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SPIIRAS’ Location
Speaker

Alexander V. Smirnov, Professor, Dr. habil., PhD

- **Head of Computer-Aided Integrated Systems Laboratory, SPIIRAS** (1996); from July 2020 is a part of SPC RAS

- **Head of International Laboratory on Intelligent Technologies for Socio-Cyber-Physical Systems, ITMO University** (2014), and Founder of Joint Master Program on Business Informatics between ITMO University and Rostock University (Germany).

- **Member:**
  - IEEE SMC TC on Cyber-Physical Cloud Systems,
  - IEEE SMC TC on Cognitive Situation Management,
  - IFAC TC 5.1 on Manufacturing Plant Control,
  - IFIP TC WG5.1 on Global Product Development for the Whole Life-Cycle.

- **Fellow of the European Academy on Industrial Management.**
Prof. Smirnov’ Team Current Research Projects in the Area of Digital Business: Main Directions

- **Information & Knowledge Management** (projects of Festo, Germany; Ford Motor Company, USA; Russian Ministry of Science & Higher Education; Russian Science Foundation; Russian Foundation for Basic Research):
  - Context-Aware Knowledge Management;
  - Ontological Modelling of Socio-Cyber-Physical Systems;
  - Infomobility;

- **Decision Support** (projects of Russian Science Foundation; Russian Foundation for Basic Research; Russian Academy of Sciences):
  - Decision Support Models & Methods Based on Human-Machine Collective Intelligence and Human-Computer Cloud;
  - Proactive & Context-Aware Recommendation Systems.

- **Human-Al-Robot Teaming** (projects of Russian Foundation for Basic Research; Russian Academy of Sciences; Festo):
  - Context-Driven Robot Coalition Formation and Control;
  - Customer-Oriented Robot Configuration.
Presentation Outline

- Introduction

- Knowledge Management (in Industrial Automation):
  - Trend 1 “Role-Based Organization”
  - Trend 2 “Dynamic Motivation”
  - Trend 3 “Multi-Aspect Ontology”

- Human-Machine Collective Intelligence

- Conclusion and Future Work
Modern Operating Model for Digitalization

Streamline processes and minimize waste
Lean process redesign

Digitize customer experience and day-to-day operations
Digitization

Drive the next wave of process outsourcing/offshoring
Business process outsourcing

Introduce intelligent automation to replace human tasks
Intelligent process automation

Provide intelligence to facilitate decisions
Advanced analytics

Digital Business

Digital business is the creation of new business designs by blurring the digital and physical worlds. Digital business promises to usher in an unprecedented convergence of people, business, and things that disrupts existing business models.

Source: http://www.gartner.com/digital-business

Digital business is built on new computing infrastructure – the pillars of mobile, cloud, Big Data, and analytics – accelerated by the Internet of Things (IoT), advances in machine learning & AI, and innovations like blockchain.

Cyber-Physical and Socio-Cyber-Physical Systems

- **People (decision makers)**
- **Networks (interrelated objects and services)**
- **Real-world objects (cars, electronic devices, etc.)**
- **Human behavior aspects**
- **Self-configuration of resources and service networks**
- **Digitalization and intellectualization**
Network-Wise Modern Socio-Cyber-Physical Systems: Networks & Supported ITs

- Social networks: who knows whom => Virtual Communities;
- Knowledge networks: who knows what => Human & Knowledge Management;
- Information networks: who informs what => Internet/Intranet/Extranet/Cloud;
- Work networks: who works where => Decision Support based on Crowdsourcing and Recommendation Systems;
- Competency networks: what is where => Knowledge Map;
- Inter-organizational network: organizational linkages => Semantic-Driven Interoperability.
Cognitive Manufacturing / Industry 4.0

Cognitive manufacturing—also known as smart manufacturing or Industry 4.0 - uses cognitive computing, the Industrial IoT, and advanced analytics to optimize manufacturing processes in ways that were not previously possible.

Cognitive manufacturing is powerful because it combines sensor-based information with machine learning and other artificial intelligence capabilities to find patterns in structured and unstructured data from plant, enterprise and industry systems.

Key Issues Cognitive Technologies Address for Manufacturers:
- Solving business challenges;
- Creating new value from manufacturing data;
- Improving product quality;
- Enhancing knowledge management.

Source: Cognitive Manufacturing: An Overview and Four Applications that are Transforming Manufacturing Today (https://www.ibm.com/downloads/cas/VDNKMWM6)
Industrial Intelligence

- **Industry 4.0 = Industry 4.0 Technologies** (IoT, blockchain, etc.) + Industrial Intelligence.
- **Industrial intelligence is the alliance of artificial intelligence with automation** and energy technology, IT platforms and intralogistics.
  - Industrial intelligence can only play its part in **driving the digital transformation** if people have the requisite qualifications to combine all these aspects in a useful way and develop them further. It is crucial that experts from a huge range of fields collaborate much more closely than in the past.
- **Industrial intelligence stands on two pillars:**
  - technology,
  - knowledge management (based on qualifications and process expertise of people).

Source: "INDUSTRIAL INTELLIGENCE" - THE NEXT BIG STEP (https://vdmaimpulse.org/article/-/article/render/210089)
Facts about Knowledge Management (1/3)

- “A traditional knowledge management (KM) project was usually a centralized effort to organize resources and content via taxonomies, cumber some e-forms and repositories, and complex review processes. It missed the point that knowledge resides with people and, especially in complex situations, is difficult to access and use without collaboration and context.”
  

- Many KM leaders agree that a successful KM implementation is 20% technology and 80% people, and includes management, incentives, culture, and communication.

Facts about Knowledge Management (2/3)

- **Knowledge sharing** can be defined as the “exchange of knowledge between and among individuals, and within and among teams, organizational units, and organizations”. Source: Schwartz D., Encyclopedia of Knowledge Management, 2006.

- Consider that **70-90% of corporate knowledge is informal** (“any unwritten information that is known within an organization unit but often unknown outside of it”), with the vast majority occurring within local workgroups and never shared across multiple inter-related functions.

- **Knowledge workers spend 15 - 30% of their time seeking specific information and these searches are successful less than 50% of the time.** Source: Harnessing Your Tribal Knowledge: Creating a more productive organization through systematic knowledge capture and dissemination. http://www.informationweek.com/whitepaper/Business-Intelligence/Knowledge-Management/harnessing-your-tribal-knowledg-wp1260312372749
Facts about Knowledge Management (3/3)

- Less than 10% of the knowledge you need to do your job is in your head. The other 90% is in other peoples’ heads. A KM framework that features **social technologies** gives us a tool by which to access the information that only resides in someone else’s brain or memory.


- According to the McKinsey Global Institute, by **using social technologies**, companies can raise the productivity of knowledge workers by 20 to 25 percent by improving collaboration and communication among and across teams.

Knowledge Management Strategies

Information ownership and responsibility: The KM can provide devolved ownership and administration of information & knowledge assets to the divisions or units responsible for creating or managing those assets.

Behaviors: The use of the KM can promote the change of individual behaviors required to improve organization management.

Best Practices: The use of the KM can promote the use of best practices in everyday business.

Adapted from [Content Management in a Knowledge Management Context; http://www.prescientdigital.com/articles/content-management/content-management-in-a-knowledge-management-context]
Semantic Technology allows the meaning of and associations between information to be known and processed at execution time.

For a Semantic Technology to be truly at work within a system, there must be a knowledge model of some part of the world (an active ontology) that is used by one or more applications at execution time.
Context in Knowledge Management

- 50% of the problems in the world result from people using the same words with different meanings.

- The other 50% of the problems results from people using different words with the same meaning.

Source: Kaplan S. The Words of Risk Analysis, Risk Analysis, Vol.17, N 4, August 1997

Fundamental categories for context information & knowledge
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Festo AG&Co KG as Use Case

- more than 300,000 customers in 176 countries supported by more than 61 companies worldwide with more than 250 branch offices and authorized agencies in further 36 countries.
- pneumatic, electronic automation equipment and products for the process industry (> 30,000 catalog products)
- benefits for component manufacturers that tend to become system vendors in general.
Festo’ Digitalization Framework and SPIIRAS Projects

DIGITAL BUSINESS MODELS
How we generate additional revenue

Software as function | Data monetization | Pay per use | Lifecycle services

DIGITAL PRODUCTS & SERVICES
What we offer to our customers

Products | Services

DIGITAL CUSTOMER
How we interact with our customers

Marketing | Consulting | Design | Sales | After Sales

DIGITAL SUPPLY CHAIN
How we produce and distribute in the future

Production | Logistics | Partnering

DIGITAL ENTERPRISE
How we work internally

Finance | Human resources | Corporate functions | IT | Digital workplace

ANALYTICS
What insights we get and how we anticipate

Data lakes
Artificial intelligence
Data mining

PEOPLE & CULTURE
Who we are and how we change

Qualification | Change | Governance | Organization

„Speed is the currency of Digitization“ Andreas Oroszi, VP Digital Business

Sources: https://ru.pinterest.com/pin/342344009160980345/
https://twitter.com/WSWMUC/status/956670302272020480
Festo’ Viewpoint: Digital Customer Journey

- Giving *customers comprehensive consultation in the virtual world* in future
- Customers' benefits
  - sales and consultation processes will be more continuous
  - the supply chain more transparent, more stable and safer
- Customers will be able to
  - configure their machinery more rapidly via a consistently structured digital interface
  - test their interaction and functioning in advance by means of simulation tools together with manufacturers and operators
- Embedded sensors in the products will warn against malfunctions or production stoppages before they can occur

- *The objective is to provide a virtual solutions consultant that bundles knowledge of our products and their interaction into a system and is at the disposal of customers and partners.*

  (Gerhard Borho, member of the Festo’ Management Board)

Knowledge Logistics Approach (proposed by Prof. A. Smirnov)

- Knowledge is critical core competency for future. Only 20% of a firm’s knowledge is effectively used by today’s organizations.
- Different users (decision makers) of knowledge & information look at it from different aspects (contexts)
- Distribution Channel (Business Network):
  - A Channel describes how a company gets in touch with its customers. Its purpose is to make the right quantities of the right products or services available at the right place, at the right time to the right people (Pitt et.al., 1999)
- Knowledge Logistics Aim:
  - Acquisition, integration, and transfer of the right knowledge from right sources in the right context to the right person in the right time for the right purpose (Smirnov et al., 2003)

Sources:
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Festo’ Product & Services Configuration: Multilevel Knowledge Management

- Customer defines Customer needs
- Context defines / maps to Requirements
- Knowledge Map connects Ontology
- Requirements on components type is-a Requirements on values domain
- Ontology ConBase contains NOC & CONCode
- Configuration model produces Functional unit
- Configuration / solution / product model is-a Configuration process
- Configuration operation Part-of, Is-a Configuration procedure e.g., performed in PAA
- Atomic configuration operation Part-of, Is-a Configuration process
- Consistency check Determines technical data
- Other rules

Defines for Germany

Defines for other plants

SePa tool

DC Alignment
CONBase Ontology for Product Classification and Code Scheme

Specifications:
- initially is based on the VDMA classification (German Engineering Federation)
- 4 level taxonomy
- more than 2000 classes
- more than 2000 characteristics
- taxonomical relationships support inheritance

Ontology organization
- Configuration model
- Application data
- Product / system constraints
- Product data
- Product classification & characteristics
Complex Products Rule Example

Valve terminal (VTUG) is not compatible with electrical accessories option C1 (individual connecting cable) if

- mounting accessories is H-rail mounting

and

- accessories for input-output link is not 5 pin straight plug M12.
Festo’ Knowledge Management Organization

Four level taxonomy with over 1000 classes (VDMA-based)

CONBase

DC Tool

SePa Tool

Customer

Lead time for other customers

Lead time for EU customers

Segmentation information

Segmentation information

Customer

Local Alignment Team

SePa Team

Solution Manager

Product Manager

Configuration Model

Used across multiple departments

Modeler

Order Code Structure Team

Non-NOC and application data classifications

NOC classification

Solution configuration

Configured solution

Non-NOC and application data classifications

NOC classification

encoway

Lead time for other customers

Non-NOC and application data classifications

Non-NOC and application data classifications

Released products and solutions with rules

Draft subsets of properties and values for solutions

Component rules, Solution classification

Public subsets of properties and values for solutions

CONSys

CONCode

Simple Products

Product Manager

Modeler

Product Manager

Product Manager

Simple Products
Role-based Perspectives of the Common Ontology

User 1 (product manager)

User 2 (product engineer)

User 3 (production engineer)

User 4 (production manager)

Ontology

Workflow 1

Workflow 2

Workflow 3

Workflow 4
Role-based Knowledge Management (*Trend* 1): Major Ideas

- **The different stages** of the PLM process in the company are associated with **different roles** like product managers, sales personnel or even customers.
- **Structural information** about workflows and the problem domain is collected and described **in the common ontology**.
- **User roles** are identified and their **relevant parts of the common ontology** are defined.
- **Tasks assigned to the identified roles** are defined.
- **Knowledge required for performing identified tasks** is defined.
- Based on the identified roles, tasks and knowledge, new **knowledge-based workflows** are defined.
- Corresponding **role-based knowledge support of the workflows** is provided based on the usage of the common ontology and knowledge / information storages.
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Knowledge Sharing in Expert Teams & Networks

- Knowledge
- Competences

- Capabilities
- Ratings, etc.
Skills, Knowledge & Attitude

Gray = current competency
Blue = required competency for Industrie 4.0

Source: VDMA Competence fields
Some Personalization Aspects

Motivation draws from research in *persuasive technologies* to further encourage adoption of behaviors. Major factors for persuasive technology *personalization*:

- **Age**: Older users are considered to rely more on social influence in their technology adoption than young ones. Younger employees tend to be more autonomous in their usage and adoption of IT.

- **Gender**: Women are motivated by immersion and social factors, while men are more achievement-oriented and display more competitiveness and need for winning than women.

- **Culture or nationality**: Europe and North America are highly individualistic cultures - foster competition and rivalry (such as leaderboards and points) have a great impact on one’s engagement. In Asia (specially China) and other countries are low in individualism - the competitive aspect are not such a strong motivator.
Expert Collaboration–Based Business Process

- Skill tree determination
- Expert profile description (competencies)
- Motivation list determination
- Task definition
- Expert group search for defined task
- Group working support
  - Chat
  - E-mail exchange
- Rewards assignment to experts
Skill Tree Determination
Expert Profile Description

Marlies

Position: proofreader full time
Proofreading languages: de->en-gb
Proofreader level: Professional
Expert level: High
Availability: Always
Local Company: en-gb
Start time at FESTO: February 15, 2010 12:00:00 AM CET

Global skill level
72.7 %
Task performance: 0.0 %
Availability: 100.0 %
Seniority: 90.6 %
Knowledge: 100.0 %
Motivations: 73.0 %

Technical skills
Marketing - 6 / 6
Corporate Communication - 6 / 6
Data security - 6 / 6
Law, human resources - 6 / 6
Catalogue, user manuals - 6 / 6
Food - 6 / 6
ELA - 6 / 6
LifeTech - 6 / 6
## Motivation List Determination

### Motivations

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Local Company</th>
<th>Budget, EUR</th>
<th>Monetary benefit, Value EUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non Material</td>
<td></td>
<td>NM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- HQ Meeting</td>
<td></td>
<td>XX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Annual HQ Meeting</td>
<td>all participants will be invited to HQ, 2/3 days workshop including free time sightseeing program</td>
<td>XX</td>
<td>1000</td>
<td>8</td>
</tr>
<tr>
<td>-- Recognition</td>
<td></td>
<td>XX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- recommendation supervisor</td>
<td>compliment and thanks to supervisor about participants role</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>-- thank you card</td>
<td>thank you card</td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Material</td>
<td></td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- chocolate package</td>
<td></td>
<td>XX</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>-- festo ware gadget</td>
<td></td>
<td>XX</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>-- Lunch</td>
<td></td>
<td>ML, en-gb, ru, fr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- One Lunch Ticket</td>
<td>Free ticket for one lunch</td>
<td>ML5</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>-- Two Lunch Tickets</td>
<td>Two Lunch Tickets for the Expert</td>
<td>ML5</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>-- Shopping</td>
<td></td>
<td>MA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- -- Voucher 20</td>
<td>Shopping voucher for 20 EUR</td>
<td>MA40</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>-- New Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

[Add new motivation][1]

[Add new motivation group][2]
Project Definition. Expert Skill Matching

Create new project

Please name this project:

Digital Sales

Description:
The project is related to the sales digitalization

Due date:
31.12.2020

Impact:
High

Sales (2): 2

Digital (5): 2

Find performers

<table>
<thead>
<tr>
<th>Group</th>
<th>Profiles Management</th>
<th>Global sales level</th>
<th>Task performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Most effective group</td>
<td>Alexey Kashevnik</td>
<td>43%</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Alexey Smirnov</td>
<td>44%</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Most available group</td>
<td>Mikhail Petrov</td>
<td>30%</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>30%</td>
<td>1</td>
</tr>
<tr>
<td>3. Experienced group</td>
<td>Alexey Smirnov</td>
<td>43%</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mikhail Petrov</td>
<td>30%</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>30%</td>
<td>1</td>
</tr>
<tr>
<td>4. Group for learning</td>
<td>Nikolay Shilov</td>
<td>45%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Alexey Kashevnik</td>
<td>45%</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>45%</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Requirements

Project Requirements Matched with the Expert Competencies
Knowledge Sharing based on Dynamic Motivation (Trend 2): Major Ideas

- Knowledge worker (expert) activities are based on motivational factors related to cooperation & competition (as social influence strategies).
- Decision makers (managers) within company could use or create different motivation strategies for their employees (knowledge worker) to join and compete for a victory.
- Company has to use different motivation strategies for different knowledge workers (roles) in different situations (context).
- Company has to use for different expert teams (functional team and project team) different motivation strategies.
- Company has to use different sets of KPI for evaluation of employees efficiency & quality (role-based motivation strategies).
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### Information Priority for Digital Customer Journey Stages

<table>
<thead>
<tr>
<th>Market evaluation</th>
<th>Engineering</th>
<th>Production</th>
<th>Sales</th>
<th>Maintenance</th>
<th>Phase out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Segment</td>
<td>Product Structure</td>
<td>Characteristics</td>
<td>Industrial Segment</td>
<td>Applications</td>
<td>Product Structure</td>
</tr>
<tr>
<td>Constraints</td>
<td>Characteristics</td>
<td>Constraints</td>
<td>Constraints</td>
<td>Product Structure</td>
<td>Characteristics</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Constraints</td>
<td>Product Structure</td>
<td>Applications</td>
<td>Characteristics</td>
<td></td>
</tr>
<tr>
<td>Product Structure</td>
<td>Applications</td>
<td>Characteristics</td>
<td>Constraints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applications</td>
<td></td>
<td>Product Structure</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- One stage (task) corresponds to one aspect.
- Different tasks of different workflows required application of different formalisms.
- These different views (aspects) have to be synchronized and matched by a formalized instrument supporting various processes of the company.
Multi-Aspect Ontology: MVP-OWL

Multi-Aspect Ontology: “Product Engineering” Aspect

- Task: definition of a new product and its possible features
  - The product engineer needs a possibility to define new classes of products and new products with their possible features and feature attributes (e.g., Cylinder XXX is a subclass of Pneumatic Cylinder and has such features as “diameter”, “stroke”, “lock in end position”, and others, that, in turn, have certain attributes).

- Formalism: OWL

- Example classes
  - “Product Family”
  - “Product Group” (subclass of Product Family)
  - “Product” (subclass of Product Group)
  - “Feature” (associated with the class Product)

- To ensure the consistency of product classes that is achieved via OWL and reasoning (the Pellet reasoner is currently used).

Multi-Aspect Ontology: “Sales” Aspect

- Task: definition of functional dependencies between parameters of products and their processing when a product or an assembly of products are being configured by/for a customer
- Formalism: object-oriented constraint networks
  - makes it possible to define functional dependencies (represented by constraints) between product parameters and then process these via a constraint solver when a particular product or a system is being configured
- Example classes
  - “Product”
  - “Parameter” (product parameter such as “mass”, “power”, etc.)
    - not the same as Feature in the “Product Engineering” aspect
  - “Constraint”

Multi-Aspect Ontology: 
“Strategic Planning and Production” Aspect

- Task: definition of lead time for each product together with the plant, where it is to be produced
- Formalism: production rules (if … then …)
- Example classes
  - “Production Class”
  - “Product”
  - “Plant”
  - “PTO” (pick to order)
  - “ATO” (assemble to order)
  - “ETO” (engineered to order)
  - “Rule”

Multi-Aspect Ontology (a part)

Global level

Viewpoint (aspect) level

Local level

Legend:
- --- bridge rule
  ➔ is-a relationship
  — other relationships

Product Engineering – New product definition (OWL and Pellet reasoner)

Sales – Product / System Configuration (Object-oriented constraint networks and constraint solver)

Strategic Planning and Production – Production strategy (Production rules)
Multi-Aspect Ontology: Major Ontology Elements

- Viewpoints (aspects)
  - Product Engineering, Sales, Strategic Planning
- Global classes
  - Thing, Product, Attribute, Dependency, Group, Resource.
- Local Classes:
  - Product Engineering: Product Family, Product Group, Product, Feature
  - Sales: Product, Parameter, Constraint
  - Strategic Planning: Product, Production Class, Plant, Rule, ATO, ETO, PTO
- Bridge Rules (bidirectional inclusion bridge rule: two concepts under different viewpoints are equal):
  - Product $\equiv$ Product$_{Sales}$
  - Product $\equiv$ Product$_{ProductEngineering}$
  - Product $\equiv$ Product$_{StrategicPlanningAndProduction}$
Multi-Aspect Ontology (Trend 3): Reference Model

Multi-Aspect PLM Ontology is represented by MVP-OWL *

Global level

Aspect level

Local level

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More Human-AI Interaction Modes Lead to Better Results (Significant Financial Benefits)

- Leaders haven’t found just one way to structure and refine human-AI interactions.
- Leaders deploy multiple modes of human-AI interaction: *AI decides and implements; AI decides, human implements; AI recommends, human decides; AI generates insights, human uses them in a decision process; Human generates, AI evaluates*.
- Organizations that successfully use all five modes are six times more likely to attain significant financial benefits than those able to use just one (5%) or two (6%).
- Companies gain the most when they increase their expertise from three-four (15%) to five modes (32%).
- Broader competencies allow organizations to fit a wider variety of interaction modes to a wider variety of situations (context).

Modes of Human-AI Interaction

- **AI decides and implements:** In this mode, AI has nearly all the context and can quickly make decisions. Human involvement would only slow down an otherwise fast process.

- **AI decides, human implements:** AI can capture the context well and make decisions, but humans — rather than software or robotics, for instance — implement the solutions.

- **AI recommends, human decides:** This mode is appropriate when organizations must make a large number of decisions repeatedly and the AI can incorporate most but not all of the business context.

- **AI generates insights, human uses them in a decision process:** In this mode, inherently creative work requires human thought, but AI insights can inform the process.

- **Human generates, AI evaluates:** Humans generate many hypothetical situations but rely on AI to tediously assess many complex dependencies.

Human-Machine Collective Intelligence (HMCI): AI and CI

- Efficient organization of groups
- Complement actions of people
- Process human-specific data (e.g., emotions)

Collective Intelligence (CI)

Artificial Intelligence (AI)

- Interpretation of ambiguities and common sense
- Learning (active learning, by example)
- Verification for compliance with ethical principles
HMCI-Environment: Motivation and Goal

- Decision support:
  - Interactive and iterative exploration of the problem
  - Uncertainty and the lack of data
  - Exact steps are not clear
- Decision support requires ad hoc planning of the low-level activities and should leverage self-organizing capabilities of the participants of the decision support process

**Goal:** to create *HMCI-Environment* supporting (and promoting) collective intelligence in the form of self-organisation of communities of the participants to solve common problem
HMCI-Environment: Major Challenges

- Self-organization (SO) protocols (based on Multi-level Socio-inspired SO model)
- CI & AI Challenges
- Soft guidance (based on Dynamic Motivation model)
- Interoperability (based on Multi-Aspect Ontologies)
Theoretical Background: Requirements

1. Elements of **self-organization** are critical, especially when solving complex problems.
2. **Social norms** and the adaptation of the behavior policies of team members.
3. **Role-based** coordination.
4. **Patterns**, structures and coordination schemes.
5. **Formal representation** of problem-related information supporting provenance.
6. **Dynamic motivation** mechanisms.
**HMCI-Environment: Principal Actors**

- **End-user (decision-maker)**
  - needs an access to problem-relevant expertise
  - middle-to-top level manager
- **Participant**
  - provides the expertise:
    - construct (and collaborate) on the reasonable workflow
    - judgments and conclusions
- **Data/service provider**
  - Integrates and supports software services. Responsible for the deployed services
HMCI-Environment: Conceptual Model

- Human-readable representation
- Machine-readable representation
- Multi-aspect ontology
- Decision support ontology
- Collaboration and coordination ontology
- Application ontology

Shared space

Decision-maker

Work on problem

Publish/Subscribe

Team

Team member selection

Available participants
Presentation Outline

- Introduction

- Knowledge Management (in Industrial Automation):
  - Trend 1 “Role-Based Organization”
  - Trend 2 “Dynamic Motivation”
  - Trend 3 “Multi-Aspect Ontology”

- Human-Machine Collective Intelligence

- Conclusion and Future Work
Conclusion

The design of the Human-Machine Collective Intelligent Environment is heavily affected by the discussed Context-Aware Knowledge Management trends:

- **Ontology-based context modeling** and specialization are at the core of the problem representation (to achieve interoperability between human and software participants).

- **Role-based organization and multi-aspect ontologies** are used to help to reconcile different aspects of the decision support (e.g., domain structure vs. process structure), because every decision-making process can be viewed as an interaction of different roles (project leader, data analyst, domain expert, etc.).

- **Dynamic motivation** mechanisms play a role in process planning and team recruiting, because reward sharing is an important aspect of process definition.
SPIIRAS’ Background: Fleet Driver Monitoring System

Cloud
Driver behavior patterns
Driver personalization module
Driver monitoring statistics
Trip reports

Internet

Smartphone: Driver Monitoring System
Camera-based monitoring
Sensor data analysis
Dangerous state detection
Recommendation generation

Statistics Consumers
Vehicle Infotainment System
SPIIRAS’ Background: Driver Behavior Analysis Based on Machine Learning & Recommender
SPIIRAS’ Background: Reference Model for Tourist Behavior Analysis

Data lake
- Mobile device
- Site API
- Tourist
- Smart city services
- Polls

Digital Pattern of life
- Sensors
- Route
- Content
- Plan

Tourist behavior
- Model results

Neural network-based Analysis Instruments
- Classification
- Clustering
- Time series prediction

Researchers
- Tourism services
SPIIRAS’ Background: Tourist Behavior Analysis based on Digital Life Model & Neural Networks
Future Work: Principles of Decision Support Based on User Digital Life Models

- Users with similar Preferences & Behaviors are grouped.
- A Group Pattern describes collected information about Preferences & Behaviors of Users belonging to this Group.
- The recommended Decision is predicted based on Group Patterns.
- The sources of User Preferences are User Profiles existing in various Domains (life areas-segments). A User can have several Profiles.
- The sources of information about the User Behavior are the User Digital Life Traces.
- User Digital Life is represented by a model that specifies the Problems that the User has ever dealt with and the decisions made with references to the Domains these Problems came from.
- User Digital Life Models & Profiles are compliant with the Domain Ontologies.
- Ontology Reasoner performs the classification of Users in a User Context (situation) into a User Group. Belonging of the User to a Group depends on the User Context. In different Contexts, the same User can be classified in different User Groups.
Future Work: Reference Model of Decision Support based on User Digital Life Model

![Diagram showing the reference model of decision support based on user digital life model. The diagram includes nodes for Domain, User profile, Context-independent user properties, User preferences, User digital life model, Problem, Decision, Problem profile, Digital life, Decision maker, Type, Axioms, User, Problem, Recommended decision, Decision support, and their relationships such as has part, instantiate, instantiate, define, corresponds, is-a, uses knowledge about, deals with, supports, and results in.]
Prof. Smirnov’ References related to Trends


IN4PL2020: International Conference on Innovative Intelligent Industrial Production and Logistics (Budapest, Nov. 2-3, 2020)

- **Digitalization at Festo: Our Way in Digital Transformation**
  *Mr. Andreas Oroszi,* Senior Vice President of Digital Business at Festo AG & Co. KG (Germany), and a Member of the Management Board for MindSphere World Association.

  **November 2: 15=00 - 16=00 (GMT)**

- **Industry 4.0 and Beyond: Challenges and Opportunities**
  *Prof. László Monostori,* Director of the Research Institute on Computer Science and Control (SZTAKI, Hungary), full professor at Budapest University of Technology and Economics, and President of the Industry 4.0 National Technology Platform, Hungary.

  **November 3: 17=00 - 18=00 (GMT)**
Thank you!!!

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