EVOLUTIONARY ANALYSIS OF AUTONOMOUS AGRICULTURAL VEHICLES

Ivan MAŠÍN[1]

[1]*Department of the Design of Machine Elements and Mechanisms, Technical University in Liberec, Studentska 2, 46117 Liberec, Czech Republic*

Abstract
The article is focused on application of evolution trends theory in the autonomous agricultural vehicles field. Trends of engineering systems evolution describe natural transitions of the engineering system from one state to another, and are generally valid for all engineering disciplines. Knowledge of these trends can more accurately predict the problems associated with the design of new technologies in the agriculture and thus increases the probability of success of the chosen solution.

Key words: *autonomous agricultural vehicles; design; evolution; trends.*

INTRODUCTION

Technology forecasting is a process that is based on the use of appropriate techniques and methods. Traditional techniques are techniques based on experience, assessment and intuition; market research techniques; time series techniques; techniques using regression analysis; other quantitative techniques (*Phaal, Farrukh, & Probert, 2010; Miles, Saritas, & Sokolov, 2016*; *Daim, Pizzaro, & Talla, 2014*). Information input for the majority of these methods is usually a subjective feeling and intuition, which of these methods makes a real mix of science and art. It is clear that the methods of technology forecasting should more include objective rules of the development of technical systems. As these methods of technology forecasting are not based on objective rules of the development of technical systems, numerous scientific activities were focused on identification of typical trends of engineering systems evolution (*Altshuller, 1984*; *Lyubomirskiy, & Litvin, 2003; Shpakovsky, 2016*). Typical trends of engineering systems evolution have been identified on the basis of a broad analysis of patent databases and historical trends in technology development. Trends occupy a special place in the innovation science and engineering field, as they offer a view of the technical system from a variety of time perspectives - from the past, through the present to the far future. They have a great potential for innovation and conceptual design phase because they describe what happened in the past to successful technology and because they are leading innovators to what is likely to happen in the future. Studies oriented on the fulfillment of evolutionary trends as a source of innovation opportunities identification also focus on agricultural technology *(Mašín, & Petrů, 2018*). As the field of autonomous agricultural vehicles is developing dynamically, it would be desirable already in the concept generating phase to check whether conceptual proposals are in line with objective trends in technology development. The aim of this article is therefore to compare whether the real development of autonomous agricultural vehicles corresponds to selected identified and described trends of engineering systems evolution.

METHODS AND INFORMATION SOURCES

For evolutionary analysis so-called trends of engineering system evolution (TESE) were used. Trends of engineering systems evolution are eleven and together they form a hierarchical system (*Lyubomirskiy, & Litvin, 2003)*. From the two main trends (the S-curve development and the trend of increasing ideality) are derived the other trends, respectively one trend may be the implementation of another trend (Fig. 1). These open patent databases served as information sources:

- Espacenet (https://worldwide.espacenet.com)
- Patenscope (https://patentscope.wipo.int/search/en/search.jsf)
- USPTO Patent Full-Text and Image Database (http://patft.uspto.gov/netahtml/PTO/search-adv.htm)

The following databases of scientific papers and professional publications also served as sources of information:

- ScienceDirect (https://www.sciencedirect.com)
- *IEEE* Xplore Digital Library (https://ieeexplore.ieee.org)

- IOPScience (https://iopscience.iop.org).

The websites of agricultural technology manufacturers and available publications *(e.g. Berns, & von Puttkamer, 2009*) also served as sources of information.

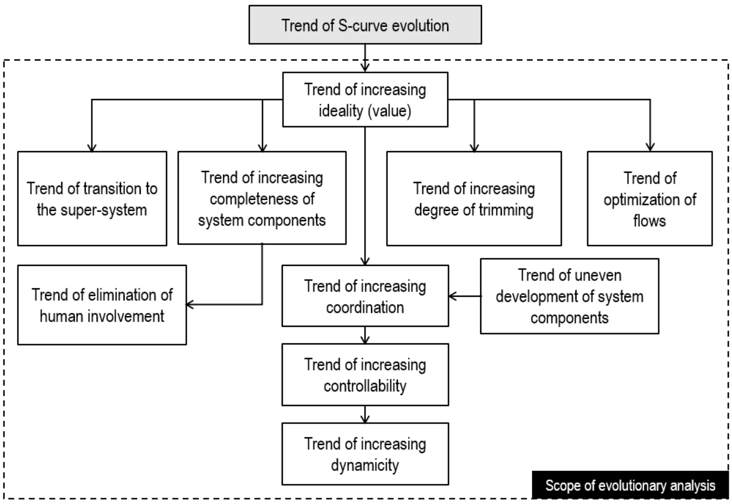

Fig. 1 Hierarchical system of trends of engineering systems evolution (adapted from *Lyubomirskiy, & Litvin, 2003*)

RESULTS AND DISCUSSION

The evolutionary analysis based on the mentioned information sources showed that the development of autonomous agricultural vehicles corresponds best with the following two trends in the evolution of engineering systems:

- trend of increasing coordination
- trend of elimination of human involvement

The trend of increasing coordination is reflected in the evolution of technical systems by gradually co-ordinating the "behavior" of the system components and consequently coordinating the "behavior" of the super system (*Lyubomirskiy, & Litvin, 2003*). Coordination is also understood as the choice of one parameter with respect to the value of another parameter. This “driving” parameter value can be pre-selected (for example, when manufacturing the agricultural machine) or in the process of its operation (for example during harvesting or weed destroying processes). For example, when developing the outer shape of a system, the shape of the developed system must be coordinated with the shape, properties, and movement of the objects that interact with the system (an example of this trend being the standard-ization of the dimensions of the interconnected parts or the ergonomic agricultural tool handle solution). From this trend viewpoint we can observe different trend mechanisms – coordination in shape, coordi-nation in rhythm, coordination of materials, coordination of action, coordination of parameter, self-co-ordination etc.

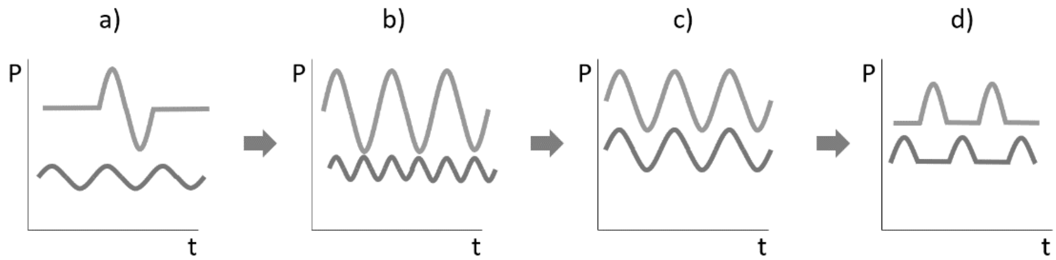

Fig. 2 Trend of increasing coordination of engineering systems (a – incoordinated actions, b – partly coordinated actions, c – coordinated actions, d – interval actions)

The trend of increasing coordination in the form of coordinated actions can be illustrated by example of a system for speed-based coordinated control of agricultural vehicles when on-the-go unloading is utilized (*Ray, 2017*) – Fig. 3a. Another example of this trend may be wireless networking of agricultural machines in a collaborative agricultural process (*Schmidt, 2017*) - Fig. 3b.

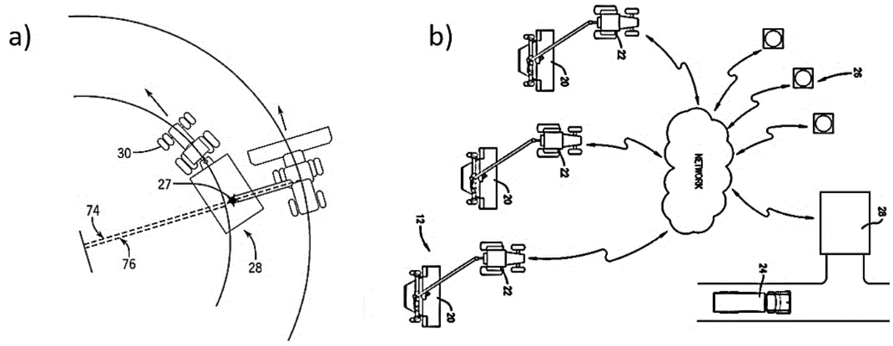

Fig. 3 (a) Automatic coordination of the agricultural vehicles speed (*Ray, 2017*) and (b) synchronization of agricultural vehicles with the help of wireless networking (*Schmidt, 2017*)

The trend of elimination of human involvement in engineering systems trend lies in the fact that during evolution, the number of functions performed in the system by human is reduced (*Lyubomirskiy, & Litvin, 2003*). This trend is particularly relevant for systems where standard subsystems such as the workpiece, transmission, power source, and control system are omitted and initially do not exist (Fig. 4). This is a special case of the trend of increasing completeness of engineering systems, because a man is often an element on which it is usually easiest to transfer the functions, which yet cannot be performed by the system.

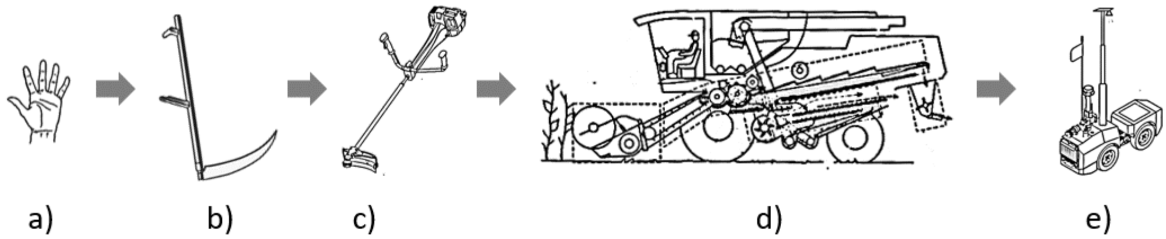

Fig. 4 Trend of elimination of human involvement in engineering systems (human roles: a – man alone, b – tool, c – energy and drive, d – control and supervision, e – only decision making)

Fulfilling this trend in autonomous agricultural vehicles field can be documented on the concept of an autonomous system (*Kavender-Bares, 2017*) or on the unmanaged robotic platform for performing multiple functions in agricultural systems (*Blackwell, Schildroth, Myers, & Becker, 2018*) - Fig. 5.

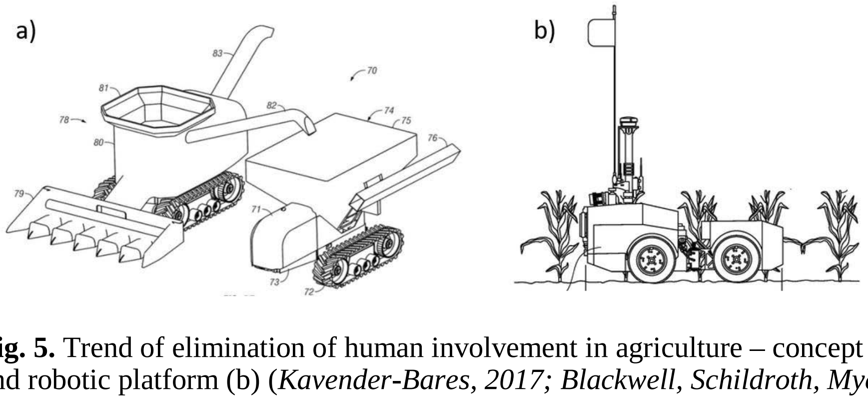

Fig. 5. Trend of elimination of human involvement in agriculture – concept of autonomous system (a) and robotic platform (b) (*Kavender-Bares, 2017; Blackwell, Schildroth, Myers, & Becker, 2018*)

CONCLUSIONS

Prognoses created using evolutionary analysis can provide management and engineers with important and more reliable input into the strategic planning process because they are based on objective patterns in the development of technical systems. Applying evolutionary analysis to the engineering systems guarantees a supply of novel ideas, and conceptual directions. The article contains one of the first applications of trends of engineering system evolution (TESE) to the field of agricultural autonomous vehicles. The study shows that TESE can be a powerful tool for autonomous agricultural vehicles innovation and forecasting. The study indicates that autonomous agricultural vehicles will develop significantly in lines of trend of increasing coordination and trend of elimination of human involvement.

ACKNOWLEDGMENT

This work is partially supported by the Ministry of Education, Youth and Sports of the Czech Republic and the European Union (European Structural and Investment Funds - Operational Programme Research, Development and Education) in the frames of the project "*Modular platform for autonomous chassis of specialized electric vehicles for freight and equipment transportation*", Reg. No. CZ.02.1.01/0.0/0.0/16_025/0007293.

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Corresponding author:
doc. Dr. Ing. Ivan Mašín, Department of the Design of Machine Elements and Mechanisms, Technical University in Liberec, Studentska 2, 46117 Liberec, Czech Republic, phone: +420 602439258, e-mail: ivan.masin@tul.cz