PAP-683

INTRODUCTION TO CANAL CONTROL ALGORITHM NEEDS

by

A.J. Clemmens, M.ASCE
C.M. Burt, M.ASCE
D.C. Rogers, M.ASCE

Presented at First International Conference on Water Resources
Engineering in San Antonio, Texas

August 1995

Introduction to Canal Control Algorithm Needs

A.J. Clemmens, M. ASCE, C.M. Burt, M. ASCE, D.C. Rogers, M. ASCE[1]

Abstract

This paper provides an introduction to a series of papers by the ASCE Task Committee on *Canal Automation Algorithms* to be presented in this proceedings. The purpose of the task committee is to promote the development of improved canal automation algorithms. The committee has had active participation from both North America and Western Europe. The committee pursued three activities; Classification of Algorithms, Canal Characteristics, and Test Cases. The task committee results on these topics are presented in 8 additional papers.

Introduction

The general trend in U.S. and overseas projects is towards modernization and rehabilitation of existing projects rather than new construction. Meeting expected project benefits may require upgrading the capabilities of the system, rather than simply rebuilding the original facilities. Thus there is increasing interest in improving the flexibility of water delivery to users. Canal automation is one method for achieving improved flexibility on some projects.

In 1987, several committees within the Irrigation and Drainage Division of ASCE presented a symposium on *Planning, Operation, Rehabilitation and Automation of Irrigation Water Delivery Systems* to summarize the state-of-the-art in providing water delivery flexibility and service (Zimbelman 1987). At that time, application of canal automation was limited to a few sites and research on canal automation was limited by the ability to conveniently simulate unsteady flow in canals. A task committee was formed in 1989 to promote the advancement of user-friendly unsteady-flow software as a tool for canal automation research. This resulted in a symposium on *Irrigation Canal System Hydraulic Modeling* (In Ritter 1991), which summarized the

[1] Respectively, Research Hydraulic Engineer, U.S. Water Conservation Laboratory, USDA/ARS, 4331 E. Broadway, Phoenix, AZ 85040; Professor, California Polytechnic State University, Irrigation Training and Research Center, San Luis Obispo, CA, 93407; Hydraulic Engineer, U.S. Bureau of Reclamation, P.O. Box 25007, D-8560, Denver, CO 80225.

progress on canal modeling by the task committee and others.

In 1993, a task committee was formed to clarify the state-of-the-art in canal automation research and to promote the development of improved canal automation algorithms. The results of this task committee on *Canal Automation Algorithms* are reported in a series of papers at this conference, with this paper providing the introduction.

Canal Control Algorithms

Numerous papers have been written over the past two decades on canal automation -- here, canal *automation* means the automatic control of canal gates and not remote-manual (supervisory) control. The fact remains that very few canals in the world operate under true automatic control. Those that are automated generally fall into one of the following categories; 1) mechanical devices for control of water levels immediately adjacent to a controlled gate, 2) very simple microprocessor-based feedback control limited in scope, or 3) control based on detailed engineering knowledge of canal hydraulic properties (which requires continual refinement).

On the other hand, the technical papers dealing with canal control cover a wide variety of methods, few of which have been implemented in a significant application. It is very difficult to get an accurate picture of the merits of one or another canal control scheme, since each researcher has independently chosen the canal conditions studied and developed his own criteria for evaluation, testing, and rating of the software and results. Some have been tested on unsteady-flow simulation models, some on a model canal at Cal Poly (Parrish & Burt, pg 481-486 in Ritter, 1991) while other have only been tested with linear approximations to the unsteady flow equations (i.e., those used to develop the controller).

It is well known that the properties of the canal on which the control method is applied has a significant influence on the performance of the controller. Thus a particular controller may work well on one canal and not another. No systematic studies have been performed to determine the conditions under which these various control algorithms are useful.

Finally, the language of control engineering may be foreign to many practicing civil engineers, making it difficult for them to discern the differences in control algorithms and to determine which type of algorithm is best suited for a particular canal.

Task Committee Objectives and Activities

The overall purpose of the task committee is to provide information and guidelines which the "consumers" of canal control automation software can use in making their decisions regarding the most applicable form to apply. The task committee is composed of active members from the U.S., Canada, Mexico, The Netherlands, France and Spain.

To address the difficulties described in the previous section, the task committee divided its activities into three areas:

- Classification of Canal Control Algorithms (proposed and in use)
- Canal Characteristics (and their influence on the suitability of various control algorithms
- Canal Automation Test Cases (and associated performance measures)

<u>Classification</u>
A survey was made regarding control algorithms and methods that have been proposed or are currently in use. Approximately 45 algorithms or methods were identified, very few of which have been implemented. This activity focused on the logic used to recommend control actions and not the method of physical implementation. The group did not deal with *system* issues, such as the mechanical means of moving gates, communication from sensors and to gate actuators, or whether the logic was performed mechanically, with electrical circuits, or by microprocessor or computer.

Three papers dealing with classification are included in this proceedings. The first deals with classification categories and categorization of the algorithms. The second presents a summary of the properties and characteristics of the various algorithms. The third presents a summary of control algorithms currently in use. While significant progress has been made on understanding the various control schemes, more research is needed to determine the effective differences -- those differences which influence the algorithms' real performance. In addition, the general area of tuning the algorithms has not been fully addressed. Tuning is the process of adjusting mechanical settings or electrical components, or, with digital logic, determining numerical values for algorithm coefficients.

<u>Canal Characteristics</u>
Canals vary widely in their ability to respond to varied water demands and control measures. This group initiated a general study to examine canal properties and characteristics which influence the potential applicability of various types of control algorithms. Unsteady-flow simulation models were used to study canal response to various demands and control measures. The St. Venant equations were put into dimensionless form to reduce the number of variables which characterize a particular canal. Several preliminary studies were performed to give the committee an idea on what properties and conditions were of interest. Considerably more work is needed in this area before these results can be applied to the selection of control algorithms.

One study was performed to determine the response of canal pools under what could be called perfect feedback with no anticipation of demands. In this scenario, a withdrawal is made at the downstream end of the pool and at the same time the same change in discharge is introduced at the upstream end. Unsteady-flow simulation is used to determine the response in the pool's water level. This is intended to define the limits under which feedback alone can be used to provide adequate control, as opposed to control with anticipated or prescheduled changes in demand in addition to feedback.

A second study has been undertaken to model the propagation of waves in irrigation pools. While such processes are well understood, the influence of the travel and deformation of the wave on a canal's controllability is not well known. Further work is needed in both studies to determine how these properties relate to specific control methods (as opposed to the ideal controllers studied here). Three papers are presented here dealing with non-dimensional approaches and the two studies outlined above.

Test Cases

The development of test cases is primarily useful in formal comparisons of control algorithms. Most control algorithms in use have generally been developed for the specific canal on which they are currently applied. Furthermore, in the literature control algorithms are typically applied to some arbitrary canal, without investigating the significance of its properties.

The task committee chose two real canals with very different properties to propose as test cases. The first is a very steep canal with very rapid response times, but very little storage. The second is a larger canal with relatively slower response. These two canals represent somewhat extreme conditions. The specific physical dimensions have been altered slightly to make the theoretical studies more convenient. Several test scenarios have been proposed for the two canals, including both scheduled (known ahead of time) and unscheduled (and unknown) changes in demand.

The task committee has also proposed a set of criteria to be used in presenting the results of the various control algorithms. There is still debate on how the results should be presented and interpreted. Control algorithms are typically designed and tuned on the basis of different criteria; thus they tend to optimize some performance criteria at the expense of others. The potential users of these algorithms should understand which are the most appropriate for their desired operations; then controllers with the desired characteristics can be chosen for a particular canal. Two papers are presented, dealing with the presentation of controller performance and the test cases.

Publications

The following additional task committee papers (with appropriate references) are included in this proceedings:

Classification of Control Algorithms
by P.O. Malaterre, D.C. Rogers, J. Schuurmans

Properties and Characteristics of Canal Control Algorithms
by V. Ruiz, J.Schuurmans, J. Rodellar

Canal Control Algorithms Currently In Use
by D.C. Rogers, J. Goussard

Dimensionless Characterization of Canal Pools
by T.S. Strelkoff, A.J. Clemmens, R.S. Gooch

Response of Ideally Controlled Canals to Downstream Withdrawals
by C.M. Burt, R.S. Gooch T.S. Strelkoff, J.L. Deltour

Propagation of Upstream Control Measures along a Canal Pool
by J.L. Deltour, J.P. Baume, T.S. Strelkoff

Guidelines for Presentation of Canal Control Algorithms
by W.Schuurmans, B. Grawitz, A.J. Clemmens

Test Cases for Canal Control Algorithms with Examples
by T. Kacerek, A.J. Clemmens, F. Sanfilippo

References

Ritter, W.F. (ed) 1991. *Irrigation and Drainage*. Proceedings of the 1991 National Conference, Irrigation and Drainage Division, ASCE, 821 p.

Zimbelman, D.D. (ed.) 1987 *Planning, Operation, Rehabilitation and Automation of Irrigation Water Delivery Systems.* Symposium Proceedings, Irrigation and Drainage Division, ASCE, 381 p.

Active Committee Members

A. J. Clemmens, Chair	U.S.
C. M. Burt, Vice Chair	U.S.
R. S. Gooch, Secretary	U.S.
D. C. Rogers, Control Member	U.S.

J. P. Baume	France
B. Deleon	Mexico
J.-L. Deltour	France
J. Goussard	France
B. Grawitz	France
T. Kacerek	U.S.
P. Kosuth	France
P. O. Malaterre	France
D. Manz	Canada
G. Merkley	U.S.
J. B. Parrish, III	U.S.
J. Rodellar	Spain
F. Sanfilippo	France
J. Schuurmans	Netherlands
W. Schuurmans	Netherlands
T. S. Strelkoff	U.S.
M. Reddy	U.S.
V. Ruiz	Mexico
E. Zagona	U.S.