

Simplicial Calculus with Geometric Algebra

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ABSTRACT. We construct geometric calculus on an oriented k -surface embedded in Euclidean space by utilizing the notion of an oriented k -surface as the limit set of a sequence of k -chains. This method provides insight into the relationship between the vector derivative, and the Fundamental Theorem of Calculus and Residue Theorem. It should be of practical value in numerical finite difference calculations with integral and differential equations in Clifford algebra.

0. Introduction

In 1968, D. Hestenes showed how Geometric Algebra can be used to advantage in reformulating ideas from multivariable calculus [1], [2]. For example, he showed that the proof of Stokes' theorem becomes a one-line identity in geometric algebra, if the integral definition of the vector derivative is adopted. In this paper, we systematically build up calculus on a k -surface in order to more closely examine the content of these theorems.

Section 1 gives a brief introduction to the geometric algebra of Euclidean n -space, including basic definitions and identities which are used in later sections. The inner, outer, and geometric products of vectors are discussed, as is the notion of a reciprocal frame of vectors. The material in this section is taken from [3], [4], and, primarily [5].

In section 2 the concept of an oriented simplex is introduced and related notions from homology theory are reviewed; more details can be found in [6], [7]. Peculiar to the present approach are the concepts of the *directed content* of a simplex, made possible by the introduction of geometric algebra, and the *simplicial variable* of a k -surface. These concepts are the basic building blocks for our theory of simplicial calculus developed in later sections.

In section 3 a k -surface is defined to be the limit set of an appropriate sequence of chains of simplices. A k -surface φ is said to be *smooth* if there exists a smooth k -vector field, called the *pseudoscalar field*, at each point of φ . Our approach is most closely related to [8].

In section 4 the *directed integral* on a k -surface is defined in terms of the directed content of the limit of the sequence of chains which defines it. The theory of directed integrals is first developed over a k -simplex, and then generalized. The most remarkable theorem of this section, which has no counterpart in the related theory of scalar-valued differential forms, expresses the *directed moment* of the boundary of a k -simplex as the inner product of the directed content of the simplex with the direction of the axis.

In section 5 the vector derivative is defined in terms of the limit of the directed integral over the boundary of the simplicial variable as this variable approaches zero. The vec-

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