N. ROUGIER (INRIA) & B. ESFAHBOD (GOOGLE)

#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### PART I: TEXTURE BASED

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### PART II : DISTANCE BASED

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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1/60

# DIGITAL TYPOGRAPHY

Bitmap font (Kilgard, 1994)

GPU Bézier (Loop & Blinn, 2005)

## 25 years of text rendering in computer graphics



SIGGRAPH '18 Course - August 12-16, 2018 - Vancouver, BC, Canada - 10.1145/3214834.3214837 Copyright 2018 © B.Esfahbod & N.P Rougier Creative Commons Attribution 4.0 International (CC BY 4.0)

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# **INTRODUCTION**

Typography is the art of arranging type to make written language legible, readable, and appealing when displayed.

However, for the neophyte, typography is mostly apprehended as the juxtaposition of characters displayed on the screen while for the expert, typography means typeface, scripts, unicode, glyphs, ascender, descender, tracking, hinting, kerning, shaping, weight, slant, etc.

Typography is actually much more than the mere rendering of glyphs and involves many different concepts.

2/60

A specimen sheet of typefaces and languages, by William Caslon I, letter founder; dated 1734.

# By WILLIAM CASLON, Letter-Founder, in Chify

ABCDEFG ABCDEFGHI ABCDEFGHIJK fe effrenata jactabit audacia ? nihilne te effrenata jactabit audacia ? ABCDEFGHIJKL ABCDEFGHIJKL ABCDEFGHIJKLMNOPQRS ABCDEFGHIJKLMN ABCDEFGHIKLMN French Cannon.

Quoufque tan-initiat quamon post finem fefe effrenata jactabit audacia i nihilne te nocturnum præfidium palatii, nihil urbis vigiliæ, nihil timor populi, nihil confen-fus bonorum omnium, nihil hic munitifimus dem abutere, ABCDEFGHIJKLMNOPORSTVUW ABCDEFGHIJKLMNOPS Catilina, pati-Quouque tandem abutere, Gatilina, patientia nostra?

Two Lines Great Primer. Quousque tandem abutere, Catilina, patientia nostra? quamdiu nos etiam Quousque tandem abutere, Catilina, patientia nostra? quamdiu nos etiam furor

Two Lines English. Quoufque tandem abutere, Catilina, patientia nostra? quamdiu nos etiam furor ifte tuus elu-Quousque tandem abutere, Catilina, patientia nostra? quamdiu nos etiam furor GO

DOUBLE PICA ROMAN.

Quousque tandem abutere, Cati- Quousque tandem abutere lina, patientia nostra ? quamdiu na, patientia nostra ? q DE nos etiam furor iste tuus eludet? nos etiam furor iste tuus quem ad finem sese effrenata jac-ABCDEFGHJIKLMNOP ABCDEFGHJIKL

GREAT PRIMER ROMAN. Quoufque tandem abutére, Catilina, pa-tientia noftra ? quamdiu nos etiam fu-ror ifte tuus eludet ? quem ad finem fe-ror ifte tuus eludet ? quem ad finem fe-

#### ENGLISH ROMAN.

Quoufque tandem abutêre, Catilina, patientia Quoufque tandem abutere, Catilina, j noftra? quamdiu nos etiam furor iste tuus eludet? tra? quamdiu nos etiam furor iste

#### PICA ROMAN.

Meltum, novis rebus fludentem, manu fua occidit. Fuit, fuit ifta quondam in hac repub. virtus, ut viri fortes acrioribus fuppliciis civem perniciofum, quam acerbiffimum hoftem coercerent. Habemus cnim fe-cerbiffimum boftem coercerent. Habemus fu natufconfultum in te, Catilina, vehemens, & grave: confultum in te, Catilina, vehemens, Ggra non deeft reip. confilium, neque autoritas hujus or-dinis: nos, nos, dico aperte, confules defumus. De-ABCDEFGHIJKLMNOPQRSTVUWX ABCDEFGHIJKLMNOPQRSTVUWX

#### SMALL PICA ROMAN. Not.

autoritatis, habemus enim hujufinodi fenatufconfultum, verumtaren inclufum in tabulis, tanquam ghalium in vagina reconsitum: quo ex fenatufconfulto confefiim interfectum te effe, Catilina, convenit. Vivis: & vivis non ad deponen-dam, fed ad confirmandam audaciam. Cupio, P. C., me effe clementem: cupio in tantis reipub, periculis non dif-ABCDEFGHIJKLMNOPQRSTVUWXYZ

habemus enim hujufmodi fenatufconfultum, veamen inclusium in tabulis, tanquam gladium in vagina inclusion in alitum : quo ex fenatulconfulto confeitim interfectum te quo ex fena effe, Catilina, convenit. Vivis : & vivis non ad deponendam, fed ad confirmandam audaciam. Cupio, P. C., me effe clementem : cupio in tantis reipub, periculis non diffolutum ABCDEFGHIJKLMNOPQRSTVUWXYZ

#### LONG PRIMER ROMAN NOT.

Veram ego hoe, quod jampridem fastum effe oportuit, certa de enuffa nondum adducor ut faciam, tum denique interficiam te, cum modam adducor ut faciam. tum denique interficiam te, cum terit, oni id non jure factum effe fateatur. Quamdiu quifquam erit eis & firmis perefidiis obfeffus, ne commovere te contra rempab. eis & firmis perefidiis obfeffus, ne commovere te contra rempab. effe. multorum te etiam oculi & zures non fentientem, ficut adhuc cerunt, fpeculabunter, atque caftedient. Etenim quid eft, Cati-ABCDEFGHIJKLMNOPQRSTUVWXYZÆ

LONO PRIMER ROMAN. NO 2. In ego hoc, quod jampidem fatum effe oportuit, certa de a nondam addaecor ut facian. tam denique interficiant te, cam a nondam addaecor ut facian. tam denique interficiant te, cam a nondam addaecor ut facian. tam familis inveniri poteon jure faltam elle fatestur. Quandia quisquam erit jure faltam elle fatestur. Quandia quisquam erit ere sudest, vives : & vives, ita ut sune vivis, moleis audest, vives : & vives, ita ut sune vivis, male meis & famis przefidii objefila, ne commovere te contra rempab. pofis. multorum te etiam oculi & aures non fentientem, ficut adhae fecerunt, fpeculabantur, atque cuftodient. Etenim quid eft, Catili-ABCDEFGHIJKLMNOPQRSTVUWXYZÆ

#### BREVIER ROMAN.

Novemb. C. Manlium aufaciar lotellitem steps adminisfrom toat? nom me frédlir Catilina, non modo no texts,tam atrox, tam iseredikila, verver, id quod mala edi, quan tuorum confiliorum rep-ABCDEFGHIJKLMNOPORSTVUWXYZÆ



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# NOPE, NOT ARABIC!

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- Font Types & Formats
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#### **PART I : TEXTURE BASED**

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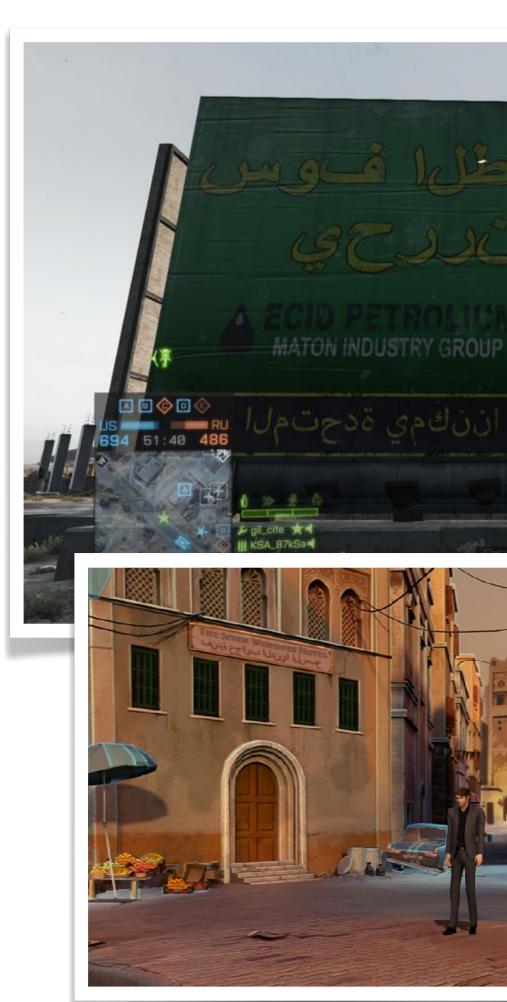
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- Beyond this course
- Questions & answers

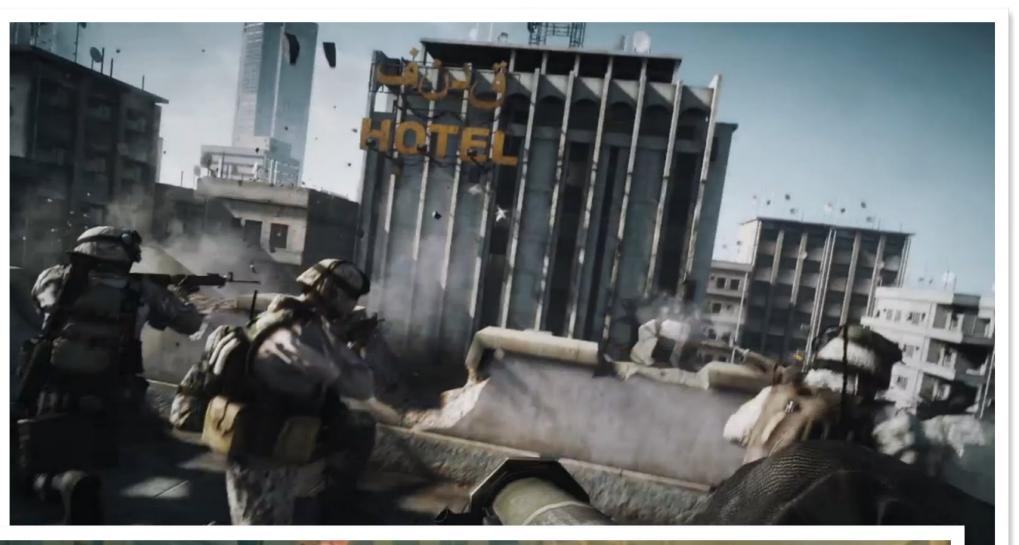


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## From "Nope, not Arabic" tumbler (https://nopenotarabic.tumblr.com/)











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- Multiple Channels

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#### CONCLUSION

- Beyond this course
- Questions & answers



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4/60

edically ldn't reaining. )P would some tax ting deal, ican door to n. A1 ers ecue sexst the . A2

nakam ils 12

in

John Boehner Øjohnboehner

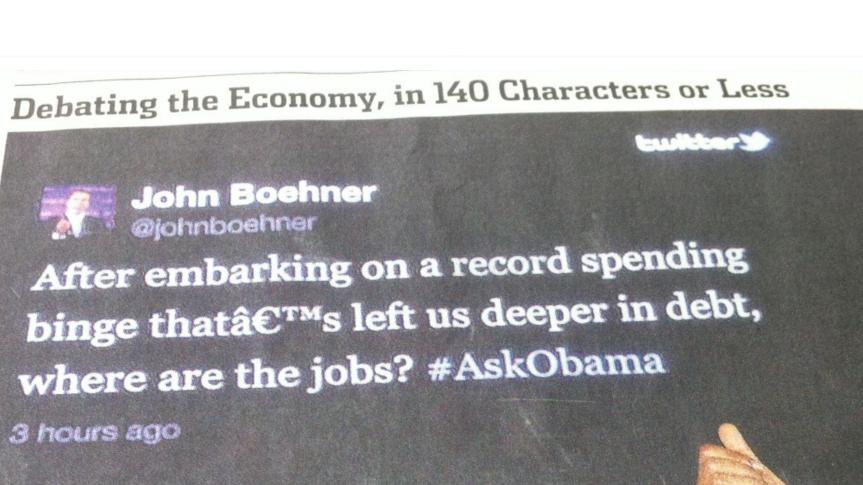
where are the jobs? #AskObama

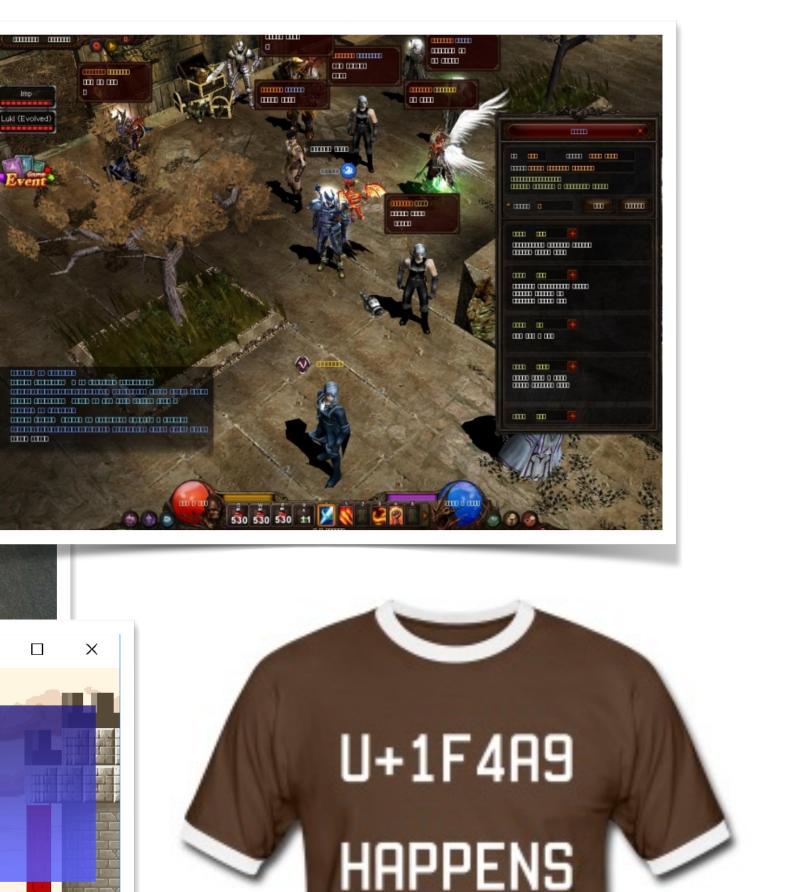
3 hours ago

TWITTER DIPLOMACY: Presiden John Boehner. (The tweet was g



# UNICODE





# HAPPENS

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# BAD KERNING (keming)

#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
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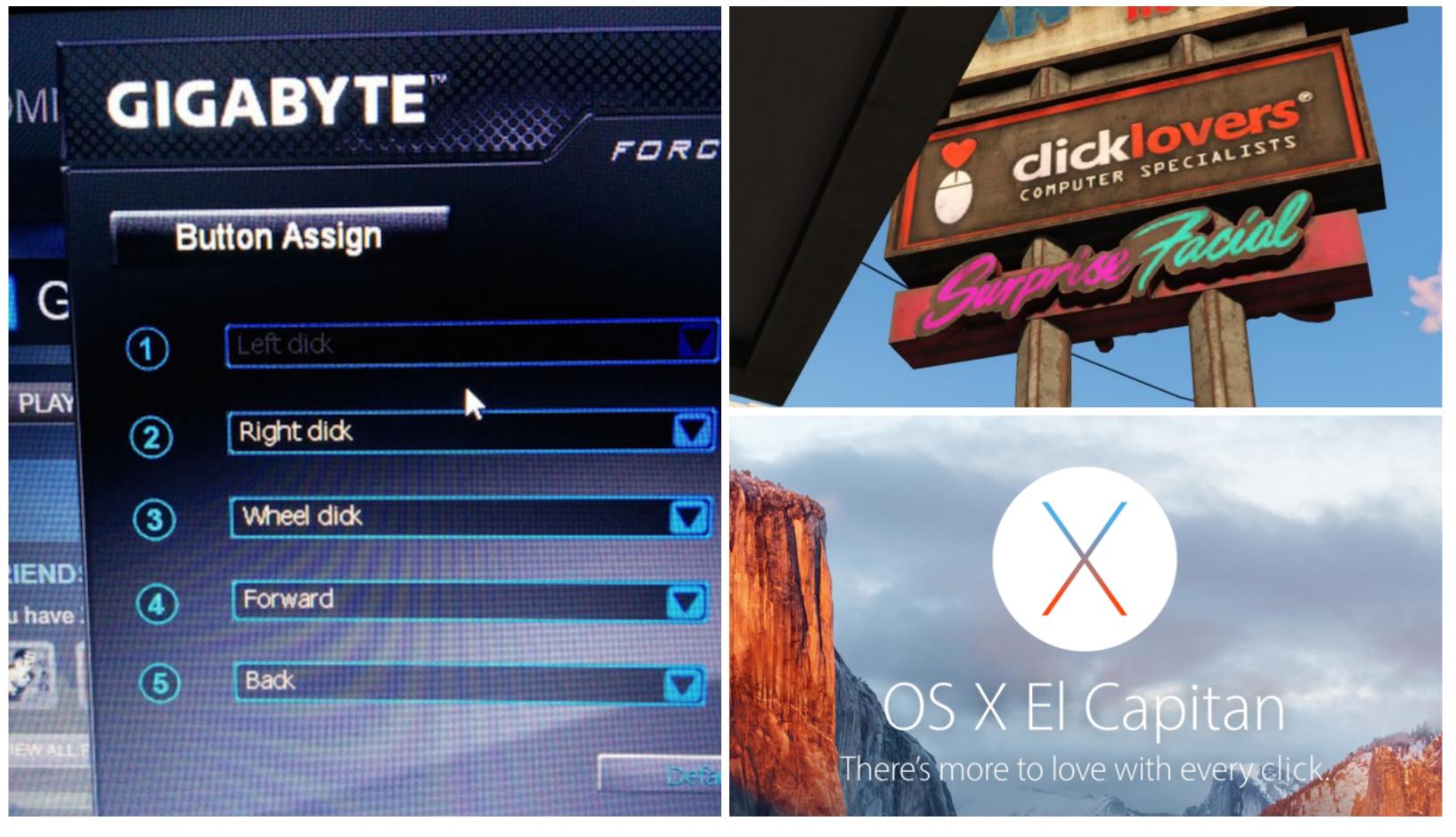
- Beyond this course
- Questions & answers



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5/60

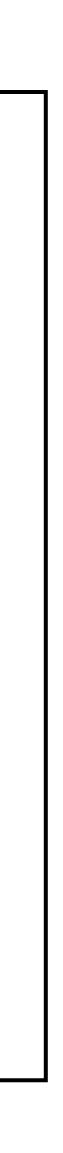
## Disaster is a space away... (FLICK, click, CLINT, FINAL)



click versus dick

#### Rockstar game removed the extra space

Apple added an extra space



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# GIBBERISH CAN BE PRETTY...

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- Font Types & Formats
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- Signed Distance Fields
- Single Channel
- Arc approximation
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#### CONCLUSION

- Beyond this course
- Questions & answers



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6/60



The Matrix code is actually a sushi recipe...



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# DIGITAL TYPOGRAPHY

#### INTRODUCTION

- Digital Typography
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#### **PART I : TEXTURE BASED**

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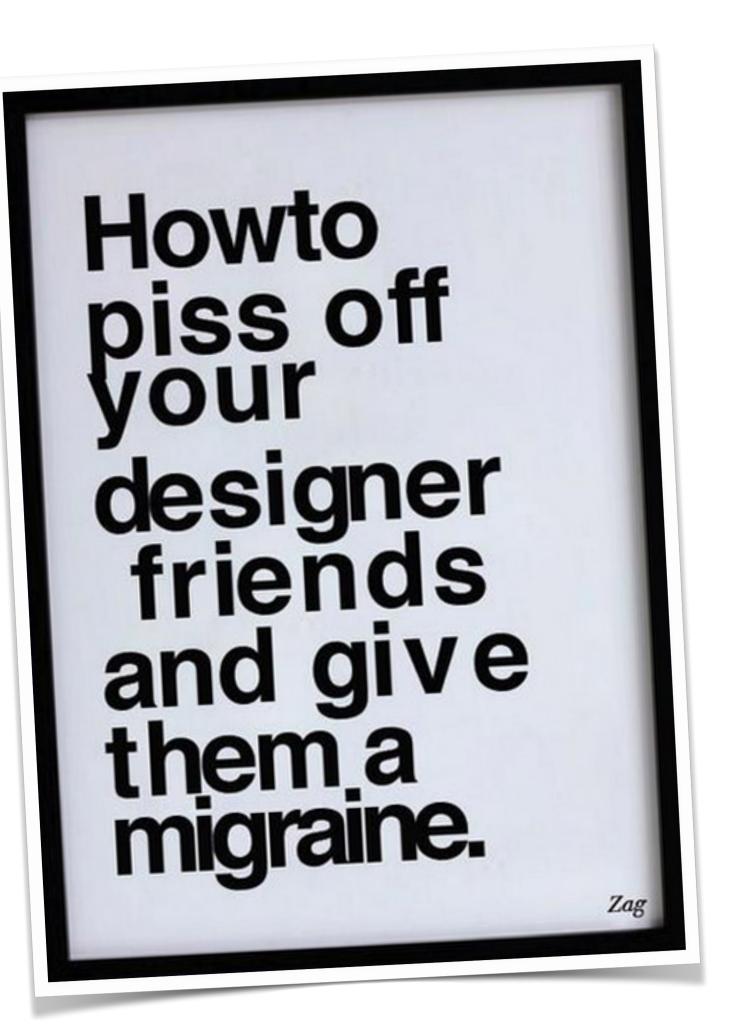
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- Questions & answers



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7/60

Typography is a vast and complex domain with many rules. You might consider to enforce some basic rules.



The Anatomy of Typography - Janie Kliever



# The Anatomy of Typograph





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- Single Channel
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- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



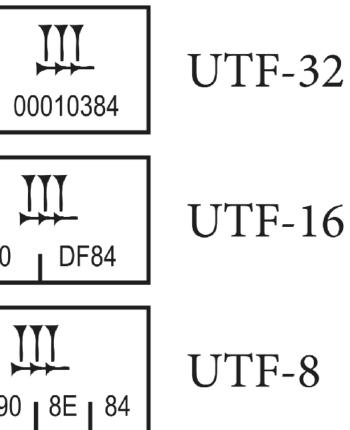
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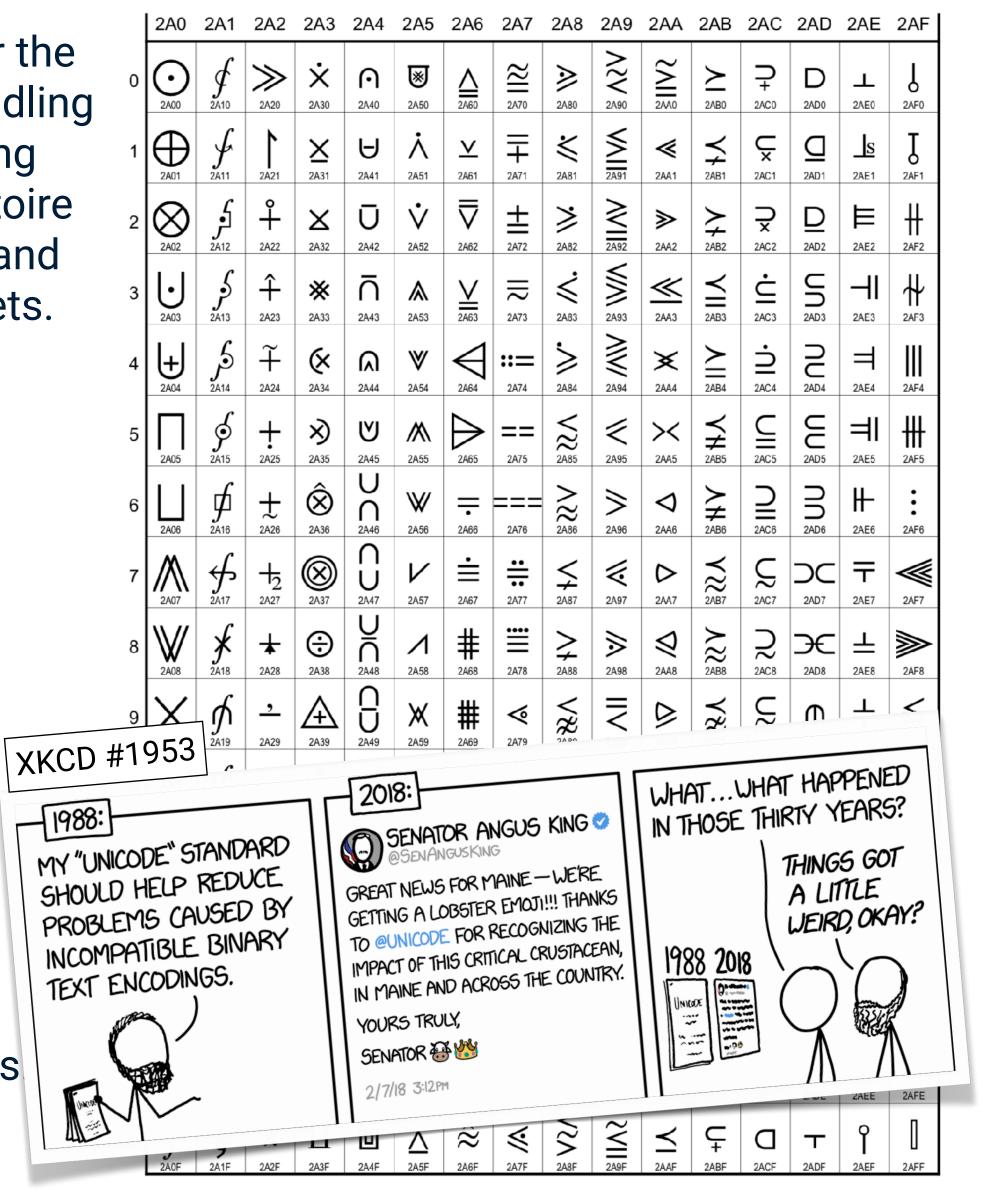
# UNICODE

Unicode is a computing industry standard for the consistent encoding, representation, and handling of text expressed in most of the world's writing systems. The latest version contains a repertoire of 136,755 characters covering 139 modern and historic scripts, as well as multiple symbol sets.

A 00000041		1 -	<b>Ω</b> 000003A9		(	言王 60008A9E		
A 0041		<b>Ω</b> 03A9		言五 百日 8A9E		D800		
A 41	CE	<b>)</b>	E	F	五 二 AA	9E	F0	9

UTF-8 (Unicode Transformation Format, RFC 3629) is a variable width character encoding capable of encoding all 1,112,064 valid code points in Unicode using one to four 8-bit bytes





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- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

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#### CONCLUSION

- Beyond this course
- Questions & answers



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9/60

# FAMOUS FONTS

Aa Qq Rr Aa Qq Rr TRIANON

Garamond

abcdefghijklm nopqrstuvwxyz 0123456789

12

Т

1495

# **Gill Sans** Aa Qq Rr Aa Qq Rr

COLLEGIUM

## abcdefghijklm nopqrstuvwxyz 0123456789

1926

Caslon Aa Ee Rr a <i>Aa Ee Rr</i> a Stacquard	Baskerville Aa Bb Cc Xx Yy Zz <i>Nutgarden</i>	Bodoni Aa Qq Rr <i>Aa Qq Rr</i>
abcdefghijklm nopqrstuvwxyz 234567890 234567890 1734	abcdefghijklm nopqrstuvwxyz 0123456789 1757	HORAT abcdefghijk nopqrstuvwz 01234567 1798
Fimes New Roman Aa Ee Rr <i>Aa Ee Rr</i> <b>Publisher</b>	Helvetica Aa Ee Rr Aa Ee Rr Kunsthalle	Arial Aa Ee Rr <i>Aa Ee Rr</i> <b>Delivera</b>
abcdefghijklm nopqrstuvwxyz 0123456789	abcdefghijklm nopqrstuvwxyz 0123456789	abcdefghijkl nopqrstuvwx 01234567
1931	1957	1982





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- GPU friendly
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#### CONCLUSION

- Beyond this course
- Questions & answers



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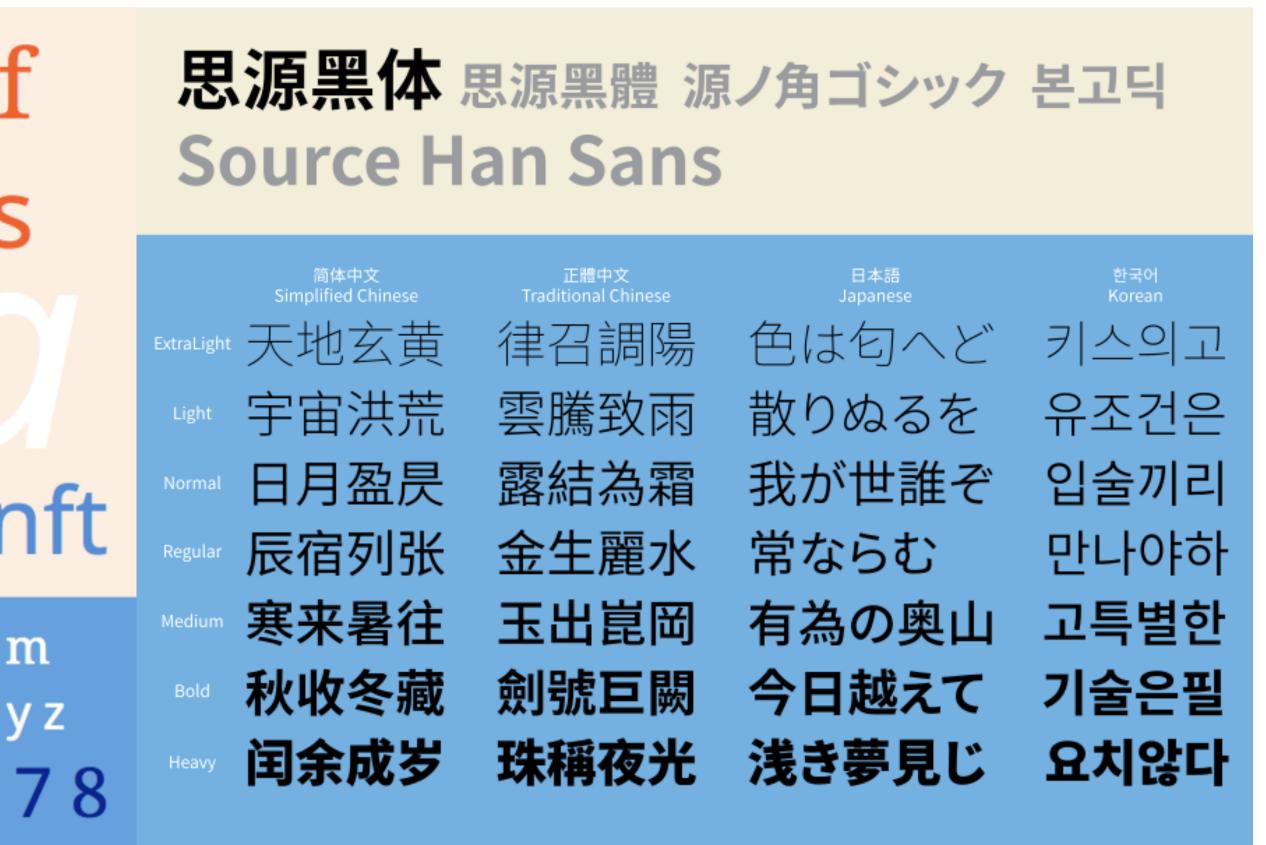
# ONE FONT TO RULE'EM ALL

When text is rendered by a computer, sometimes characters are displayed as "tofu". They are little boxes to indicate your device doesn't have a font to display the text. Google has been developing a font family called Noto, which aims to support all languages with a harmonious look and feel. Noto is Google's answer to tofu.

Noto Serif Noto Sans Aa Gg *Yy* Aa Gg Yy Ankunft

abcdefghijklm nopqrstuvwxyz 012345678

10/60



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# **ITSY BITSY BITMAP FONTS**

#### INTRODUCTION

- Digital Typography
- Font Types & Formats
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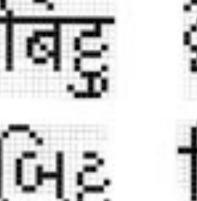
#### CONCLUSION

- Beyond this course
- Questions & answers



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11/60







الآمَمْ مُخاطَبون

Ibn al-Arabi Interpreted by Lebanese calligrapher and art critic Samir Sayegh

الحروف One of the great Sufis of the Middle Ages. لِساناً وأوضَحُه بَياناً . إبن عربي

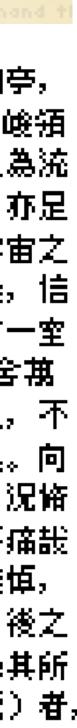
whose life and writings are shown nowadays to have deeply. penetrated the thought of East & West alike

மொமீ





永和九年,成在癸丑,获春之初,會於會楷山陰之蘭亭, 俗復(裡) - **李也。母賢**畢至,少長成集。此地有崇山峻領 \_ 茂林脩竹;又有清流澈湍,映**带**左右,引以為流 (猫), - 列坐其次。雖無將竹管弦之盛,一觸一詠,亦足 鶴曲水。 以锡敍幽情。是日也,天朗氣淸,惠風和暢。仰觀宇宙之 '俯察品預之盛。所以遊目**鸮惚,**足以極視聴之娛,信 夫人之相舆, · 俯仰一世,或取諸懐抱,悟言一室 可樂也。 |或因審所託,放浪形骸之外。雖趣(取/趨)舍萬| 之内; · 哲得於己,快然自足, 靜躁不同, 當其欣於所遇, - 及其所之既倦,情髓事湮,感慨慑之矣。向 知老之將至; 俯仰之間,已為陳迹,猶不能不以之興愧;況俗 之所欣, 短隨化, 「死生亦大矣。」豈不痛哉! |終期於盡。古人云:| **每报(覽)昔人興感之由,若合一契,未當不臨文嗟悼** 不能喻之於愧。固知一死生為虚誕,齊彭殤為妄作。後之, 祝今,亦由(猫)今之祝昔,悲夫!故列敍時人,錄其所。 述,雖世殊事異,所以與愧,其致一也。後之挋(覽)者, 亦將有感於斯文。



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# **BASIC TYPOGRAPHY**

#### INTRODUCTION

- Digital Typography
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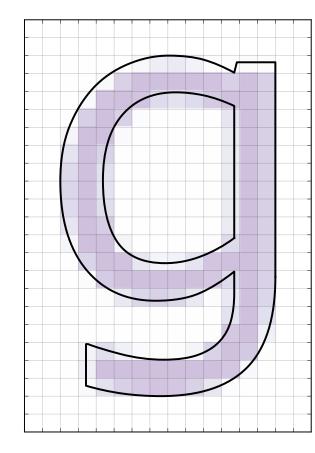
#### CONCLUSION

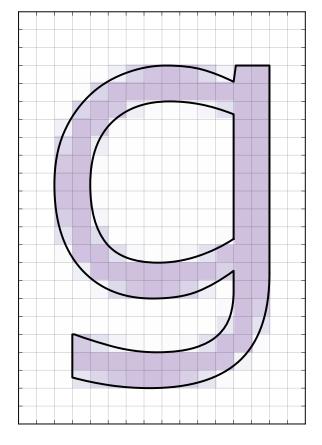
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- Questions & answers



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Kerning is the process of adjusting the spacing between characters in a proportional font.

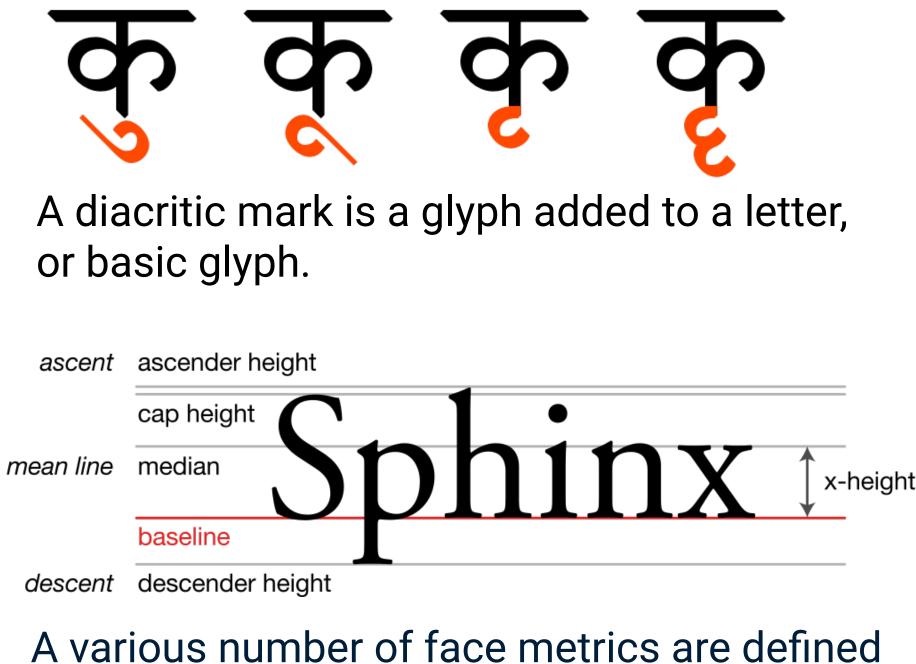




Hinting is the use of instructions to adjust the display of a font so that it lines up with a rasterized grid.

# 

A ligature occurs where two or more graphemes or letters are joined as a single glyph.



for all glyphs in a given font.



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**ADVANCED TYPOGRAPHY** 

العربى

Text shaping is the process of converting Unicode text to glyph indices and positions.



Stylistic alternate allows to replace a glyph by some variant.



The set of rules applied to produce the correct order at the time of display are described by the Unicode Bidirectional Algorithm.

13/60

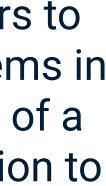




Complex text layout (CTL) refers to the typesetting of writing systems in which the shape or positioning of a grapheme depends on its relation to other graphemes (wikipedia).

# in Arabic. مفتاح معايير الويب The title is





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# **ADVANCED TYPOGRAPHY**

## Anatomy of the Hindi Font by Aditya Dipankar.

#### INTRODUCTION

- Digital Typography
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#### **PART I : TEXTURE BASED**

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- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



14/60

Upper Cap line The upper limit of the matra

Cap line  $\_$ The line which connects all consonants

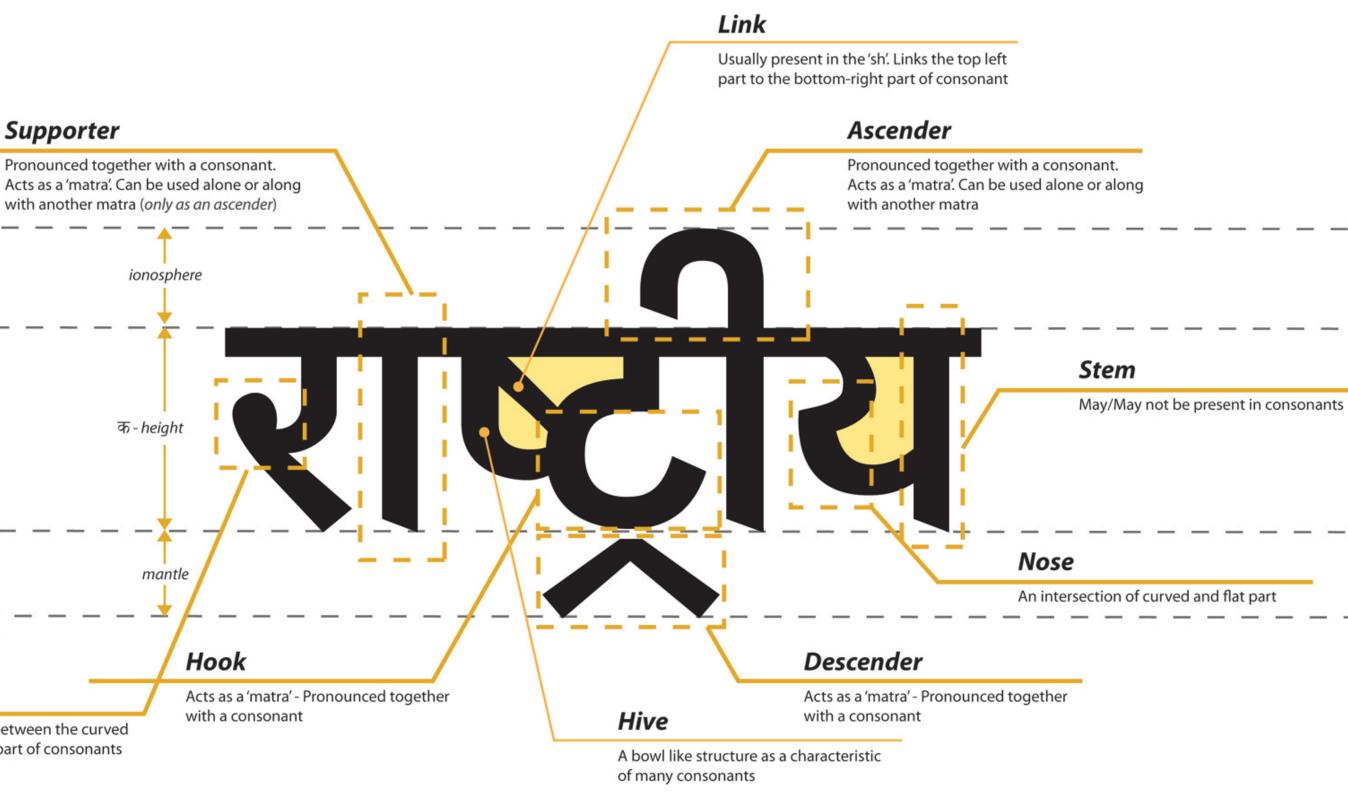
Base line The implied line where the base lies

Lower Base line The lowest possible line where the descender ends

Cusp

A connection between the curved part and slant part of consonants

Language Hindi / Script Devanagari



**Counter Space** 



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# **OTHER FORMS OF COMPLEX LAYOUT**

#### INTRODUCTION

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- Font Types & Formats
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#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
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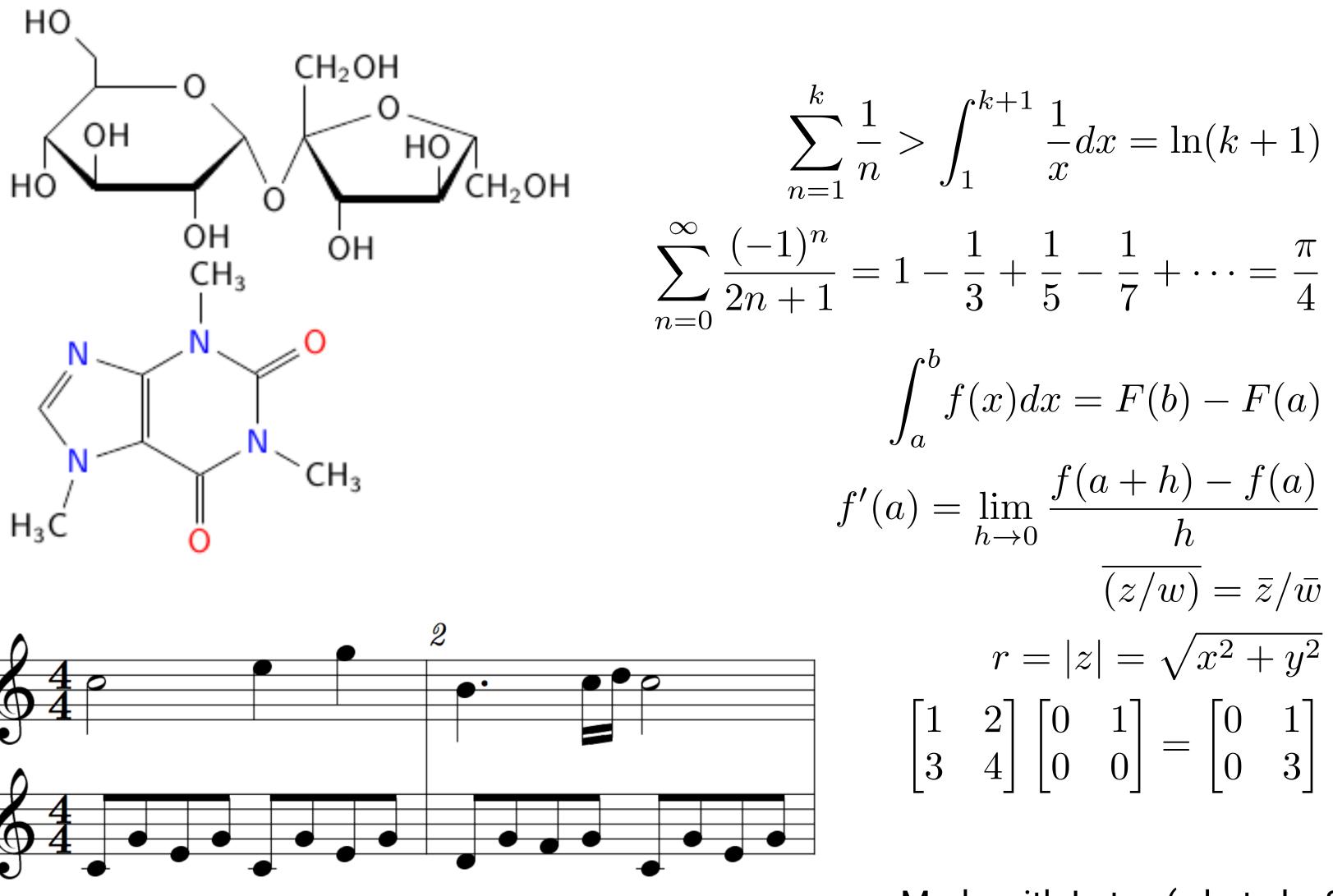
#### CONCLUSION

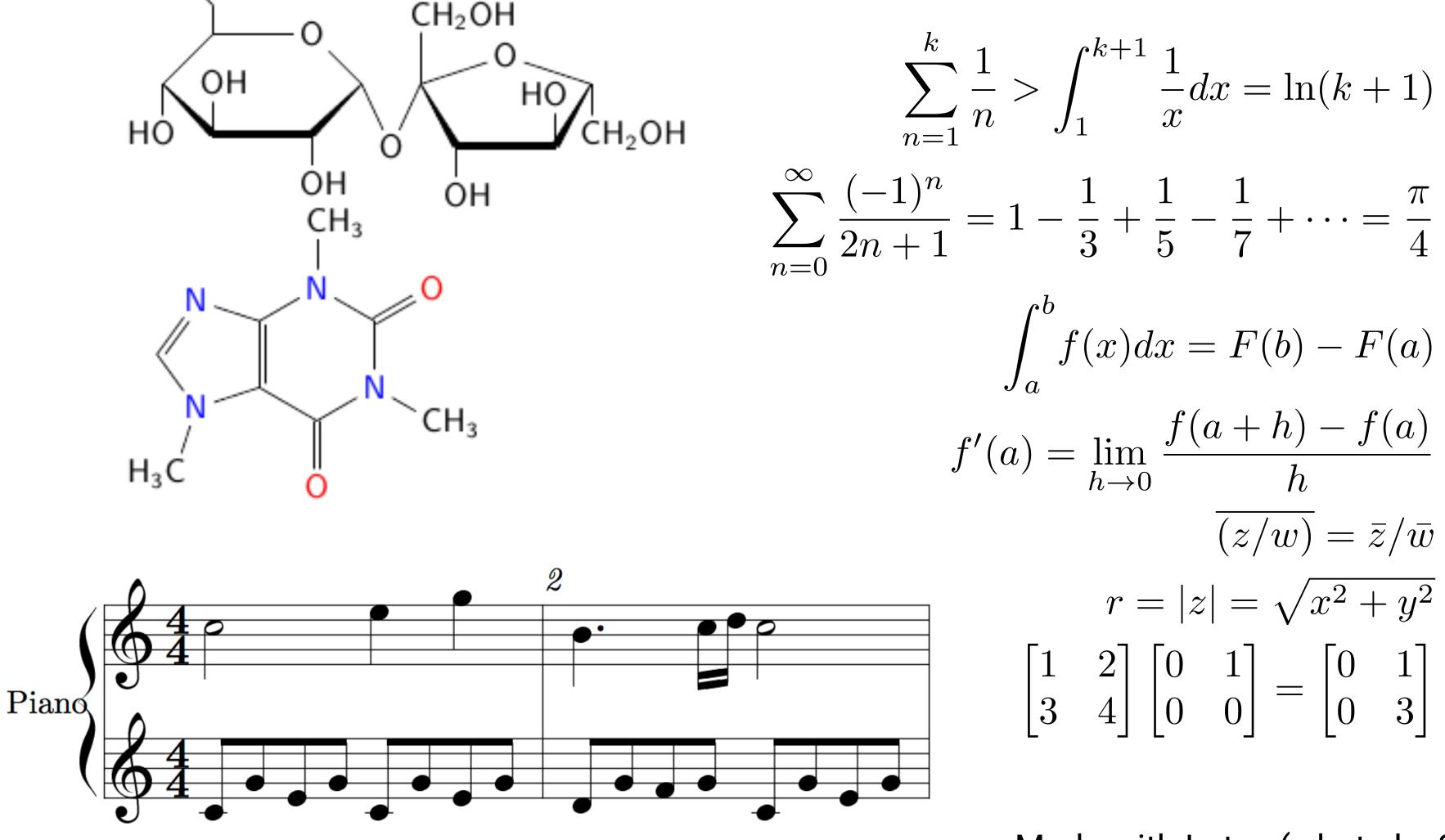
- Beyond this course
- Questions & answers



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15/60





Made with Latex (what else?)

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# **FONT FORMATS**

Types

#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

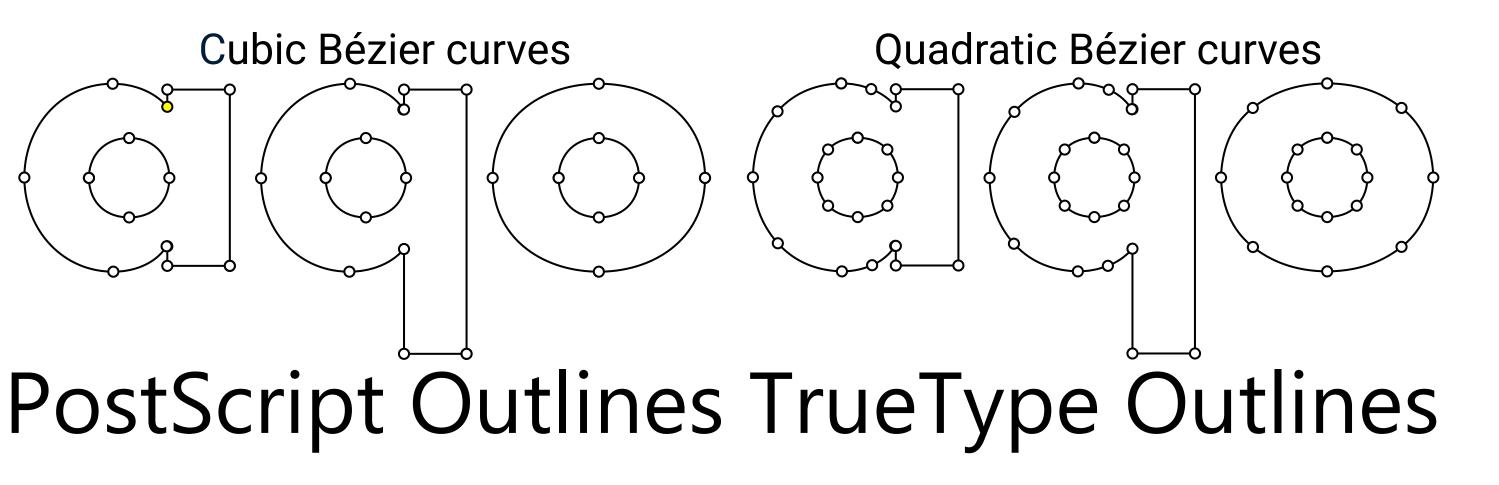
- Beyond this course
- Questions & answers



GEMERATIONS SIGGRAPH2018

16/60

Type 1(.pfm, .pfb): glyphs are described with cubic Bézier curves True Type (.ttf): glyphs are described with quadratic Bézier curves Open Type (.otf): glyphs are described with quadratic or cubic Bézier curves Web Open Font (.woff): compressed TrueType or Open Type And many more actually...





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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



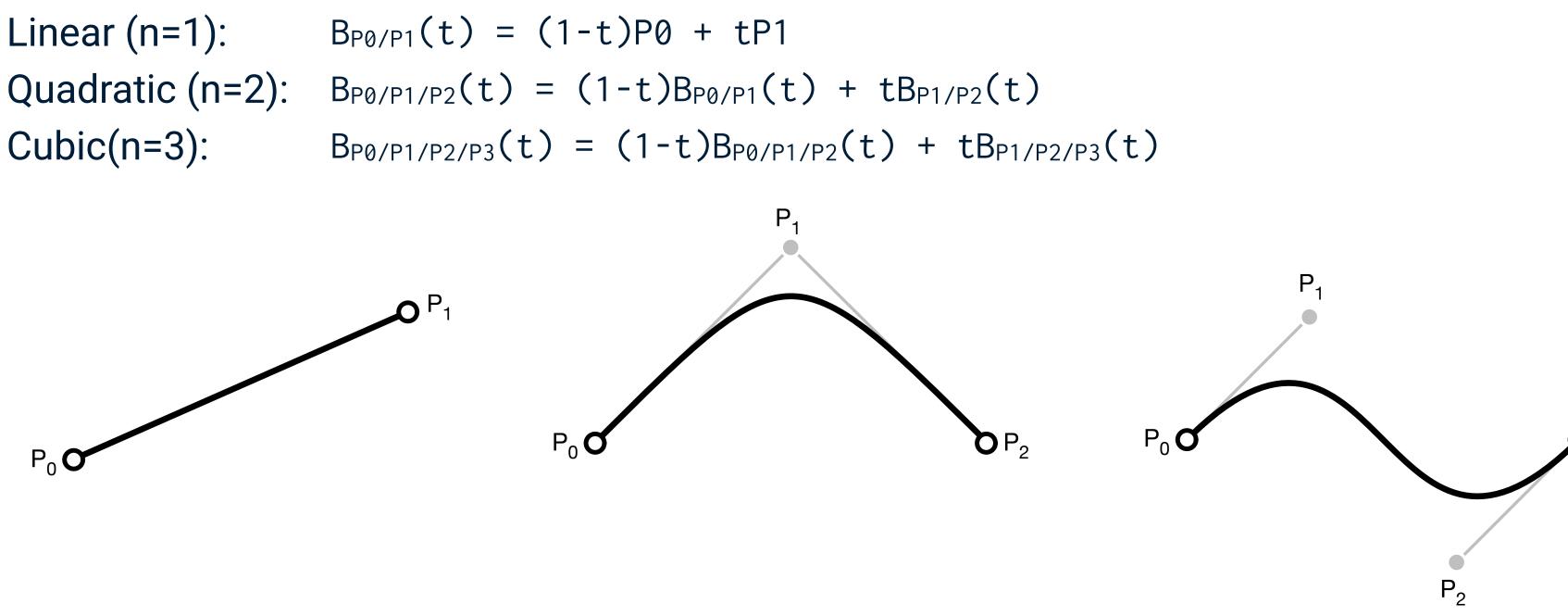
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17/60

# **A PRIMER ON BÉZIER CURVES**

## Pomax (2017) A primer on Bézier curves

Linear (n=1): Cubic(n=3):



- Sergei Natanovich Bernstein (1912) / Paul de Casteljau (1959) / Pierre Bézier (1962)
- A Bézier curve is defined by a set of control points  $P_0$  through  $P_n$ , where n is called its order. The first and last control points are always the end points of the curve.

Some related problems: signed distance, thick curves, subdivision, bounding box, linear speed, self-intersection, curve splitting, arc length, approximation of a cubic with quadratics, etc.



 $O P_{q}$ 

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# A PRIMER ON BÉZIER CURVES

#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

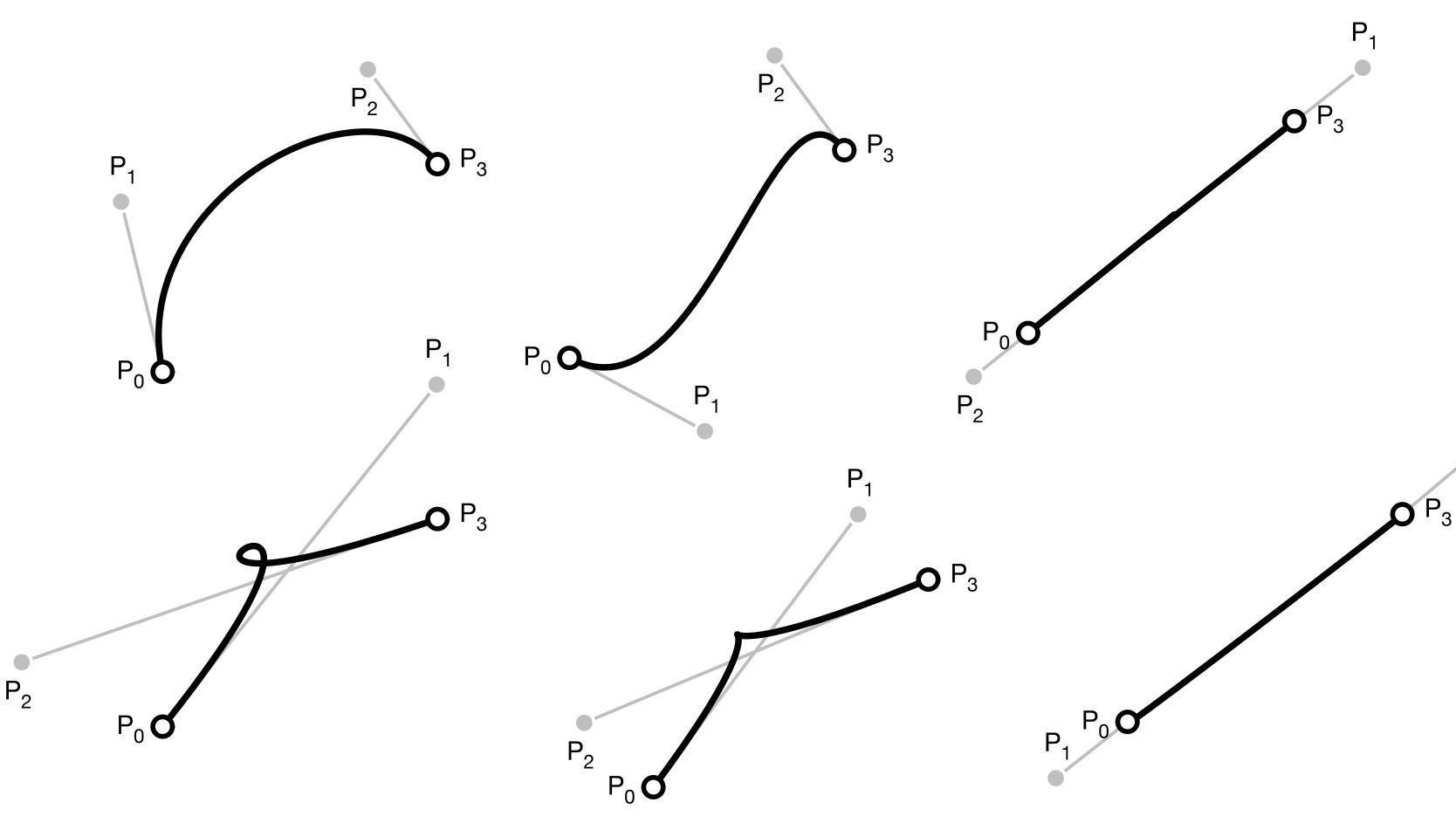
#### CONCLUSION

- Beyond this course
- Questions & answers



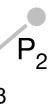
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18/60



#### Pomax (2017) A primer on Bézier curves

Cubic Bézier curves have a lot of corner cases: inflection points, cusp, loop, overlap



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

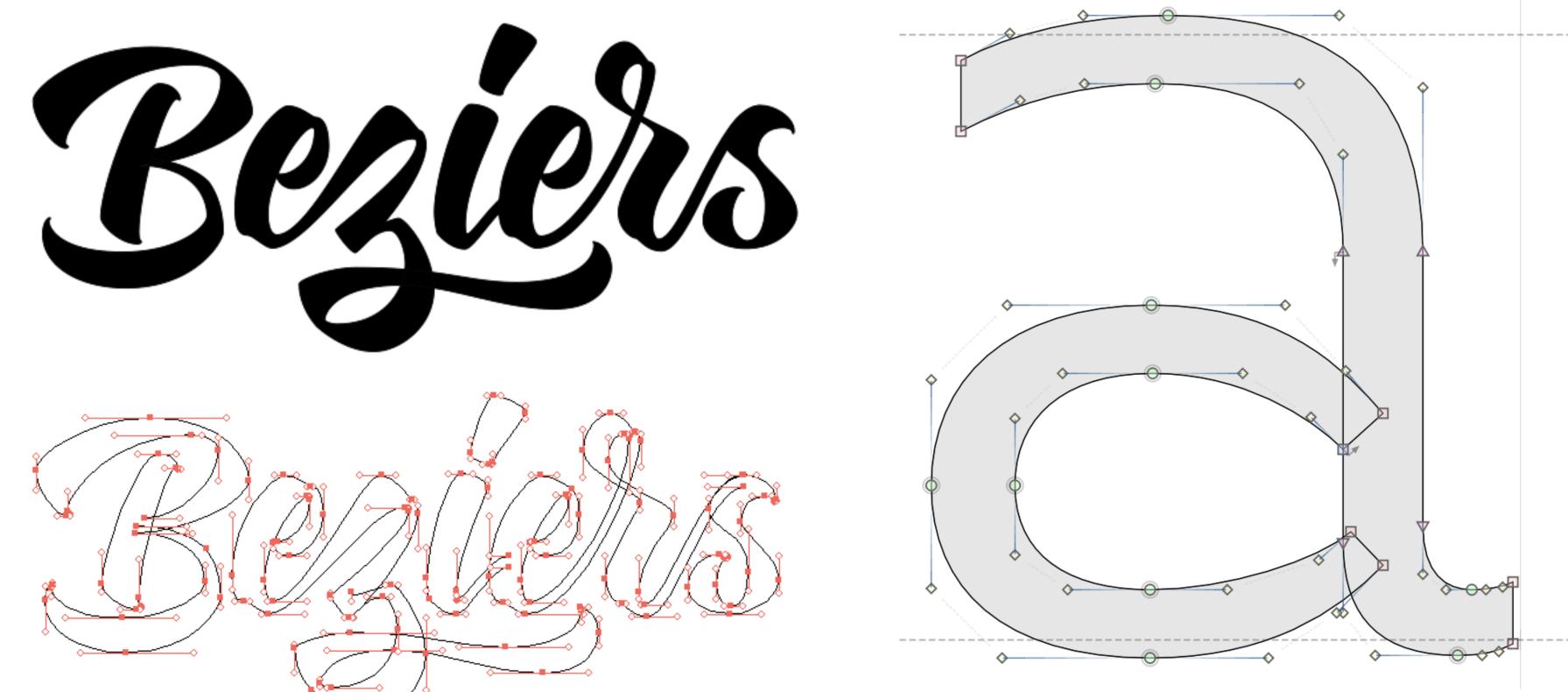
- Beyond this course
- Questions & answers

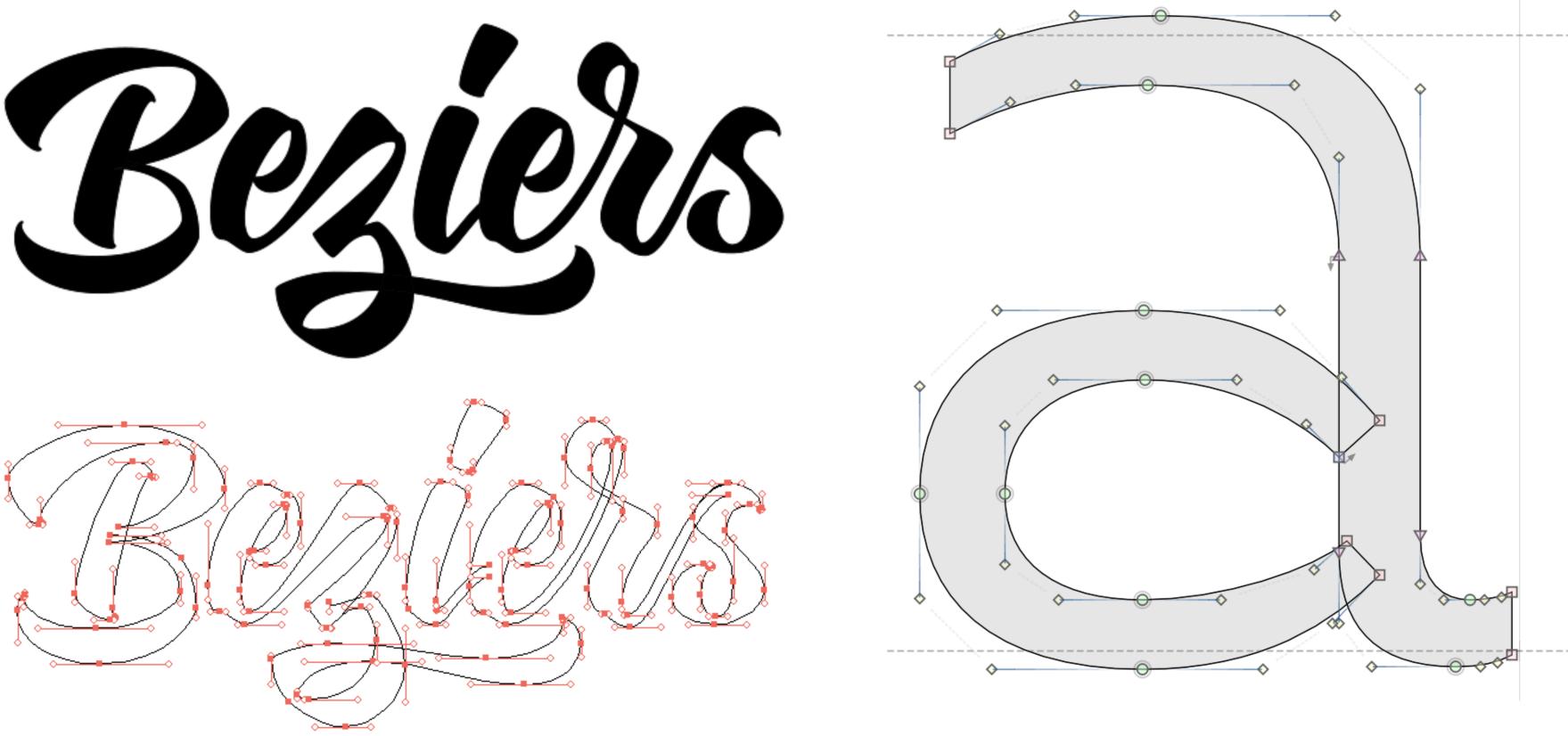


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# **ANATOMY OF A GLYPH**

Vector fonts are collections of vector images, consisting of lines and curves defining the boundary of glyphs (wikipedia). Type 1 and Type 3 Postscript fonts are described with cubic Bézier curves. Truetype fonts are described with quadratic Bézier curves.





Images by The Australian Graphic Supply Co

19/60

Images by FontLab



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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FONT TABLES **Open Type Tables BASE:** Baseline data

CMAP: Character to glyph mapping GDEF: Glyph definition data GSUB: Glyph substitution data Single: Replaces one glyph with one glyph. Alternate: Replaces one glyph with one of many glyphs. Ligature: Replaces multiple glyphs with one glyph. Context: Replaces one or more glyphs in context. GPOS: Glyph positioning data **JSTF: Justification data** 

and many more...

#### Libraries

STB\_truetype (single header file, basic support) → https://github.com/nothings/stb → https://www.freetype.org HarfBuzz (advanced support with text shaping) → https://harfbuzz.github.io

20/60

the FreeType Project

- Multiple: Replaces one glyph with more than one glyph.
- Chaining: Replaces one or more glyphs in chained context.

- FreeType (standard support without text shaping)





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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

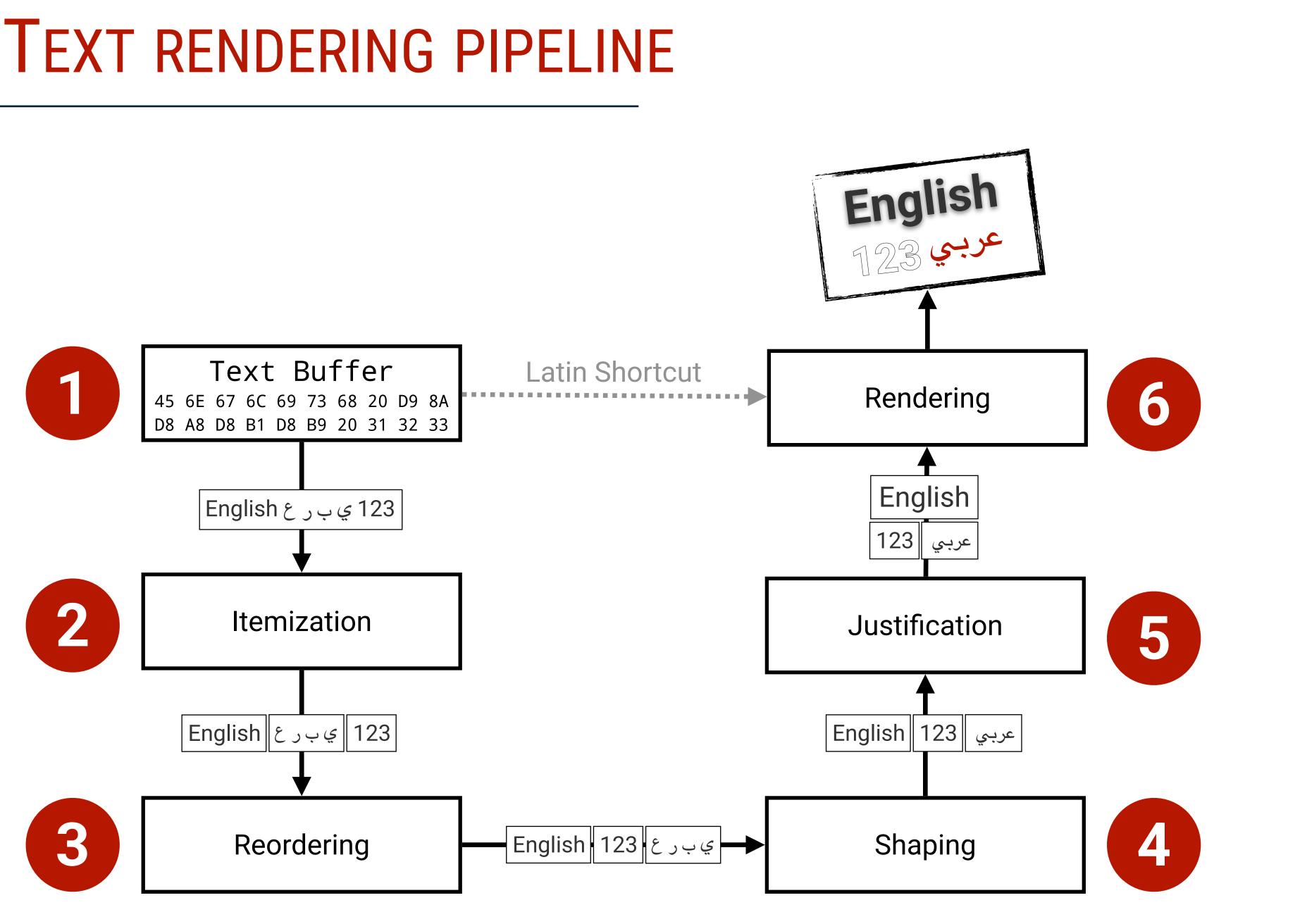
- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers

21/60





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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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# PART I

Near the end of the last century (1997), Mark Kilgard introduced a simple OpenGL-based API for texture mapped text.

The method packed many rasterized glyphs into a single alpha-only texture map and used a lookup table to assign texture coordinates to a quadrilateral to extract a glyph when rendering.



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



SIGGRAPH2018

23/60

# **2D RASTERIZATION**

#### Same input, different outputs

コンピュータによる CJKV(中国語、日本語、韓国語、ベトナム語)テキスト処理は、 多くの謎や複雑な仕組み(intrigue)に包まれている。そこにはたしかにたくらみ (intrigue) があることは認めるが、それよりも謎の多いことのほうが問題である。

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## Quartz Rendering

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#### **FreeType Native CFF Rasterizer**

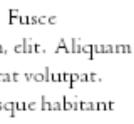
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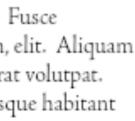
#### FreeType Light Auto Hint Rasterizer

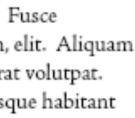
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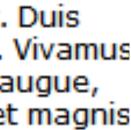
#### **FreeType using the New Adobe CFF Rasterizer (2013)**

## ClearType Rendering









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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### PART II : DISTANCE BASED

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
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- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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# **2D RASTERIZATION**

# (Source Adobe Typekit Blog)



24/60

GDI rendering of FacitWeb (above) and Minion Pro (below) with no antialiasing.

# abcefghijop 123 🏻

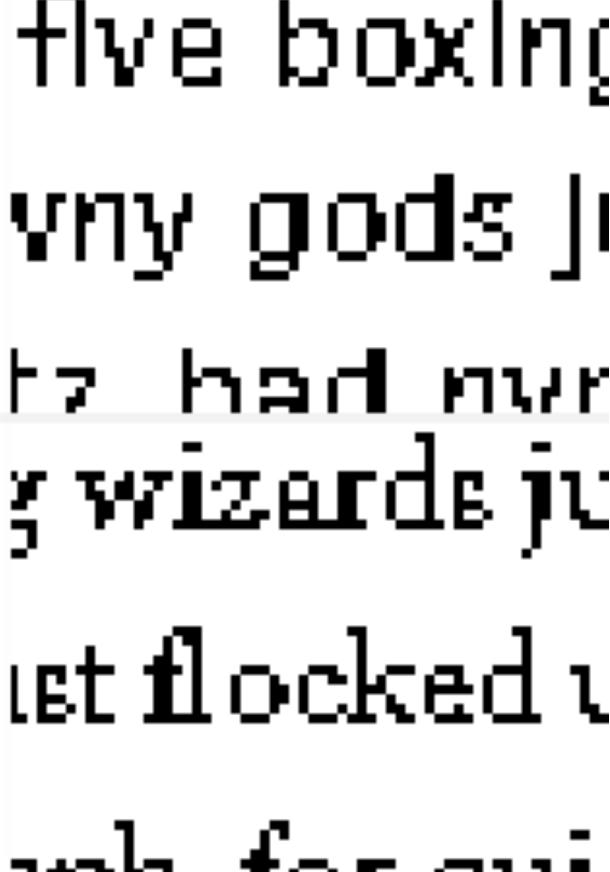
The five boxing wizards jump -Brawny gods just flocked up to Waltz, bad nymph, for quick  $||_i|$ Vamp fox held quartz duck jus

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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
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- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



SIGGRAPH2018

25/60

# **2D RASTERIZATION**

# (Source Adobe Typekit Blog)

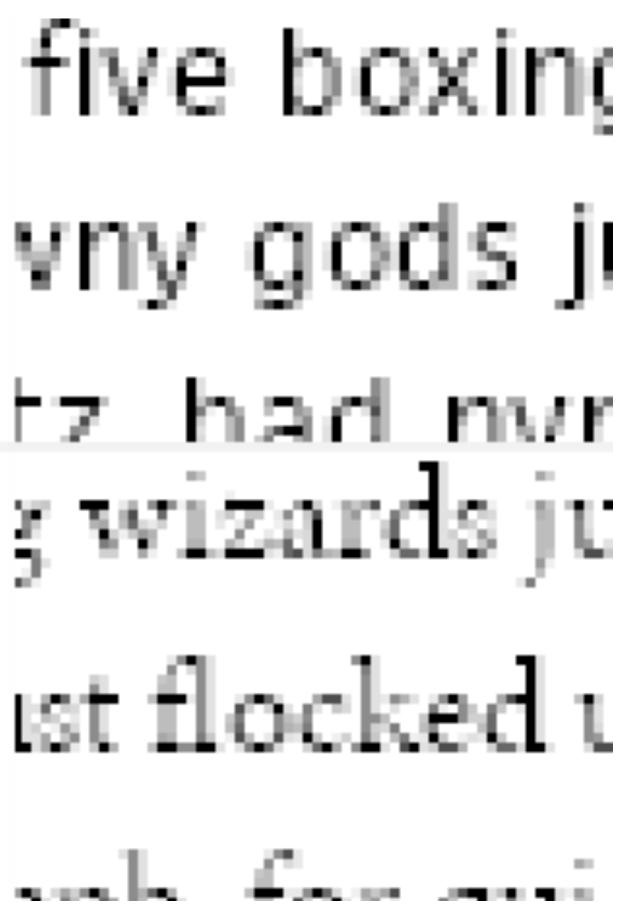


GDI rendering of FacitWeb (above) and Minion Pro (below) with standard antialiasing.

# abcefghijop 123 /

The five boxing wizards jump The five boxing wizards jump of Brawny gods just flocked up to Distance Colors Waltz, bad nymph, for quick jig Vamp fox held quartz duck jus

# abcefghijop 123 ACT WIZATOS JU The five boxing wizards jump qu Brawny gods just flocked up to q Waltz, bad nymph, for quick jigs Vamp fox held quartz duck just b



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



SIGGRAPH2018

26/60

# **2D RASTERIZATION**

# (Source Adobe Typekit Blog)







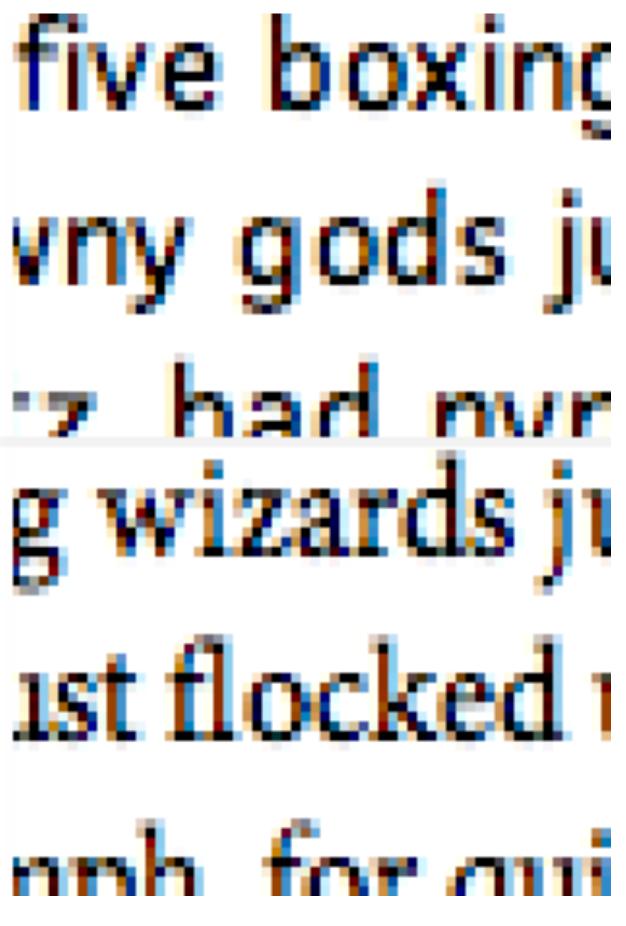
Core text rendering of FacitWeb (above) and Minion Pro (below).

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The five boxing wizards jump qu Brawny gods just flocked up to q Waltz, bad nymph, for quick jigs Vamp fox held quartz duck just b



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### PART I: TEXTURE BASED

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



SIGGRAPH2018

27/60

# **2D RASTERIZATION**

# (Source Adobe Typekit Blog)





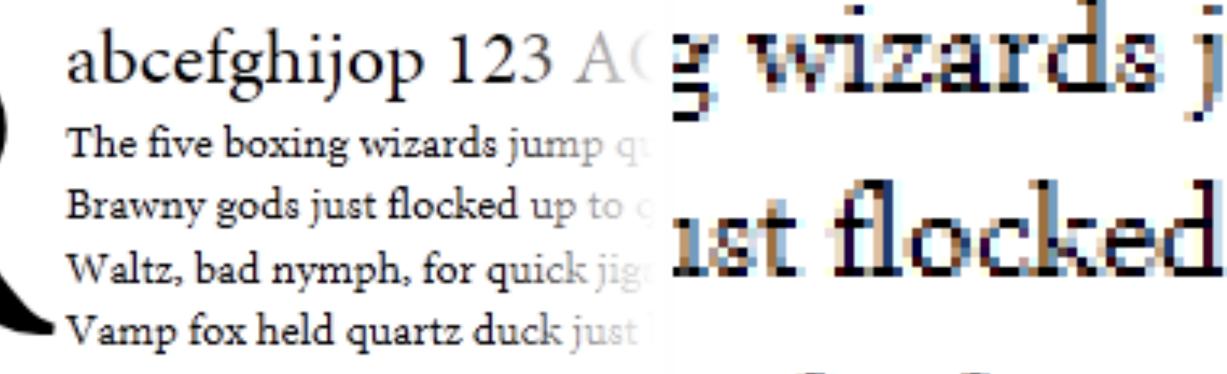


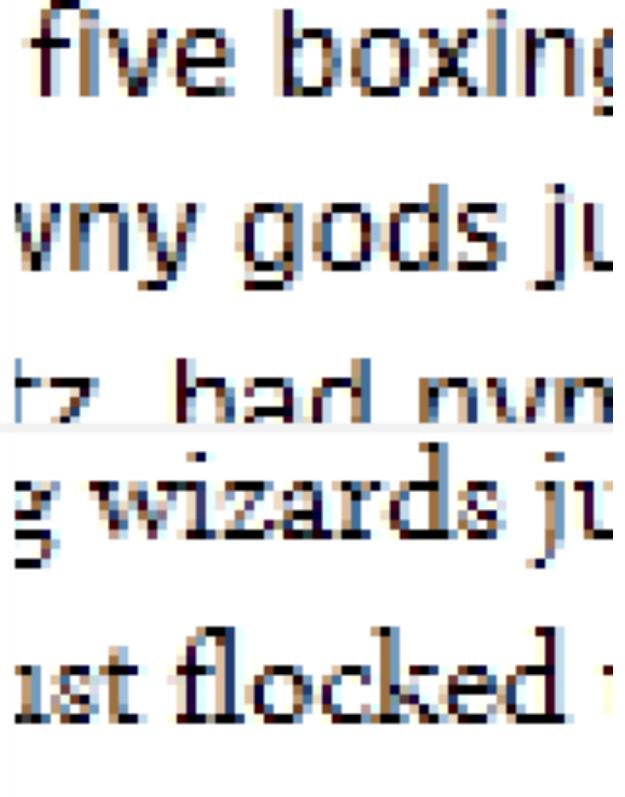


DirectWrite rendering of FacitWeb (above) and Minion Pro (below).

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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### PART I: TEXTURE BASED

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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28/60

# **2D RASTERIZATION**

# (Source Adobe Typekit Blog)





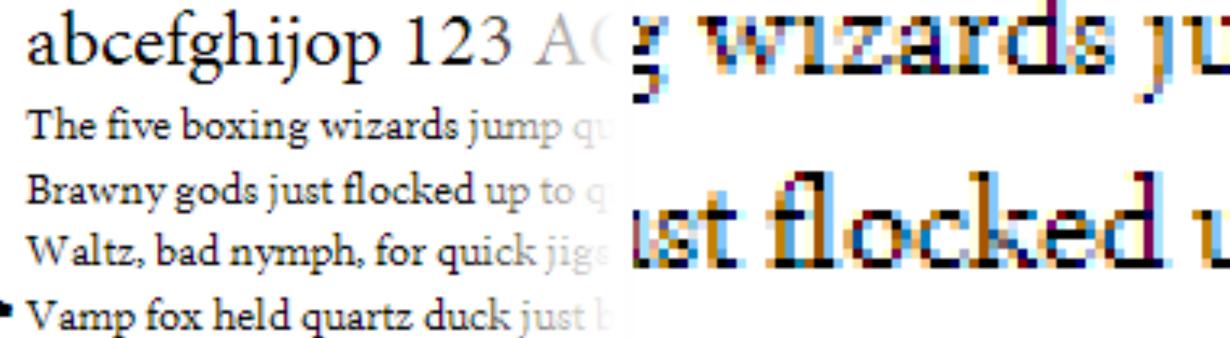




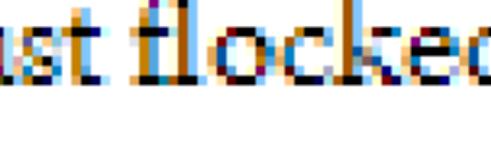
GDI rendering of FacitWeb (above) and Minion Pro (below) with ClearType enabled.

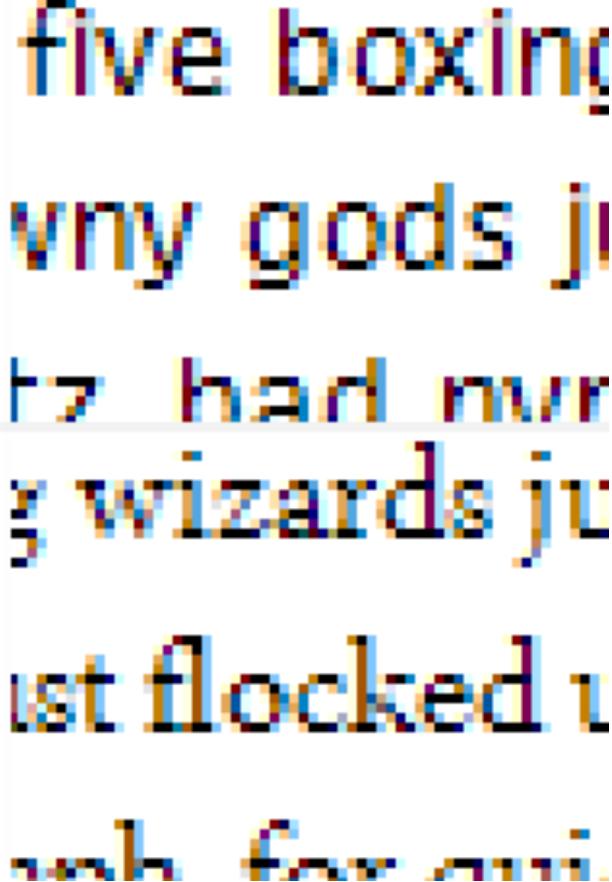
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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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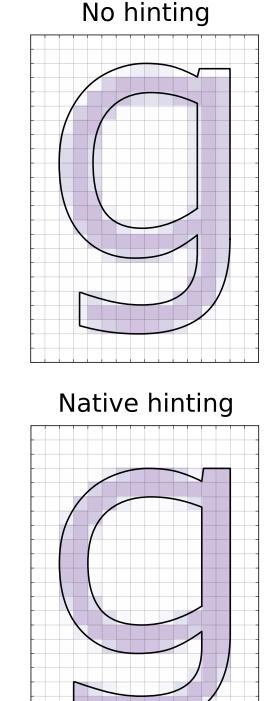
29/60

# **2D RASTERIZATION**

### Gamma correction, hinting, energy distribution, etc.

The quick brown fox jumps over the lazy dog. 0123456789. The quick brown fox jumps over the lazy dog. 0123456789.

## The quick brown fox jumps over the lazy dog. The quick brown fox jumps over the lazy dog. The quick brown fox jumps over the lazy dog. The quick brown fox jumps over the lazy dog.



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

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- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



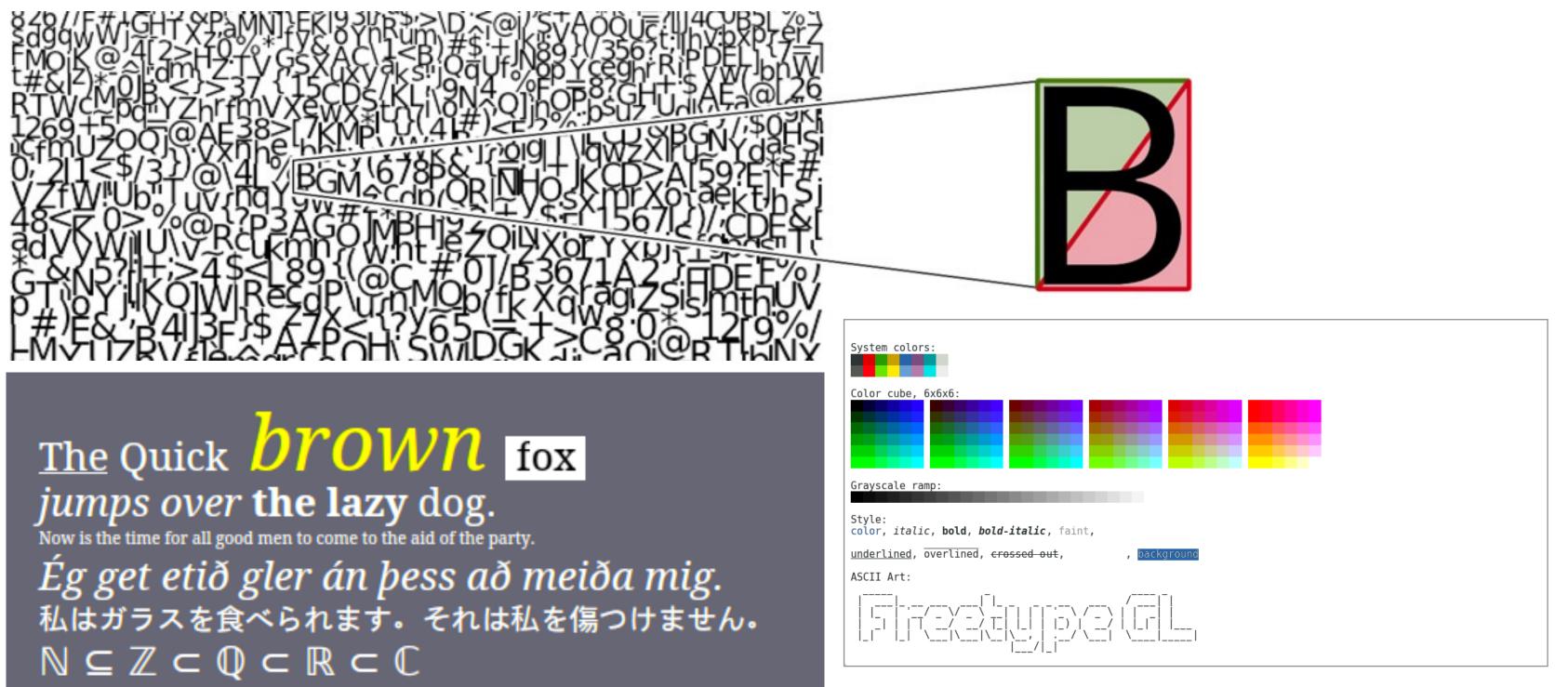
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30/60

# **TEXTURE FONT**

## **Kilgard (1997)** A Simple OpenGL-based API for Texture Mapped Text

Texture mapping is well suited for rendering text because textures can be rendered quickly with current 3D hardware and even via clever programming of today's fast CPUs. Textures can be stretched. rotated, scaled, and even projected (assuming the texture mapping is perspective) correct) so that texture mapped text looks reasonable in 3D scenes.



https://github.com/rougier/freetype-gl



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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# **BIN PACKING ALGORITHMS**

### Jylänky (2010) A Thousand Ways to Pack the Bin

Several algorithms that can be used to solve the problem of packing rectangles into twodimensional finite bins. Most of the algorithms have well been studied in literature, but some of the variants are less known and some are apparently regarded as "folklore" and no previous reference is known. Different variants are presented and compared.

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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



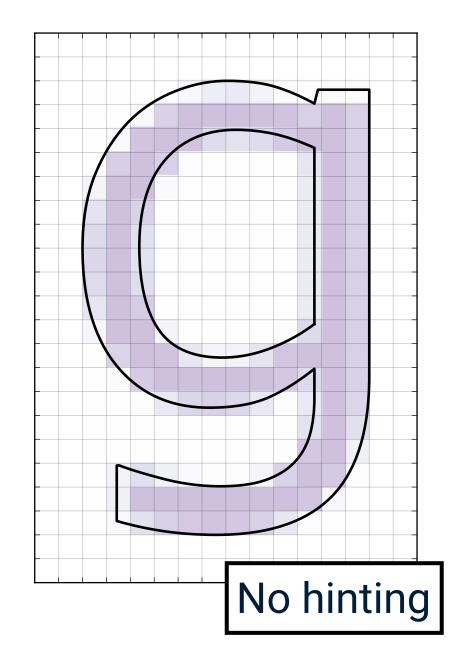
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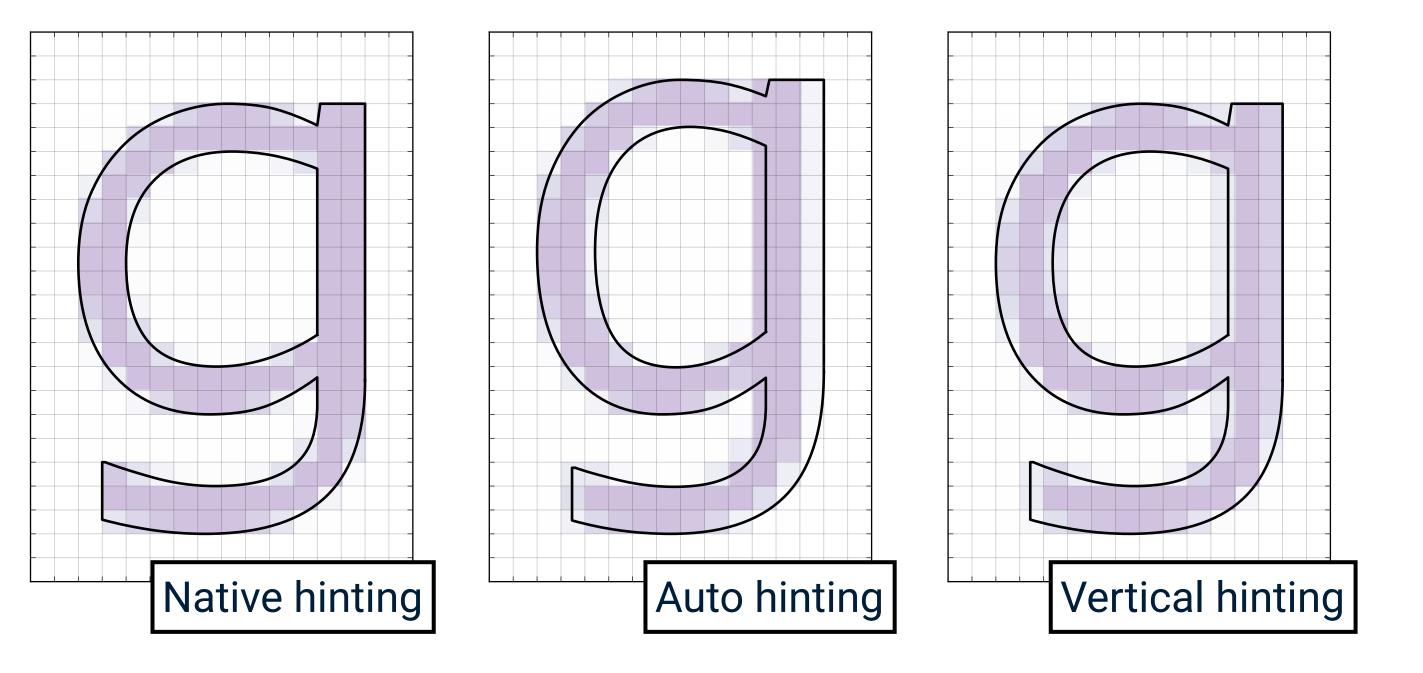
32/60

# **TEXTURE FONT II**

## Rougier (2013) Higher Quality 2D Text Rendering

When displaying text on low-resolution devices (DPI < 150), one typically has to decide if one wants to respect the pixel grid (e.g., Cleartype technology / Microsoft / native hinting) for crisp rendering or, to privilege glyph shapes (Quartz technology / Apple / no hinting) at the cost of blurring. There is, however, a third way that may combine the best of the two technologies (vertical hinting).







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# **TEXTURE FONT II**

#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### PART I: TEXTURE BASED

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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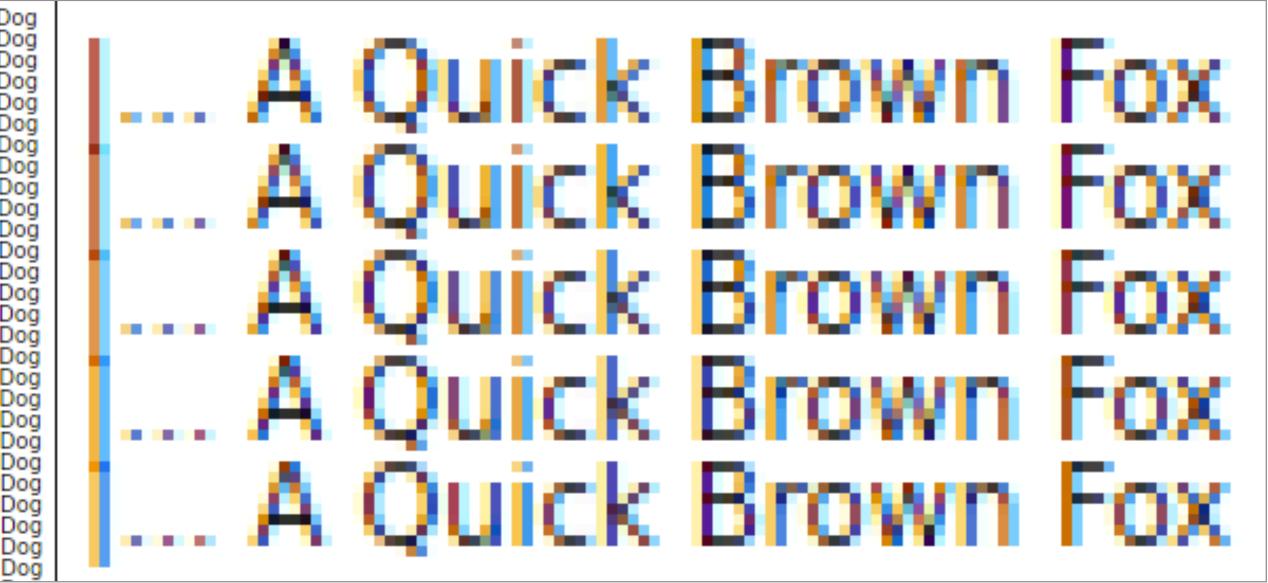
### Rougier (2013) Higher Quality 2D Text Rendering

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	A Quick Brown Fox	Jumps Over The Lazy D
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	A Quick Brown Fox	Jumps Over The Lazy D
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33/60

Use horizontal RGB sub-pixel anti-aliasing for LCD flat panels. Use vertical hinting only and completely discard the horizontal one. Use accurate glyph advance values from unhinted glyph Use accurate, high resolution values from the kerning table.



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### PART I: TEXTURE BASED

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers

34/60



# **TEXTURE FONT II**

## Rougier (2013) Higher Quality 2D Text Rendering

### Subpixel rendering on the CPU Subpixel positioning on the GPU

$0 < s \le 1/3, t = 3s$	$R_{\rm out} = tB_{\rm left}$
	$G_{\rm out} = tR +$
	$R_{out} = tB_{left}$ $G_{out} = tR + B_{out} = tG + B_{out}$
$1/3 < s \le 2/3, t = 3s - 1$	$R_{\rm out} = tG_{\rm lef}$
	$G_{\rm out} = tB_{\rm lef}$
	$B_{\rm out} = tR +$
$\frac{2}{3 < s < 1, t = 3s - 2}$	$R_{\rm out} = tR_{\rm left}$
	$G_{\text{out}} = tG_{\text{left}}$
	$R_{out} = tG_{left}$ $G_{out} = tB_{left}$ $B_{out} = tR + R_{left}$ $G_{out} = tR_{left}$ $B_{out} = tG_{left}$



```
ft + (1-t)R
+(1-t)G
+(1-t)B
a_{\rm ft} + (1-t)B_{\rm left}
R_{\rm ft} + (1-t)R
-(1-t)G
_{\rm ft} + (1-t)G_{\rm left}
eft + (1-t)B_{left}
f_{t} + (1-t)R
```

الشمس إذ يزغت خود كمثل الشمس إذ بزغت – يحظى صف خلق خود

```
uniform sampler2D texture;
uniform vec2 pixel;
varying float shift;
void main()
                  = gl_TexCoord[0].xy;
    vec2 uv
    vec4 current = texture2D(texture, uv);
    vec4 previous = texture2D(texture, uv+vec2(-1,0)*pixel);
    float r = current.r;
    float g = current.g;
    float b = current.b;
    float a = current.a;
    if( shift <= 1.0/3.0 )
        float z = 3.0*shift;
        r = mix(current.r, previous.b, z);
        g = mix(current.g, current.r, z);
        b = mix(current.b, current.g, z);
    else if( shift <= 2.0/3.0 )</pre>
        float z = 3.0 + \text{shift} - 1.0;
        r = mix(previous.b, previous.g, z);
        g = mix(current.r, previous.b, z);
        b = mix(current.g, current.r, z);
    else if( shift < 1.0 )</pre>
        float z = 3.0 * \text{shift} - 2.0;
        r = mix(previous.g, previous.r, z);
        g = mix(previous.b, previous.g, z);
        b = mix(current.r, previous.b, z);
    gl_FragColor = vec3(r,g,b,a);
```



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



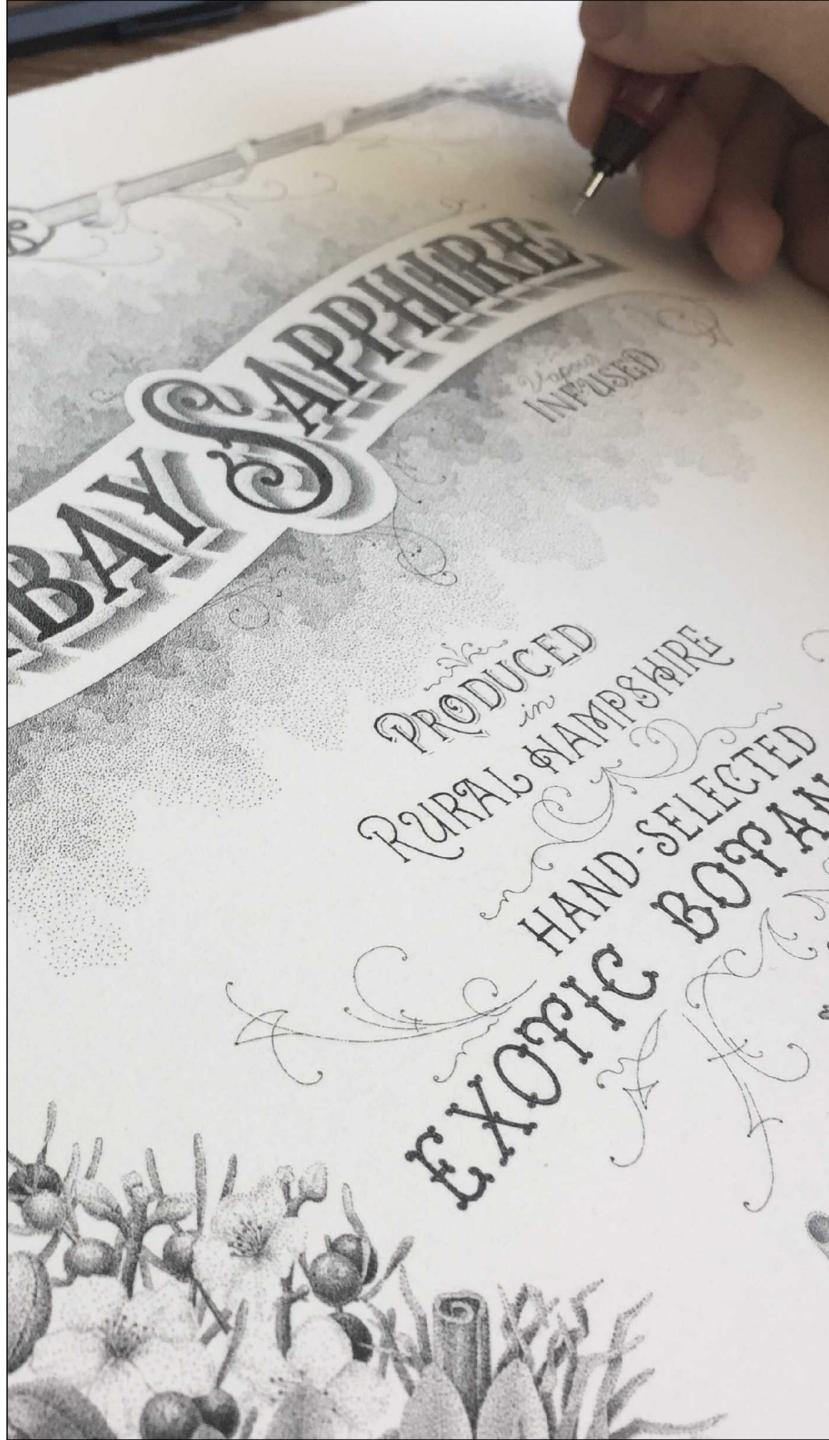
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35/60

# PART II

Distance based rendering takes advantage of a signed distance function (that can be approximated) to compute the individual coverage for each pixel.

The coverage can be selected to implement various effects (stroke, thinner, thicker, shadow, etc)



Work & image by Xavier Casalta casaltaxavier.com

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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### PART I: TEXTURE BASED

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### PART II : DISTANCE BASED

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



GENERATIONS SIGGRAPH2018

# **DISTANCE BASED RENDERING**

Distance based rendering takes advantage of a signed distance function (that can be approximated) to compute the individual coverage for each pixel. The coverage can be selected to implement various effects (stroke, thinner, thicker, shadow, etc)



36/60

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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers

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# **COMPUTING SDF**

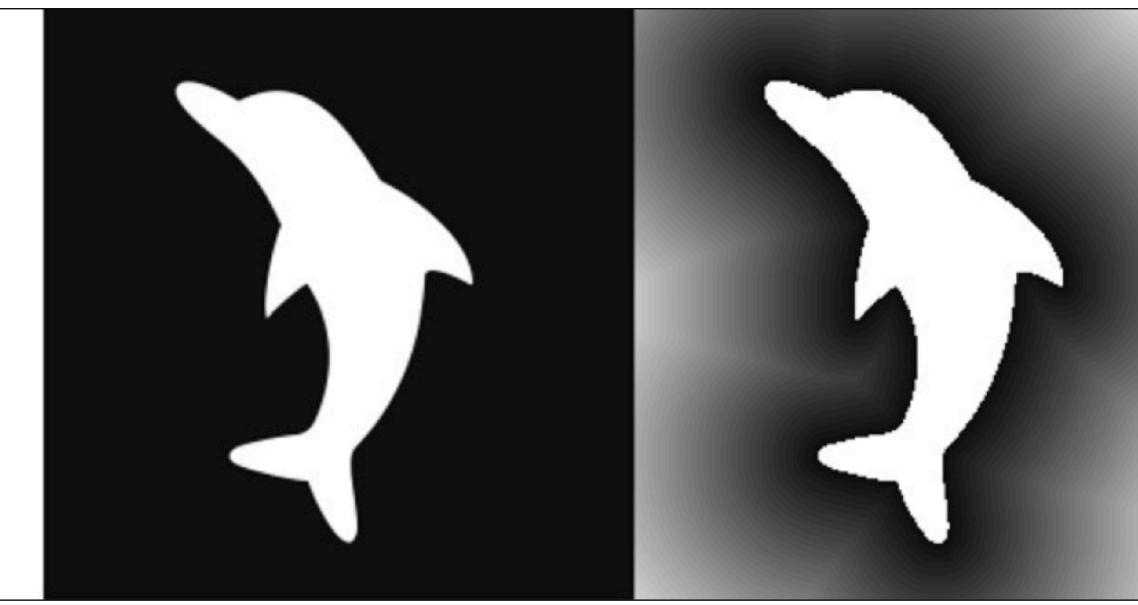
### Gustavson & Strand (2011) Anti-Aliased Euclidean distance transform

We present a modified distance measure for use with distance transforms of anti-aliased, area sampled grayscale images of arbitrary binary contours. The modified measure can be used in any vector-propagation Euclidean distance transform. Our test implementation in the traditional SSED8 algorithm shows a considerable improvement in accuracy and homogeneity of the distance field compared to a traditional binary image transform.

### See also http://contourtextures.wikidot.com



37/60







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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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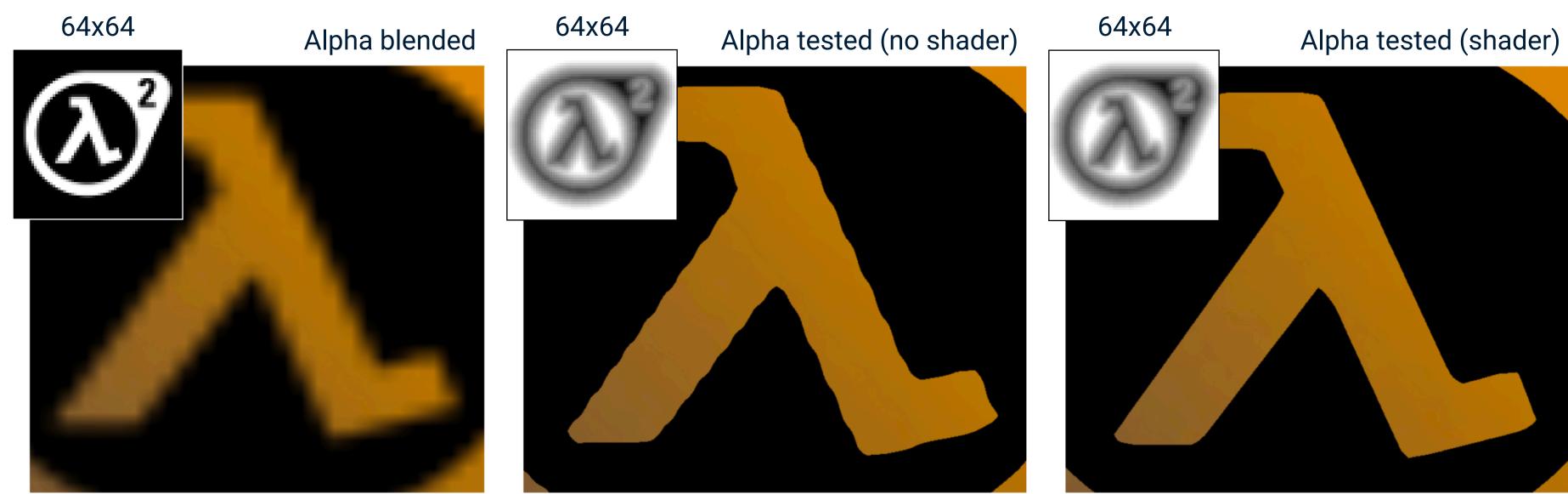
38/60

# SINGLE CHANNEL SDF

### **Green (2007)** Improved Alpha-Tested Magnification for Vector Textures

A distance field is generated from a high resolution image, and then stored into a channel of a lower-resolution texture. In the simplest case, this texture can then be rendered simply by using the alpha- testing and alpha-thresholding feature of modern GPUs, without a custom shader. This allows the technique to be used on even the lowest-end 3D graphics hardware. With the use of programmable shading, the technique is extended to perform various special effect renderings, including soft edges, outlining, drop shadows, multi-colored images, and sharp corners.







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# **SDF: MULTIPLE CHANNELS**

#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



# SEMERATIONS SIGGRAPH2018

39/60

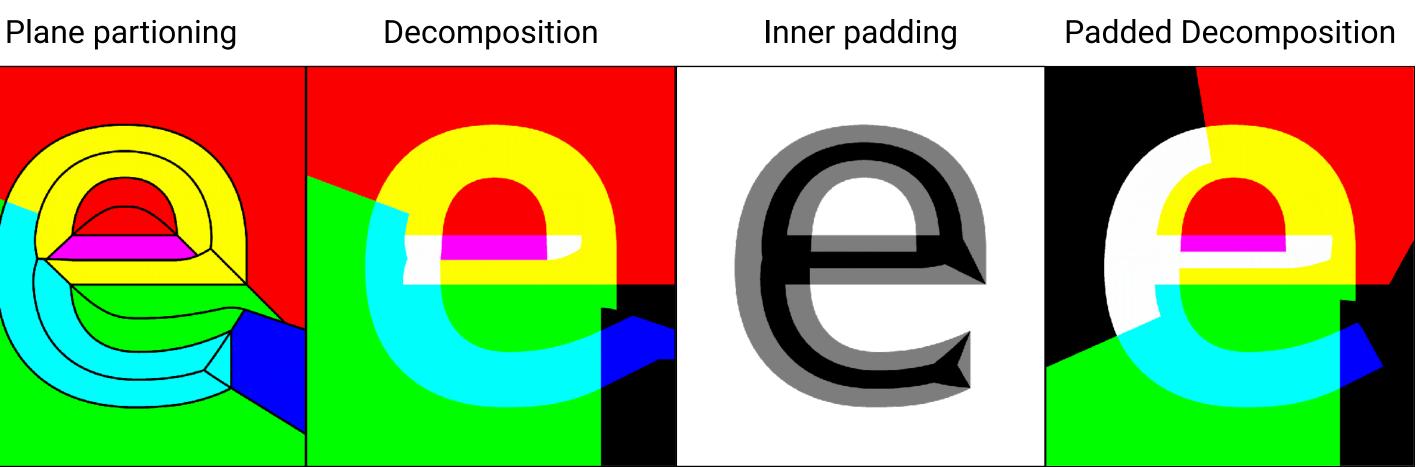




# Edge Coloring

### Chlumsky (2015) Shape Decomposition for Multi-channel Distance Fields







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# **SDF: MULTIPLE CHANNELS**

#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



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### Chlumsky (2015) Shape Decomposition for Multi-channel Distance Fields



Single channel SDF

Multi channel SDF

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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

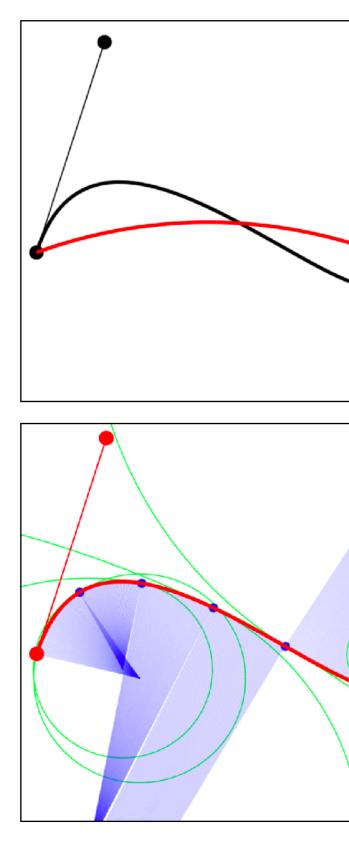
- Beyond this course
- Questions & answers

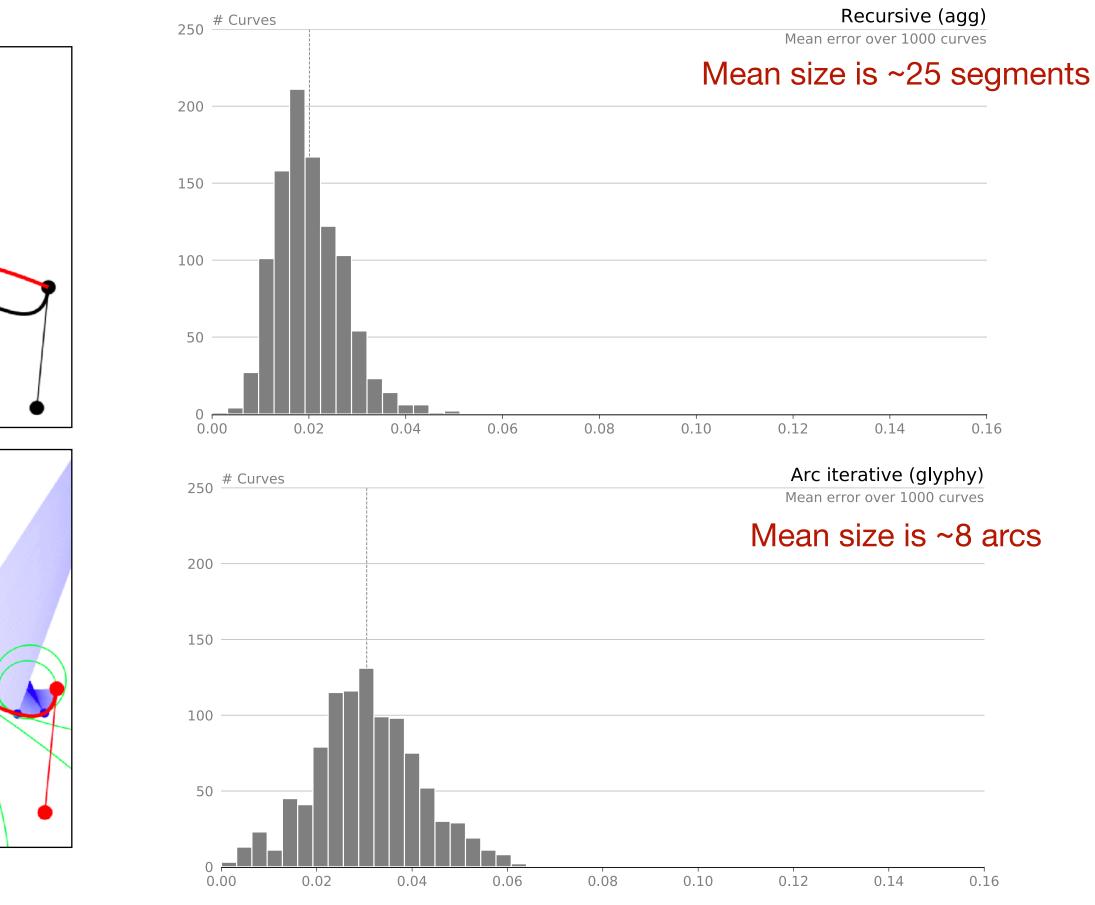


# **ARC APPROXIMATION**

### Esfahbod (2012) Glyphy

Since distance to arbitrary Bézier curves is hard, we can instead first convert a glyph into (approximated) circular arc splines and upload this converted vector glyph to the GPU. Distance are then computed onto the GPU. Corner cases are overlapping contours, tangent arcs and float precision.





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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



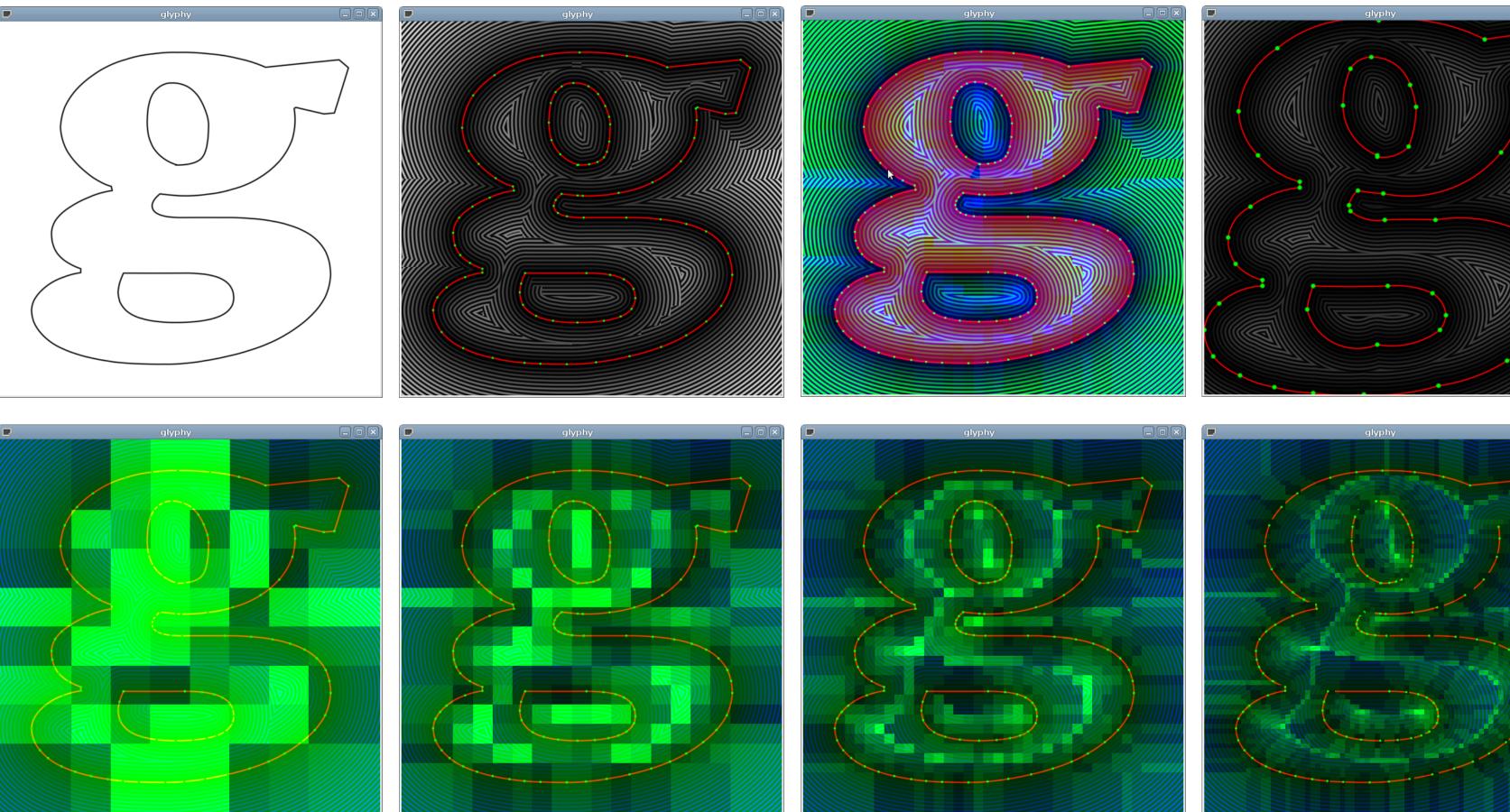
# GENERATIONS SIGGRAPH2018

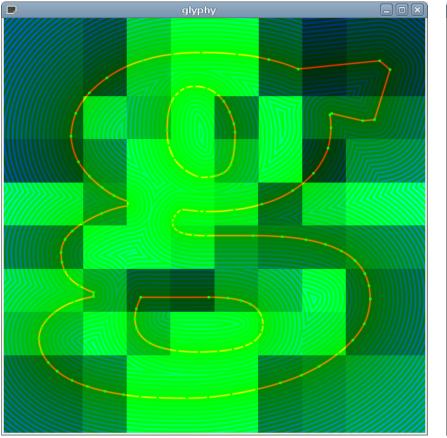
42/60

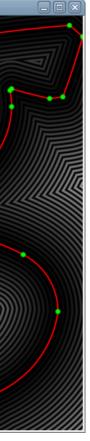
# **ARC APPROXIMATION**

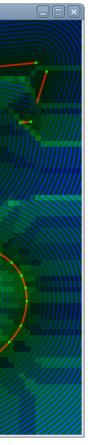
### Esfahbod (2012) Glyphy

### SDF-based antialiasing + subpixel positioning + random access (coarse grid).









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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### PART I: TEXTURE BASED

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### PART II : DISTANCE BASED

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



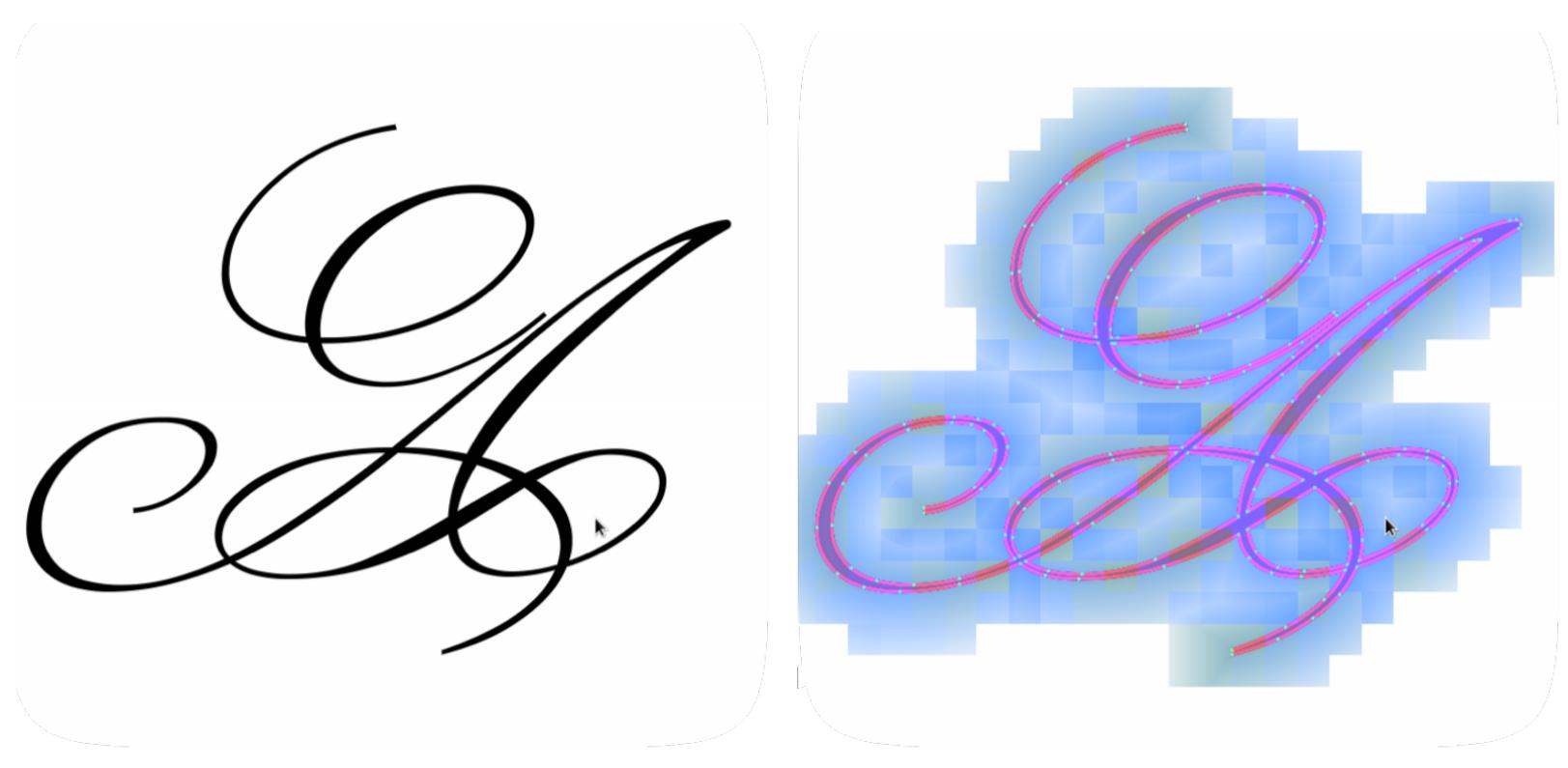
#### SEMERATIONS SIGGRAPH2018

43/60

# ARC APPROXIMATION

### Esfahbod (2012) Glyphy

### Drawback: Memory and speed are font dependent



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### PART I: TEXTURE BASED

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### PART II : DISTANCE BASED

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



GENERATIONS SIGGRAPH2018

44/60

# Part III

Charles Loop and Jim Blinn introduced in 2005 a new approach for resolution-independent rendering of quadratic and cubic spline curves.

By tessellating a glyph the proper way, they offered de facto a method for resolution independent rendering of a glyph with good rendering quality.



Image by Black[Foundry] black-foundry.com



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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers

GENERATIONS SIGGRAPH2018

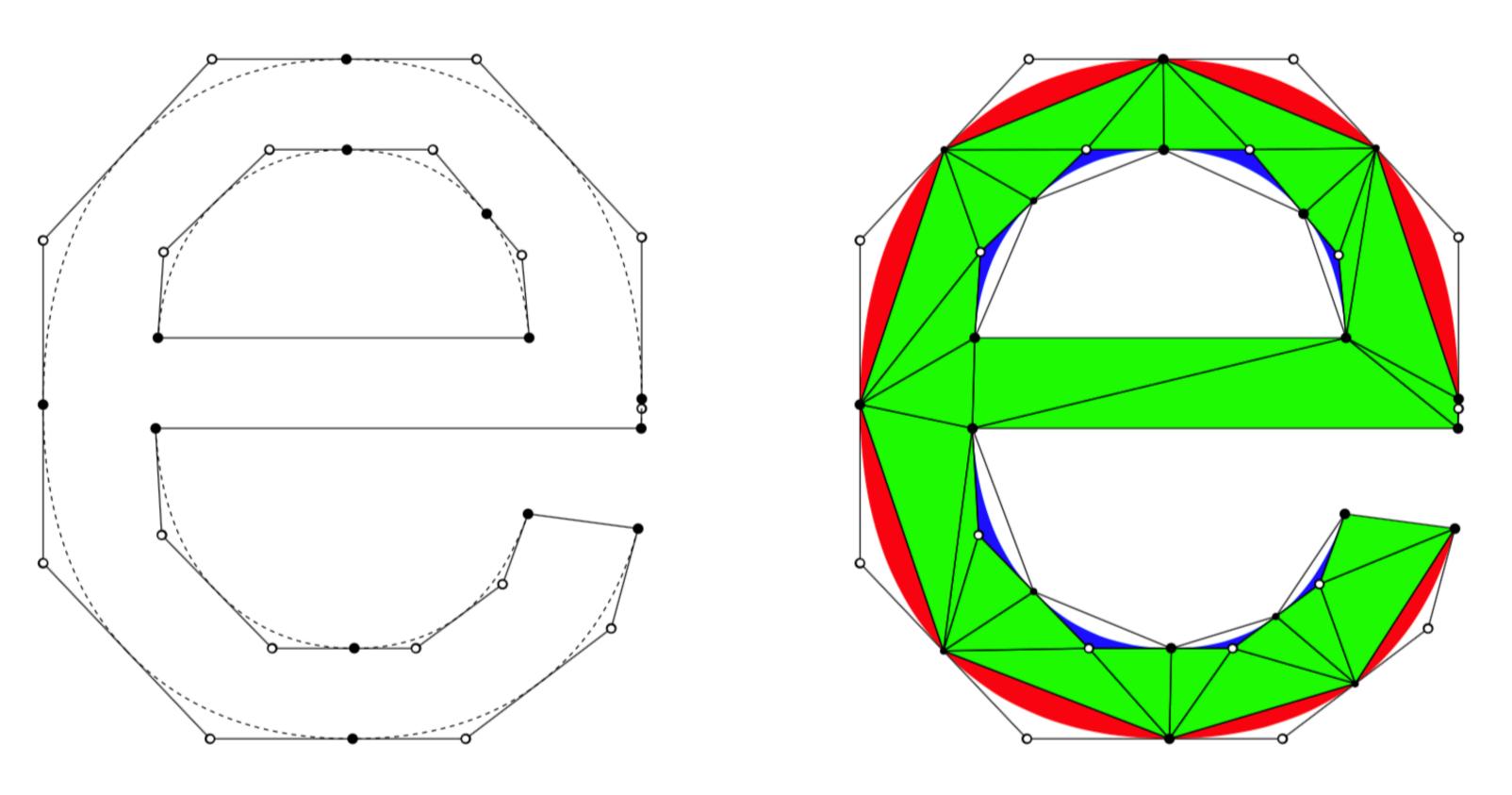
45/60



# **GPU FRIENDLY**

### Loop & Blinn (2005) Resolution Independent Curve Rendering

We present a method for resolution independent rendering of paths and bounded regions, defined by quadratic and cubic spline curves, that leverages the parallelism of programmable graphics hardware to achieve high performance. Our result is a mechanism for rendering vector geometry that has the following properties: resolution independence, compact geometric representation, high performance.





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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### PART III : GEOMETRY BASED

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers

SIGGRAPH2018

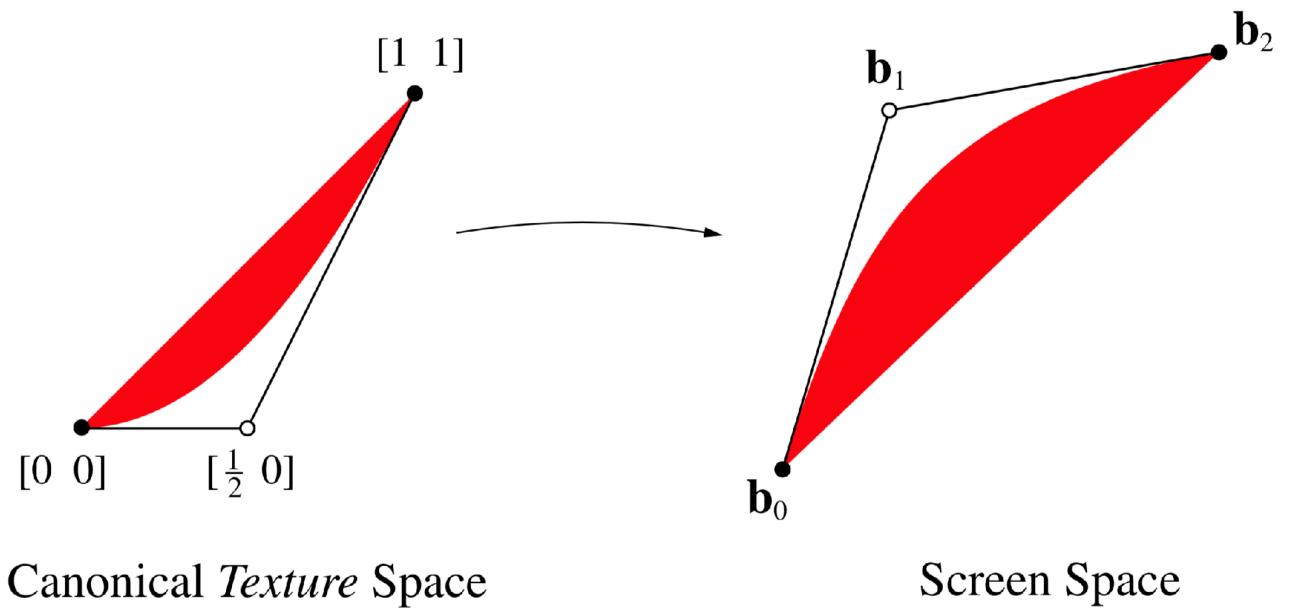
46/60



# **GPU FRIENDLY**

### Loop & Blinn (2005) Resolution Independent Curve Rendering

We determine if the pixel is inside or outside the curve by evaluating  $f(u, v) = u^2 - v$  in a pixel shader program. If f(u, v) < 0 then the pixel is inside the curve, otherwise it is outside.



# See also

"Rendering Vector Art on the GPU" (Charles Loop & Jim Blinn, GPU Gems 3, Chapter 25) "Easy Scalable Text Rendering on the GPU" (Evan Wallace Medium)

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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers

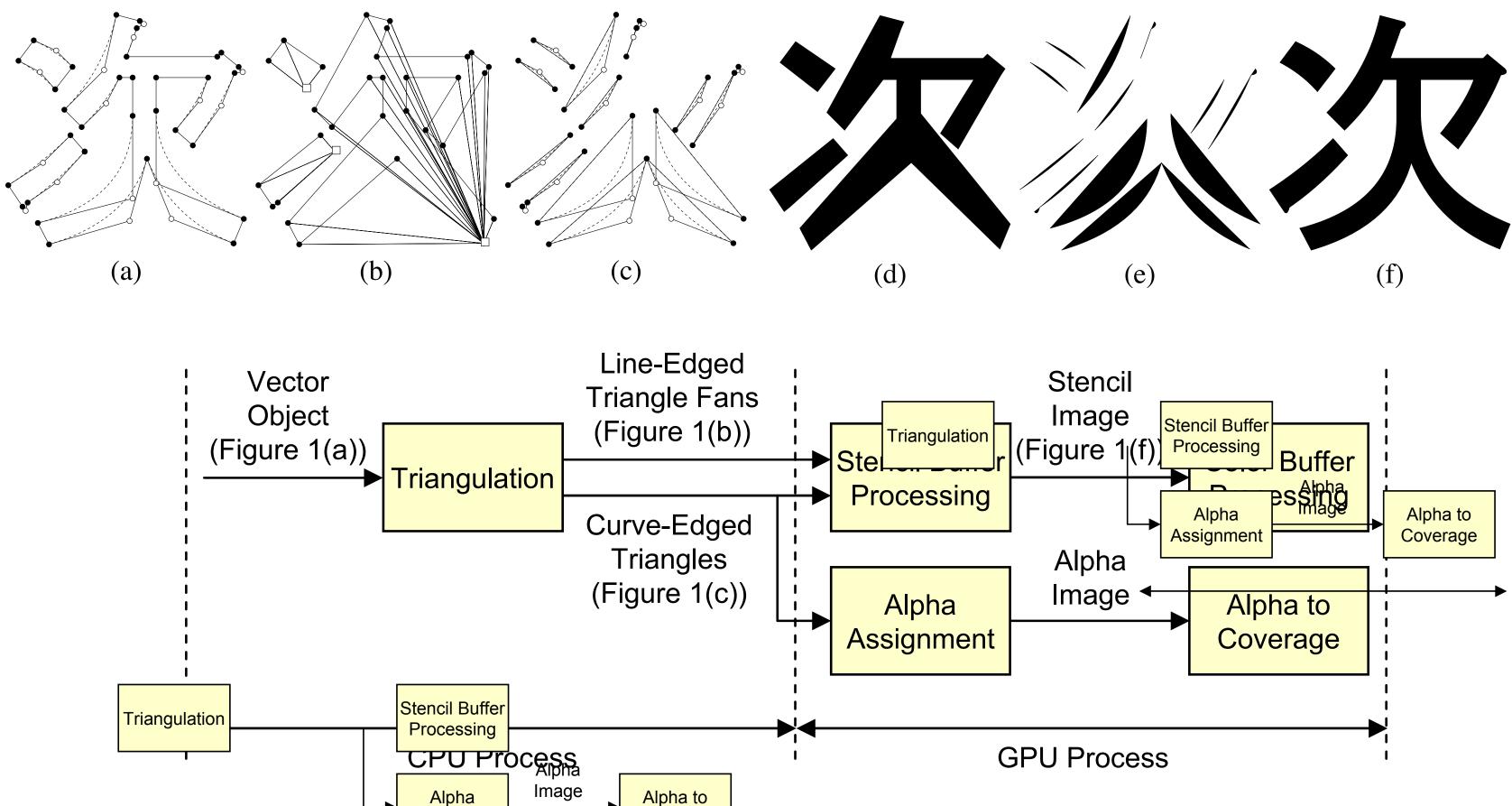
47/60

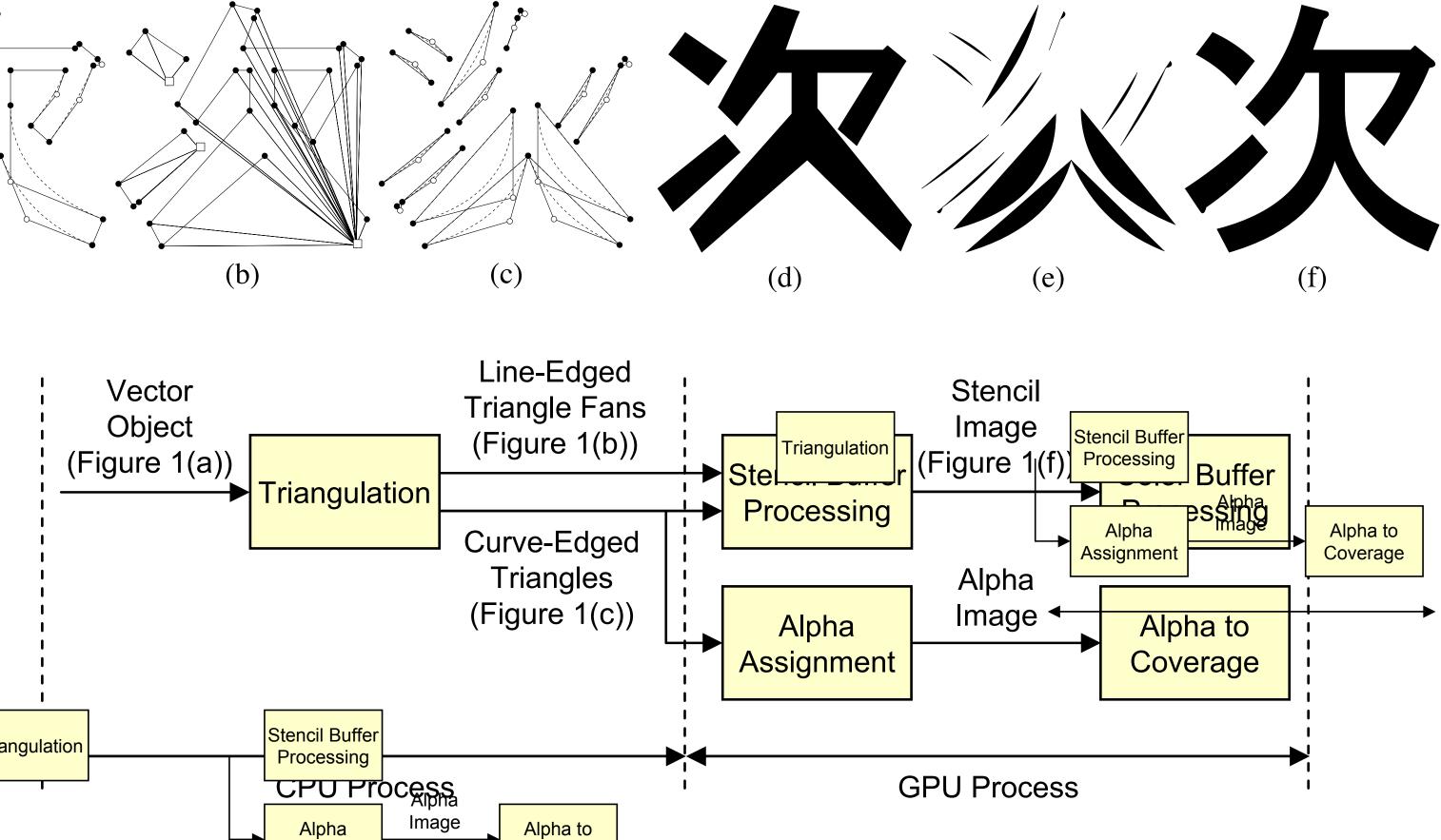


# **GPU FRIENDLY**

### Kokojima et al (2006) Resolution Independent Rendering of Deformable Vector Objects

This sketch presents a new method for resolution independent rendering of vector images suitable for programmable graphics hardware. We have enhanced a previous method [Loop and Blinn 2005] by using a stencil buffer and transparency multisampling.







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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



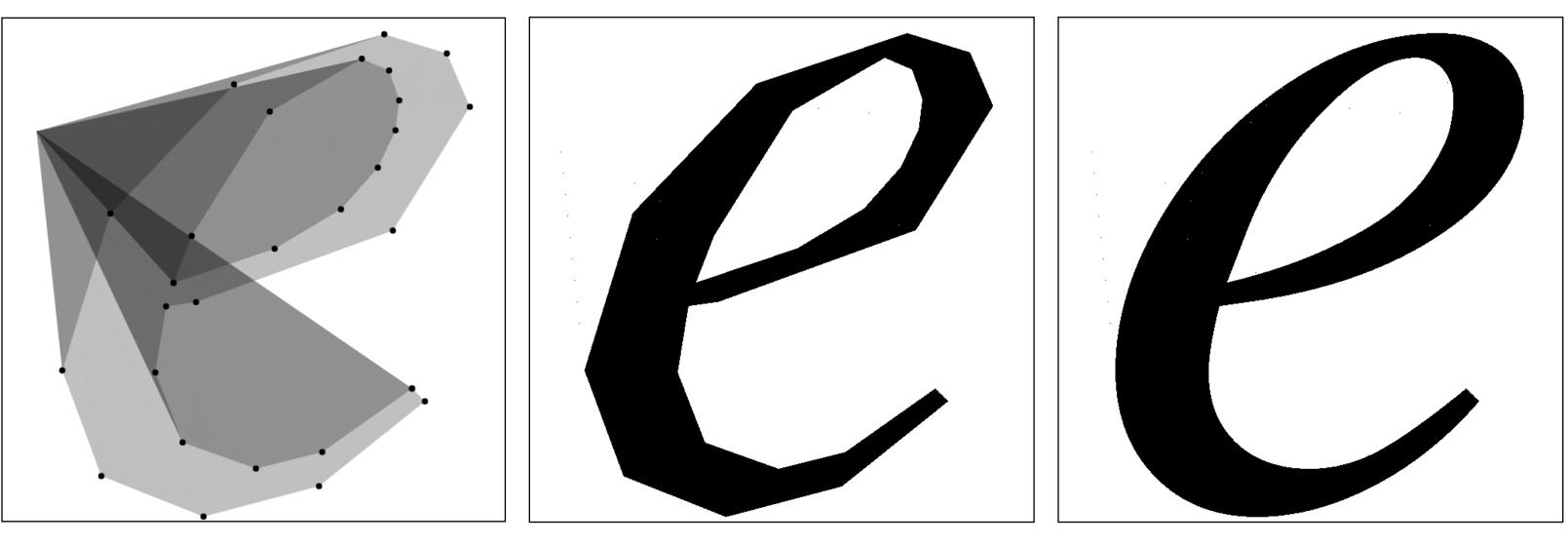
SIGGRAPH2018

48/60

# **GPU FRIENDLY**

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This sketch presents a new method for resolution independent rendering of vector images suitable for programmable graphics hardware. We have enhanced a previous method [Loop and Blinn 2005] by using a stencil buffer and transparency multisampling.



Animations by Evan Wallace (Easy Scalable Text Rendering on the GPU)





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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



49/60

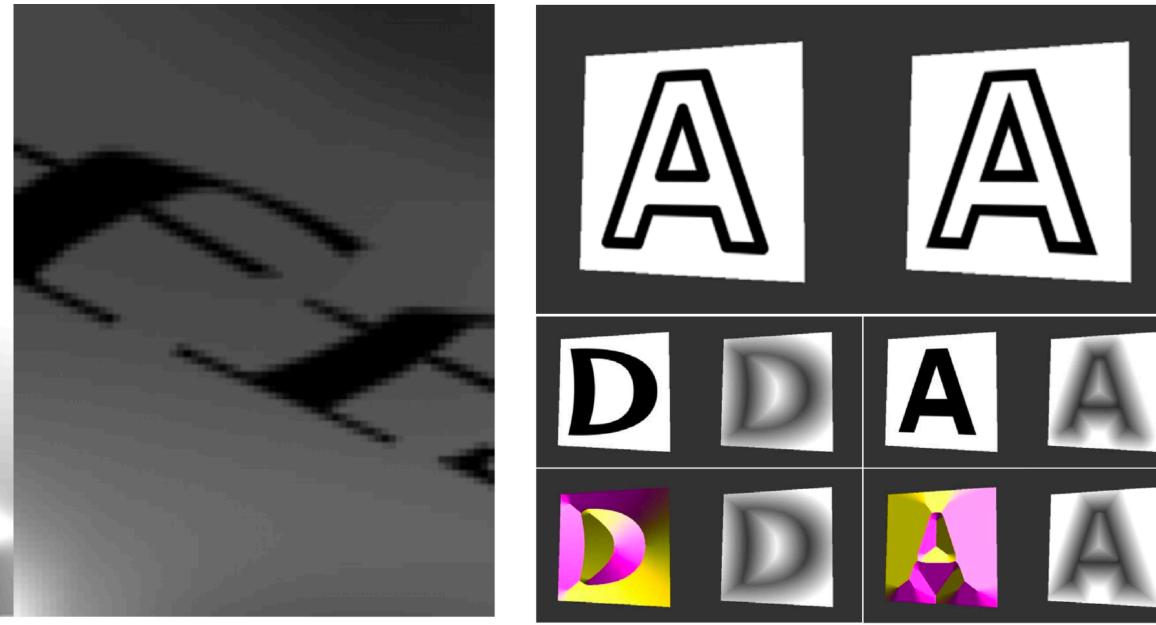
# **GPU FRIENDLY**

### Qin et al (2006) Real-Time Texture-Mapped Vector Glyphs

We present a vector graphics representation suitable for real-time rendering on GPUs. Our representation can be used in place of a texture map, and renders precise antialiased edges at any magnification. A combination of texture data and procedural computation is used to evaluate an exact signed distance to a contour and its gradient.

Anisotropic antialiasing technique + GPU-based representation of contours + Packed grid accelerator structure based + Sprite mapping technique + Special effects









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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



SIGGRAPH2018

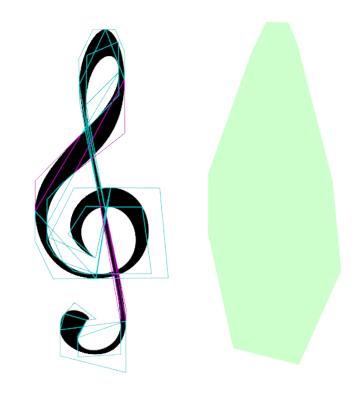
50/60

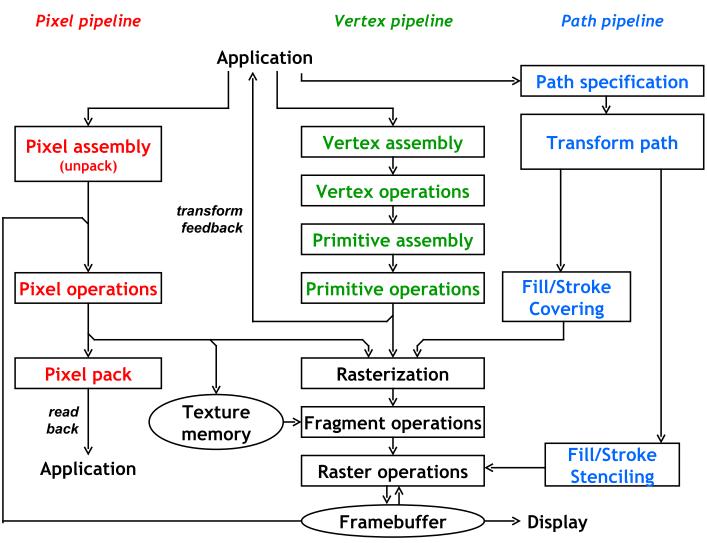
# **GPU FRIENDLY**

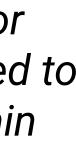
### Kilgard & Bolz (2012) GPU-accelerated Path Rendering

We introduce a two-step "Stencil, then Cover" (StC) programming interface. Our GPU-based approach builds upon existing techniques for curve rendering using the stencil buffer, but we explicitly decouple in our programming interface the stencil step to determine a path's filled or stroked coverage from the subsequent cover step to rasterize conservative geometry intended to test and reset the coverage determinations of the first step while shading color samples within the path.









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#### INTRODUCTION

- Digital Typography
- Font Types & Formats
- Text Rendering Pipeline

#### **PART I : TEXTURE BASED**

- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



SIGGRAPH2018

51/60

# **GPU** ONLY

### Lengyel (2017) GPU-Centered Font Rendering Directly from Glyph Outlines

This paper describes a method for rendering antialiased text directly from glyph outline data on the GPU without the use of any precomputed texture images or distance fields. This capability is valuable for text displayed inside a 3D scene because, in addition to a perspective projection, the transform applied to the text is constantly changing with a dynamic camera view. Our method overcomes numerical precision problems that produced artefacts in previously published techniques and promotes high GPU utilization with an implementation that naturally avoids divergent branching.

### See demo at sluglibrary.com See also GPU-Centered font rendering & GPU font rendering





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- Rasterization
- Fast & Versatile (but ugly)
- Fast & Beaufitul (but only 2D)

#### **PART II : DISTANCE BASED**

- Signed Distance Fields
- Single Channel
- Arc approximation
- Multiple Channels

#### **PART III : GEOMETRY BASED**

- Bézier curves & glyphs
- GPU friendly
- GPU only

#### CONCLUSION

- Beyond this course
- Questions & answers



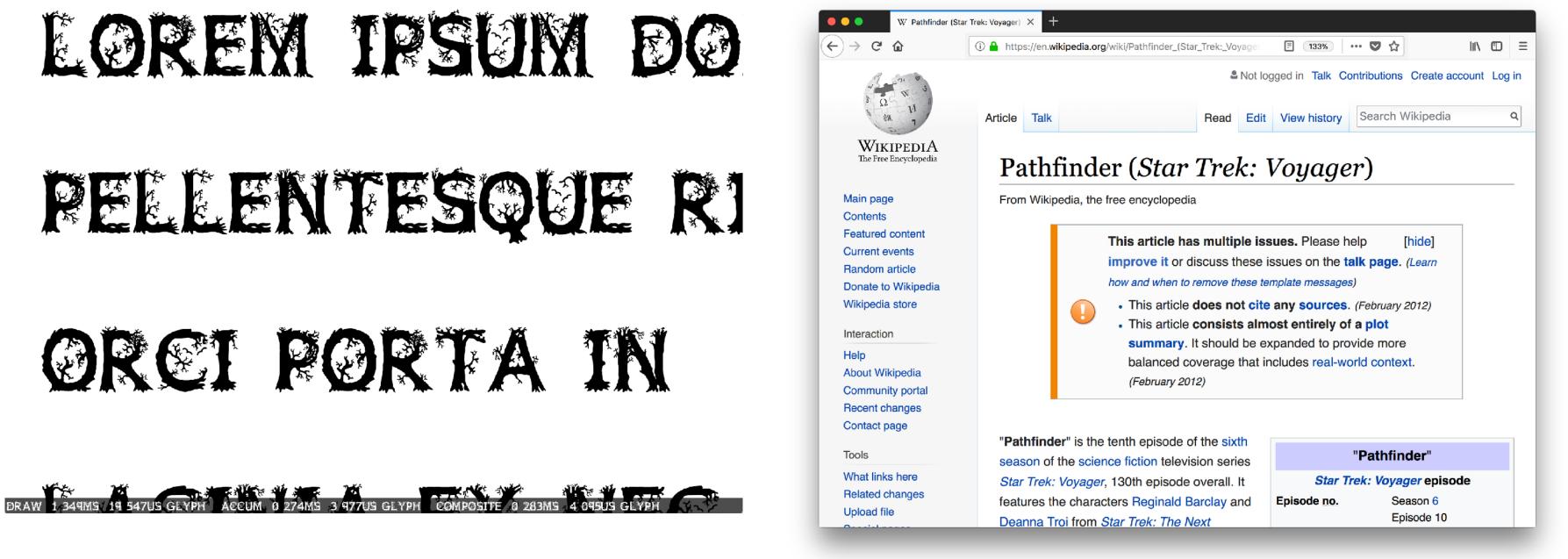
SIGGRAPH2018

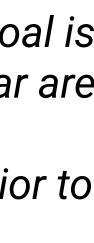
52/60

# **GPU ONLY**

### Walton (2017) Pathfinder, a fast GPU-based font rasterizer in Rust

"Today I'm pleased to announce Pathfinder, a Rust library for OpenType font rendering. The goal is nothing less than to be the fastest vector graphics renderer in existence, and the results so far are extremely encouraging. Not only is it very fast according to the traditional metric of raw rasterization performance, it's practical, featuring very low setup time (end-to-end time superior to the best CPU rasterizers), best-in-class rasterization performance even at small glyph sizes, minimal memory consumption (both on CPU and GPU), compatibility with existing font formats, portability to most graphics hardware manufactured in the past five years (DirectX 10 level), and security/safety."







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# **GPU ONLY**

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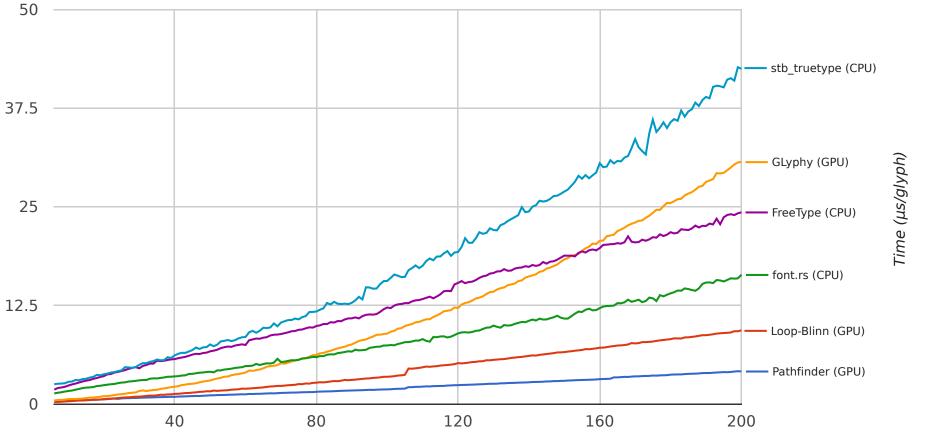
PathFinder algorithm takes advantage of compute shaders (GL 4.3) & post-transform cache and rasterization occurs on the fly on the GPU. CPU setup time is minimal. Subpixel antialiasing & positionning, 2D, 3D, outline, etc.



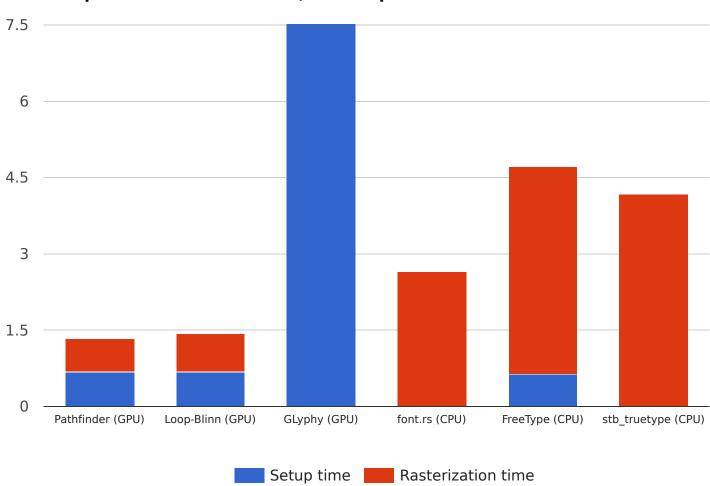
53/60



**Rasterization time, Arial** 



It is mostly a (highly efficient) translation of CPU rasterization onto the GPU.



#### Setup and rasterization time, Arial 24px

Font size (px)

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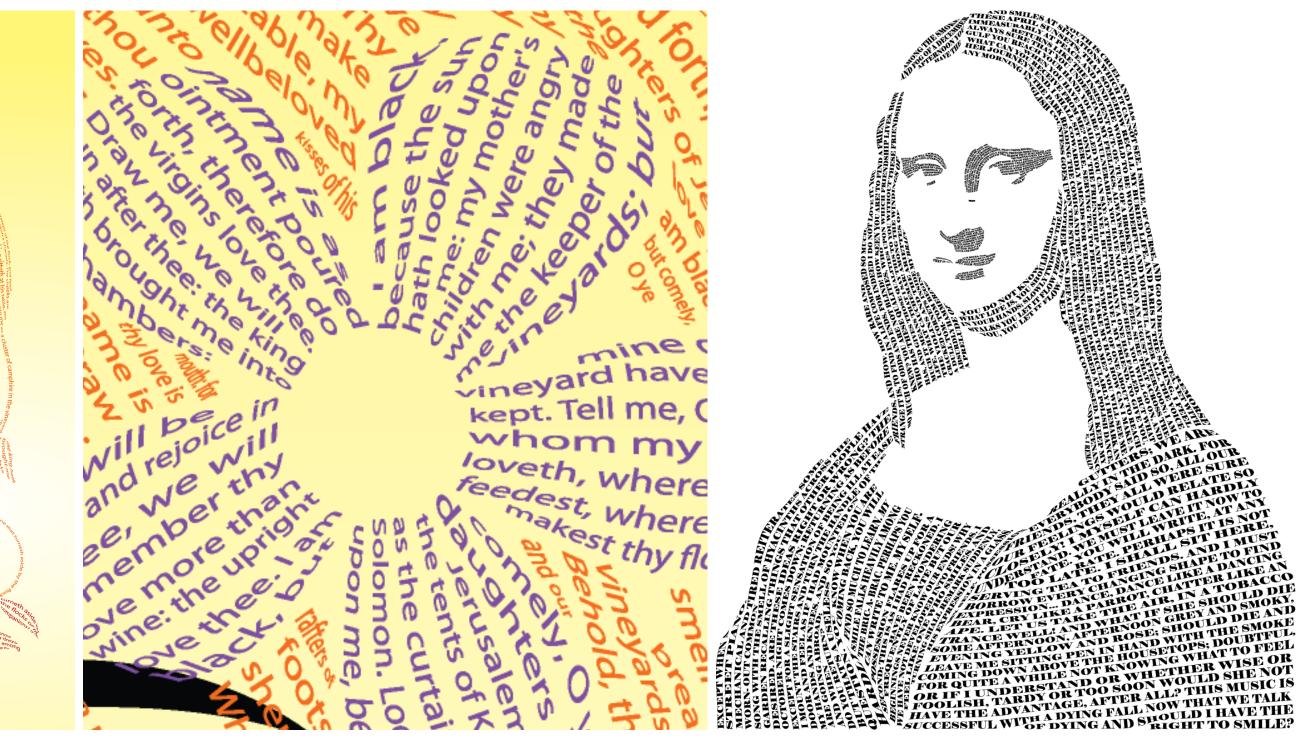
54/60

# **BEYOND MERE GEOMETRY**

### Maharik et al (2011) Digital Micrography

We present an algorithm for creating digital micrography images, or micrograms, a special type of calligrams created from minuscule text. These attractive text-art works successfully combine beautiful images with readable meaningful text.







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55/60



# CONCLUSION

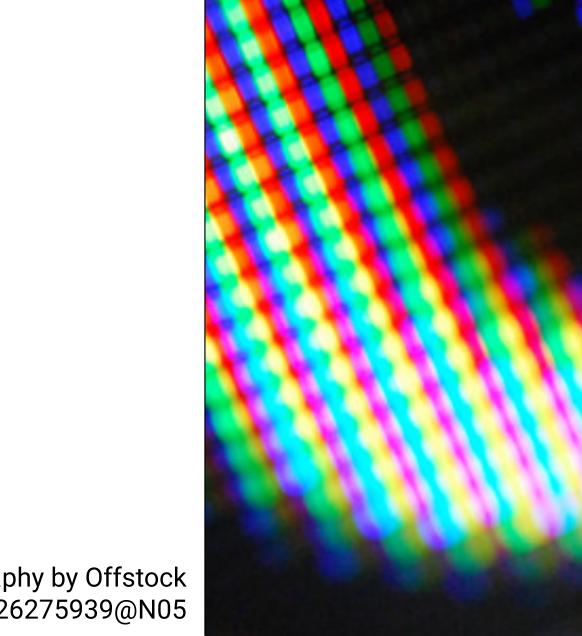
Many available techniques. Choice is dependent of usage (2D or 3D, dynamic or static, memory vs speed vs accuracy, etc).

PathFinder and Slug library seem to be the main players in 2018. Loop & Blinn still competitive.

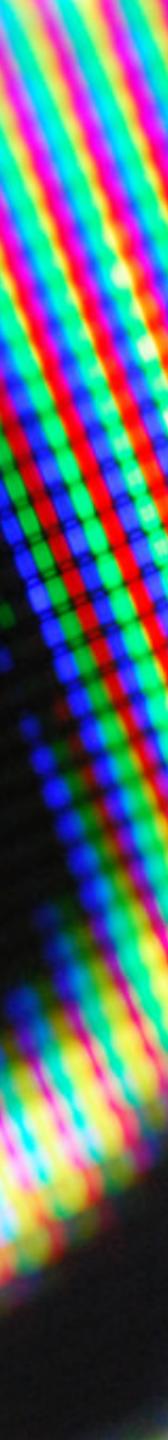
Hinting and anti-aliasing still needed until we (all) get screen with dpi > 600.

Complex text layout is (really, really) difficult, you don't want to do it yourself: github.com/ HOST-Oman/libraqm

Lot of patents around !



Television typography by Offstock www.flickr.com/photos/126275939@N05



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- Beyond this course
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# SIGGRAPH2018

56/60

# FURTHER READING

#### Web

The Technology of Text - Kevin Larson (2007) State of Text Rendering - Behdad Esfahbod (2012) CS 354 Typography - Mark Kilgard (2012) Android's Font Renderer - Romain Guy (2014) Complex Text on Simple Devices - Pedro Navarro (2016) Introducing DirectWrite - Microsoft (2017) A Primer on Bézier curves - Pomax (2017)

#### Papers

Behdad Esfahbod. Glyphy (2011) Ron Maharik et al. Digital Micrography (2011) Patrick Walton. Path Finder (2017)

```
Texts Rasterization Exposures - Maxim Shemanarev (2006)
Treatise on Font Rasterisation - Freddie Witherden (2010)
High-DPI, Subpixel Text Positioning, Hinting - Behdad Esfahbod (2012)
```

```
Mark Kilgard. A Simple OpenGL-based API for Texture Mapped Text (1997)
Sarah F. Frisken, et al. Adaptively sampled distance fields (2000)
Charles Loop and Jim Blinn. Resolution Independent Curve Rendering (2005)
Zhipei Qin et al, Real-Time Texture-Mapped Vector Glyphs (2006)
Chris Green. Improved Alpha-Tested Magnification for Vector Textures and Special Effects (2007)
Stefan Gustavson. 2D Shape Rendering by Distance Fields (2012)
Mark Kilgard and Jeff Bolz. GPU-Accelerated Path Rendering (2012)
Nicolas P. Rougier. Higher Quality 2D Text Rendering (2013)
Viktor Chlumsky. Shape Decomposition for Multi-channel Distance Fields (2015)
Eric Lengyel. GPU-Centered Font Rendering Directly from Glyph Outlines (2017)
```

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# **RELATED SHADERTOYS**

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- Beyond this course
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# SIGGRAPH2018

57/60









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# **QUESTIONS?**

- Where to find good fonts? dafont.com, fontsquirrel.com
- When does cleartype patent end ? Not clear (ha ha)
- Are hinting and aliasing still needed? Yes
- What are the most complete font families? Noto, DejaVu
- How many languages in the world? Around 7000
- How many scripts in latest unicode (11.0)? 146
- How many characters in latest unicode (11.0)? 137,439
- Is there any forthcoming support for text in Vulkan? No
- Should I tell my colleagues I love Comic Sans? No
- Are there any open source tools to design fonts? FontForge
- Why "ff" & "fi" disappear when I copy text ? Ligatures
- Should I apply AA before or after gamma correction? Before
- Should I stay or should I go? stay (a few more minutes)

#### Any other questions?

58/60

# should i use comic sans?

will your document be viewed by the public?

yes

no

# don't use comic sans!













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# **DIGITAL TYPOGRAPHY**

### Between art & design.



59/60

ASwiss Dots production, in association	Heaturing: Michael Berut Neville Brock	Lars Muller Norm Mike Parker	Massimo Vignelli Hermann Zapf	Director cf Photography: Luke Geissbühler	Additional Editing: Laura Weinberg	Sound Recording: Nara Garber	Music: The Album Lea! Battles
with Veer	Matthew Carter	Michael C. Place	Produced and		Sound Editor:	Victor Horstink	Caribou
	Eavid Carson	Rick Poynor	Directed by	Additional	BrianLangman	Dan Johnson	Chicago Undergrou
dats Veet	Wim Crouwel Experimental Je/set	Stefan Sagmeister Leslie Savan	Gary Fustwit	Photography: Colin Brown	Sound Mixer:	Jörg Kidowski Sam Pullen	Quartet FITen Flaven
	Tobias Frere-Jones	Paula Scher	Editor	Gary Hustwit	AndyKris	Reto Stamm	Four Tat
Helvetica	Otmar Hoafer	Manfred Schulz	Shelby Siegel	Pate Sillen			Kim Horthey
Adocumentary firm	Jorathan Hoefer	Erik Spiekermann		Chris Watton	Motion Graphics:	Peater by	Motohiro Nakashin
by Gary Hestwit	Alfred Hoffmann	Bruno Steinort	helveticafilm.com	Bor Wolf	Tralibück & Ca.	Experimental Jetsot	Sam Frekop

#### Gary Hustwit

Raghed Abu Hamdan

Unknown artist



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Digital Typography Rendering - Nicolas P. Rougier & Behdad Esfahbod SIGGRAPH '18 Course - August 12-16, 2018 - Vancouver, BC, Canada - 10.1145/3214834.3214837 Copyright 2018 © N.P Rougier & B.Esfahbod - Creative Commons Attribution 4.0 International

