UNIVERSITY OF SOUTHERN QUEENSLAND

Improved irrigation of cotton via real-time, adaptive control of large mobile irrigation machines

A Dissertation submitted by

Alison Christine McCarthy, B.Eng (Hons)

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by

Alison Christine McCarthy

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Abstract

Improving the efficiency of water use in agriculture is increasingly essential to maintain the profitability and sustainability of farms. This involves applying only the minimum necessary irrigation water to maintain or improve the yield of individual plants. Improving cotton yield involves management of flower/fruit production in relation to vegetative growth. The cotton industry represents a significant proportion of agricultural production and water use in Australia.

Irrigation control strategies can be used to improve site-specific irrigation. These control strategies generally require weather, plant and/or soil data to determine irrigation volumes and/or timing that improve crop water use efficiency while maintaining or improving crop yield. In this dissertation the difficulties in applying standard control theory to irrigation control are reviewed, in particular that the system, the growing crop, varies with time and does not have fully-defined dynamics. Hence, as the plant response and environmental conditions fluctuate throughout the season, control strategies which accommodate temporal and spatial variability in the field and which locally modify the control actions (irrigation amounts) need to be ‘adaptive’. Such irrigation control systems may then be implemented on large mobile irrigation machines, both ‘lateral move’ and ‘centre pivot’ configurations, to provide automatic machine operation.

This dissertation presents the specification and creation of a simulation framework ‘VARIwise’ to aid the development, evaluation and management of spatially and tem-
porally varied site-specific irrigation control strategies. The cotton model OZCOT has been integrated into VARIwise to provide feedback data in the control strategy simulations. VARIwise can accommodate sub-field scale variations in all input parameters using a 1 m² cell size, and permits application of differing control strategies within the field, as well as differing irrigation amounts down to this scale.

An automatic model calibration procedure was developed for VARIwise to enable real-time input of field data into the framework. The model calibration procedure was accurately implemented with measured field data and the calibrated model was then used to evaluate the effect of using different types of data in an irrigation control system. With the field data collected, the model was most effectively calibrated using the full set of plant, soil and weather data, while either weather-and-plant or soil-and-plant input provided adequate inputs to the control system if only two inputs were available.

A literature review of control systems identified three adaptive control strategies that are applicable to irrigation, namely: (i) Iterative Learning Control (ILC) which involves applying irrigation volumes to cells in the field calculated by comparing the desired and measured value of the input variable for control (e.g. soil moisture deficit); (ii) iterative hill climbing control which involves applying test irrigation volumes to test cells in the field to determine the application that produced the best crop response and applying that volume to the remainder of the field; and (iii) Model Predictive Control (MPC) which involves using a calibrated crop model to evaluate various irrigation applications and timings to determine which irrigation decision to implement.

The three control strategies were implemented and simulated in VARIwise to evaluate their respective robustness to limitations in data availability and system constraints. These strategies effectively adapted to temporal changes in weather conditions and spatially variable soil properties. For the set of field conditions simulated in VARIwise, the ILC, iterative hill climbing and MPC controllers produced their highest yield and water use efficiency with soil data, weather-and-plant data, and the full data input, respectively. MPC was most sensitive to spatially sparse input data but performed well with spatially variable rainfall and limited machine capacity. ILC was least sensitive to
spatially sparse input data and variable rainfall, whilst iterative hill climbing control was most sensitive to spatially sparse input data and variable rainfall. Hence, in situations of high data input MPC should be implemented, whilst in situations of low data input ILC should be implemented. Iterative hill climbing control was most sensitive to limited irrigation machine capacity.

It is further concluded that cotton yield and irrigation water use efficiency may be significantly improved using adaptive control systems; and that adaptive control systems can adjust the irrigation application and improve the irrigation performance despite various data availability limitations and irrigation hardware constraints.
Certification of Thesis

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

__________________________________________  _______________________
Signature of Candidate                        Date

ENDORSEMENT

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Signature of Supervisors                       Date
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List of Publications

The following articles have been published or submitted for publication about the research contained within this dissertation.

**JOURNAL**


**CONFERENCE**


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