr>
<td></td>
<td></td>
<td>ABAP (restricted)</td>
<td>Workbench</td>
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<td></td>
<td>SAP HANA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classic</td>
<td>On-premise only</td>
<td>SAP Fiori</td>
<td>SAP Web IDE</td>
<td>Recommended: public local APIs: CDS views, ABAP class APIs, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other ABAP UI techniques</td>
<td>Eclipse</td>
<td></td>
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<td>ABAP</td>
<td>ABAP</td>
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<td></td>
<td></td>
<td>SAP HANA</td>
<td>Workbench</td>
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<td></td>
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<td></td>
<td>No technical restrictions</td>
</tr>
</tbody>
</table>

Table 12.1 Programming Models, Tools, and APIs for SAP S/4HANA Extensions

The side-by-side extensibility approach is recommended for most cases going forward. This approach provides the following benefits:

- Adjacent application layer hosting extensions creates a decoupled feature update timeline for SAP applications and enables parallel lifecycles of application development; reduced or no reliance on deployment windows and cutovers.
- Uses the latest development advantages from cloud technologies and toolsets, including a move to continuous integration, delivery, or deployment.
- Far wider choice and flexibility when selecting the right programming languages, frameworks, and run times from open-source options that are the best of breed for the intended use case; in addition, enables faster leverage of emerging technologies as new services are released from cloud providers.
- Retains SAP S/4HANA and other SAP applications running near best practices, with significantly reduced regression impact, enabling faster innovation cycles from SAP product updates.
- Cost efficiencies from cloud providers when running extensions using microservices (or, soon, serverless) runtime architecture.

However, when compared to development of in-app extensions, the development of side-by-side extensions requires a lot of initial effort, including cultural changes (which will be challenging for SAP ERP process-embedded developers and IT operations), such as the following:

- Redesign of architecture to encompass microservices (or, soon, serverless) options.
- New interfaces.
- New development processes and best practices to be instilled, including a path to production changes (such as continuous integration, delivery, or deployment). For example, there’s a significant adjustment for build management, moving away from cherry-picking transports that move object version updates to environments and toward continuous code delivery environment updates based on updates to GitHub source control that trigger task runners.
- New project deliveries and prioritizations (i.e., agile methodologies) with associated mentality changes (developers work with key/end users).
- New developer and operations teams instilled with new way of working (developers work with operations and automate what they can to reduce burden/workload overall—as with DevOps).
12.2 SAP Cloud Platform

SAP Cloud Platform, the rebranding of SAP HANA Cloud Platform, is a PaaS offering that provides various solutions and services to leverage in application development. As shown in Figure 12.7, SAP Cloud Platform is to be the glue between SAP applications on-premise, application in the SaaS model, and all extensions.

![SAP Cloud Platform Overview](Figure 12.7 SAP Cloud Platform Overview)

SAP is positioning SAP Cloud Platform as a unified PaaS by keeping already developed solutions and services in its “Neo” ecosystem but, going forward, using only Cloud Foundry and leveraging established best-of-breed cloud providers such as Amazon Web Services and Microsoft Azure. By leveraging Cloud Foundry, SAP ensures that it can easily bind/use any services and solutions provided by other PaaS offerings with Cloud Foundry, such as IBM Bluemix, Google Cloud Platform, Pivotal Web Services, Swisscom Application Cloud, or other cloud providers, including Oracle Cloud, Force.com App Cloud, and others.

SAP has built SAP Leonardo solutions and services on top of SAP Cloud Platform (a strategy used by all other cloud providers). SAP has seated application development on SAP Cloud Platform for the side-by-side extensions next to the SAP Leonardo Digital Innovation System solutions and services, thereby providing extensions within easy reach of emerging technologies such as services for machine learning, IoT, blockchain, and mobile—all of which are high on businesses strategic imperatives and watchlists.

According to the new official definition, SAP Cloud Platform is now the key strategic PaaS infrastructure that provides the foundation for SAP Leonardo and end-to-end microservices for machine learning, analytics, big data, security, UX, user management, and backend integration services to optimize IT landscapes, drive agility, and accelerate digital transformation. With numerous possibilities and a large scope of innovation, the possible use cases for SAP Cloud Platform center on three main areas (see Figure 12.8):

1. **Building brand-new cloud applications**

   The main idea here is to leverage SAP HANA capabilities for, for example, advanced analytics and IoT to build enterprise collaboration solutions (e.g., connect SAP JAM or use SAP JAM predefined UI widgets or REST/OData APIs) to add social capabilities into applications and business processes and connect users, information, and processes.

2. **Extending cloud and on-premise solutions**

   Protecting existing investments into on-premise solutions while at the same time taking advantage of new technologies and recent innovations is the key demand of any client. The extension is focused mainly on extending cloud solutions (SAP Hybris Cloud for Customer, SAP S/4HANA Cloud, SAP SuccessFactors, Concur, SAP Fieldglass, SAP Business ByDesign, and other products in the roadmap) and on-premise solutions (SAP and non-SAP, including SAP Business Suite and on-premise SAP S/4HANA). The other key aspects of extension include innovative UX using SAP Fiori apps and mobile-enabled solutions developed on top of SAP Cloud Platform Mobile Services. It also helps you to take advantage of standard SaaS offerings to differentiate your business from the competition by building or enabling unique processes. It’s a seamless integration with the same look and feel as in the core application, but it’s built as a side-by-side scenario.

3. **Integrating applications and data**

   By taking advantage of integration technologies on SAP Cloud Platform, your business processes and data can be harmonized in a very secure and reliable environment. Also, provisions to commercialize integration content (prepackaged), adapters for integration with cloud- or on-premise SAP applications, and third-party applications provide an edge.
SAP Cloud Platform has evolved over the years into a comprehensive PaaS offering capable of simplifying the development and operation of new cloud applications and building extensions for existing SAP solutions, both on-premise and in the SaaS model. This has now turned into a designated extension, integration, and, most importantly, digital innovation platform for SAP’s entire portfolio and forms the technical foundation for a whole set of new applications and products evolving around machine learning and IoT. Also, support for Cloud Foundry and OpenStack as the technologies for deployment and management simplifies deployment of business applications built with or on top of SAP Cloud Platform, including adding flexibility to select the data center of your choice and generating greater business value at a lower development and ownership cost while leveraging a multitude of innovations, such as bring your own language (BYOL). Overall, SAP Cloud Platform in combination with Cloud Foundry services and new SAP Leonardo services offers choice, flexibility, and enterprise-grade innovation.

In addition to providing a wide variety of services, SAP Cloud Platform with the Cloud Foundry environment enables developers to develop extensions or new solutions with different programming languages, runtimes, and frameworks, including the following:

- Java
- XSJS
- Ruby

- Node.js (with the Node.js package)
- HTML5
- SAPUI5 (now with more ready-to-use templates)
- Python (with library support for data manipulation, machine learning, and analysis)
- BYOL (bring your own language and runtime of choice)

With enhanced IDEs and new toolkits, you now have more power and can use less effort to build new applications or extend your existing applications. Some of your options are as follows:

- **SAP Web IDE**
  The newly improved SAP Web IDE now includes support for HTML5, SAPUI5 (with drag-and-drop controls on canvas), JavaScript, Node.js, Java (deploy only), and SAP HANA design artifacts (SQLScript and CDS, along with the calculation view modeler), with a rich, integrated Git client, including a history of committed changes, cherry picking, comparing commits, and so on.

- **SAP HANA Web-Based Development Workbench**
  SAP HANA Web-Based Development Workbench is a browser-based IDE for creating, editing, and debugging SAP HANA objects that can be used in place of SAP HANA Studio.

- **SAP IoT Application Enablement Toolkit plug-in**
  The SAP IoT Application Enablement Toolkit inside SAP Cloud Platform Web IDE supports rapid development of IoT applications through a wizard-based approach; no coding is necessary for this.

- **Hybrid Application Toolkit plug-in**
  The Hybrid Application Toolkit inside SAP Cloud Platform Web IDE supports quick development of Apache Cordova hybrid apps, with the support of templates, including live preview on a device emulator or a mobile device.

- **SAP Build**
  SAP Build is an open-source design tool that allows you to collaborate and develop prototypes based on design-thinking principles and understand the designing process. The tool also includes provisions to capture user feedback, and you can jumpstart designing by choosing one of the prototype examples from the gallery.
12.3 Internet of Things and Cognitive Analytics

IoT services are designed to facilitate and support the implementation of IoT applications. These services provide interfaces for registering devices and their specific data types, sending data to and storing data in a database running on SAP Cloud Platform, and providing easy access to the data stored. They support replication to and synchronization with remote databases into a consolidated SAP HANA database in the cloud. For example, you can consolidate sensor data from a remote database and build an analytical application on top for analytics and monitoring. In the context of IoT, SAP Cloud Platform provides capabilities to process high-volume data from any kind of machine, device, or sensor and then combine this information with the transactional data from the system of record or with additional information from social media, for example. The following are key features of IoT services:

- **Text analysis**
  Extract and process unstructured text data from various files with support for up to 31 languages. This allows you to identify a sentiment on seven different levels (e.g., strong positive, minor problem, etc.) in a tweet and analyze social media data. This is done by using language-based, full-text search text indexing and fuzzy search.

- **Geospatial processing**
  Store, process, manipulate, share, and retrieve spatial data by using SAP HANA.

- **Operational intelligence**
  Manage operational risk with end-to-end process visibility and better analytics supported by decision support and real-time insights.

- **Series data processing**
  Measure data and forecast trends (e.g., utilities and smart metering) with native series data storage and high-volume processing.

- **Graph engine modeling**
  Discover, manage, and analyze complex relationships for proximity- and location-based analytics.

- **Multitenant architecture**
  Logically isolate databases while sharing underlying system resources to optimize efficiency.

To extend IoT to manage and process IoT data, a set of services is available via SAP Cloud Platform to provide full control over your IoT lifecycle:

- **Remote device management**
  Manage devices from onboarding to decommissioning. Receive device information, configure devices remotely, and send commands to devices.

- **Message management services**
  Support various transport protocols and messaging formats to send, receive, and store IoT data in the persistence layer of SAP Cloud Platform.

- **Application enablement**
  Apply functionalities for remote device management and message management in your applications through APIs.

SAP Cloud Platform also can be leveraged to build cognitive solutions in multiple ways. All types of data can be leveraged using the SAP Cloud Platform IoT service to connect devices and sense the world or by performing text analysis using the built-in SAP HANA text analytics functionality. Of course, all other methods of analyzing business data using SAP HANA are also available. Although no computer vision service is yet available, SAP Cloud Platform makes it easy to tap into the API economy and leverage its connectivity service to integrate with, for example, IBM’s Watson Developer Cloud to identify objects within an image.

Forming hypotheses isn’t supported out of the box in SAP Cloud Platform. However, SAP HANA offers the powerful Predictive Analytics Library, which the developer can use to build models for testing hypotheses and training the cognitive solution. These models can be layered; for example, an SAP Cloud Platform solution might evaluate a hypothesis in a health care scenario, such as “Patient condition is worsening,” based on an IoT stream of medical devices that signal an increase in temperature combined with textual analysis of the diagnosis. The solution then correlates that information with its medical knowledge to determine that temperature is a critical factor in the condition diagnosed.

Because SAP Cloud Platform is an ideal single place to gather data, it’s easy to have solutions continually learn from new data fed into retraining the hypothesis model. SAP Cloud Platform makes it easy to develop SAP Fiori apps that allow users to give feedback on the recommendations and support they received from their cognitive solutions. The cognitive solution on SAP Cloud Platform can then periodically retrain itself.

The wide range of IoT services on SAP Cloud Platform lets you securely onboard devices over an extensive variety of protocols with full flexibility to process IoT data and derive relevant data either at the edge of the network or on SAP Cloud Platform.
Additional services on SAP Cloud Platform enable you to feed the relevant data into IoT applications, including real-time IoT analytics. SAP Leonardo on SAP Cloud Platform is the latest “digital transformation system” from SAP to enable IoT.

### 12.4 SAP Leonardo and Machine Learning

SAP recently acquired the Plat.One IoT platform and launched SAP Leonardo, which embraces different technology components such as design thinking, machine learning, big data, IoT, data intelligence, Blockchain, and analytics to make machines smarter and drive the end-to-end digital transformation across enterprises. SAP Cloud Platform as the strategic PaaS infrastructure provides the underlying framework for the SAP Leonardo foundation.

**Figure 12.9 SAP Leonardo Innovation Portfolio**

SAP Leonardo, as the innovation portfolio for IoT, is most relevant in the context of developing a side-by-side SAP S/4HANA IoT extension using SAP Cloud Platform and is well-structured to enable the Internet of Everything. SAP Leonardo includes the following components:

- **SAP Leonardo IoT Edge**
  SAP Leonardo IoT Edge acts as an IoT gateway to collect data irrespective of connectivity, latency, or device protocol concerns.

- **SAP Leonardo IoT Foundation**
  SAP Leonardo IoT Foundation is at the center of the SAP Leonardo IoT portfolio. It’s a combination of business services to build IoT solutions rapidly by creating digital twins, reusable application services, and applying predictive algorithms; and core technical services to perform stream analytics and run predictive scenarios. These new services run on the Cloud Foundry stack on SAP Cloud Platform. SAP Leonardo IoT Foundation technical services available on SAP Cloud Platform provide developers with efficient capabilities for a wide range of protocol support, including conversion, device management, scalable messaging, streaming analytics, big data connectors, integration services, user management, security, and IoT application enablement services.

Machine learning has been around for many years. With recent advances in cloud computing, there has been significant movement in the past decade, starting with IBM Watson and the explosion of machine-learning services since the start of 2016. SAP Leonardo Machine Learning Foundation basically provides two different categories of machine-learning services including business and functional services that cover a wide range of capabilities to understand the content and meaning of a variety of data types, such as image, video, audio and speech, tabular and time-series, natural language data, and so on. The underlying technology of these machine learning APIs is based on Google’s TensorFlow machine intelligence framework.

The new SAP Leonardo machine-learning services can add new dimensions and unseen analytics to any side-by-side extensibility of SAP S/4HANA on SAP Cloud Platform.

The SAP Leonardo machine-learning business services are meant for comprehensive tasks—for example, smartly classifying and processing an incoming ticket for a support center, routing it to the most appropriate agent, and suggesting possible solutions, thus reducing repetitive manual tasks and shortening the time to resolution. Available services include the following:

- The SAP Intelligent Financing API can be used to analyze the financial health score of a user based on historical activities.
- SAP Service Ticket Intelligence—Classification can be used to classify the type of ticket, especially at customer support centers.
SAP Service Ticket Intelligence—Recommendation can be used to recommend possible solutions for customer support tickets, especially at customer support centers.

The SAP Leonardo machine learning functional services run on pretrained models and are more useful for image classification, topic detection, product image classification, time-series changepoint detection, language detection, similarity scoring, and so on. In side-by-side extensibility of SAP S/4HANA on SAP Cloud Platform, using these kinds of functional services can help businesses make decisions more intuitively, and these services run on a self-learning model. Available services include the following:

- Document Feature Extraction API, to extract feature vectors from a document and use them for comparison or clustering.
- Image Classification API, to return classifications for a given image, including probability for correct classification.
- Image Feature Extraction API, to extract feature vectors for a given image for comparison.
- Language Detection API, to detect language for a given text.
- Product Image Classification API, to classify a given image based on preset categories.
- Product Text Classification API, to classify products into specific categories based on product descriptions.
- Similarity Scoring API, to compare vectors extracted through Image Feature Extraction or Document Feature Extraction to find similarity between images or documents.
- Time-Series Changepoint Detection API, to return the probability of a changepoint for each data point in time-series data.
- Time Series Forecast API, to predict the next data points for the given time-series data.
- Topic Detection API, to extracts and return the score for the most relevant topic in a document.
- Translation API, to translate a given string from one language to another.

These machine-learning services are available as RESTful APIs and exposed through SAP API Business Hub (see Figure 12.10). Therefore, while developing an extension or new application on SAP Cloud Platform, you can add machine-learning dimensions to your solution via these RESTful APIs.
A possible side-by-side SAP S/4HANA IoT extension on SAP Cloud Platform can include IoT and machine learning along with other extension components by using SAP Leonardo IoT Foundation; the possible architecture of such an extension will look like that shown in Figure 12.12.

This kind of extension will help you onboard and manage your sensors and the data coming from them. You will be able to access the SAP Cloud Platform Cockpit to perform the following activities:

- Replicate on-premise data to SAP Cloud Platform using SAP Cloud Connector through destination configuration.
- Set up IoT message types and device types and register sensor devices.
- Bind IoT services to SAP HANA.
- Create HTTP destinations for IoT services and SAP HANA data services.
- Set up HTTP destinations to access machine-learning services.
- Consume on-premise data from SAP HANA databases on SAP Cloud Platform.
- Apply appropriate SAP Leonardo machine-learning REST-based services from SAP Cloud Platform API Business Hub to add intelligence on top of regular business logic.
- Develop UI extensions with SAPUI5 using SAP Web IDE to display the necessary business data.
- Integrate your extension into SAP Fiori launchpad.

12.5 Summary

In this chapter, we discussed the extension possibilities for future SAP solutions and covered how SAP S/4HANA can be extended via in-app and side-by-side extensions. We also took a detailed look at the strategy and purpose of both extension possibilities. We outlined possible side-by-side scenarios to illustrate the different options available via SAP Cloud Platform, including SAP Leonardo on SAP Cloud Platform, which is the latest digital transformation system from SAP and which supports IoT and machine learning. Finally, we took a quick look at SAP Leonardo.
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