Defining the Action Principle Based on the Functional Analysis of a Technical System

Aleksey M. Pinyayev

Abbreviations
VEA – Value Engineering Analysis
TRIZ – Theory of Inventive Problem Solving
TS – Technical System

Abstract
The definition of the principle of TS’s action and a method for its revelation are suggested based on the functional analysis approach. The principle of action is defined as a simplified function and component model of the TS. The simplified model includes the components and functions necessary for the adequate performance of the system’s main and auxiliary functions. This model also includes some of the components and functions, which control the system’s harmful functions. In order to be included, these components and functions must be vital for controlling the system’s harmful functions during at least one of the stages of the system’s life cycle. The rest of the functions in the component and function model are not included into the action principle. The algorithm of the revelation of the action principle is based on building a complete component and function model of the system and elimination from this model the components and functions, which do not satisfy the definition of the action principle.

Introduction
Principle of action is one of the fundamental concepts of the theory of engineering design. Principle of action, on one hand, allows to single out the system under consideration from the technosphere by pointing out its essential features. On the other hand, the principle of action allows to «recognize» this system in a multitude of its design variations. By using the principle of action, we can differentiate a flash light and a projector and at the same time see that the flash light remains a flash light no matter its size, light intensity, the type and size of its batteries and so on – as long as the functions and action principles of its components do not change.
Thus, the action principle allows us to correctly choose the objects of analysis for revealing the trends of technology evolution. It also allows us to select the pairs of alternative systems during the synthesis of a combined system. The action principle plays major role in functionally oriented search by allowing to correctly define the leading technology area for a given function. It is also very important to correctly define the action principle in the process of technology prediction.

In theory of engineering design [1] and axiomatic design [2], the definition of the action principle is discussed in sufficient details and the recommendations are provided on how to use the action principle in the synthesis of new TS. However, in spite of its importance for engineering design and TRIZ, the precision and usefulness of the existing definitions are insufficient for TS synthesis and development in the overwhelmingly complex, information-overloaded modern technosphere. Therefore, a new, more specific and utilitarian definition is needed – the one allowing fast, reliable and precise technology analysis. The development of such definition is the objective of the current research paper.

**Proposed Definition of Action Principle**

The following definition is being proposed: *the action principle of a technical system is a combination of its components and functions which is necessary and sufficient for performing the principal and auxiliary functions of the technical system and an acceptable level of performing its harmful functions.*

In such a way, the proposed definition is based and allows to use well-developed method of VEA+TRIZ, especially its component and function analysis part.

It is necessary to indicate that the components mentioned in the proposed definition in many cases include the elements of the supersystem. So, a correct definition of the bicycle’s principle of action is not possible without taking the driver’s functions into account.

It is also important that the proposed definition includes the physical, chemical, geometrical and other effects and phenomena the operation of the
system is based on. These effects are included via indication of the specific TS components. Thus, the principle of action of the jet will be different from that of the propeller airplane, although the functional models of these two TS are similar. It is even possible to suggest a measure of the difference in the action principles based on the number of different components and functions.

It follows from the proposed definition that the description of the TS on its top hierarchical level is sufficient for the purpose of defining the system’s principle of action.

In practice, the definition of the action principle is done in two steps:

Building a complete component and function model of the TS at its top hierarchical level; done by applying VEA+TRIZ methodology.

The check on the necessity of the components and functions in the complete model for performing the principal and auxiliary functions of the TS without exceeding the acceptable level of the harmful functions; done by applying the technique described below.

**Technique for Revelation of Action Principle**

The technique consists of a series of virtual experiments where components and functions are imagined to be eliminated from the TS. Eliminating a component or function, we follow the effects of this change on the principal, auxiliary and harmful systemic functions. If the effects are insignificant, the component or function is eliminated from the model. Thus, in the simplified model, only the components and functions absolutely necessary for the system’s normal operation remain. This simplified model is, by the proposed definition, the TS’s principle of action. The examples of the analyses of different TS according to the proposed technique are presented in the Appendix.

**Examples of Defining the Action Principle**

For each example in the Appendix, a component and function model in a table form is presented. The transition to the principle of action is shown by crossing the components and/or functions out from the complete model in accordance with the above-described technique.
**Example 1.** Apparatus for producing granules by waterjet cutting

This TS is described in [4] and is designed for producing the dry granular detergent from a viscous mixture of raw ingredients. The system is capable of producing quasi-monodisperse granules, which are beneficial for the end use by consumer and for the dry product packaging.

The analysis according to the proposed technique has shown that some of the functions at the upper hierarchical level are not absolutely necessary for performing the principal function of the system. Thus, the function of the Distributor «to distribute the product flows in space» is not necessary if the Distributor makes only one product flow, which does not contradict the action principle.

Due to a similar reason, the function of the Nozzle Assembly «to distribute the water jets in space» is also not absolutely necessary.

When a function «to rotate the water jet» of the Nozzle Assembly was analyzed, the action «rotate» was replaced with more general action «move», because this particular action is necessary for the performance of the principal function.

When the functions of the Catcher were considered, it was revealed that the functions «swirl the water jet» and «convert the water jet into still water» are related to one possible way of the Catcher’s operation which is not critical for the main function of the TS as long as the Catcher’s basic functions «accept water jet» and «direct water to the drain» are performed.

Overall, the principle of the Apparatus’s action is close to its component-function model. This is characteristic for a majority of the modern TSs, because when they are designed, a significant attention is given to cost reduction by the reduction of redundancy.

**Example 2.** Industrial Ohmic Heater

This TS [5] is designed to heat liquids by passing electrical current through them. The peculiarity of this example is in that one of the system’s components – Connecting Pipe – performs only the transport functions and is not absolutely
necessary for performing the principal function of the heater. Accordingly, the Connecting Pipe is not included into the action principle.

**Example 3.** Electro-mechanical Toothbrush with a Light-emitting Component [6]

Component-function model of this system coincides with its principle of action.

**References**

4. US Pat. # 6733709.
6. US Pat. # 7845039.

**Appendix.** Examples of Defining the Action Principle

Example 1. Apparatus for producing granules by waterjet cutting

Principal Function:

Convert the flow of liquid product into the flow of dry granules.

Action Principle:

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distributor</td>
<td>Contain liquid product</td>
</tr>
<tr>
<td></td>
<td>Separate liquid product into flows</td>
</tr>
<tr>
<td></td>
<td>Distribute product flows in space</td>
</tr>
<tr>
<td></td>
<td>Define diameter of the flow</td>
</tr>
<tr>
<td></td>
<td>Hold the Nozzle Assembly</td>
</tr>
<tr>
<td>Nozzle Assembly</td>
<td>Interrupt product flow</td>
</tr>
<tr>
<td></td>
<td>Consume water</td>
</tr>
<tr>
<td></td>
<td>Shape water jet</td>
</tr>
<tr>
<td></td>
<td>Direct water jet</td>
</tr>
<tr>
<td><strong>Catcher</strong></td>
<td>Accept water jet</td>
</tr>
<tr>
<td></td>
<td>Swirl water jet</td>
</tr>
<tr>
<td></td>
<td>Convert water jet into still water</td>
</tr>
<tr>
<td></td>
<td>Direct still water into drain</td>
</tr>
</tbody>
</table>

| **Product Pump** | Accept product from its source  |
|                  | Compress product  |
|                  | Move product  |

| **Product Source** | Convert raw ingredients into liquid product  |
|                    | Move liquid product  |
|                    | Supply Product Pump with liquid product  |

| **Drying Chamber** | Remove moisture from product droplets  |
|                    | Contain hot air  |
|                    | Contain product droplets  |

| **Fan** | Move hot air  |

| **Conveyor** | Move granules  |

| **Water Pump** | Accept water from Water Source  |
|                | Compress water  |
|                | Move water  |

| **Water Source** | Supply water  |
|                 | Purify water  |

| **Water Drain** | Remove water  |

| **Gravity Field** | Move product droplets  |
|                   | Accelerate product droplets  |

Example 2. Industrial Ohmic Heater
Principal Function:
Convert electrical energy into heat.
### Action Principle:

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Chamber</td>
<td>Contain product, Direct product, Pass electric current through the product, Heat product, Convert specialized electric energy into electric current</td>
</tr>
<tr>
<td>Connecting Pipe</td>
<td>Contain product, Direct product</td>
</tr>
<tr>
<td>Product Pump</td>
<td>Move Product, Compress product</td>
</tr>
<tr>
<td>Power Supply</td>
<td>Consume regular electric energy, Produce specialized electric energy</td>
</tr>
<tr>
<td>Control System</td>
<td>Turn regular electric power on/off, Change parameters of specialized electric energy</td>
</tr>
<tr>
<td>Product Source</td>
<td>Supply Product Pump with product</td>
</tr>
</tbody>
</table>

### Example 3. Electro-mechanical Toothbrush with a Light-emitting Component

#### Principal and Auxiliary Functions:
- Remove contaminants from the surfaces of teeth.
- Apply gel or paste onto the surfaces of teeth.
- Remove organic matter from gum pockets.
- Discolor dental pigments.
- Massage gums.

#### Action Principle:

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning Head</td>
<td>Hold bristles, Move bristles</td>
</tr>
<tr>
<td>(with neck)</td>
<td></td>
</tr>
</tbody>
</table>
| **Connector** | Connect Cleaning Head with Handle  
|              | Disconnect Cleaning Head from Handle  
|              | Transfer electrical energy from Handle to Cleaning Head  
|              | Let shaft go through |
| **Handle**   | Connect toothbrush with hand  
|              | Contain battery  
|              | Contain motor  
|              | Connect battery with motor  
|              | Connect battery with Connector  
|              | Rotate shaft  
|              | Hold shaft  
|              | Turn electric current on and off |