PREFACE

This special issue is based on the *2nd International Workshop on Multidimensional (nD) Systems* held at Czocha Castle, Poland, on 27–30 June 2000. Selected authors were invited to prepare extended versions of their presentations given during the Workshop. These papers cover a range of theoretical contributions, including developments in algebraic theory, optimal control in nD systems, controllability, etc. A number of papers develop the connections between 2D systems and the field of Iterative Learning Control (ILC), and these come from a special guest session on the subject organised by Richard Longman.

Multidimensional system theory has been an area of very active growth over the past two to three decades, both in the underlying theory and in the expanding number of application areas where the use of the multidimensional systems setting is necessary to address the problems. The key feature of the dynamics of a multidimensional system is its dependency on more than one indeterminate so that information is propagated in two or more independent directions. There are many physical systems, data analysis procedures, as well as computational algorithms and learning algorithms that have a natural multidimensional structure. This can be attributed to the presence of more than one spatial variable, or the combined effect of both space and time, or the combined effect of time and an integer index representing iteration, pass or trial number.

Processes with repetitive, or multipass, behaviour are a sub-class of multidimensional linear systems, as they are characterized by a series of sweeps through a set of dynamics defined over a fixed finite duration known as the pass length. On each pass, the output, or pass profile, is produced which acts as a forcing function on, and hence contributes to, the next pass profile. They pose open systems theoretic questions with immediate end uses in application areas such as iterative learning control, iterative solution algorithms for nonlinear dynamic optimal control problems based on the maximum principle, and many industrial applications such as long-wall coal cutting and metal rolling.

Iterative learning control addresses applications where a control system repeatedly performs the same tracking task, for example, robots in manufacturing operations. Feedback control systems produce deterministic errors in responding to tracking commands, and iterations in ILC aim to converge to a modified command that causes the system to produce the desired output. These applications are specialised in the sense that the initial conditions for each execution of the task repeat, there is a fixed time duration for each run but the run index can go to infinity, and there is no dynamic behaviour in the repetition or trial domain – the system will do the same thing in the next trial unless the input is changed.

The special issue consists of the following three parts:

- *Mathematical methods for general multidimensional systems.* This part starts with two papers on the algebraic theory of multidimensional systems (functorial and polynomial approaches). Next, there are two papers exploiting various aspects of partial differential equation theory to solve optimal control problems for 2D systems. The next two papers examine basic system theoretic features and concepts for 2D/nD systems, such as controllability, reconstructability, and canonical forms. The final paper of the section is devoted to presenting a framework for continuous and discrete multidimensional systems.

- *Repetitive processes.* This part presents one paper dealing with linear repetitive process control theory applied to metal rolling operations. Such repetitive processes form a bridge from nD systems to Iterative Learning Control.

- *Iterative learning control.* The first paper, based on the plenary lecture by Richard Longman, highlights the interactions among theory, experiments, and simulation needed for the development of practical learning control algorithms. The facts that ILC iterates with the real world instead of a model, and that it insists on getting zero error, is seen to push the limits of the abilities in each of these three approaches. The next paper is devoted to understanding the behavior of ILC applied to over- or under-determined systems, and in the process develops understanding and improved Tikhonov regularization methods to handle the ill-conditioning difficulty inherent in most discrete time ICL applications.

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