

Primer on Vector Calculus

Advanced Econometrics 1
MSc Econometrics – University of Amsterdam

1 Differential and Gradient

Let $f : \mathbb{R}^2 \rightarrow \mathbb{R}; y = f(x_1, x_2)$ be a real-valued function of two variables. If the function is differentiable in the point (x_1, x_2) , then a linear approximation (or first-order Taylor series approximation) in this point is

$$f(x_1 + h_1, x_2 + h_2) - f(x_1, x_2) \approx \frac{\partial f(x_1, x_2)}{\partial x_1} h_1 + \frac{\partial f(x_1, x_2)}{\partial x_2} h_2.$$

Here h_1 and h_2 represent the difference between an arbitrary point $(x_1 + h_1, x_2 + h_2)$ and the point in which we make the linear approximation (x_1, x_2) . These differences do not have to be especially small (“infinitesimal”), but we know that the approximation error goes to zero as $|h_1| \rightarrow 0$ and $|h_2| \rightarrow 0$, and is of smaller order than $\|h\| = \sqrt{h_1^2 + h_2^2}$. After relabelling $dx_1 = h_1$ and $dx_2 = h_2$, the right-hand side of the equation above is called the total differential, given by

$$df(x_1, x_2) := \frac{\partial f(x_1, x_2)}{\partial x_1} dx_1 + \frac{\partial f(x_1, x_2)}{\partial x_2} dx_2.$$

It is therefore the linear approximation to the change in f as we change its argument from (x_1, x_2) to $(x_1 + dx_1, x_2 + dx_2)$.

This can be generalised to a function of n variables: if

$$f : \mathbb{R}^n \rightarrow \mathbb{R}; \quad y = f(\mathbf{x})$$

is differentiable in $\mathbf{x}$, then the (total) differential is

$$\begin{aligned} df(\mathbf{x}) &= \frac{\partial f(\mathbf{x})}{\partial x_1} dx_1 + \dots + \frac{\partial f(\mathbf{x})}{\partial x_n} dx_n \\ &= \begin{pmatrix} \frac{\partial f(\mathbf{x})}{\partial x_1} & \dots & \frac{\partial f(\mathbf{x})}{\partial x_n} \end{pmatrix} \begin{pmatrix} dx_1 \\ \vdots \\ dx_n \end{pmatrix} \\ &= \left(\frac{\partial f(\mathbf{x})}{\partial \mathbf{x}} \right)' d\mathbf{x}. \end{aligned}$$

Here $\partial f(\mathbf{x})/\partial \mathbf{x}$ is a column vector of partial derivatives (the gradient vector), and $d\mathbf{x}$ is a vector with components dx_i .

The following examples are useful:

- **Linear combination:** if $\mathbf{a} = (a_1, \dots, a_n)'$ and $f(\mathbf{x}) = \mathbf{a}'\mathbf{x} = \sum_{i=1}^n a_i x_i$, then

$$\frac{\partial(\mathbf{a}'\mathbf{x})}{\partial \mathbf{x}} = \begin{pmatrix} \frac{\partial \sum_{i=1}^n a_i x_i}{\partial x_1} \\ \vdots \\ \frac{\partial \sum_{i=1}^n a_i x_i}{\partial x_n} \end{pmatrix} = \begin{pmatrix} a_1 \\ \vdots \\ a_n \end{pmatrix} = \mathbf{a}.$$

Primer For Calculus

Arthur Stafford Hathaway



Primer For Calculus:

A Primer for Calculus Leonard I. Holder,1978-01-01 **Primer For Calculus** Holder,Jones Staff,1984-01-01

Primer for Calculus Leonard Irvin Holder,2003

A Primer for Calculus Leonard Irvin Holder,1978-01-01

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for Calculus Clawson,1982-01-01

Primer for Calculus Leonard I. Holder,1996

A Primer of Calculus Arthur

Stafford Hathaway,2015-06-11 Excerpt from A Primer of Calculus This Primer has been written to meet the needs of the author first for a primary course in the calculus and secondly for an outline of topics in a more advanced course that is suitable for combined lecture and text book instruction The author s method of development is essentially Newton s method of fluxions as presented by Hamilton in his Elements of Quaternions Bk III ch II This method is clear logical and scientific and it deserves more recognition than it has received in general analysis if for no other reason than that it is the method of the original discoverer of the calculus Its failure to be adopted is due to want of early publication and defective notation since it is remarkably perfect and general in principle The subsequent discoverer Leibintz gained the field by publications in a desirable notation although founded upon inferior infinitesimal principles Lagrange attempted a modification of the infinitesimal into the idea of a principal part as determined by first terms of expansions and made the differential co efficient the primary quantity Modern text books have returned to Newton s method of limits as applied to Lagrange s differential co efficient there is here offered a complete return to Newton with the fluxion or differential as the primary quantity About the Publisher Forgotten Books publishes hundreds of thousands of rare and classic books Find more at www.forgottenbooks.com This book is a reproduction of an important historical work Forgotten Books uses state of the art technology to digitally reconstruct the work preserving the original format whilst repairing imperfections present in the aged copy In rare cases an imperfection in the original such as a blemish or missing page may be replicated in our edition We do however repair the vast majority of imperfections successfully any imperfections that remain are intentionally left to preserve the state of such historical works A Primer of Calculus (Classic Reprint) Arthur Stafford Hathaway,2017-12-24 Excerpt from A Primer of Calculus This Primer has been written to meet the needs of the author first for a primary course in the calculus and secondly for an outline of topics in a more advanced course that is suitable for combined lecture and text book instruction About the Publisher Forgotten Books publishes hundreds of thousands of rare and classic books Find more at www.forgottenbooks.com This book is a reproduction of an important historical work Forgotten Books uses state of the art technology to digitally reconstruct the work preserving the original format whilst repairing imperfections present in the aged copy In rare cases an imperfection in the original such as a blemish or missing page may be replicated in our edition We do however repair the vast majority of imperfections successfully any imperfections that remain are intentionally left to preserve the state of such historical works **A Primer of Calculus** Arthur Stafford Hathaway,1901 *A Primer of Calculus* Arthur Stafford Hathaway,2000

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Primer For Calculus Introduction

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