Contents lists available at ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

Creativity and heuristics in process control engineering

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ARTICLE INFO

Article history:
Received 7 March 2015
Received in revised form 12 June 2015
Accepted 9 July 2015
Available online 17 July 2015

Keywords:
Process control
Creativity
Heuristics
Concurrent design

ABSTRACT

We study the relationship between heuristics and standard tool application in the design of process control systems. This relationship is illustrated by classical control history examples. Features of modern engineering objects are highlighted that challenge classical control approach and leave substantial space for creative solutions. We focus on inevitable heuristics in control design for modern complex process systems. The study suggests new systematic approach to heuristic control design. The approach is based on simplification technique and follow three steps. First, certain assumptions (e.g. negligible nonlinearity or dynamic behavior) help to develop the simplified model and problem setup. Second, standard control design is performed on this reduced model. Third, the perturbation theory methods help to find corrections to the obtained control to cope with the real plant. Special attention is given to the paradigm of concurrent (or integrated) plant and control design. The study suggests finding a proper compromise between investments in the process and its control. Several cement manufacturing process examples demonstrate that this method can generate better effect comparing to autonomous approach.

1. Introduction

Creativity is known as the individual ability to accept and generate conceptually new ideas, ideas that differ to traditional or conventional schemes. Whether this competence is required for process control design engineers nowadays? Walking through a modern enterprise we can hardly encounter a human being. Should we see one, she or he is sitting in front of a monitor with blinking interface of graphs, diagrams and schemes. Everything seem to have been done and solved already. We take a risk to advocate the opposite, assuming that the most important problems of automations are to be solved yet. What has been done is just a preparatory work for the most difficult and desired goal: design of integrated intellectual manufacturing control. Indeed, if we analyze the monitor's interfaces we conclude that most of them just visualize measured signals and inform operators on the current process status. Field engineers of different levels are mostly responsible for hard control decisions that influence the economic life of the enterprise. And the choice of the proper control decision is not an easy procedure since the problems are substantially difficult. The result is the excessive use of energy or materials, high reject rates, manufacturing plan failures. Why not to use powerful methods of modern control theory? The theory has already been successfully applied for control of such complex objects like spacecrafts, airplanes and robots! This is the main discussion point for the paper. We describe the difficulties, which automation engineers encounter when applying standard control theory in process automation practice. And we present an approach how to overcome the difficulties by combing the modern theory with heuristic (intuitive) ideas.

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http://dx.doi.org/10.1016/j.cherd.2015.07.010

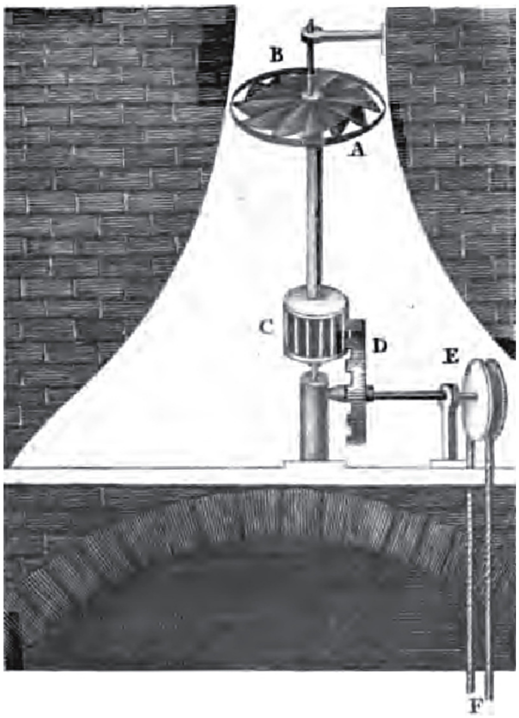

Fig. 1 – Idea of self-controlling roasting jack drive, from *A Treatise of Mechanics* (1826). Rotation rate of the roasting jack, connected to the belt F, is proportional to the fire strength due to the turbine places in the chimney.

2. Automation evolution trajectory: From inventions to abstract science

In this paragraph we speculate on the subject of retrospective analysis of control system evolution as a stage of inventive and systematic design interplay.

All known examples of early automation widely presented in books on the history of technics are examples of inventions, original engineering designs. These are artifacts of technical creativity rather than science since they description lack generalization. The principles of system design is not there yet. Although they obviously demonstrate the knowledge and understanding of some basic physics: mechanics, hydraulics or thermodynamics (see for example, temple door drive automation and other inventions of *Heron of Alexandria*, 10–70 AD). We can also cautiously state the almost all those early invention are served as drives, power amplifiers or programmed control devices.

Ensuring constant level of a liquid turned to be the first stabilization challenge for first engineers. A watercourse dam could be claimed as the simplest example of a solution. Ancient water clocks and oil lamps with float level regulator mechanism, known already by Greeks and Arabs, demonstrate more sophisticated design for this action. One of *Leonardo da Vinci's* invention seems to have been the first advanced automation design that provides motion stabilization control (Fig. 1). Still, with contrast to other mechanical inventions, Leonardo does not provide a general principle of stabilization.

Another famous invention in different physical field is *Cornelis Drebbel*'s temperature stabilization system or thermostat (1624), see Fig. 2. And possibly the most famous in control history system for rotation rate stabilization is *Watt*'s governor

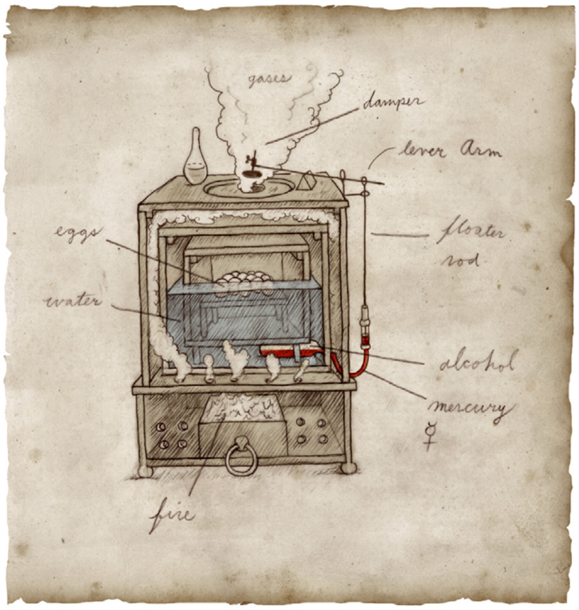

Fig. 2 – Modern reconstruction drawing of first invented thermostat. The temperature in the incubator is proportional to the vent size, that is changed by lever arm, connected to the mercury plunge (drawing from http://nautil.us/issue/12/feedback/the-vulgar-mechanic-and-his-magical-oven).

(Fig. 3), although it could be just an adaptation of windmill speed controller known by that time (Fig. 4). The same idea but based on deviations from gyroscopic axis was widely used for mechanical course control devices for ships and airplanes until the mid of XX. And we can find essentially the same idea in the invention for the system of different physical nature: steam boiler feed system level control by the float linked to the valve. Various mechanical hydrostats can be found nowadays as modern analog of this level control system.

The general principle of all these *inventions* is called "negative feedback control" or "deviation control" in modern control theory. Another definition that can be better understood by non-professional in the field is "self-stabilization".

The beginning of the control theory is marked by the study of new phenomenon emerged in first inventions on automation. These are two well known studies of instability of steam turbine controlled by the abovementioned governor

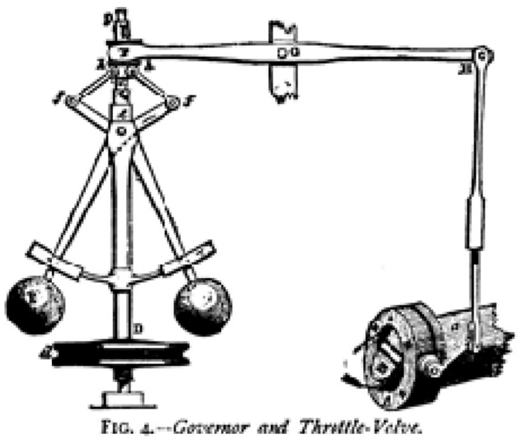

Fig. 3 – Watt's governor principal scheme. Turbine steam supply valve opening is proportional to the rotation rate due to centrifugal forces effect.