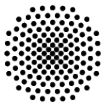

Universität Stuttgart

Inventing Time Travel: Theory and Applications of the Flux Capacitor

Vom Stuttgarter Zentrum für Simulationswissenschaften der Universität Stuttgart zur Erlangung der Würde eines Doktors der Naturwissenschaften (Dr. rer. nat.) genehmigte Abhandlung

Vorgelegt von

Emmett Brown

aus Hill Valley, California

Hauptberichter:	Prof. Dr. Albert Einstein
Mitberichter:	Prof. Dr. Blaise Pascal
	Prof. Dr. Marie Curie
	Prof. Dr. Charles Darwin

Tag der mündlichen Prüfung: 21. Oktober 2015

Institute for Advanced Time Travel

2015

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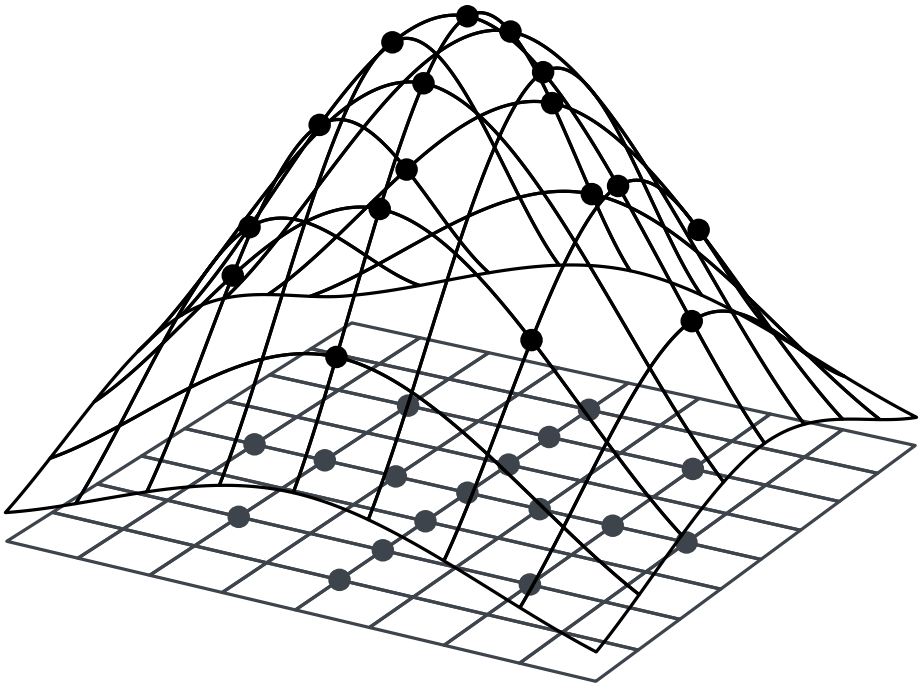
Emmett Brown

INVENTING TIME TRAVEL

Theory and Applications of the Flux Capacitor



University of Stuttgart
Germany

SimTech

IPVS

SGS

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> *It seems that it is not enough to have a good idea or insight. One needs, like Schoenberg, the appreciation and courage to develop the idea systematically, make its objects mathematically presentable by giving them names, and give them much exposure in many papers.*
>
> — Carl de Boor [Boo16]

COVER FIGURE A regular sparse grid in two dimensions *(dots)* as a subset of the full grid *(mesh, bottom)* with a bicubic B-spline *(mesh, top)*.

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Committed as 8d11cdc* on February 11, 2018 at 11:39pm

Contents

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Symbols and Acronyms

Symbol	Meaning	Page
$\mathbb{N}$	$1, 2, 3, \ldots$	
$\mathbb{N}_0$	$\mathbb{N} \cup \{0\}$	
SG^{++}	Sparse grid toolbox for C++	13
WTF	Acronym that you can't spell out on TV	

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Abstract/Kurzzusammenfassung

Abstract

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special contents, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

Kurzzusammenfassung

Dies hier ist ein Blindtext zum Testen von Textausgaben. Wer diesen Text liest, ist selbst schuld. $\sin^2(\alpha)+\cos^2(\beta) = 1$. Der Text gibt lediglich den Grauwert der Schrift an $E = mc^2$. Ist das wirklich so? Ist es gleichgültig, ob ich schreibe: „Dies ist ein Blindtext“ oder „Huardest gefburn“? Kjift – mitnichten! Ein Blindtext bietet mir wichtige Informationen. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. An ihm messe ich die Lesbarkeit einer Schrift, ihre Anmutung, wie harmonisch die Figuren zueinander stehen und prüfe, wie breit oder schmal sie läuft. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. Ein Blindtext sollte möglichst viele verschiedene Buchstaben enthalten und in der Originalsprache gesetzt sein. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$. Er muss keinen Sinn ergeben, sollte aber lesbar sein. $\mathrm{d}\Omega = \sin\vartheta \mathrm{d}\vartheta \mathrm{d}\varphi$. Fremdsprachige Texte wie „Lorem ipsum“ dienen nicht dem eigentlichen Zweck, da sie eine falsche Anmutung vermitteln.

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Preface

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special contents, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

Stuttgart, October 21, 2015
Emmett Brown

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1 Introduction

> *Ah, Jesus Christ! Jesus Christ, Doc, you disintegrated Einstein!*
>
> — Marty McFly

TODO: write

Citations: [Boo72]

Hello World! `Hello World!`

Now I'm citing all references for demonstration purposes. TODO: don't cite everything

Here are some umlauts: äöüß

I'm testing the glossary: SG^{++} is very cool.

1.1 Bla

This isTODO: write definedTODO: write as $a := 2b$. This is the function f (which is defined as $y =: f(x)$).

$$X \times Y \tag{1.1}$$

$$A \cdot \boldsymbol{x} = \boldsymbol{b} \tag{1.2}$$

$$\min_{x \in [0,1]} \int_{\Omega} f(\boldsymbol{x}, \boldsymbol{y}) d\boldsymbol{y} \tag{1.3}$$

$$4(a+b) f(x) g(x) h(x) p(x) (c+d) f g h f' g' h' \tag{1.4}$$

$$f(x) \cos(x) g(x) \tag{1.5}$$

$$\mathrm{f}(x) \cos(x) \mathrm{g}(x) \tag{1.6}$$

Table 1.1

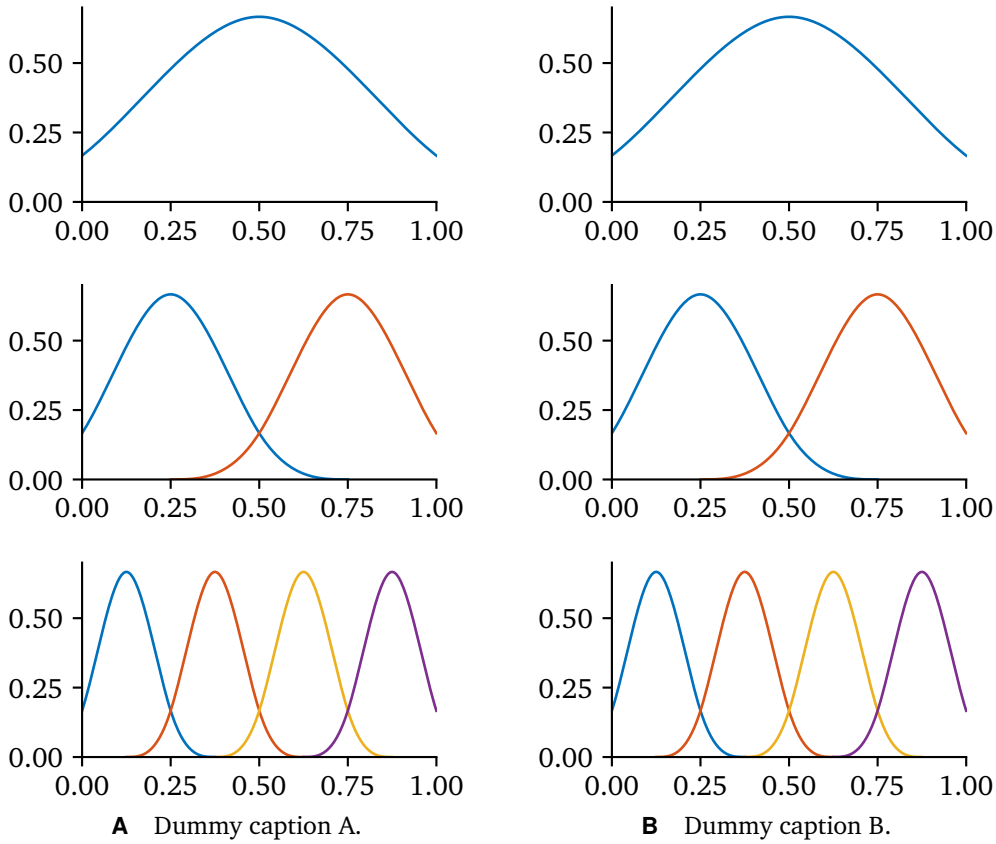

FIGURE 1.1 This is a test caption.

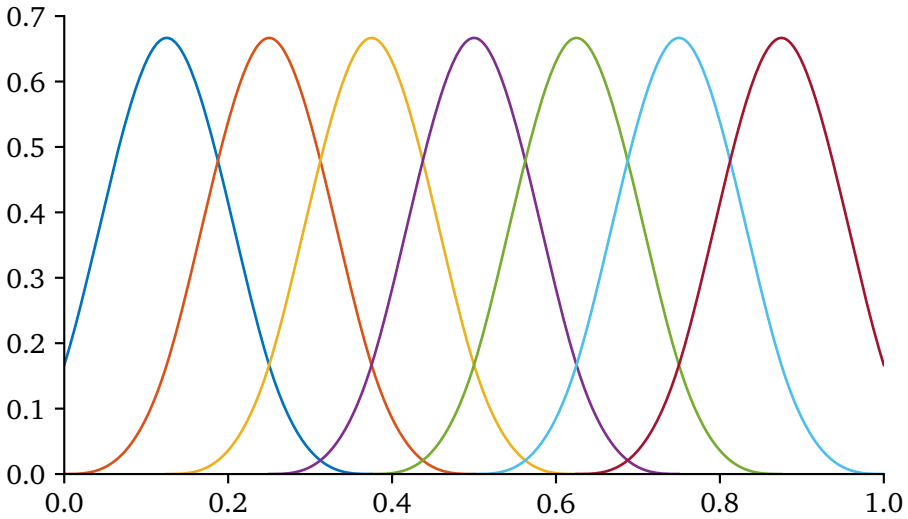

FIGURE 1.2 This is a test caption. This is a test caption. This is a test caption. This is a test caption. This is a test caption. This is a test caption. This is a test caption. This is a test caption. This is a test caption.

Header 1	Header 2	Header 3	Header 4
bla	bla	bla	bla
bla	bla	bla	bla
bla	bla	bla	bla

TABLE 1.1 This is a test table.

```
1  function a = GetAffectedBasisFunctions(X, α, x, t, ℓ, j, b)
2    if x_{ℓ,j} ∉ X then return 0                ⇝ nichts tun, falls Gitterpunkt nicht vorhanden
3    if t = d then
4      a ← α_{ℓ,j} · (b · φ_{ℓ_d,j_d}(x_d))      ⇝ letzte Dimension: Summanden zu Ergebnis addieren
5      if x_{ℓ,j}^{(rn(d))} ∈ X then a ← a + α_{ℓ,j}^{(rn(d))} · (b · φ_{ℓ_d,j_d}^{(rn(d))}(x_d))
6      if x_{ℓ,j}^{(ln(d))} ∈ X then a ← a + α_{ℓ,j}^{(ln(d))} · (b · φ_{ℓ_d,j_d}^{(ln(d))}(x_d))
7    else
8      a ← GABF(X, α, x, t+1, ℓ, j, b · φ_{ℓ_t,j_t}(x_t))          ⇝ nächste Dimension
9      if x_{ℓ,j}^{(rn(t))} ∈ X then a ← a+GABF(X, α, x, t+1, ℓ, j^{(rn(t))}, b · φ_{ℓ_t,j_t}^{(rn(t))}(x_t))
10     if x_{ℓ,j}^{(ln(t))} ∈ X then a ← a+GABF(X, α, x, t+1, ℓ, j^{(ln(t))}, b · φ_{ℓ_t,j_t}^{(ln(t))}(x_t))
11   if x_t > j_t h_{ℓ_t} then a ← a + GABF(X, α, x, t, ℓ^{(rc(t))}, j^{(rc(t))}, b) ⇝ nächster
     Level
12   else a ← a + GABF(X, α, x, t, ℓ^{(lc(t))}, j^{(lc(t))}, b)
13   return a
```

ALGORITHM 1.1 Approximative Auswertung von Linearkombinationen auf dünnen Gittern, Zeilen 5, 6, 9, 10 nicht für stückweise lineare Basisfunktionen,
input: Gitter $X = \{\boldsymbol{x}_i\}_i$, Koeffizienten $\boldsymbol{\alpha} = (\alpha_i)_i$, Auswertungspunkt $\boldsymbol{x} \in [0,1]^d$, aktuelle Dimension $t \in \{1,\dots,d\}$ (anfangs 1), Level und Index $(\boldsymbol{\ell}, \boldsymbol{j})$ des aktuellen Punkts (für randlose Gitter anfangs $(\boldsymbol{e}, \boldsymbol{e})$) und aktuelles Produkt b von 1D-Auswertungen (anfangs 1),
output: $a \approx \widetilde{f}(\boldsymbol{x}) = \sum_{k=1}^{N} \alpha_k \varphi_k(\boldsymbol{x})$ (für stückweise lineare Funktionen sogar $a = \widetilde{f}(\boldsymbol{x})$)

Fig. 1.1

Fig. 1.1a

Fig. 1.1b

Fig. 1.2

Algorithm 1.1

THEOREM 1.1 (TODO Theorem)

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. *If you read this text, you will get no information* $E = mc^2$. *Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this*

> *gives you information about the selected font, how the letters are written and an impression of the look.* $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. *This text should contain all letters of the alphabet and it should be written in of the original language.* $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. *There is no need for special contents, but the length of words should match the language.* $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

LEMMA 1.2 (TODO Lemma)
TODO

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special contents, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

DEFINITION 1.3 (TODO Definition)
Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special contents, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

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$$\bar{x} = \frac{1}{n}\sum_{i=1}^{i=n} x_i = \frac{x_1 + x_2 + \ldots + x_n}{n}$$

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special contents, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

$$\int_0^\infty e^{-\alpha x^2} \mathrm{d}x = \frac{1}{2}\sqrt{\int_{-\infty}^{\infty} e^{-\alpha x^2} \mathrm{d}x \int_{-\infty}^{\infty} e^{-\alpha y^2} \mathrm{d}y} = \frac{1}{2}\sqrt{\frac{\pi}{\alpha}}$$

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$$\sum_{k=0}^{\infty} a_0 q^k = \lim_{n\to\infty} \sum_{k=0}^{n} a_0 q^k = \lim_{n\to\infty} a_0 \frac{1-q^{n+1}}{1-q} = \frac{a_0}{1-q}$$

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$$x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-p \pm \sqrt{p^2 - 4q}}{2}$$

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$$\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial y^2} + \frac{\partial^2 \Phi}{\partial z^2} = \frac{1}{c^2} \frac{\partial^2 \Phi}{\partial t^2}$$

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special contents, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

2 The Flux Capacitor

> *If my calculations are correct, when this baby hits 88 miles per hour... you're gonna see some serious shit.*
>
> — Emmett Brown

TODO: write

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3 Conclusion

TODO: write

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A Proofs

This is an appendix chapter.

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B Bibliography

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[Bun04] **Bungartz**, H.-J.; **Griebel**, M.: *Sparse grids*. Acta Numerica 13 (2004), pp. 147–269. 10.1017/S0962492904000182.

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