The bispectral problem and polynomial solutions

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Abstract

Some properties and relations satisfied by the polynomial solutions of the bispectral problem are studied. Given a differential operator, under certain restrictions its polynomial eigenfunctions are explicitly obtained, as well as the corresponding eigenvalues. Also the inverse problem is approached, giving conditions for the existence of a differential operator from its eigenpolynomials and eigenvalues.

1 Introduction

We consider the ordinary differential operator

$$L = \sum_{i=0}^{N} a_i(x) \partial_x^i \tag{1}$$

where $a_i(x)$ are polynomials, $\deg(a_i) \leq i$, and $\partial_x^i = \frac{d^i}{dx^i}$, $i = 1, \ldots, N$. We also consider a sequence $\{\lambda_n\} \subset \mathbb{C}$ of its eigenvalues and the corresponding sequence of eigenfunctions $\{P_n\}$, which we assume that are monic polynomials with $\deg(P_n) = n$ for each $n \in \mathbb{N}$. This is,

$$\sum_{i=1}^{N} a_i(x) \partial_x^i P_n(x) = \lambda_n P_n(x), \quad \forall n \in \mathbb{N}. \tag{2}$$

The polynomials P_n verifying (2) are called *eigenpolynomials* in this work. The Sturm-Liouville polynomial problem deals with the relations between the operator L and its eigenvalues and eigenpolynomials. We are interested in families of such eigenpolynomials that are at the same time eigenfunctions of a certain difference operator D. More precisely,

$$D \begin{pmatrix} P_0(x) \\ P_1(x) \\ \vdots \end{pmatrix} = x \begin{pmatrix} P_0(x) \\ P_1(x) \\ \vdots \end{pmatrix}. \tag{3}$$

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