Information architecture to support technical education training for Industry 4.0

Authors:
Vitaly Martynov
Elena Filosova
Alena Zaytseva
Ufa state aviation technical university

Speacker’s
Vitaly Martynov,
Elena Filosova
USATU
Industry 4.0 is defined as "a concept used to describe related technological advances that provide a Foundation for increasing the level of digitization of industrial and business environments".
Information architecture to support technical education training for Industry 4.0

Industry 4.0 core technologies

**Industrial Internet of Things (IIoT)** and the Internet of Everything (IoE). IoT is the global infrastructure for the information society, providing the interconnection (physical and virtual) of things based on existing and developing ways of information and communication technologies.

**Cloud computing.** Many companies already use software and analysis systems based on cloud platforms. Industry 4.0 expects an increase in data flows that go beyond a single company.
Industry 4.0 core technologies

CPS-platforms are designed to support enterprise processes and networks by connecting them in order to ensure reliable communication between employees, facilities and systems.

Big Data. In the production process, all the information collected in the physical space in the form of Big Data is sent to cyberspace, where it is structured, analyzed and used. The main task for enterprises here is to optimally interpret the data for the future use.
Information architecture to support technical education training for Industry 4.0

Основные технологии Индустрии 4.0

**Artificial Intelligence (AI).** This technology involves the use of artificial intelligence methods in all areas of human activity - in business, in public administration and even in private life, which makes it possible to create large systems based on the cybernetic approach.

- **Additive technologies** (3D printing);
- **Collaborative robots** - Collaborative Robot (CoBot);
- **Virtual reality** and others.
Information architecture to support technical education training for Industry 4.0

Formation of the enterprise information architecture

<table>
<thead>
<tr>
<th>Planner’s View</th>
<th>Owner’s View</th>
<th>Designer’s View</th>
<th>Builder’s View</th>
<th>Subcontractor’s View</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Things Important to Business</td>
<td>List of Processes the Business Performs</td>
<td>List of Locations Important to Business</td>
<td>List of Organizations Important to Business</td>
<td>List of Events Significant to Business</td>
</tr>
<tr>
<td>Entity=Class of Business Thing</td>
<td>Function=Class of Business Process</td>
<td>Node=Major Business Location</td>
<td>Agent=Major Org Unit</td>
<td>Time=Major Business Event</td>
</tr>
<tr>
<td>Data Function Network People Time Motivation</td>
<td>List of Business Goals/Strategies</td>
<td>End/Means=Major Business Goal/CSF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Methodologies for describing enterprise architecture:
- Zachman Framework,
- TOGAF (The Open Group Architecture Framework),
- DoDAF (Department of Defense Architecture Framework) etc.
Problems of formation of enterprise architecture

• the architecture of large-scale systems is functionally complex, design takes a long time (years), and it is difficult to evaluate due to changing requirements, complex business processes, a large number of distributed systems, emerging new technologies and business paradigms;

• low formalization of methods for planning the transition from the current state of the AP to the target, methods for developing the overall structure of the system, ways to organize the relationship between its elements and the external environment;

• the challenge of designing and evaluating architecture for very large systems is the lack of a complete set of concepts, consistent modeling tools, and established design principles;

• existing reference models for AP consist of several views (mostly text and graphics) and models that are often integrated into only one group, although in fact full integration has not been achieved. For example, business processes and system requirements are still difficult to combine.
IN Variant Aspects in the Architecture Description

- Business processes
- Business system
- Applications
- Data
- Technologies
Information architecture to support technical education training for Industry 4.0

Business Process Architectural View

\[ Q_B = \ln \left[ (X_1 X_2 (X_3)^2) \right] \]

\[ M_B = 1 - e^{\frac{-1}{R_B Q_B}} \]

- **\( X_1 \)**: Number of business processes per business organization
- **\( X_2 \)**: Average number of activities per business process
- **\( X_3 \)**: Number of business organizations
Business Systems Architectural View

\[
Q_S = \ln \left[ (Y_1)^2 Y_2 Y_3 Y_4 (Y_5)^2 Y_6 Y_7 Y_8 \right]
\]

\[
M_S = 1 - e^{\frac{-Q_S}{R_S}}
\]

\(Y_1\): Number of levels of decomposition in the hierarchical tree of business systems;
\(Y_2\): Number of business systems at Level 1;
\(Y_3\): Number of business systems at Level 2;
\(Y_4\): Number of business systems at Level 3;
\(Y_5\): Number of interface types;
\(Y_6\): Number of interfaces at Level 1;
\(Y_7\): Number of interfaces at Level 2;
\(Y_8\): Number of interfaces at Level 3;
Information architecture to support technical education training for Industry 4.0

Data Architectural View

\[ Q_D = \ln \left( \frac{D_1 D_2 (D_3)^2}{D_4} \right) \]

\[ M_D = 1 - e^{-\frac{Q_D}{R_D}} \]

- **D_1**: No. of Tables (i.e., entities)
- **D_2**: No. of Data Elements (i.e., fields)
- **D_3**: Relationship Types among Tables
Information architecture to support technical education training for Industry 4.0

Applications Architectural View

\[ Q_A = \ln \left[ A_1 A_2 A_3 A_4 A_5 A_6 \right] \]

\[ M_A = 1 - e^{-\frac{1}{R_A} Q_A} \]

- \( A_1 \): Number of Applications that manage data
- \( A_2 \): Number of Applications that support operational business systems
- \( A_3 \): Number of Applications that support strategic business systems
- \( A_4 \): Number of APIs to common services
- \( A_5 \): Number of lines of CUSTOM code (in thousands)
- \( A_6 \): Number of lines of COTS code (in thousands)
Technology Architectural View

\[ Q_T = \ln\left( \frac{T_1 T_2 T_3 T_4 T_5 T_6 T_8}{T_7} \right)^K \]

\[ MT = 1.0 - e^{-\frac{Q_T}{R_T}} \]

\begin{align*}
T_1 &: \text{No. of Class 1 Platforms} \\
T_2 &: \text{No. of Class 2 Platforms} \\
T_3 &: \text{No. of Routers} \\
T_4 &: \text{No. of MIPS/CPUs} \\
T_5 &: \text{MBs of RAM} \\
T_6 &: \text{GB of Disk Space} \\
T_7 &: \text{Network Number of I/O Ports} \\
T_8 &: \text{Network Data Rate, in million bits per second (Mbps)}
\end{align*}
Information architecture to support technical education training for Industry 4.0

EA mathematical model

\[ EA = \{R, B, S, D, A, T, C, M\} \]

gде
\[ R = (r_1, r_2, r_3, \ldots, r_n) \] – a set of system requirements;
\[ B = (b_1, b_2, b_3, \ldots, b_p) \] – a set of business processes;
\[ S = (s_1, s_2, s_3, \ldots, s_q) \] – a set of business systems in the architectural representation of business systems;
\[ D = (d_1, d_2, d_3, \ldots, d_g) \] – this is a set of data elements in the architectural form of data;
\[ A = (a_1, a_2, a_3, \ldots, a_k) \] – this is a set of applications in the architectural view of applications;
\[ T = (t_1, t_2, t_3, \ldots, t_w) \] – this is a set of technologies in a technological architectural representation;
\[ C = (c_1, c_2, c_3, \ldots, c_h) \] – a set of resource restrictions, metadata, and business rules;
\[ M = (m_1, m_2, m_3, \ldots, m_p) \] – this is a set of AP metrics that characterize the enterprise architecture.
Information architecture to support technical education training for Industry 4.0

**INFORMATION TECHNOLOGIES TO SUPPORT ENGINEERING TRAINING FOR INDUSTRY 4.0**

**Digital Thread** - data collection and analysis must take place in real time, with instant results, and systems must be able to make their own decisions.

**Digital Twin** - should enable the conversion of disparate data elements by linking with virtual simulations into specific solutions and results.

The **Cyber Physical System** should not only provide the ability to communicate via the Internet of things, but also quickly adapt to changing requirements by replacing or expanding individual modules.
Task: forming a thesaurus of the subject area, building and using a mechanism for determining the necessary competencies.

Solution: building an ontology of a specific subject area in order to model the object under study in the form of a formalism.
Information architecture to support technical education training for Industry 4.0
For this it is necessary to solve the following tasks:

- to describe the business processes of the educational institution.
- to develop an architectural representation for business systems and applications.
- to evaluate existing technologies and to make the transition to new, defining Industry 4.0.

Initially, each of several architectural design representations refers to a subset of design variables. As the design of the CAPM becomes more specific (conceptual, logical, then physical layers), several architectural representations should support and reinforce each other.
Information architecture to support technical education training for Industry 4.0

Adaptive EA cycle

Model «Adaptive Integrated Digital Architecture Framework - AIDAF»
Thank you for attention!

Speaker’s contacts:

Vitaly Martynov, vvmartynov@bk.ru
Elena Filosova, filosova@yandex.ru
USATU