ATTENUATION-BASED LIGHT FIELD DISPLAYS

Bachelor Thesis

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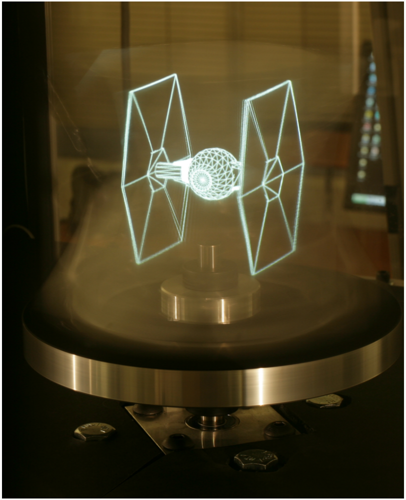
June 3, 2016

Institut für Informatik und angewandte Mathematik

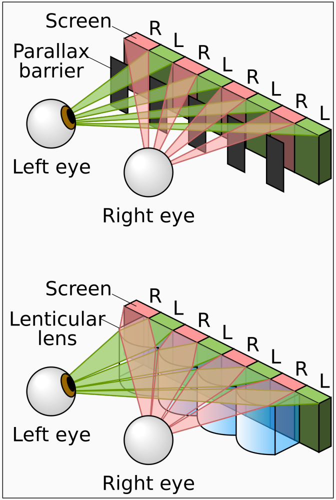
OUTLINE

MOTIVATION

EXISTING 3D DISPLAYS



Jones et al. [2007]

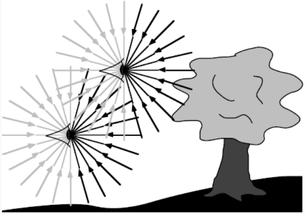


en.wikipedia.org/wiki/Autostereoscopy

INTRODUCTION TO LIGHT FIELDS

THE PLENOPTIC FUNCTION

- Measures light in the world
- Position, viewing direction
- Time, Wavelength
- $P(x, y, z, \theta, \phi, t, \lambda)$
- 7D



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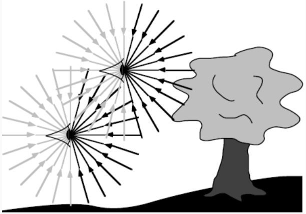

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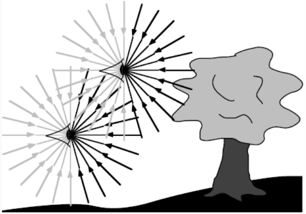

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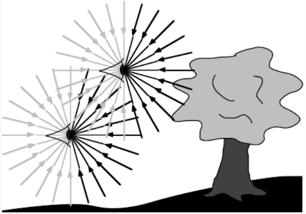

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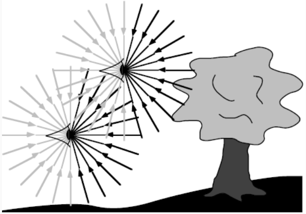

THE 4D LIGHT FIELD

- Reduce dimensions of P
- $L(u, v, s, t)$
- Defined by two planes

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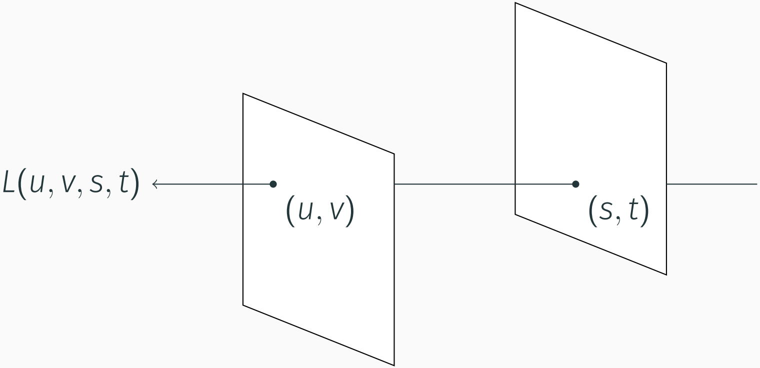

LIGHT FIELD ACQUISITION

- Camera array
- Gantry
- Plenoptic camera

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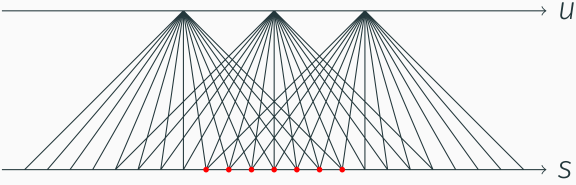
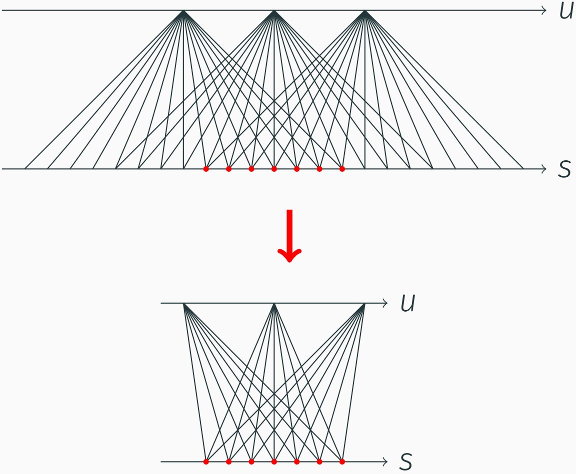
RE-PARAMETERIZATION TO GLOBAL COORDINATES



RE-PARAMETERIZATION TO GLOBAL COORDINATES



RE-PARAMETERIZATION TO GLOBAL COORDINATES

Raw

Rectified

RE-PARAMETERIZATION TO GLOBAL COORDINATES

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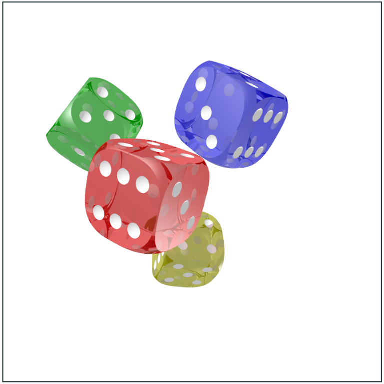
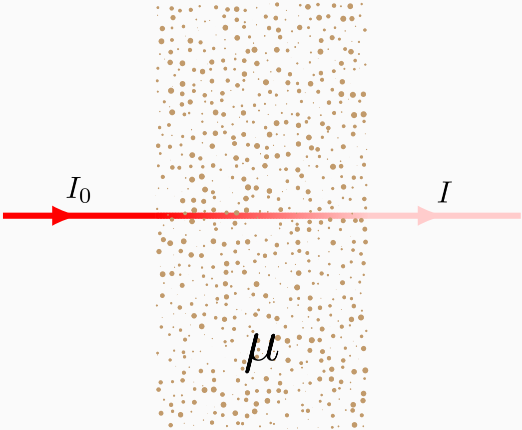


Rectified

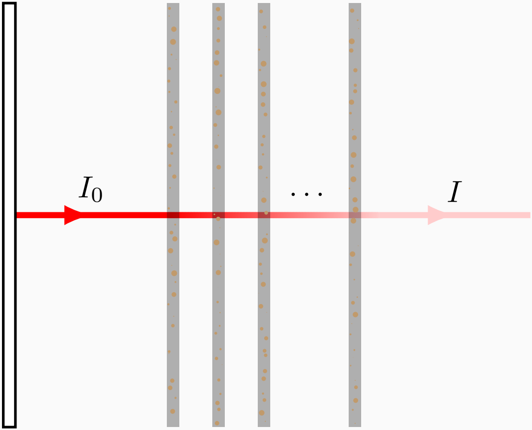
ATTENUATION DISPLAY

THE BEER-LAMBERT LAW



$$\frac{I}{I_0} = \exp\left(-\int_{\mathcal{R}} \mu(r)\mathrm{d}r\right)$$

THE BEER-LAMBERT LAW



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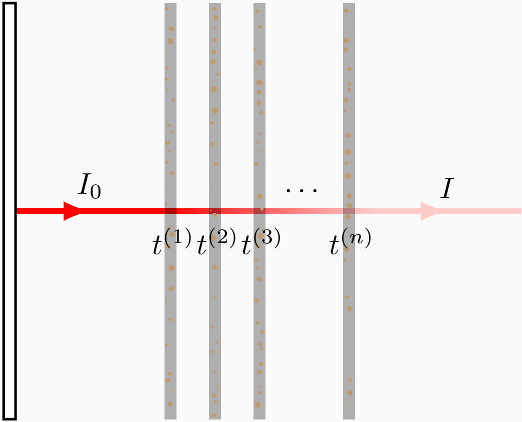

$$\frac{I}{I_0} = \exp\left(-\int_{\mathcal{R}} \mu(r)\mathrm{d}r\right) = \prod_i t^{(i)}$$

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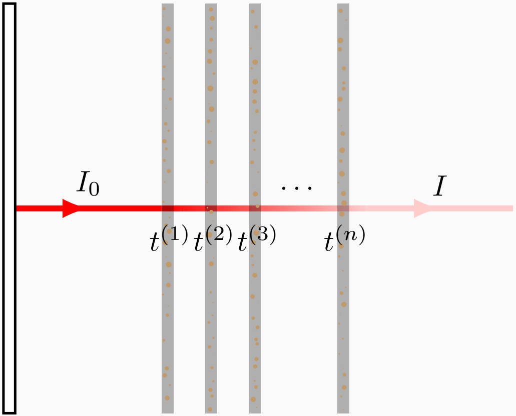
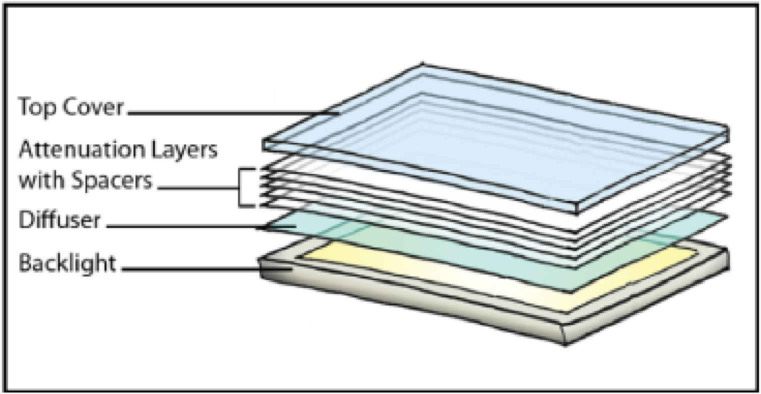
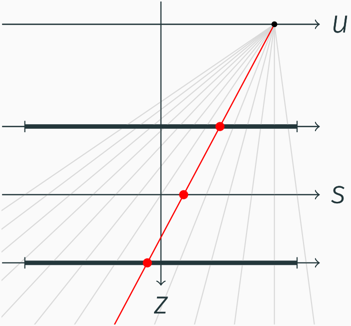


$$\frac{I}{I_0} = \exp\left(-\int_{\mathcal{R}} \mu(r)\mathrm{d}r\right) = \prod_i t^{(i)} = \exp\left(-\sum_i a^{(i)}\right)$$

DISPLAY ARCHITECTURE



LIGHT TRANSMISSION



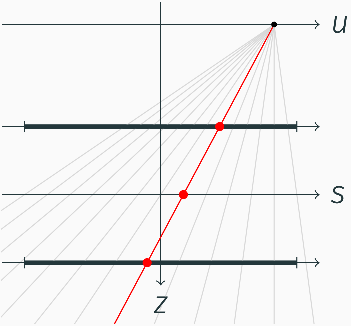
$$L_m = L_0 \prod_{n=1}^{N} t^{(n)}(h(m,n))$$

L_m Color of ray m

t Transmission

h Intersection

LIGHT TRANSMISSION



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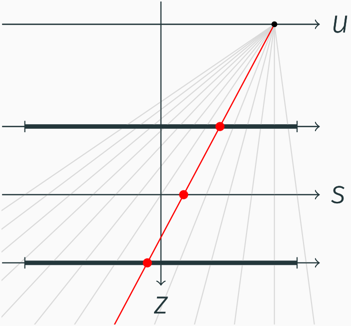

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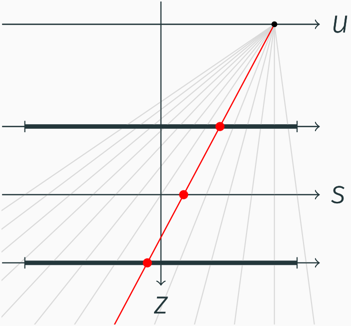

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L_m Color of ray m

t Transmission

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From now on: $L_0 = 1$

FROM TRANSMISSION TO ABSORBANCE

- Transmission values unknown

$$L_m = \prod_{n=1}^{N} t^{(n)}(h(m,n))$$

FROM TRANSMISSION TO ABSORBANCE

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- Solve equations simultaneously for all rays

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- This is hard
- Transform to log-domain

$$L_m = \prod_{n=1}^{N} t^{(n)}(h(m,n))$$

$$\Big\downarrow \quad t = e^{-a}$$

$$\log(L_m) = -\sum_{n=1}^{N} a^{(n)}(h(m,n))$$

FROM TRANSMISSION TO ABSORBANCE

- Transmission values unknown
- Solve equations simultaneously for all rays
- This is hard
- Transform to log-domain
- Solve for absorbance

$$L_m = \prod_{n=1}^{N} t^{(n)}(h(m,n))$$

$$\Big\downarrow \quad t = e^{-a}$$

$$\log(L_m) = -\sum_{n=1}^{N} a^{(n)}(h(m,n))$$

RAY CASTING

- One linear constraint per ray
- Create a big matrix P
- Matrix encodes intersections

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$$
P = \begin{array}{cc}
 & \begin{array}{cccccccccc} \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & \alpha_6 & \alpha_7 & \alpha_8 & \alpha_9 & \alpha_{10} \end{array} \\
\begin{array}{c} \overline{L}_1 \\ \overline{L}_2 \\ \overline{L}_3 \\ \overline{L}_4 \\ \overline{L}_5 \\ \overline{L}_6 \\ \overline{L}_7 \\ \overline{L}_8 \\ \overline{L}_9 \\ \overline{L}_{10} \\ \overline{L}_{11} \\ \overline{L}_{12} \end{array} &
\left(\begin{array}{ccccc|ccccc}
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 & 1 & & & & & & & 1 &
\end{array}\right)
\end{array}
$$

THE EQUATION

$$\log(L) = -P\alpha$$

- $\log(L)$ Vectorized log light field
- α Vector holding unkowns

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OPTIMIZATION PROBLEM

$$\begin{aligned} \underset{\alpha}{\operatorname{argmin}} \quad & \|P\alpha + \log(L)\|^2 \\ \text{subject to} \quad & \alpha \geq 0. \end{aligned}$$

- Proposed by Wetzstein et al. [2011]
- System is overdetermined
- Need iterative solver

THE CONSTRAINT $\alpha \geq 0$

- Negative absorption ($\alpha < 0$) is physically not possible
- The theoretical model supports negative absorption
- Constraint reduces the space of possible solutions

EXAMPLES

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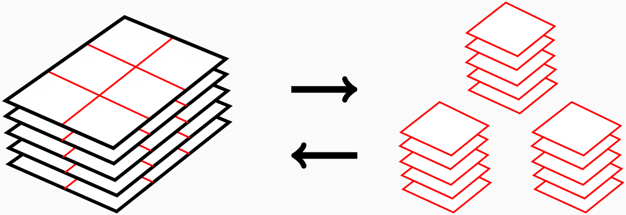
EXAMPLES

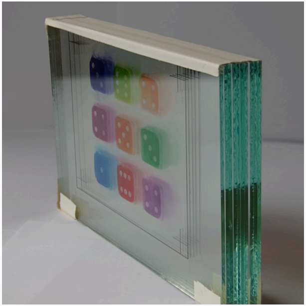
1. Slice attenuator into smaller pieces
2. Solve optimization problem for every slice
3. Reconnect the slices



ATTENUATOR TILING

- Problem: Rays can overlap with multiple slices at borders
- Slices need to overlap
- Blend slices with mask

THE FINISHED PRODUCT



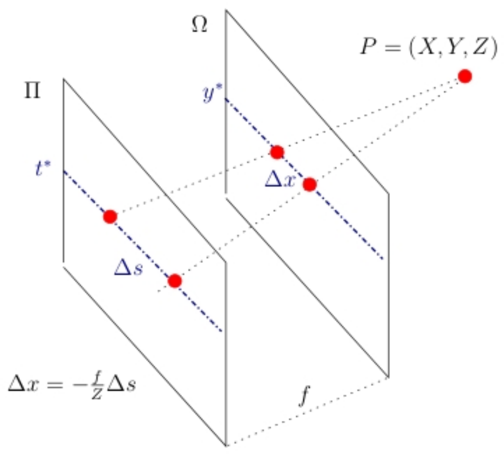
THE FINISHED PRODUCT

QUESTIONS

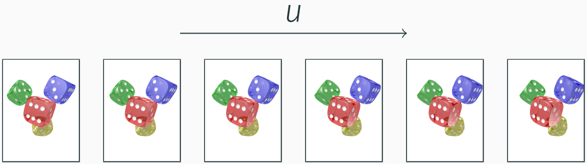
- Impact of more layers?
- Does thickness of display matter?
- What are the limitations?

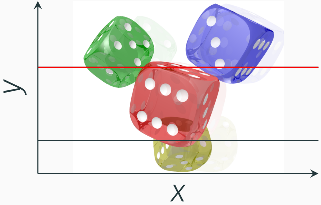
ASSESSMENT

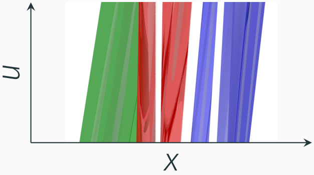
EPIPOLAR PLANE GEOMETRY



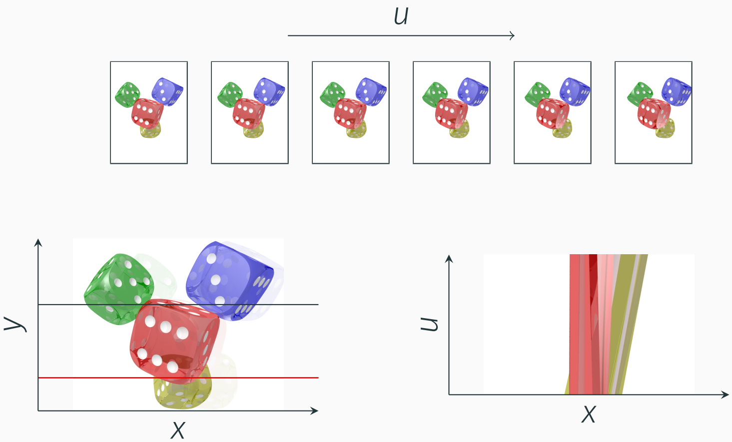
EPIPOLAR PLANE IMAGE



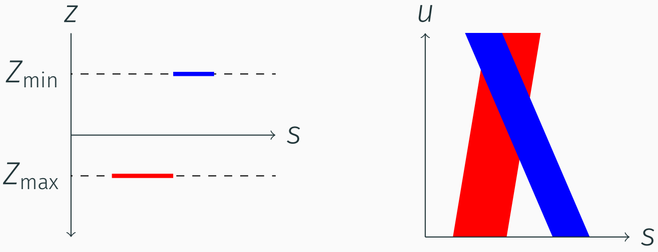




EPIPOLAR PLANE IMAGE

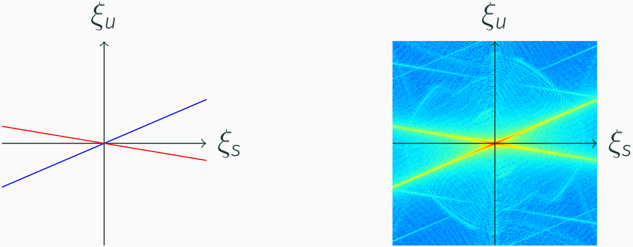


SPECTRAL ANALYSIS



$$\frac{\mathrm{d}u}{\mathrm{d}s} = \frac{z - Z_u}{z - Z_s}$$

SPECTRAL ANALYSIS



$$\widehat{f}(\xi) = \int_{\mathbb{R}^n} f(x) e^{-2\pi i x \cdot \xi} \, dx$$

CONCLUSION

REFERENCES

E. H. Adelson and J. Bergen. The plenoptic function and the elements of early vision. *Computational Models of Visual Processing*, pages 3–20, 1991.

A. H. Andersen and A. C. Kak. Simultaneous algebraic reconstruction technique (SART): A superior implementation of the ART algorithm. *Ultrasonic Imaging*, 6(1):81–94, 1984.

B. G. Blundell and A. J. Schwarz. *Volumetric Three-Dimensional Display Systems*. Wiley-VCH, Mar. 2000. ISBN 0-471-23928-3.

R. C. Bolles, H. H. Baker, and D. H. Marimont. Epipolar-plane image analysis: An approach to determining structure from motion. *International Journal of Computer Vision*, pages 7–55, 1987.

The *mtheme* is a Beamer theme with minimal visual noise inspired by the HSRM Beamer Theme by Benjamin Weiss.

Enable the theme by loading

```
\documentclass{beamer}
\usetheme{m}
```

Note, that you have to have Mozilla's *Fira Sans* font and XeTeX installed to enjoy this wonderful typography.

SECTIONS

Sections group slides of the same topic

```
\section{Elements}
```

for which the *mtheme* provides a nice progress indicator …

TYPOGRAPHY

```
The theme provides sensible defaults to \emph{empha
text, \alert{accent} parts or show \textbf{bold} re
```

becomes

The theme provides sensible defaults to *emphasis* text, accent parts or show **bold** results.

LISTS

Items

- Milk
- Eggs
- Potatos

Enumerations

1. First,
2. Second and
3. Last.

DESCRIPTIONS

PowerPoint Meeh.

Beamer Yeeeha.

ANIMATION

- This is important

ANIMATION

- This is important
- Now this

ANIMATION

- This is important
- Now this
- And now this

ANIMATION

- This is really important
- Now this
- And now this

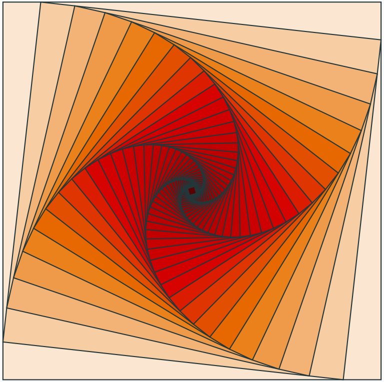


Figure: Rotated square from texample.net.

Table: Largest cities in the world (source: Wikipedia)

City	Population
Mexico City	20,116,842
Shanghai	19,210,000
Peking	15,796,450
Istanbul	14,160,467

This is a block title

This is soothing.

MATH

$$e = \lim_{n \to \infty} \left(1 + \frac{1}{n}\right)^n$$

QUOTES

Veni, Vidi, Vici

plainDark background

SUMMARY

Get the source of this theme and the demo presentation from

`github.com/matze/mtheme`

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plainQuestions?