



Simulation of Black Hole Binary System

2022 물리연구 1주차

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September 14, 2022



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Why numerical relativity?

1 Introduction

- How to determine the dynamical evolution of a physical system governed by Einstein's equations of general relativity?
- Analytic solutions for the evolution of such systems do not exist.
- We have to recast Einstein's 4-dimensional field equations into a form that is suitable for numerical integration.

3+1 decomposition

1 Introduction

- The problem of evolving the gravitational field in GR can be posed in terms of a traditional initial value problem or “Cauchy” problem.
- The evolution of a general relativistic gravitational field is determined by specifying the metric quantities g_{ab} and $\partial_t g_{ab}$ at a given (initial) instant of time t .
- In particular, we need to specify the metric field components and their first time derivatives everywhere on some 3-dimensional spacelike hypersurface labeled by coordinate $x^0 = t = \text{constant}$.



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기존 배열의 문제

2 동적 배열

- 처음에 배열을 선언할 때 배열의 크기를 지정해야 하며, 그 이상의 자료를 집어넣을 수 없다.
- 자료의 개수가 변함에 따라 크기가 변경되는 동적 배열을 사용하자.



동적 배열의 특성

2 동적 배열

동적 배열은 기존 배열이 갖는 다음의 특성을 그대로 이어받는다.

- 원소들은 메모리의 연속된 위치에 저장된다.
- 주어진 위치의 원소를 반환하거나 변경하는 동작을 $\mathcal{O}(1)$ 에 할 수 있다.



동적 배열의 특성

2 동적 배열

반면 동적 배열은 다음과 같은 특성을 추가로 지닌다.

- 배열의 크기를 변경하는 `resize()` 연산이 가능하다. 이 동작을 수행하는 데는 배열의 크기 N 에 비례하는 시간이 걸린다.
- 주어진 원소를 배열의 맨 끝에 추가함으로써 크기를 1 늘리는 `append()` 연산을 지원한다. 이 동작을 수행하는 데는 상수 시간이 걸린다.

Beamer vs. PowerPoint

2 동적 배열

Compared to PowerPoint, using L^AT_EX is better because:

- It is not What-You-See-Is-What-You-Get, but
What-You-*Mean*-Is-What-You-Get:
you write the content, the computer does the typesetting
- Produces a pdf: no problems with fonts, formulas, program versions
- Easier to keep consistent style, fonts, highlighting, etc.
- Math typesetting in T_EX is the best:

$$i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t) = -\frac{\hbar^2}{2m}\nabla^2\Psi(\mathbf{r},t) + V(\mathbf{r})\Psi(\mathbf{r},t)$$



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Selecting the Class

3 Editing

After the last update to the graphic profile, the `sintef` theme for Beamer has been updated into a full-fledged class. To start working with `sintefbeamer`, start a \LaTeX document with the preamble:

Minimum SINTEF Beamer Document

```
1 \documentclass{sintefbeamer}
2 \begin{document}
3 \begin{frame}{Hello, world!}
4 \end{frame}
5 \end{document}
```



Title page

3 Editing

To set a typical title page, you call some commands in the preamble:

The Commands for the Title Page

```
1 \title{Sample Title}
2 \subtitle{Sample subtitle}
3 \author{First Author, Second Author}
4 \date{Defaults to today's}
```

You can then write out the title page with `\maketitle`.

You can set a different background image than the default one with the `\titlebackground` command, set before `\maketitle`.

In the `backgrounds` folder, you can find a lot of standard backgrounds for SINTEF presentation title pages



Writing a Simple Slide

It's really easy!

- A typical slide has bulleted lists



Writing a Simple Slide

It's really easy!

- A typical slide has bulleted lists
- These can be uncovered in sequence



Writing a Simple Slide

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Code for a Page with an Itemised List

```
1 \begin{frame}
2   \frametitle{Writing a Simple Slide}
3   \framesubtitle{It's really easy!}
4   \begin{itemize}[<+>]
5     \item A typical slide has bulleted lists
6     \item These can be uncovered in sequence
7   \end{itemize}
8 \end{frame}
```

Adding images works like in normal \LaTeX :

Code for Adding Images

```
1 \usepackage{graphicx}
2 % ...
3 \includegraphics
4 [width=\textwidth]{images/default}
```





Splitting in Columns

3 Editing

Splitting the page is easy and common; typically, one side has a picture and the other text:

This is the first column

And this the second

Column Code

```
1 \begin{columns}
2   \begin{column}{0.6\textwidth}
3     This is the first column
4   \end{column}
5   \begin{column}{0.3\textwidth}
6     And this the second
7   \end{column}
8   % There could be more!
9 \end{columns}
```

- The paramount task of fonts is being readable
- There are good ones...
 - Use serif fonts only with high-definition projectors
 - Use sans-serif fonts otherwise (or if you simply prefer them)
- ... and not so good ones:
 - Never use monospace for normal text
 - Gothic, calligraphic or weird fonts should always be avoided

- To change the colour of the title dash, give one of the class options `cyandash` (default), `greendash`, `magentadash`, `yellowdash`, or `nodash`.
- To change between the light and dark themes, give the class options `light` (default) or `dark`. It is not possible to switch theme for one slide because of the design of Beamer—and it's probably a good thing.
- To insert a final slide, use `\backmatter`.
- The aspect ratio defaults to 16:9, but you can change it to 4:3 for old projectors by passing the class option `aspectratio=43`; any other values accepted by Beamer are also possible.



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Good Luck!

4 Summary

- Enough for an introduction! You should know enough by now
- If you have corrections or suggestions, [send them to me!](#)



Q&A

Thank you for listening!

Your feedback will be highly appreciated!