ROUGH CONTROL

Zdzislaw PAWLAK
Institute of Theoretical and Applied Informatics
Polish Academy of Sciences
ul. Baltycka 5, 44 000 Gliwice, Poland
e-mail: zpw@ii.pw.edu.pl

Abstract

Rough set theory is a new mathematical particularly suited to reasoning about imprecise or incomplete data, and discovering relationships in this data.

Recently there has been a growing interest in rough set theory among researchers in many AI related disciplines. The theory has found many real life applications in many areas. The primary application of rough sets so far have been in data and decision analysis, databases, knowledge based systems, and machine learning. Some information about application of the theory can be found in [20].

Although there has been some research on rough control [4, 8, 9, 10, 11, 12, 13, 23, 25, 27, 28, 29] their number and domains have been relatively small, and they are all academic rather than real life applications. It is worthwhile to mention in this context however that two rough controllers have been implemented in hardware [4, 13] – displaying very attractive features. First of all their speed of operation is much higher than speed of any other compatible controllers, based on different principles.

Observing the importance of rough control applications to practical problems, an informal Rough Control Research and Development Group was initiated in March 1995, and Toshinori Munakata has been named as the first Chair.

The major objective of this article is to discuss motivation, principle, implementation, potential application areas, advantages and future problems of rough control – applications of rough set theory to control problems. Whether rough control will succeed is yet to be seen, but there are several reasons for its high potential.

Control has been the most successful application domain for recently evolved AI areas, such as fuzzy sets [7, 16] and chaos theory [5]. Simply stated, control is a mapping problem from inputs to outputs. There are some similarities between fuzzy and rough sets. The experience gained in fuzzy control probably can be tested for rough control. More importantly, the fundamental strengths of rough set theory, such as making sense out of a complex information system where some of the information is possibly vague, appear to be particularly useful for certain types of control problems.

The control problem in general is to determine the numeric values of the outputs for given values of the inputs. That is, the problem is to develop a formula or a lgorithm for mapping from the inputs to the outputs.

We expect that such rough control systems may be particularly useful when either input and output values or input-to-output mapping rules are imprecise or incomplete. Rough control will give the "best" output values based on its criteria.

For difficult problems, conventional methods are typically expensive and depend on mathematical approximations (e.g., linearization of nonlinear problems), which may lead to poor performance. This is the type of problems where fuzzy control has been successful, and where our major target domain is centered for rough control as well. In essence, fuzzy control deals with the hard problems by allowing gradual and continuous transition of logic and human-like descriptive or qualitative expressions such as "moderately slow." Rough control,

on the other hand, deals with the hard problems by identifying degrees of significance for input and output attributes and by means of "quantization" to discern vague information. Rough control also allows descriptive or qualitative expressions. Both techniques aim at exploiting the tolerance for imprecision and uncertainty to achieve tractability, robustness, and low cost in practical applications.

The control may by described by an input-output mapping table. Such a table can be constructed initially in various ways. For example, if there are any existing methods to approximate the mapping, they can be used. Also, experiments can be conducted by human experts, possibly involving trial-and-errors.

The input-output table can now be treated like a decision table and by employing techniques offered by the rough set theory we can generate from it an optimal set of control rules, which can be put and executed by a rough set controller.

For fast system response, such as for real-time control, involving a large rule base, concurrent (parallel or distributed) computation may be necessary. Concurrent implementation of rough control should be relatively easy since all the control rules are represented in table form. For example, each of output may be determined independent of others by allocating an
appropriate number of processors. In the following, we discuss different phases of rough control applications.

(1) Rule generation andsimplification.
One of strengths of rough set theory is data reduction and discovery. Given a set of control rules, rough sets can simplify the system by reducing certain rules to fewer but equivalent ones, or eliminating redundant input, output and rules. Also, less important rules may be downgraded in priority or weighted by smaller factors.

(2) Output generation.
Under an assumption of control rules, output values are determined for "rough," i.e., imprecise or incomplete, input and parameter values and/or rules. The basic concept here is to explore the most typical feature of rough set theory. That is, in context of rough control, we perform input-to-output mapping under possibly an imprecise and incomplete environment.

(3) Derivation of numeric output values for any of the above.
Often, values of condition and decision attributes in rough sets are given in descriptive expression such as "slow". For control problems, we need to derive numeric output values. The situation is similar to the case of fuzzy control. Possible methods of deriving numeric output values include the following.

- Making the control rules fine enough to directly produce numeric values.
- Depending on the number of input and output variables and their ranges, Method (i) may not give satisfactory answers. In such case, some kinds of a "weighted mean" of candidate output values can be computed. Given current input variable values, closest matching rules in the table are found, with a measure of "closeness" between the current and each of the rules.
- Use of consistency measure. When there are inconsistent control rules consistency measures may become useful to determine output values.

Hybrid systems can also implemented. The key concept of hybrid systems is to complement each other's weakness, thus creating new approaches to solve problems. This hybrid system concept is probably one of the most promising for practical applications. For example, fuzzy control has many established application cases while rough control has relatively few. Integrating rough control with successful fuzzy control cases could be relatively easy for accomplishing real world practicality of rough control.

Similarly, neural network + rough system may enhance the system. One major bottleneck of the backpropagation model in terms of practicality is the slowness of the learning process. Rough sets may be used as a front-end of the neural network system to pre-process the training patterns or learning process, or as an aid for pre-designing the neural network architecture.

Genetic algorithms are computer models based on genetics and evolution. Their basic idea is the genetic programs works toward finding better solutions to problems, just as species evolve to better adapt to their nvironments. One common problem in genetic algorithms is the slowness of the evolution. As in case of neural networks, rough sets may be used to "clean up" parameter or gene values, especially there are certain vagueness involved in these values.

References

1. Czogala, E., Mrozek, A., Pawlak, Z.: The idea of rough-fuzzy controller. International Journal of Fuzzy Sets and Systems **72** (1995) 61–63

2. Lin, T. Y.: Rough – fuzzy controllers for complex systems. In: P. P. Wang (ed.), Proc. Second Annual Joint Conference on Information Sciences, September 28 – October 1, Wrightsville Beach, North Carolina, USA (1995) 18–21

3. Lin, T. Y.: Fuzzy controllers: An integrated approach based on fuzzy logic, rough sets, and evolutionary computing. In: T. Y. Lin (ed.), Proc. of the Workshop on Rough Sets and Data Mining at 23-rd Annual Computer Science Conference, Nashville, Tenessee, 2 March (1995)

4. Lin, T. Y., Wildberger, M.: Algebra and geometry of rough logic controllers In: S. Tsumoto, S. Kobayashi, T. Yokomori, H. Tanaka and A. Nakamura (eds.), The fourth International Workshop on Rough Sets, Fuzzy Sets, and Machnine Discovery, Proceedings (RS96FD), November 6–8, The University of Tokyo (1996) 111–117

5. Mrozek, A.: Rough sets in computer implementation of rule-based control of industrial processes. In: R. Slowinski (ed.), Intelligent Decision Support. Handbook of Applications and Advances of the Rough Set Theory. Kluwer Academic Publishers, Boston, London, Dordrecht (1992) 19–31

6. Mrozek, A., Plonka, L., Winiarczyk, R.: Rough sets for controller synthesis. In: T. Y. Lin (ed.), Proceedings of the Third International Workshop on Rough Sets and Soft Computing, San Jose, November 10–12 (1994) 498–505

7. Mrozek, A., Plonka, L.: Knowledge representation in fuzzy and rough controllers. Proceedings of III International Symposium on Intelligent Information Systems, Wigry, Poland, June 6–10, 1994, Institute of Foundations of Computer Science PAS, Warsaw (1994) 324–337

8. Mrozek, A., Plonka, L., Kedziera, J.: The methodology of rough controller synthesis. Proc. of the 5th IEEE International Conference on Fuzzy Systems FUZZ-IEEE'96, September 8–11, New Orleans, Louisiana (1996) 1135–1139

9. Munakata, T., Pawlak, Z.: Rough control application of rough set theory to control. Fourth European Congress on Intelligent Techniques and Soft Computing, Proceedings EUFIT'96), Volume I, September 2–5, Germany (1996) 209–218

10. Plonka, L., Mrozek, A.: Rule-based stabilization of the inverted pendulum. Computational Intelligence: An International Journal **11** (1995) 348–356
11. Pulaczewski, J., Sienkiewicz J.: A rough set approach to process control – simpulations and results. Fourth European Congress on Intelligent Techniques and Soft Computing, Proceedings EUFIT'96), Volume I, September 2–5, Aachen, Germany (1996) 197–201
12. Skowron A., Polkowski, L.: Rough mereological controller. EUFIT-96: Proc. of The Fourth European Congress on Intelligent Techniques and Soft Computing, September 2–5, Aachen (1996) 223–227
13. Skowron, A., Polkowski, L.: Rough mereological foundations for design analysis synthesis and control in distributive systems.Information Sciences International Journal (in print)
14. Szladow, A. J., Ziarko, W.: Knowledge-based process control using rough sets. In: R. Slowinski (ed.), Intelligent Decision Support. Handbook of Applications and Advances of the Rough Set Theory, Kluwer Academic Publishers, Boston, London, Dordrecht (1992) 49–60
15. Szladow, A., Ziarko W.: Adaptive process control using rough sets. Proceedings of the International Conference of Instrument Society of America, ISA/93, Chicago (1993) 1421–1430
16. Szladow, A., Ziarko W.: Application of rough sets theory to process control. Proceedings of Calgary 93 Symposium of Instrument Society of America, Calgary (1993)
17. Ziarko, W.: Acquisition of control algorithms from operation data. In: R. Slowinski (ed.), Intelligent Decision Support, Handbook of Applications and Advances of the Rough Set Theory, Kluwer Academic Publishers, Boston, London, Dordrecht (1992) 61–75
18. Ziarko, W.: Generation of control algorithms for computerized controllers by operator supervised training. Proceedings of the Eleventh IASTED International Conference on Modelling, Identification and Control, Innsbruck, Austria (1992) 510–513
19. Ziarko, W., Katzberg, J.: Control algorithms acquisition, analysis and reduction: machine learning approach. In: Knowledge-Based Systems Diagnosis, Supervision and Control, Plenum Press, Oxford (1989) 167–178
20. Ziarko, W., Katzberg, J.: Rough sets approach to system modelling and control algorithm acquisition. Proceedings of IEEE WESCANEX 93 Conference, Saskatoon (1993) 154–163