

Large Language Models (LLMs) as A Tool for Supporting Communication in Operational Management Information Systems and in Industry 4.0 Supply Chains*

Michał Fertsch and Marek FERTSCH

Poznan University of Technology, Poznan, Poland

Correspondence should be addressed to: Michał Fertsch; michal.fertsch@put.poznan.pl

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Abstract

A large language model is a language model with massive parameters that undergoes pretraining tasks (e.g., masked language modeling and autoregressive prediction) to understand and process human language by modeling the contextualized text semantics and probabilities from large amounts of text [Y. Yao at all. 2024]. This article considers the possibility of using large language systems as communication support tools in IT systems for operational management and in Industry 4.0 supply chains. The conditions that must be met and the limitations that may arise when using large language models in IT systems supporting the management of manufacturing and service enterprises and supply chains will be identified. Particular attention will be paid to the conditions and requirements created by IT systems in enterprises and Industry 4.0 supply chains. The concept of incorporating large language models into the IT systems of these organizations will be outlined.

Keywords: Large Language Models (LLMs); Artificial Intelligence; Communication Support; Cyber-Physical Systems

Introduction

Large language models are excellent tools for natural language or image processing. They utilize neural networks. They are trained based on massive datasets. The network training process is lengthy, generates a huge demand for computing power, and is possible due to the widespread availability of large amounts of data that can be used in this process. In industrial communication, we don't always use natural language. We often use "industry-specific languages," which are intentionally created to describe phenomena and relationships occurring or specific to specific areas of business practice. Marek Fertsch once participated in the development of the Polish version of the "dictionary of logistics terminology" [Fertsch Marek (ed.), 2016]. This was a very interesting experience that required not only translation but also solving problems resulting from the different definitions of certain concepts, their structure, and the relationships between them in different languages (the dictionary was developed using English, German, and Polish as the basis). Consultations with practitioners also revealed the existence of "workshop languages" created and used within individual companies and corporations.

The concepts of Industry 4.0 and the Internet of Things (IoT) open up a new dimension to communication problems in enterprise IT systems and supply chains. They assume interoperability, meaning the exchange of information between machines, devices, products, or services, and people operating the technical subsystem of a production or logistics system, and customers – buyers of products or services. Machines, devices, products, and

services communicate via "communication protocols" imposed by their designers. These are intentionally created sets of information – codes – that are distinct from natural language. An example of such a protocol is the GS1 system in logistics. In the field of automation and robotics, there are many different communication protocols developed by manufacturers of machines and devices. They are often a tool for building a competitive advantage for a given manufacturer – machines and devices manufactured by one manufacturer can only "talk" to machines and devices supplied by the same manufacturer [Pawar, P., Trivedi, A. 2018]. The authors of this article are realistic and do not propose standardizing the communication system in every enterprise and supply chain. From a management perspective, the communication system is a resource of every enterprise and will always remain a tool for building its competitive advantage [Cross W., pp. 403–408, 1995]. They propose the use of large language models as communication support tools in IT systems for operational management and in Industry 4.0 supply chains. They present the concept of this process and the tools for its implementation

State of the art in the problem of operational management information systems and Industry 4.0 supply chains.

The models of operational management information systems presented in the literature are inspired by the needs of production [Fertsch M, p. 221–223, 1918]. They refer to a production plant. It has economic autonomy (accounting for the economic effects of its operations) and a complex internal structure.

The literature presents the following solutions:

- a model focused on production control, resulting from the implementation of the First Framework Programme of the European Union [Bau. A. at all., 1994],
- an architectural model offered by an ERP system. Its starting point is technical dependencies (BoM, technological processes), but subsequently focuses primarily on organizational dependencies. The evolution of this model – early variants based on modules – intuitively separated programs or sets of programs [Gray C.D., Landvater D.V., 1989]. Currently, the most advanced ERP systems are composed of blocks of modules. In their case, it is difficult to identify criteria for selecting modules for individual blocks and for isolating blocks of modules. A cursory analysis suggests that these criteria have something to do with management,
- the Japanese kanban model [Black, J. 2007],
- the CIM model (Y model) proposed by A.W. Scheer. Its premise is to integrate the technical aspects of a manufacturing enterprise with the business aspects [Scheer A.W. 1994],
- a model developed in the USA as part of the ICAM program by a team working at the Wright-Paterson base. It is very comprehensive and extensive. Its development emphasized the problem of designing information flow and processing processes and utilized tools from the IDEF family for this purpose [Mayer R.J. at all. 1995],
- two models of intelligent manufacturing systems proposed by C. Dagli. They introduce a new dimension to the field of consideration. This is the environment in which the enterprise operates [[Dagli C. H. (ed.), 1995]], [Dagli C. H., Meyyappan L. 2005],
- model of a cybernetic-physical system proposed by Lee [Lee Y. at all, 2015] This model assumes that the model architecture of an information system consists of five levels. Each of the distinguished levels consists of a series of components and performs specific tasks. The individual distinguished levels are: These are, from lowest to highest:
 - data collection device level - This consists of data collection devices – sensors installed on machines and devices whose task is to capture signals from the surrounding environment, recognize and record them, and a network that amplifies the signals and transmits them over long distances for further processing using digital techniques and computers, as well as for storing them.

- data transformation level - This level consists of a set of programs that collect and process data collected by the data collection device layer. These programs can be hosted on a single central computer, on several computers, or in the "cloud." The tasks of this level include:
 - diagnosing the condition of machines, devices, and the operating environment,
 - predicting machine and device failures and environmental threats and their potential impact on system operation,
 - analyzing collected data to identify temporal, spatial, and causal relationships for system and environmental diagnostics,

Some tasks at this level can also be performed by embedded systems, which are components of the physical layer. The division of tasks related to transforming data into information between the physical layer and the IT layer is not clearly defined. It is difficult to identify criteria for this division. It seems that the main criterion should be maximizing the operational reliability of the entire production system.

- the information analysis level - consists of a set of programs that collect and process information collected by the data-to-information layer. The tasks of this level include:
 - modeling the behavior of machines, devices, and changes in resource availability over time,
 - analyzing the distribution (statistics) of events, activities, and system states over time to predict their frequency and duration,
 - grouping collected information based on similarity for analysis using large dataset analysis techniques.
- the system operation recognition (diagnosis) level consists of a set of programs that collect and process information collected by the information analysis layer. It also organizes communication within the system by controlling the flow of data and information between individual layers. The tasks of this level include:
 - preparing information and data visualization for computer-human communication,
 - conducting simulations and integrating information to forecast resource demand,
 - organizing collaboration for shared (human-human and computer-human) situation assessment and joint decision-making.
- the system configuration level (organizing, planning) consists of a set of programs that process information collected by the system analysis level. It also collaborates with the highest levels of system management. The tasks of this level include:
 - planning system operation under normal operating conditions and under system disruptions and changes in the system environment,
 - proposing changes to the system's operation to adapt to changes in the environment,
 - proactively proposing changes to the system's structure and operation to improve its operational flexibility.

In supply chain IT systems, emphasis is placed on standardizing communication – the form and content of exchanged information. This task is carried out by the GS1 system. This set of standards enables organizations to identify, capture, and share information smoothly, creating a common language that underpins systems and processes worldwide [Hałas E. (ed) 2012].

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The presented concept assumes the use of a large language model as a tool for supporting communication in operations management information systems and Industry 4.0 supply chains. The analysis of the state of the art in the architecture of IT systems supporting operations management in enterprises and supply chains, presented in Chapter 3 of this article, revealed the existence of numerous architectural models of these systems, based on different assumptions and originating from different stages of their development. Large language models are also not free from limitations [Wang Z. et al., 2025]. The most common problems are a lack of explainability, limited applicability, and inflexible strategy. These limitations hinder and limit the use of large language models in various applications. In practice, implementing a large language model may result in an environment composed of many diverse systems processing different information, employing different communication protocols, and using different natural languages. Attempting to master communication in such an environment with a large language model may encounter the barrier of unavailability of sufficiently large, representative sets of information for training the system. The role of a large language model in such a complex environment also requires defining. Communication in management is a process that results in the transfer of information from one person to another. Before communication can occur, the intention to transmit a message (information) is necessary. The message passes from the sender (source) to the recipient. It is encoded (transformed into symbolic form) and transmitted via some channel (medium) to the recipient, who decodes it [Robins S., De Cenzo D., pp. 513-516, 2002]. In IT systems for operational management and in Industry 4.0 supply chains, this definition requires some modification. The list of potential senders and recipients should be expanded. It should be assumed that the sender or recipient of information can be a person, an IT system, a device, a product, or a service.

Supporting communication in the conditions described above should primarily involve selecting information based on its importance. Practical experience indicates that 80% of data transferred in management IT systems is standard information related to recording events, such as an employee's arrival at work or the retrieval of materials from a warehouse. In the context of Industry 4.0 IT systems, this data is combined and processed into information at the "data-to-information conversion level."

Traditional communication in production systems and supply chains is characterized by a high degree of formalization and is based on standard documents and communications. This ensures the uniqueness of the message and its high communicativeness, and therefore allows for the elimination of redundancy. Achieving this state of full interoperability—in which we allow communication between machines, devices, products, services, and people using the Internet of Things—can be a serious challenge. The management process, according to the classical definition, is realized "by people and for people." Its functioning is based on the existence of a hierarchy. Under conditions of full interoperability, there is a question of whether this hierarchy should be included and, if so, at which level, machines, products, and services. There is also the issue of enforcing compliance with such a "mixed" hierarchy.

Large language models are designed to recognize syntactic, grammatical, and orthographic dependencies that govern the rules of natural language use. These dependencies are distinct from the dependencies resulting from hierarchical dependencies. Typical communication dependencies in a system with hierarchical dependencies divide transmitted messages into certain standard groups, such as commands, reports, queries, and messages. The latter group is particularly broad, encompassing information of various nature, transmitted "top-down," "bottom-up," and "across" hierarchical dependencies. Communication rules in natural languages are identified by large language models based on statistical dependencies. This approach can be highly unreliable in communication systems with hierarchical dependencies. The frequency of occurrence of the message "serious machine failure threatening human life or environmental damage" will be rather low, but its significance for the safe operation of a technical or technical-social system can be very significant.

Various methods are used to effectively train large language models. The most common are:

- reinforcement with human feedback [Lee H. et al. 2024],
- expert blending [Smith, Reid G., and Joshua Eckroth, 2017],

- instruction-based tuning [Wang J. et al., 2024].

In this article, the authors propose a new method to facilitate communication between large language models and information systems supporting communication in operational management information systems and Industry 4.0 supply chains. They propose to call this concept "baiting," analogous to the practice used by anglers. It involves introducing an additional communication module between operational management information systems and Industry 4.0 supply chains and large language models. This module will pre-process and select information from operational management information systems and Industry 4.0 supply chains, and then transmit it to the large language model. The concept of such an information system is presented in the next chapter.

An IT system supporting communication between the IT system for operational management and the Industry 4.0 supply chain system and a large-scale language model.

The proposed system consists of two modules. The first is an information classification matrix. This is a database that classifies information from the enterprise's IT system for operational management or supply chain management according to two criteria:

- **significance:** this criterion takes a value from 1 to n, where n is an integer greater than 1. The value 1 corresponds to the highest significance. The value of n is determined by experts. They consider various scenarios. For example, the workload of station A in the current period is x%, which is critical for the ongoing implementation of the production plan. The expert will assign this information a specific significance value based on the current situation. When assessing the situation from a future perspective, they can simultaneously assign different significance values to the same information. Therefore, each piece of information can be assigned multiple significance values.
- **the importance of a given piece of information:** is determined based on its similarity to the importance of other pieces of information. The importance of information is determined by comparing the information with the highest importance rating with the given piece of information. The importance rating of a given piece of information is compared with the importance rating of the information with the highest importance rating.

Creating an information classification matrix is performed according to the following procedure:

- establish a list of importance criteria. Order the criteria by importance – from most important to least important.
- describe each piece of information under consideration according to the established criteria.
- construct a matrix with the following structure: columns – criteria under consideration, rows – weights of the information, and place the individual classified pieces of information within it.
- moving individual rows, sort the information under consideration by degree of similarity.

Table 1. Simplified form of the information classification matrix.

	Significance								
		1	2	3	4	5	6	7	8
The importance of a given piece of information	1	x	x		x	x			
	2		x		x	x			

	3		x	x	x				
	4	x			x				x

The second proposed module is the message generation module. Its task is to select information transferred from an operational management IT system or an Industry 4.0 supply chain system into a large language model. Selection is based on the content of the information classification matrix. The message generation module analyzes the information classification matrix, selecting information based on its consistency. The message consistency coefficient s is determined for sets of subsequent information, ordered by their importance, according to the formula:

$$s = (1 / (m \times k)) \times \sum(a_i) \text{ for } i = 1 \text{ to } m$$

$$0 \leq s \leq 1$$

$$s(S) = (1 / (|S| \times k)) \times \sum(a_i) \text{ for } i \in S$$

$$0 \leq s(S) \leq 1$$

where:

s = message consistency coefficient,

a_i - number of criteria for information i ,

m - number of information included in the information classification matrix,

k - number of criteria considered in the information classification matrix. The selection of information for the set to be passed to the large language model is performed in the following steps:

- the information assigned the highest weight is started,
- the next piece of information, according to its weight, is added to the set created from the selected information,
- the message consistency coefficient is calculated for the created set of information,

The steps described above are repeated for subsequent pieces of information until all m pieces of information have been considered. The set of information with the highest message consistency coefficient is selected as the message to be passed to the large language model. The authors will examine the operation of the message generation module using the example of a simplified information classification matrix shown in Table1. It contains four pieces of information, assigned weights from 1 to 4. For each set, the message consistency coefficient s is:

- information 1 and 2 $s = 0.437$
- information 1, 2, and 3 $s = 0.416$
- information 1, 2, 3, and 4 $s = 0.406$

The set containing information 1 and 2 will be selected as the message to be passed to the large language model.

Future Research Plan

The concept of a new method proposed in this article, which aims to facilitate communication between large language models and information systems supporting communication in operational management information systems and Industry 4.0 supply chains, requires verification. The authors of this article intend to conduct this process in the following steps:

- selecting the research object – an information system supporting communication in operational management information systems. This will be the cybernetic-physical system model proposed by Lee [Lee Y. et al., 2015],
- selecting the location of the large language system within the information system. The first step of the research will be a location between the level analyzing information and the level recognizing (diagnosing) system operation. Further research may also explore other potential locations,
- selecting a large language model. This step may require a comparative analysis of the properties of several available models and developing criteria for selecting a large language model,
- developing and programming an information classification matrix. This step will require developing information classification criteria, including two criteria for information relevance and weighting,
- developing and programming a message generation module,
- integrating the information system supporting communication within the operations management IT system with the large language model and with the IT system supporting communication between the operations management IT system and the Industry 4.0 supply chain system and the large language model.
- developing systems for evaluating the achieved results,
- evaluating the achieved results,
- possibly repeating the above steps using one or more other large language models and comparing the results.

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