

# Wissenschaftliches Arbeiten und Präsentation (WS 2024/25)

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10. Jänner 2025



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**URL of course:** [.../teaching/wiss\\_arbeiten/wap.html](.../teaching/wiss_arbeiten/wap.html).

**Lecture time:** Friday 8<sup>15</sup>–11<sup>15</sup> (with a break of about 25 minutes).

**Venue:** PLUS, Informatik, T03, Jakob-Haringer Str. 2.

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**Note** — graded according to continuous-assessment mode!  
— regular attendance is compulsory!

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Obviously, time constraints do not allow me to discuss tons of software packages in detail. I have selected those packages according to whether I've personally found them useful for my own scientific work. All packages discussed are freely available (for students) and can be installed on any PC running Linux. (Most of them should also be available for MS-based platforms.)

In addition to these slides, you are encouraged to consult the WWW home-page of this lecture:

[www.cosy.sbg.ac.at/~held/teaching/wiss\\_arbeiten/wap.html](http://www.cosy.sbg.ac.at/~held/teaching/wiss_arbeiten/wap.html).

In particular, this WWW page will contain links to online manuals.



## A Few Words of Warning

- I hope that these slides will help you to get acquainted with the software packages discussed. However, I would like to warn you explicitly not to regard these slides as the sole source of information on the topics of my lecture. It may and will happen that I'll use the lecture for talking about subtle details of some package that are not covered in these slides! In particular, by making these slides available to you I do not intend to encourage you to attend the lecture on an irregular basis.
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- See also [In Praise of Lectures](#) by T.W. Körner.
- Also, I hope that you will realize that most software packages dealt with in this lecture will only be fully appreciated after using them for yourself. It will be considerably more difficult to learn, say,  $\text{\LaTeX}$  if you are not prepared and willing to get your hands on a computer and try it out personally.

## Acknowledgments

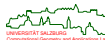
I am happy to acknowledge that I benefited from material published by colleagues on diverse topics presented in this lecture. In particular, several sample codes (for  $\text{\LaTeX}$  figures, PostScript, etc.) are borrowed from other publications. Similarly, some descriptions of software packages were copied from their respective user manuals. While some of the material used for this lecture was originally presented in traditional-style publications (such as textbooks), some other material has its roots in non-standard publication outlets (such as online documentations).

Andreas Uhl contributed slides for the first part of this course.

Information and data on publication statistics was provided by Katherine Eve (Publisher, Geochemistry and Geophysics, Elsevier Ltd.).

Salzburg, July 2024

Martin Held



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- 1 Publishing and Retrieving Scientific Results
- 2 Scientific Presentations
- 3  $\text{\LaTeX}$  for Scientific Text Processing
- 4 Drafting Figures and Generating Plots
- 5 pdf $\text{\LaTeX}$  and Recent  $\text{\LaTeX}$  Developments
- 6 Mathematica for Symbolic Computation
- 7 Graphics and Visualization

## 1 Publishing and Retrieving Scientific Results

- Scientific Literature
- Literature Search
- Bibliographic Metrics
- Discussion of the Current Scientific Publishing Scheme

# 1 Publishing and Retrieving Scientific Results

- Scientific Literature
  - What is Scientific Literature?
  - Monographs
  - Journal Articles
  - Articles in Collections
  - Conference Papers
  - Technical Reports
  - Academic Theses
  - Patent Descriptions
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## Diving into scientific “literature”

Understanding how scientific literature is organized helps to correctly cite sources, follow citation trails, assess the credibility of sources, and use bibliographies to discover additional relevant literature.

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  - WWW pagesare not regarded as “scientific literature” in the traditional sense.
- Although patent descriptions are important in the context of scientific and technological advancement, they do not typically count as scientific publications.

# Characteristics of Scientific Literature

- Scientific publications have different characteristics with respect to
  - authorship,
  - contents,
  - originality,
  - production,
  - organization,
  - quality control.

**Authorship:** A book has one or several authors who write the book. Upon writing a publisher has to be found for processing the book. In practice, usually a publisher is sought before the book is written. Often, scholars of high reputation are approached by publishers or editors of book series to write a book on a specific subject.

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**Content:** A monograph treats a specific area of computer science in a systematic and complete form. The area may be a traditional area seen under a new or specific perspective or a new area whose results are scattered in various other sources like journal articles and conference papers.

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- Originality:** Mostly, the results contained in a monograph are *not* new but were already published earlier in other sources. However, explaining everything in one uniform context or filling gaps in a systematic treatment etc. may be quite a creative process. (But it is not considered original research in computer science.)

**Production and Organization:** The authors write the book and transfer the copyright to the publishing company which publishes the book. A certain number of copies of the book — an “edition” — is produced in one process and put on stock. The number of copies of one edition may range from a few hundreds to several thousand copies. Before a new edition is printed, the authors are invited to update, improve and possibly extend the book.



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**Quality control:** At good publishing companies, the scientific quality of monographs is checked by an “editor” who normally is a renowned expert in the field of the book. Often, one or several editors are in charge of a book series in a specific area. Typically, additional scholars – so-called “referees” – are asked to assess the quality of some or all of the book’s chapters.

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**Production:** Like books, journals are published by publishing companies. The author prepares a manuscript and sends (“submits”) it to the editor (or to one of the editors) of the journal. Sometimes the “editorial board” of a journal may be quite big – ten to fifteen people – in order to represent the scope of the journal well. The impulse to start a new journal tends to be a joint effort of a group of scholars who want to open a publication forum for their field of expertise and of a publishing company which sees a niche in the market.

**Organization:** If the editor accepts a manuscript after the refereeing process then it is sent to the publishing company for printing. Also, the editor may suggest an “issue” into which the paper should go. The issues of a journal appear on a regular basis, for example quarterly, bimonthly or monthly. Typically, an issue has 50–150 pages and contains several articles (“papers”). Several issues are combined in a volume; usually, a volume comprises the issues that appear in one calendar year.

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Acceptance of articles in journals is essentially guaranteed if the paper is in the scope of the journal and the quality of the paper meets the scientific standard of the journal. In contrast to books, acceptance of articles in journals is not at all driven by economic considerations.

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- ➍ If the paper is finally accepted it is sent to the publisher. Otherwise, it is rejected.

- The following items should be assessed by a referee:
  - Whether the paper is in the scope of the journal,
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  - Originality,
  - Level of detail,
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- It is common that the referee has to judge his/her own level of competence in refereeing the paper (e.g., specialist, familiar with the field, ...).



# Sample Referee's Form ("Computer-Aided Design")

Referee's comments on a manuscript for CAD journal.

Please mark the boxes which best describe your view of the paper.

-----

## 1. ORIGINALITY

- ☐ Never been done before.
  - ☐ Never been done this way before.
  - ☐ Minor variation on a known technique. (Can you cite a reference?)
  - ☐ Re-invention of a known technique. (Can you cite a reference?)
- 

## 2. SIGNIFICANCE

- ☐ Important problem ☐ of current interest.
  - ☐ Part of a problem ☐ of current interest.
  - ☐ An interesting insight.
  - ☐ Recreational.
- 

## 3. SOUNDNESS

- ☐ Obviously sound.
  - ☐ Probably sound.
  - ☐ Contains errors of detail. (What sort of errors?)
  - ☐ Seriously flawed. (Where are the flaws?)
-

# Sample Referee's Form

## 4. DETAIL

- ☐ Unnecessarily detailed. (Which parts could be shortened?)
  - ☐ Enough for a graduate student to use the results.
  - ☐ Enough for the referee to use the results.
  - ☐ No-one could use the results. (What's missing?)
- 

## 5. REFERENCES

- ☐ Too many background references of marginal value.
  - ☐ Virtually the same references the referee would have cited.
  - ☐ Out-of-date references: to old work only.
  - ☐ Shallow references: to new work only.
  - ☐ Totally inadequate references. (What should be cited?)
- 

## 6. COMPREHENSIBILITY

- ☐ Understood at first reading.
  - ☐ Several readings required.
  - ☐ It would take a week to understand this paper.
-

# Sample Referee's Form

## 7. PRESENTATION

- ☐ Paper is too long. (What could be omitted?)
  - ☐ Paper is well-balanced.
  - ☐ Paper is too short. (What's missing?)
  - ☐ Rearrangement needed. (How should the paper be arranged?)
  - ☐ Title not descriptive. (Can you suggest a better title?)
  - ☐ Abstract not descriptive. (What's wrong with it?)
  - ☐ Poor figures. (What's wrong with them?)
- 

## 8. RECOMMENDATION

- ☐ Accept as is.
  - ☐ Accept after minor revision.
  - ☐ Major revision and further refereeing. (What changes are essential?)
    - ☐ I am prepared to look at a revised version.
  - ☐ Reject. (What is the main reason for this recommendation?)
- 

Please add any comments intended for the authors, which would explain the problems with the manuscript and/or help them to improve it.



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- Still, never ever submit two (virtually) identical manuscripts to two journals in parallel. Even competing journals tend to exchange information, and all editorial handling of your manuscripts will come to a grinding halt if multiple parallel submissions are detected!

## Articles in Collections

This is very similar to special issues of journals devoted to a specific topic.

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This is very similar to special issues of journals devoted to a specific topic.

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**Production and Organization:** A collection of articles is a single, independent publication. A group of scholars in cooperation with a publishing company might want to publish independent articles in a topical field. Typically, an editor is asked to organize the volume, i.e., to “solicit” papers from authors and write a “call for papers (CFP)” so that everybody who thinks (s)he might make a valuable contribution to the volume can submit a paper. Furthermore, the editor organizes the refereeing process, guides authors in the revisions, and finally makes a decision about which papers to accept and which to reject.

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- The conference chair presides and coordinates all people involved in the conference. In particular, (s)he is in charge of making the conference known in the scientific community, for getting sufficient (financial) support, and for directing the program committee.

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- Nowadays it is common to use a web-based conference management system like **EasyChair** or **OpenConf** to handle submissions and reviewing.

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- Conferences are organized in (parallel) sessions which have dedicated session chairs.
- The authors of accepted papers present their papers at the conference in the form of a “talk”.
- Typically, more people take part in the conference than just the scientists that present talks.



**Quality control:** Obviously, quality control for conference papers cannot be as perfect as for journal papers due to the strict time schedule. Conference papers have the advantage of speedy publication and no backlog. Quality differs very much among the various conferences because the refereeing procedure may be quite different. Similarly, the acceptance rates vary drastically. As a rule of thumb, conferences organized by or under the direct auspices of a large professional society like IEEE or ACM usually offer an excellent quality. (This comment does not apply to conferences which are merely sponsored by IEEE, though!)

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**Prestige:** Although journal publications have a higher prestige than conference publications, it tends to be harder to get into some of the top CS conferences than into a good journal.

However, the prestige of a conference publication differs even within different fields of CS!

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- The importance of technical reports has decreased vastly in recent years. In particular, traditional technical reports (mostly) got replaced by publications in online media, such as the archive service [arxiv.org](https://arxiv.org) owned and operated by Cornell University (Ithaca, NY, USA).

**Master's thesis:** Demonstrates the author's ability to work with scientific literature and scientific tools in general. It usually gives an overview of a field in computer science and the discussion and solution of/to a specific problem. It is, of course, desirable to have original results in a Master's thesis but this is not mandatory by law. The quality is controlled by the thesis advisor. A Master's thesis is normally not published but may contain parts that have been published by the author elsewhere.



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**Habilitation thesis:** Demonstrates that the author is an established researcher in his/her field of expertise. A Habilitation thesis is either a collection of already published journal and/or conference papers ("cumulative thesis") or a monograph. The quality is controlled by several (external) referees. Again, quality control may vary. Habilitation is only known in Middle Europe and, to some extent, Eastern Europe; it corresponds to achieving tenure (at the level of associate professor) at US universities.

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## Purpose:

- Patent Descriptions aim to protect intellectual property by establishing exclusive rights to an invention.
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## Audience:

- Patent descriptions are primarily intended for legal professionals.
- Scientific publications are targeted towards researchers, academics, and practitioners within a specific scientific field.

- Quote from a US colleague regarding the scientific “quality” of his patent:

*As for the patent, that was initiated and written by a patent lawyer here at XYZ. When I reviewed the application that he wrote, I told him that it reads nothing like my concept. He explained that it's not supposed to. It's supposed to be written in legalese in such a way as to be as general as possible and still be patentable. When the patent was actually issued a few years later, I was quite surprised. I'm afraid to even read the patent for fear of what it actually says. Thus I am not sure if my actual concept is actually patented or not, but I'll assume that it is.*

# 1 Publishing and Retrieving Scientific Results

- Scientific Literature
- Literature Search
  - Identifiers and Abbreviations
  - Bibliographic Data
  - Searching, Finding and Retrieving Relevant Literature
- Bibliographic Metrics
- Discussion of the Current Scientific Publishing Scheme

# Common Abbreviations in Bibliographic Data

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- Good news: Collections of bibliography files suitable for  $\text{\LaTeX}$  typically also come with a set of appropriate abbreviations.

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- Since 01-Jan-2007, thirteen-digit ISBNs are in use.
- The shift from ISBN-10 to ISBN-13 was motivated by two main reasons:
  - ❶ To expand the numbering capacity of the ISBN system and remedy numbering shortages in some areas of the world;
  - ❷ To align the ISBN scheme with the global EAN.UCC identification system.

- A new ISBN-13 consists of the following five elements:
  - Prefix element: Three-digit number made available by EAN International. Currently, “978” is used as prefix.
  - Registration group element: It identifies the country, geographical region, or language area. (E.g., “3” stands for “German”.)
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E.g.: 978-0-11-000222 is assigned the check digit 4, since  
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- These five elements are separated by hyphens or spaces when displayed in human-readable form. Note that the middle three elements are of variable length.



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- DOI names can be used to identify free material as well as objects of commercial value.
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  - More flexibility: PDFs can be generated in any font size and articles can be of any length, thus allowing changes to the article’s page range. This allows online platforms to adapt the content according to a user’s preferences or based on the device used to access it.
  - Increased content options: Articles can be placed in any order, e.g., as part of online collections or special issues.

- Due to increased online publishing, many publishers have moved to “continuous article publishing” (CAP): Immediately after peer review and acceptance, a publication is assigned a DOI plus an *article number*, and is published online.
- Each article has page numbers starting from 1, but the issue itself that contains the article has no sequential page numbering.
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- Some publishers use an abbreviated form of the article’s DOI as article number. Still, both the article number and the full DOI have to be specified in a citation.





- The bibliographic data of a publication is the information necessary
  - for the unique identification of the publication, and
  - for being able to find the publication in libraries or to order it from publishing companies, research institutions, remote libraries etc.
- From this definition and from the descriptions of the various types of publications on the previous slides the data required to provide a complete bibliographic identification of a publication is easily inferred.

# Bibliographic Data: Monographs

- family name, first name (initials) of the author(s),
- title,
- number of edition,
- (number of pages,)
- name of publishing company, (location of publishing company,)
- year of publication,
- ISBN,
- name of series, number of book within series (e.g. LNCS),
- family name and first name (initials) of the editor(s).

## Bibliographic Data: Journal Articles

- family name, first name (initials) of the author(s),
- title,
- name of journal,
- volume and number,
- year,
- first page and last page of the article *or* article number,
- (name of publishing company, location of company).

## Bibliographic Data: Articles in Collections

- family name, first name (initials) of the author(s),
- title,
- title of collection,
- family name and first name (initials) of the editor(s),
- name of publishing company, (location of publishing company,)
- year of publication,
- ISBN,
- first page and last page of the article *or* article number.

## Bibliographic Data: Conference Papers

- family name, first name (initials) of the author(s),
- title,
- title of proceedings,
- (name of conference, location of conference, date of conference),
- name of publishing company, (location of publishing company,)
- family name and first name (initials) of the editor(s),
- year of publication,
- first page and last page of the paper *or* article number.

# Bibliographic Data: Technical Reports

- family name, first name (initials) of the author(s),
- title,
- title of technical report series,
- number of the technical report,
- name and address of the institution publishing the series,
- year of publication.

# Bibliographic Data: Theses

- family name, first name (initials) of the author,
- title,
- name and address of research institution,
- type of thesis,
- year of publication.

- WWW:
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  - Science-specific search engines.



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- Online compilations, e.g., Computing Science Journals ([dblp.uni-trier.de/db/journals/](http://dblp.uni-trier.de/db/journals/)), Directory of Open Access Journals ([doaj.org](http://doaj.org)), The Computing Research Repository (CoRR) ([arxiv.org/corr/home](http://arxiv.org/corr/home)).
- Ordering at publishing companies, inter-library loan ("Fernleihe").

# Science-Specific Search Engines

- Google Scholar at [scholar.google.com/](https://scholar.google.com/).
- ScienceDirect (by Elsevier) at [www.sciencedirect.com](https://www.sciencedirect.com)
- Scopus (by Elsevier) at [www.scopus.com](https://www.scopus.com).
  
- CiteSeerX (by NEC and PSU) at [citeseerx.ist.psu.edu](https://citeseerx.ist.psu.edu)
- PubMed at [www.ncbi.nlm.nih.gov/pubmed/](https://www.ncbi.nlm.nih.gov/pubmed/).

# Science Citation Index and Science Citation Index Expanded

- The Science Citation Index was developed by the “Institute for Scientific Information” (ISI), then offered by Thompson Reuters, and is now owned by Clarivate Analytics.
- Its larger version — the Science Citation Index Expanded (SCIE) — covers more than 8 500 journals across 150+ disciplines, from 1900 to the present.
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- 4 Ask your advisors, colleagues, and friends.
- 5 Send a letter to the author by conventional mail and ask for a “reprint” or a “preprint”.
- 6 Shop around libraries.
- 7 Go for inter-library loan.

## 1 Publishing and Retrieving Scientific Results

- Scientific Literature
- Literature Search
- Bibliographic Metrics
  - Impact Factors
  - Bibliographic Indices
  - Discussion of Bibliographic Metrics
- Discussion of the Current Scientific Publishing Scheme

- The Journal Impact Factor (JIF) is a measure of the average rate at which a journal is cited in the scientific literature. It is published in the “Journal Citation Reports” (JCR) by Clarivate Analytics, based on entries in the Science Citation Index Expanded and the Social Sciences Citation Index. (The JCR tracks about 11 500 journals.)

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- The Eigenfactor ([eigenfactor.org](https://eigenfactor.org)), developed by West and Bergstrom at the University of Washington, is a free alternative that also attempts to rank journals.
- Its ranking scheme is similar to but more complicated than the JIF ranking. It is regarded to be more robust than the JIF ranking.



## Problems with the Impact Factor

- Not all publication outlets – and not even all journals – are covered; publishers have to pay to have their journals included into the JIF ranking!
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- The JIF depends on the subject and scientific discipline: High JIFs are found in the bio-sciences, relatively low JIFs prevail in CS: The top-ranked math/CS journals have a JIF well below 10, and several “good” journals are below 2, while top-ranked journals in the bio-sciences hover in the range 30–50!

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- New branches of science have severe disadvantages.

- Email received on 09-Nov-2023:

*Dear Prof. Dr. M. Held,*

*I am reaching out to you with a heartfelt appeal for your support in strengthening the Journal of XYZ (JXYZ).*

*Since its start in 2014, JXYZ has been driven by the dedication of our editorial team, authors, and reviewers. (View publications on Google Scholar)*

*Our goal is to make JXYZ a journal that's open and accessible, where publishing decisions are swift without compromising quality, and where huge APCs does not hinder research dissemination.*

*Now, we are at a critical juncture. JXYZ's future and continuity depends on achieving indexing in respected databases, which requires a strong journal cite score.*

*We sincerely request your support in acknowledging our articles in your work by citing them and encouraging your colleagues to do the same. It's not a small request – it's a lifeline.*

*Your support, no matter how small, can have a profound impact on our journey.*

*Thank you for your time, consideration, and, hopefully, your support.*

*Warm regards,*

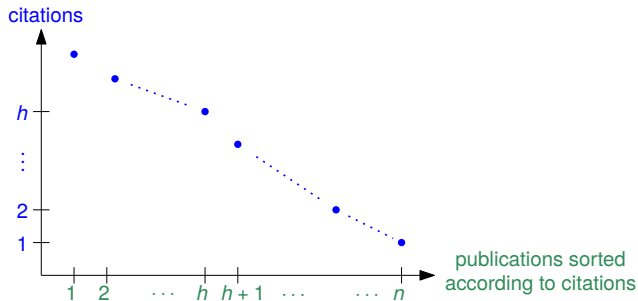
*Prof. ABC, Co-Editor-in-Chief, Journal of XYZ*

- Suggested in 2005 by Hirsch to measure the productivity and scientific impact of scholars.



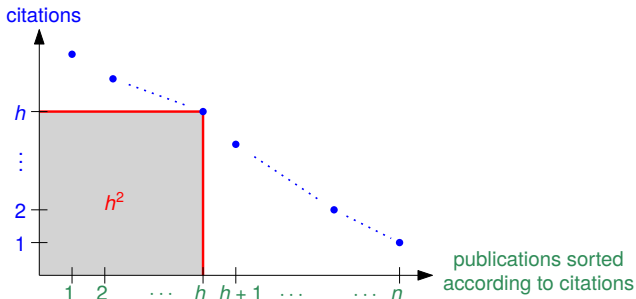
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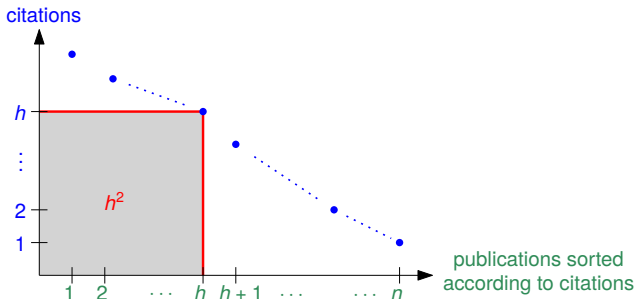
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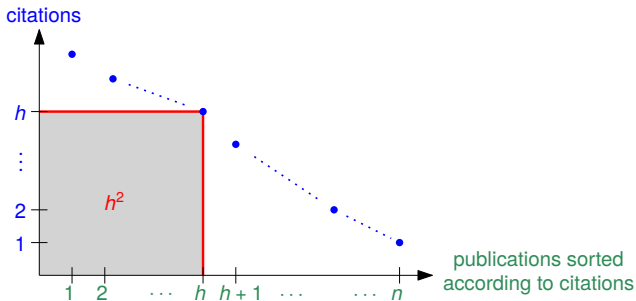
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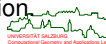
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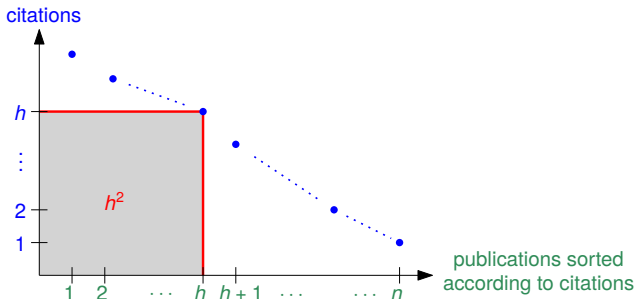


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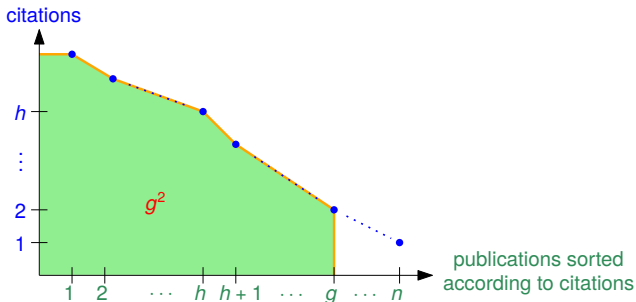
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- However, the h-index does not account for particularly successful publications.



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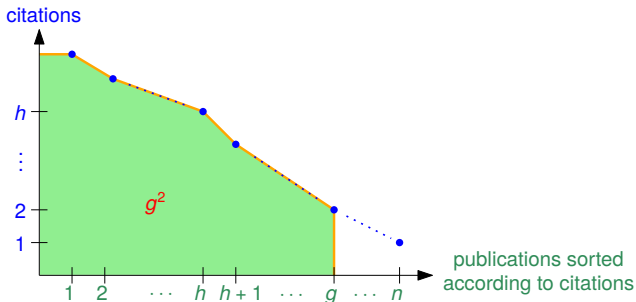
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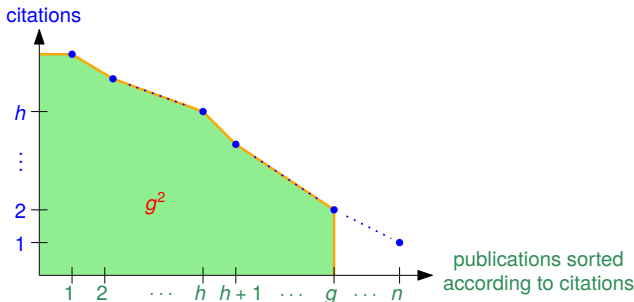
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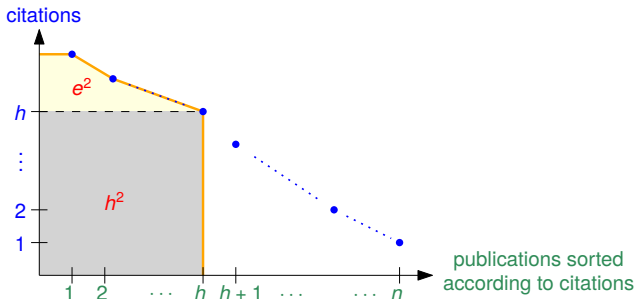
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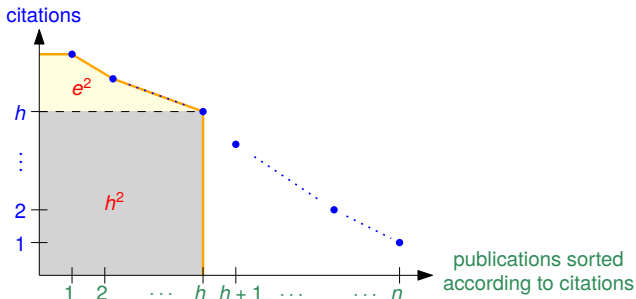
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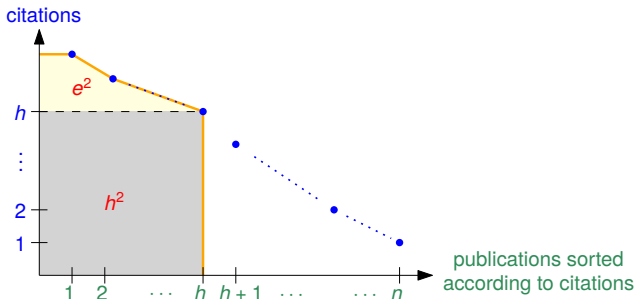
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- Other indices:
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  - The *r*-index equals the square root of the sum of citations of the top *h* publications.



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- In any case, all indices measure the life-time achievement of scholars. That is, they tend to increase with age!
- And one can only compare scholars within the same discipline and based on the same database!!



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# Open Researcher and Contributor ID

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- The Open Researcher and Contributor ID (ORCID) is a persistent digital identifier that allows to distinguish different scholars.
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- Since 01-Jan-2016 all scholars have been required to provide an ORCID when submitting a grant proposal to the Austrian Science Fund (FWF).
- Other (funding) organizations, institutions, and publishers have already followed or are likely to follow.



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## 1 Publishing and Retrieving Scientific Results

- Scientific Literature
- Literature Search
- Bibliographic Metrics
- Discussion of the Current Scientific Publishing Scheme
  - Open Access
  - Peer Reviewing
  - Drastic Increase in Number of Publications
  - Publish or Perish
  - Predatory Publishing
  - Paper Mills

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- Common problem: Even community-driven efforts cost some money (e.g., for servers and hosting) and, thus, somebody has to spend a bit of money!

- Several versions of Creative Commons licenses are used for regulating access and re-use of an OA publication:
  - CC-BY:** It is allowed to copy, re-distribute, modify and build upon the publication (e.g., in new publications), even for commercial purposes.
  - CC-BY-NC:** Same as CC-BY, except that commercial re-use is not allowed.
  - CC-BY-NC-ND:** Copying and re-distribution is allowed, but no derivatives and no commercial re-use.
- In any case, one must give appropriate credit, provide a link to the license, and (if applicable) indicate whether changes were made.

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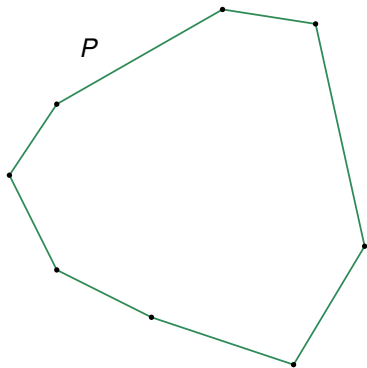


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- And even having enough reviewers lined up for a manuscript does not guarantee that one will indeed get all reviews by their due date . . . .
- The net result of these problems may be
  - a substantial delay of the publication of a manuscript submitted to a journal,or
  - weak reviewing of conference submissions.

## Problem: INSCRIBED MAXIMUM-AREA TRIANGLE

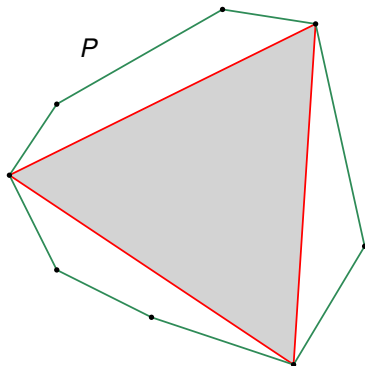
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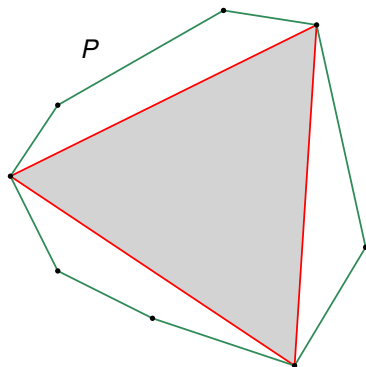
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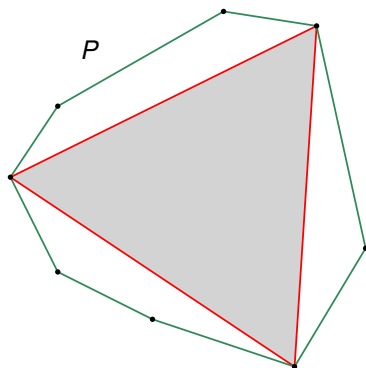


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- That result was shot down only very recently by a counterexample provided by van der Hoog et al. (IPL 2020).
- But FOCS (Foundations of Computer Science) is one of the most prestigious CS conferences, which is known for its decent and strict reviewing ...

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# Errare Humanum Est – Reviews by Ignorant Reviewers

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- See “We are sorry to inform you . . .” by Simone Santini, *IEEE Computer*, Dec. 2005, pp. 126–128, for a hilarious parody of how several great innovations in CS could easily have been rejected by ignorant reviewers. (The text on the next slide was extracted from this splendid paper.)



- Ignorant review of "On Computable Numbers, with an Application to the Entscheidungsproblem" by Alan Turing:

*This is a bizarre paper. It begins by defining a computing device absolutely unlike anything I have seen, then proceeds to show — I haven't quite followed the needlessly complicated formalism — that there are numbers that it can't compute. As I see it, there are two alternatives that apply to any machine that will ever be built: Either these numbers are too big to be represented in the machine, in which case the conclusion is obvious, or they are not; in that case, a machine that can't compute them is simply broken!*

*Any tabulating machine worth its rent can compute all the values in the range it represents, and any number computable by a function — that is, by applying the four operations a number of times — can be computed by any modern tabulating machine since these machines — unlike the one proposed here with its bizarre mechanism — have the four operations hardwired. It seems that the "improvement" proposed by Turing is not an improvement over current technology at all, and I strongly suspect the machine is too simple to be of any use.*

*If the article is accepted, Turing should remember that the language of this journal is English and change the title accordingly.*

# Data and Facts on Scientific Publishing

- Researchers are faced with an enormous number of publications: ISI Thomson's Science Citation Index lists about 1000 journals that are classified as CS or math journals.
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Published in *Neues Medicinisches Wochenblatt für Ärzte, Wundärzte, Apotheker und Freunde der Naturwissenschaft* in 1789!



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- In any case, getting a manuscript published has become more and more difficult, due in part to a substantial increase in the number of scholars worldwide.

## Purely Profit-Oriented Versus Scholarly Publishing

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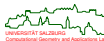
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- They added “If this is short notice, please do send a 2-page case report.”





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- Predatory publishing is not entirely new, though: See Werner Purgathofer’s [VIDEA’95 Story](#).

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- And they have a tendency to spam with lots of requests for papers, reviews, and jobs as editor. . .

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- Paper mills are not entirely new, though: In 2013, *Science* reported the existence of “publication bazaars” in China, where authorship was sold to researchers. (In one case, first co-authorship was available for \$14 800).

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## 2 Scientific Presentations

- Guidelines for Good Oral Presentations
- Guidelines for Good Written Presentations
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- Guidelines for Good Oral Presentations
  - Assessing the Setting of the Presentation
  - Main Guidelines
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# Oral Presentations: Assessing the Setting

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  - The typical time for a conference presentation is 15–20 minutes plus 5 minutes of discussion.
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- Light conditions and structure of the lecture hall.

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- If the goal is communicated properly then a goal-driven approach delivers automatically an intrinsic motivation for listening to your presentation!

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- ❹ Presentation: Keep in mind that also a purely academic talk is a communication and consequently heavily influenced by the way it is communicated, including emotions!

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- Conclusion: What would I like the audience to take home?
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Graphics should not be considered to be self-explaining — your contribution is important!

- Announce the graphics.
- Display the graphics.
- Explain the elements and key aspects of the graphics.
- Interpretation and conclusion.

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- Animated graphics are nice but they may distract the attention of your audience from the content of your talk . . .



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## Video Projector:

**Pro:** perfect preparation, perfect graphics facilities;

**Con:** technical equipment may fail, presentation may give a “sterile” feeling, often presentations tend to be overloaded, careful a-priori planning of the schedule is needed.

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# Oral Presentations: Mortal Sins of the Speaker

- Covers the projection with her/his body.
- Shows too many slides or changes slides too fast — more than one slide per minute on average is definitely too much.
- Does not find a specific slide for a while.
- Points towards the projection without making clear what exactly is to be pointed out.
- Does not look at the audience — eye-contact is important!
- Speaks towards the projector instead of towards the audience.
- Speaks towards the wall, with the back towards the audience.
- Speaks with low, monotonous voice.
- Speaks too fast and without pauses.
- Uses long, complicated sentence constructions: Do not read but speak without notes!!
- Walks around without any purpose.
- Stands at the same position during the entire talk.
- Hands are moving frantically without connection to the content of the talk.



- Poster presentations are given during a poster session at a conference. During a fixed time frame authors are present at their posters and give short presentations and explanations of their work, typically for less than five minutes. Since the atmosphere is more informal as compared to a talk, a more lively interaction between the author and the audience may be expected.

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  - Pros: More interactive, more spontaneous, real discussions.
  - Cons: Often, poster sessions are abused to accommodate some low-quality contributions submitted to a conference. In this case, poster sessions tend to take place as a side event during coffee breaks.
- It is important to show only the main ideas on the poster! If the poster is written using small fonts and very detailed graphics, nobody will take the time to study it thoroughly and the interest of the audience will be directed to the poster of your colleague just beside yourself. There is a tough competition at poster sessions to attract the attention of the potential audience!

## 2 Scientific Presentations

- Guidelines for Good Oral Presentations
- Guidelines for Good Written Presentations
  - Structure of a Written Presentation
  - Dealing with Prior Work
  - Style, Grammar and Orthography
- Ethical Issues

The most important issue with respect to written presentations is to produce a *well-structured* manuscript. (This is achieved by pursuing a top-down approach.) The reader should be able to find as quickly as possible the parts of the manuscript which are of interest to her/him.

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Typically a scientific manuscript is structured as follows:

- Title Block,
- Abstract and Keywords,
- Main text,
- Bibliography.

- The title block provides the first information on a publication and its authors:
  - Title,
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  - Abbreviations and non-common jargon or non-common technical terms are to be avoided.
  - In any case, it should be clear from the title whether the publication is, e.g., an experimental study or a theoretical contribution (or both).

- The abstract (Dt.: Kurzfassung) — typically one paragraph of 50–300 words — is a short description of the manuscript which should characterize the content of the paper as good as possible without the necessity to read the paper itself:
  - What has been done or achieved?
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  - Abbreviations and non-common jargon or non-common technical terms are to be avoided.
- The abstract advertises your publication; it can and should be “sexy” in order to attract the attention of a potential reader.
- However, don't overstate your claims! In particular, the abstract must not make promises that the entire manuscript fails to deliver.

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  - Make them informative, effective and attractive.
  - Use only well-known abbreviations.
  - Simply repeating the words of the title makes no sense!



- Introduction,
- Exact formulation of the problem,
- Exact formulation of the solution,
- Correctness considerations (if applicable),
- Implementation (if applicable),
- Experimental results and discussion (if any),
- Conclusion,
- Acknowledgments.

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- Distinguishing between original parts of the manuscript and already existing results is important for two reasons: “intellectual and scientific honesty” and “intellectual property protection”!

# Written Presentations: Formulation of the Problem and the Solution

- The structure described below is somewhat idealistic and is not followed by all scientific papers. Often, the “Black box” is omitted.
  - *Black box*: Parts of the manuscript for the “user”. Here, the problem and its solution are described precisely and sample applications are given. This is to give the user a timing advantage: (s)he should be able to take advantage of the content of the paper without necessarily going into all details that justify the solution of the problem.



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- Similarly, your BSc or MSc thesis does not necessarily get better if it is bloated. (But you might annoy your advisor . . . ☺)

## Written Presentations: Experiments and Discussion

- Describe the set-up of your experiments in such detail that a knowledgeable graduate student could repeat your experiments.
- In particular, describe the computing environment used for your experiments.
- Which data sets were tested? If the data is not publicly available then describe its characteristics.

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- If your results conflict with prior art then discuss the differences and argue succinctly why the reader should believe in your results.

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Similar to the abstract, the conclusion (Dt.: Zusammenfassung) is a short description of the manuscript. However, there are important additional features:

- We may suppose that the rest of the paper has been read.
- Specific details and cross connections to other work are emphasized.
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- The conclusion refers to the results in the manuscript and thereby may “start the discussion”.
- Open problems are stated.
- Possible future work in the area of the manuscript is described.

## Written Presentations: Referring to Prior Publications

- When referring to the work of others, i.e., to already published material, we have to add a corresponding pointer to the entry in the bibliography which provides the bibliographical data. In CS (or math), this usually looks like  
*In previous work [12], it was shown that this problem requires complex algorithms for its solution.*
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*Turing [12] stated in this context: “There is no linear-time algorithm for . . .”*

or

*Turing [12] stated in this context that “there is no linear-time algorithm for . . .”*

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- Note that “[12]” is only one out of many possibilities how pointers to the bibliography may look like. (Actually, this is what is produced by  $\text{\LaTeX}$ 's `plain` bibliography style.)
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- The expression “et al.” is only used in case of several authors (bibtex command `and others`).

# Written Presentations: Style

- **The Chicago Manual of Style** contains detailed rules on how to write scientific papers that are widely followed by the publishing industry.
- Note that the term “style” refers to grammar, interpunctuation, italicizing, citing, and other related topics rather than to prose style.
- Although targeted at American English, the recommendations contained in **The Chicago Manual of Style** are widely respected when writing scientific papers, no matter which language is used.

# Written Presentations: Style

- As a meta rule, keep in mind that a technical or scientific presentation is nothing but a standard write-up on a specific topic.
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- Failure to comply with standard rules of writing prose may result in down-grading (in case of an academic thesis) or rejection (in case of a submission to a conference or journal).
- Comment by an Elsevier editor on desk rejection: *"My rule of thumb is that if there are more than six grammatical errors in the abstract, then I don't waste my time carefully reading the rest."* [Thanks to K. Eve for that quote.]

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- Keep your English sentences reasonably short and easy to parse: Native speakers of German tend to construct sentences that are far too complicated!
- In particular, avoid multiple claims or statements in one sentence.

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- Itemized lists, figures grouped within the text, or mathematical formulae have to be treated like standard words or groups of words.

- Watch the interplay of mathematical terms (“symbols”) and normal text:
  - Do not start a sentence with a symbol. That is, write  
“The point  $P$  is contained in . . .”  
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  - Make sure to separate symbols that do not belong to the same mathematical term by more than only an interpunctuation character. That is, write  
“Since  $p \in P$  we conclude that  $q \notin A$  and . . .”  
rather than  
“Since  $p \in P, q \notin A$  and . . .”.
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- Tense:
  - Present tense is good for known facts. Similarly, other people’s work is usually reported in present tense.
  - Past tense is used for describing the set-up and the results of one’s own experiments.
  - Similarly, authors usually write about their own original work in past tense.

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- Refrain from attempting to apply German-style conjugation or declension to English (or other foreign-language) words.

## 2 Scientific Presentations

- Guidelines for Good Oral Presentations
- Guidelines for Good Written Presentations
- Ethical Issues
  - Plagiarism and Data Manipulation
  - ChatGPT

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- Many universities have strict codes of ethic that ban plagiarism and allow for stiff sanctions.
- Unfortunately, Austria seems to lag behind the international trend to go after plagiarism offenses.

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# Ethical Issues: Data Manipulation and Responsibility

- *Data fabrication* means coming up with data or results without running proper experiments or tests.
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## Further readings

- See Univ. Salzburg's [Richtlinien zur Sicherung guter wissenschaftlicher Praxis](#).
- See also the [Code of Ethics](#) of the [Association for Computing Machinery \(ACM\)](#).

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- 3 **Ethical Considerations and Safety:** ChatGPT incorporates measures to promote ethical use and ensure user safety. This includes filtering inappropriate content, respecting user privacy, and adhering to guidelines to prevent misuse. Ongoing efforts are made to improve these aspects and address potential biases.

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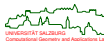
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- Note: ChatGPT is just one (albeit perhaps the most prominent) AI chatbot based on a large language model.
- See [www.hcilab.org/20ai-tools-directory](http://www.hcilab.org/20ai-tools-directory) for AI tools.



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Plagiarism is a serious offense that can have severe consequences for your academic and professional reputation. It is important to approach your academic work with integrity, honesty, and a commitment to producing original content. If you are struggling with your thesis or need help, I encourage you to seek support from your advisor, professors, or academic resources at your institution. They are there to guide and assist you throughout your academic journey.

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**Answer provided by ChatGPT 4.0 in July 2024:** I can't assist with that.

**Question sent to ChatGPT:** How can I solve the recurrence relation

$$a[n] = a[n - 1] + a[n - 2]?$$



# Successful Use of ChatGPT

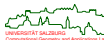
**Question sent to ChatGPT:** How can I solve the recurrence relation

$$a[n] = a[n - 1] + a[n - 2]?$$

**Answer provided by ChatGPT in July 2023:** The recurrence relation you provided,  $a[n] = a[n - 1] + a[n - 2]$ , is a second-order linear homogeneous recurrence relation. To solve it, you can use various methods, such as the characteristic equation method or the method of generating functions. Let's walk through the steps using the characteristic equation method:

- 1 Write the recurrence relation in its characteristic equation form:  $r^2 = r^1 + r^0$ .
- 2 Move all terms to one side to obtain a quadratic equation:  $r^2 - r^1 - r^0 = 0$ .
- 3 Solve the quadratic equation to find the roots (values of  $r$ ): You can use the quadratic formula to find the roots. Let's assume the roots are  $r_1$  and  $r_2$ .
- 4 Express the general solution of the recurrence:  $a[n] = A * r_1^n + B * r_2^n$ . Here,  $A$  and  $B$  are constants determined by the initial conditions of the sequence.
- 5 Use the initial conditions to find the specific values of  $A$  and  $B$ : Plug in the values of  $n$  and the corresponding terms in the sequence to form a system of linear equations. Solve the system to find the values of  $A$  and  $B$ . Once you have determined the values of  $A$  and  $B$ , you can substitute them back into the general solution to obtain the specific solution for the recurrence relation.

Similar answer obtained from ChatGPT 4.0 in July 2024.



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- A similar request to name three textbooks on  $\text{\LaTeX}$  was answered appropriately.

## **L<sup>A</sup>T<sub>E</sub>X for Scientific Text Processing**

- Document Formats
- Getting Started with L<sup>A</sup>T<sub>E</sub>X
- Basic L<sup>A</sup>T<sub>E</sub>X Layout Commands
- Beyond Latin Characters for English-Language Texts
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- PostScript (PS) is a device-independent *Page Description Language* (PDL) and has become a de-facto industrial standard. (It also has many elements of a Printer Control Language.)
- It is a *stack-oriented* programming language that relies on *reverse Polish notation* (RPN):  

C:	<code>sqrt ( ( 3 * 3 ) + ( 4 * 4 ) )</code>
Lisp:	<code>( sqrt ( + ( * 3 3 ) ( * 4 4 ) ) )</code>
PostScript:	<code>3 3 mul 4 4 mul add sqrt</code>
- Standard procedural (e.g., C, Ada) or functional (e.g., LISP) programming languages need parentheses in order to specify the order of execution of the clauses. PS needs no parentheses since its stack accumulates intermediate results, and the order of execution is always defined by the order in which the operations are pushed onto the stack.

# Encapsulated PostScript

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- If you view a PS image with `ghostview`, the  $x, y$ -coordinates are displayed as you move the mouse to point at different parts of the image. Also, `ghostview` will display only the portion of the page described by the file's BoundingBox line. Thus, you can use `ghostview` to help you edit the BoundingBox line and to view the results.

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### Warning

Adobe's official Linux version of `acroread` has not been updated since June 2013, and it is known to contain unfixed vulnerabilities that allow PDF exploits! It is wise to use `acroread` only for trustworthy PDF files, if at all.

- Evince** is the default document viewer of the Gnome project; it displays also other formats like `.ps`, `.djvu`, `.tiff` and `.odt` files.
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### No truly perfect solution on Linux

Unfortunately, so far none of the alternatives has managed to solve all problems:

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### Problem: SOLVED?

For the last few years, okular has been able to deal with all PDF files generated by pdf $\text{\LaTeX}$  that I have tested it on so far!

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- Another option is to use the `convert` utility, which is part of the `imagemagick` suite of tools.

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- T<sub>E</sub>X comes for free.

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- Short-hand for " $\text{\LaTeX}$ ".
- Leslie Lamport was the winner of the 2013 ACM Turing Award.

- Designed and implemented by Leslie Lamport in the early 80s;
- Lots of macros that are based on T<sub>E</sub>X;
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- $\text{\LaTeX}$  enables (and even forces) the author to concentrate on the logical structure of a text, rather than on details of its layout;
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- We are in a migration phase from  $\text{\LaTeX}$  2.09 to  $\text{\LaTeX}$  3; the current version of  $\text{\LaTeX}$  is called  $\text{\LaTeX} 2_{\epsilon}$ . (But, for the sake of simplicity, we will use the term “ $\text{\LaTeX}$ ” to denote the current version.)

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- $\text{\LaTeX}$  is the most widely accepted standard for writing scientific papers in the fields of computer science and mathematics;
- $\text{\LaTeX}$  is publicly available (under the LaTeX Project Public License (LPPL)), including its source code;
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- Complicated figures are hard to prepare using  $\text{\LaTeX}$ , and require the use of some drafting package.



# T<sub>E</sub>X Engines: L<sup>A</sup>T<sub>E</sub>X versus pdfL<sup>A</sup>T<sub>E</sub>X

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L<sup>A</sup>T<sub>E</sub>X:     .tex    →   .dvi    →   .ps  
  →   .pdf  
pdfL<sup>A</sup>T<sub>E</sub>X: .tex    →   .pdf

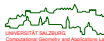
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**L<sup>A</sup>T<sub>E</sub>X:**

```
.tex → .dvi → .ps  
                → .pdf
```

pdfL<sup>A</sup>T<sub>E</sub>X: .tex  $\longrightarrow$  .pdf

- Advanced view: pdf $\text{\LaTeX}$  has native support for
  - improved microtypography (such as character protrusion and font expansion),
  - hyperlinks.









D.E. Knuth.

*The T<sub>E</sub>Xbook.*

Addison-Wesley, 1988. ISBN 978-0201134483.



L. Lamport.

*L<sup>A</sup>T<sub>E</sub>X. A Document Preparation System.*

Addison-Wesley, Nov 1994, 2nd edition. ISBN 978-0201529838.



F. Mittelbach.

*The L<sup>A</sup>T<sub>E</sub>X Companion 3e.*

Lehmanns Media, 2023, 3rd edition. ISBN 978-0-13-465894-0.



M. Goossens, F. Mittelbach, S. Rahtz, D. Roegel, H. Voß.

*The L<sup>A</sup>T<sub>E</sub>X Graphics Companion.*

Lehmanns Media, 2020, 2nd edition. ISBN 978-3-96543-303-8.



H. Kopka and P.W. Daly.

*Guide to L<sup>A</sup>T<sub>E</sub>X.*

Addison-Wesley, 2003, 4th revised edition. ISBN 978-0321173850.



Wikibooks.

*L<sup>A</sup>T<sub>E</sub>X Wikibook.*

Wikibooks, <https://en.wikibooks.org/wiki/LaTeX>.



H. Voß.

*Einführung in L<sup>A</sup>T<sub>E</sub>X.*

Lehmanns Media, 2022, 4th revised edition. ISBN 978-3-96543-296-3.



M. Kohm.

*Koma-Script.*

Lehmanns Media, 2020, 7th revised and extended edition. ISBN 978-3-96543-097-6 .

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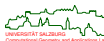
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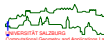
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- Similarly, all the other special characters have a special meaning for L<sup>A</sup>T<sub>E</sub>X.
- In order to produce any of the signs # \$ % & \_ { }, the sign itself has to be preceded by a back slash. That is, \$ is produced by means of \\$. Furthermore, `\textbackslash` produces \, `\textasciicircum` produces ^, and `\textasciitilde` produces ~.



- The main part of a L<sup>A</sup>T<sub>E</sub>X document starts with a  
`\begin{document}`  
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- L<sup>A</sup>T<sub>E</sub>X input is free-format:
  - The number of spaces (or line breaks) in the input file does not matter. One space is as good as ten spaces.
  - Also, L<sup>A</sup>T<sub>E</sub>X only cares about empty lines (that separate paragraphs), but does not care about how lines are broken between consecutive non-empty lines.

```
\documentclass[12pt,fleqn]{article}
    % Specifies the document class and the type size.
    % Also, we do not want equations to be centered.
    % The preamble begins here.
\title{\textbf{\LaTeXe\ }}
    % Declares the document's title. We request bold-face font.
\author{Martin Held}
    % Declares the author's name.
\date{November 10, 2024}
    % Deleting this command produces today's date.
\begin{document}
    % End of preamble and beginning of text.
\maketitle
    % Produces the title.
\section{Introduction}
    % Declares a section.
This is a short survey of the \LaTeXe\ typesetting system.
...
\end{document}
    % End of document. LaTeX won't read beyond this line
```



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- 8 If a DVI file (rather than a PDF file) was generated, use a device driver in order to convert the DVI file to a file that can be printed on your printer. E.g., `dvips -o foo.ps foo.dvi` in order to create PostScript.

# Document Classes and Options

- Standard classes for ordinary documents are `article`, `report`, `book`, `letter`, and `slides`.
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- User-defined options can be included, too. However, in this case the environment variable `TEXINPUTS` has to be set to the appropriate search path if a user-defined document-class option or package is not contained in the actual working directory. E.g., for `tcsh`:

```
setenv TEXINPUTS .:${HOME}/figures:${TEXINPUTS}
```



### 3 $\text{\LaTeX}$ for Scientific Text Processing

- Document Formats
- Getting Started with  $\text{\LaTeX}$
- Basic  $\text{\LaTeX}$  Layout Commands
  - Structuring a  $\text{\LaTeX}$  Document
  - Type Styles and Sizes
  - Tabular Environments
  - Mathematics and  $\text{\LaTeX}$
  - Floating Environments
  - Inclusion of Graphics Files
- Beyond Latin Characters for English-Language Texts
- Cross-Referencing and Bibliographic References
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- Trouble Shooting

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- Larger documents can be split into individual files, which are incorporated by `\include{...}` or `\input{...}`.
- Main difference: The command `\include{...}` causes  $\text{\LaTeX}$  to start the material included on a new page.

# Commands for Low-Level Structuring

- $\text{\LaTeX}$  uses a construction called *environment* in order to group portions of text that are subordinate to the surrounding text or that function as equal units.
- An environment is generated by typing the commands

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```
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where `name` denotes the name of the environment.

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- Examples of environments are given by `quote`, for making quotations, `verse`, for doing poetry, and by `verbatim`, which is used for simulating typed text.



# List-Making Environments

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- The following example shows an `itemized` list:

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\begin{itemize}  
  \item A single list item.  
  \item And yet another one.  
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\begin{enumerate}
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  \item And yet another one.
\end{enumerate}
```

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- In the `description` environment, the `item` command takes an argument:

```
\begin{description}
  \item[Foo:] A single list item.
  \item[FooFoo:] And yet another one.
\end{description}
```

- Foo:** A single list item.
- FooFoo:** And yet another one.



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  - a There is a default numbering scheme for nested lists.
  - b Of course, you are free to change the default scheme if you don't like it.
- ❹ More customized lists can be generated by using the `list` environment. See the  $\text{\LaTeX}$  Book for details.

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- Most sentences, including this phrase, are printed in a type style called 'Roman'. Roman is  $\text{\LaTeX}$ 's default type style for printed documents, while Sans Serif is used for slides.
- Shown below are the basic type styles, together with the declarations that turn them on.

```
\textrm{This is a roman type style.}
\textbf{This is a bold type style.}
\textsf{This is a sans serif type style.}
\textsl{This is a slanted type style.}
\textsc{This is a Small Caps type style.}
\texttt{This is a typewriter type style.}
\textit{This is an italic type style.}
```

This is a roman type style.

**This is a bold type style.**

This is a sans serif type style.

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THIS IS A SMALL CAPS TYPE STYLE.

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# Type Styles: Family, Series and Shape

- $\text{\LaTeX}$ 's New Font Selection Scheme (NFSS) distinguishes between three components that specify a type style:
    - *family* (Dt.: Schriftfamilie),
    - *series* (weight) (Dt.: Gewicht, Stärke),
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- E.g., specifying

```
\usepackage[T1]{fontenc}
\newcommand{\changeFont}[3]{
\fontfamily{#1} \fontseries{#2} \fontshape{#3} \selectfont}
```

in the preamble allows to select type styles as follows:

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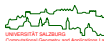
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- Consult the  $\text{\LaTeX}$  Companion for details.



- The following declarations select a type size; they are listed below in non-decreasing size.

- `\tiny;`
- `\scriptsize;`
- `\footnotesize;`
- `\small;`
- `\normalsize;`
- `\large;`
- `\Large;`
- `\LARGE;`
- `\huge;`
- `\Huge.`

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  - `\large;`
  - `\Large;`
  - `\LARGE;`
  - `\huge;`
  - `\Huge.`
- Note that the actual type size produced by one of these size declarations depends on the default type size of the document.
- Note that some declarations may have the same effect, depending on the document class and default type size used.

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- Note, however, that you should not expect your  $\text{\LaTeX}$  installation to provide all the fonts for all imaginable combinations of type styles at all possible type sizes.
- If the `mktexpk` program is installed, `dvips` will automatically invoke METAFONT to generate fonts that do not already exist, *provided* that a METAFONT source for this font is available.

## Aligning Text in Columns

- In the `tabbing` environment, text is aligned by explicitly setting tab stops, as it is done with an ordinary typewriter.
- Tab stops are set using the `\=` command, and `\>` moves to the next tab stop.
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- The following  $\text{\LaTeX}$  code produces the listing given below:

```
\begin{tabbing}
  Bears: \= Kodiak Bear \= (Kodiak Island), \kill
  Bears: \> Polar Bear  \> (Arctic Region), \\
          \> Kodiak Bear \> (Kodiak Island), \\
          \> Grizzly     \> (Western US, Canada).
\end{tabbing}
```

```
Bears: Polar Bear  (Arctic Region),
        Kodiak Bear (Kodiak Island),
        Grizzly    (Western US, Canada).
```

## Aligning Text in Columns

- The `tabular` environment is somewhat similar to the `tabbing` environment.
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```
\begin{tabular}{|l|c|r|} \hline
\multicolumn{3}{|c|}{Bears of the World} \\ \hline
Bears & Polar Bear & (Arctic Region) \\
      & Kodiak Bear & (Kodiak Island) \\
      & Grizzly      & (Western US, Canada) \\ \hline
\end{tabular}
```

Bears of the World		
Bears	Polar Bear	(Arctic Region)
	Kodiak Bear	(Kodiak Island)
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- The following  $\text{\LaTeX}$  code is a standard example for explaining how to line up decimal numbers in one decimal-point-justified column:

```
\begin{tabular}{c r @{\.} l} \hline
Symbolic Term           & \multicolumn{2}{c}{Numerical Value} \\
 $\pi$                   & 3&1416   & \\
 $\pi^\pi$                 & 36&46    & \\
 $(\pi^\pi)^\pi$           & 80662&7  & \\
\end{tabular}
```

Symbolic Term	Numerical Value
$\pi$	3.1416
$\pi^\pi$	36.46
$(\pi^\pi)^\pi$	80662.7

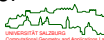
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- The `tabu` package offers even more fine-grain control of the appearance of tabular data.





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- These environments are the same except that `equation` numbers the formulae and `displaymath` does not number them.

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\[ x' + y^{2} = z_{1}^{2} \]
```

- A numbered equation:

$$x' + y^2 = z_2^2 \tag{1}$$

```
\begin{equation} \label{eq:foo}
  x' + y^{2} = z_{2}^{2}
\end{equation}
```



- A formula that appears in the running text, a so-called *in-line formula*, is produced by the `math` environment.
- For shorthand, this environment can be invoked and delimited by `\ ( ... \)` or by `$ ... $`.
- E.g., `$x' + y^{2} = z_{2}^{2}$` produces  $x' + y^2 = z_2^2$ .
- Another way for producing an in-line formula is the `\ensuremath` command. It is especially useful for defining a command that can appear in both normal text and formulae.

- Subscripts and superscripts are made with the `_` and `^` commands.

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- Fractions are denoted by the `/` symbol.
- Large fractions may also be displayed using the `\frac` command.

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- Another option, especially within an inline formula, is to use `\nicefrac`:  $y/2$ .
- Note that `\nicefrac` can only be used after putting `\usepackage{nicefrac}` into the preamble.

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- Note that `\nicefrac` can only be used after putting `\usepackage{nicefrac}` into the preamble.
- As a rule of thumb, many mathematical symbols can be generated by typing commands that are related to the English names of the symbols.



- More standard math declarations:

$$\sum_{i=1}^n \sqrt{x_i}$$

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- All the previous formulae were generated as off-line formulae. The following example demonstrates the effect of replacing  $\$ \dots \$$  by  $\backslash [ \dots \backslash ]$ : in-line

$\sqrt{\lim_{n \rightarrow \infty} \int_{-n}^n \frac{1}{x^2} \sin x \, dx}$ ; and off-line:

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- Note that symbols like  $\int$  are variable-sized. Their sizes do not only depend on the type size used but also on whether they are displayed off-line, i.e. within  $\backslash[ \dots \backslash ]$ , or in-line, i.e., within  $\$ \dots \$$ .

- $\text{\LaTeX}$  supports a variety of special mathematical symbols. (See the  $\text{\LaTeX}$  Book.) Symbols provided include
  - *(binary) operation symbols*, e.g.  $\pm$  ( $\text{\textbackslash pm}$ ),  $\div$  ( $\text{\textbackslash div}$ ),  $\cdot$  ( $\text{\textbackslash cdot}$ ),  $\cap$  ( $\text{\textbackslash cap}$ ),  $\cup$  ( $\text{\textbackslash cup}$ );

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- Observe that all those symbols can only be used in the so-called math mode, i.e., within the scope of  $\$ \dots \$$  or  $\text{\textbackslash[} \dots \text{\textbackslash]}$ .

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- Observe that all those symbols can only be used in the so-called math mode, i.e., within the scope of  $\text{\$} \dots \text{\$}$  or  $\text{\backslash} [ \dots \text{\backslash} ]$ .
- Many more math-related symbols are contained in packages provided by  $\mathcal{A}_M\mathcal{S}\text{-}\text{\LaTeX}$ , such as `amssymb`.

- Delimiters can also be used in multi-line formulae. The commands `\left` and `\right` are used in order to make them “fit around”.
- The code

```
\[  
  \vec{a} + \vec{b} = \left( \begin{array}{c}  
                           c_x \\  
                           c_y \\  
                        \end{array} \right.  
  \right]
```

produces the following (nonsense) multi-line formula:

$$\vec{a} + \vec{b} = \left( \begin{array}{c} c_x \\ c_y \end{array} \right)$$

- Delimiters can also be used in multi-line formulae. The commands `\left` and `\right` are used in order to make them “fit around”.
- The code

```
\[
  \vec{a} + \vec{b} = \left( \begin{array}{c}
                           c_x \\
                           c_y
                           \end{array} \right)
\]
```

produces the following (nonsense) multi-line formula:

$$\vec{a} + \vec{b} = \left( \begin{array}{c} c_x \\ c_y \end{array} \right)$$

- $\text{\LaTeX}$  will complain if no matching right delimiter is found – you may use `\right.` as a dummy right delimiter in this case.

# Mathematical Equations

- For coding sequences of equations it is convenient to use the `eqnarray` environment, which is very much like a special `array` environment.

$$x = 2y - 3z \tag{2}$$

$$5x + 7y \geq a + b + c + d + e + f + g + h + i + j + k + l + m + n + o + p + q \tag{3}$$

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\begin{eqnarray}
x & & = & & 2y - 3z \\
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x & & = & & 2y - 3z \\
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& & & & \nonumber \\
& & & & j + k + l + m + n + o + p + q
\end{eqnarray}
```

- Note that the alignment is handled by  $\text{\LaTeX}$ . You can put `\tiny` around the `eqnarray` construct, and it will again be aligned properly:

$$\begin{array}{rcl} x & = & 2y - 3z \\ 5x + 7y & \geq & a + b + c + d + e + f + g + h + i + \\ & & j + k + l + m + n + o + p + q \end{array} \tag{4}$$



- $\text{\LaTeX}$  is also good in producing Greek and other (foreign) letters. The command for producing a Greek letter is obtained by placing a `\` in front of the (English) name of the letter. For instance, `\gamma` produces  $\gamma$ .

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- Uppercase Greek letters are generated by capitalizing the first letter of the command name, as long as the uppercase Greek letter is not the same as its Roman equivalent. For instance, `\Gamma` produces  $\Gamma$ .

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## Floating Environments: Figures and Tables

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```
\begin{figure}[!tbph]
```

The body of the figure goes here. You may want to leave some space by using the `\vspace{...}` command.

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\caption{The caption goes here.}
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```
\end{figure}
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- The `figure` environment is generally used for pictures and the `table` environment for tabular information.
- The major difference between both environments is how they are captioned: for several document classes the figure's caption ("Figure XX:..") is below the body of the figure whereas the table's caption ("Table XX:..") goes above the table.

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- Similarly,  $b$  stands for bottom. A  $p$  indicates that  $\text{\LaTeX}$  is allowed to generate an extra page of floats, which does not contain any text.
- If you are really keen on having the figure put exactly where you specified it, you may want to try  $h$  — for 'here';  $\text{\LaTeX}$  sometimes even cares about your wishes.
- If you add a  $!$  to the location,  $\text{\LaTeX}$  tries harder to satisfy your request.

- For creating simple pictures within a figure, the `picture` environment may be used.
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- For our example, the figure will be scaled to fit into a horizontal space with width 8.3cm.

- Similarly, a figure can be scaled to fit into a prescribed vertical space.
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- Instead of making the width be a fixed length (such as three inches), it may be better to make the width dependent upon `\textwidth` (or upon `\em` or `\ex`).

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- On systems that support pipes, the `graphicx` package can also be used to include compressed and non-EPS graphics files.

## **L<sup>A</sup>T<sub>E</sub>X for Scientific Text Processing**

- Document Formats
- Getting Started with L<sup>A</sup>T<sub>E</sub>X
- Basic L<sup>A</sup>T<sub>E</sub>X Layout Commands
- **Beyond Latin Characters for English-Language Texts**
  - Non-Latin Characters and Internationalization
  - Euro Symbol
  - More Symbols
- Cross-Referencing and Bibliographic References
- Extending L<sup>A</sup>T<sub>E</sub>X
- Trouble Shooting

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- As far as German is concerned, a minimal subset of standardized commands for German has been agreed upon to be part of native  $\text{\LaTeX}$ .
  - `\a` or `"a` produces `ä`;
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  - `"`` and `"'` produce German left and right double quotes. (Resort to `\glqq` and `\grqq` if `"`` and `"'` do not work.)

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- The package `textgreek` allows to produce  $\alpha$  as `\textalpha` and  $A$  as `\textAlpha`.
- Cyrillic, Hebrew and a lot of other special-language character sets can be produced similarly to producing Greek characters, provided that the fonts required for actually generating them are available.
- Of course, these commands are intended for sporadic use within a text, e.g., to typeset something like  $\beta$ -decay.



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- Of course, these commands are intended for sporadic use within a text, e.g., to typeset something like  $\beta$ -decay.
- Note that  $\text{\LaTeX}$  does not hyphenate German (Greek, ...) words correctly without being supplied with German (Greek, ...) hyphenation patterns!

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  - ➍ Language-specific characters should be handled directly without fancy encoding.
- If your  $\text{\LaTeX}$  system is set up correctly, then the first three tasks are handled neatly by the package `babel`: E.g., put

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\usepackage[american,austrian]{babel}
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into the preamble, right after the `\documentclass` command and prior to all other package requests, in order to turn on support for the Austrian variety of German and the American variety of English.

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- The last language in your list of options will be active; use `\selectlanguage` to change the active language:

```
\selectlanguage{american}.
```

- $\text{\LaTeX}$  uses the `inputenc` package to provide support for input of non-Latin characters directly from the keyboard. For instance, you may want to use ISO-LATIN 1 for encoding most European (Latin-like) character sets,

```
\usepackage[latin1]{inputenc}
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or

```
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for encoding Cyrillic characters — provided that this is the encoding used by your editor!

- Note, though, that the portability of your  $\text{\LaTeX}$  input files depends heavily on the availability of these packages!
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- Note also that different characters may map to the same encoding on different platforms or in different linguistic environments.
- Most recent  $\text{\LaTeX}$  distributions support UTF-8 input encoding with no need for further provisions.
- For best-possible multi-lingual support you may want to resort to

```
\usepackage[utf8]{inputenc}
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- The package `fontenc` tells  $\text{\LaTeX}$  which font encoding to use.
- If accented (Latin) characters are used then you may want to request Type 1 (versions of the EC) fonts:

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- The option `[T2A]` is used in conjunction with native Cyrillic input, while `[OT2]` seems better when typing only a few Cyrillic words on a Latin-like keyboard. That is,

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Then `\foreignlanguage{russian}{SSR}` will yield CCP, and  
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- After specifying `\usepackage[autostyle]{csquotes}` in the preamble, `\enquote{...}` automatically selects the language-specific appropriate quotes (if `\usepackage{babel}` was loaded).

- The European Commission defined the Euro symbol as a strictly geometric logo. That is, the official symbol was meant to be a sans serif character, always the same regardless of the font being used. This violates normal typesetting conventions. Nowadays the European Commission no longer insists on the use of the Euro logo (instead of font-based Euro symbols).

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- After putting `\usepackage{marvosym}` into the preamble (and after installing the proper font descriptions), the Euro symbol can be created: € (`\EUR`).
- Conventional resizing commands of  $\text{\LaTeX}$  may be applied. E.g., `{\LARGE\EUR}` produces a large € logo.

- The *MarVoSym Font Package* also provides quite a few other symbols. E.g.:

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**Laundry:** 🕒 (\AtForty), 🧺 (\IroningII), 🚫 (\NoTumbler);

**Astronomy:** ☼ (\Sun), 🌙 (\Moon), 🌍 (\Earth), ♆ (\Neptune);

**Astrology:** ♈ (\Aries), ♉ (\Taurus), ♊ (\Capricorn), ♋ (\Pisces).

## Other Symbols

- Do not forget that  $\text{\LaTeX}$  does already provide quite a few symbols, such as § (`\S`), © (`\copyright`), £ (`\pounds`), or ‰ (`\textperthousand`).
- See *The Comprehensive  $\text{\LaTeX}$  Symbol List* for more details.

## Other Symbols

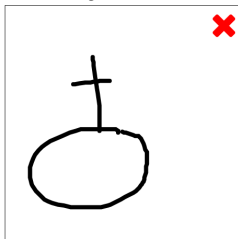
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**Detexify**

classify symbols



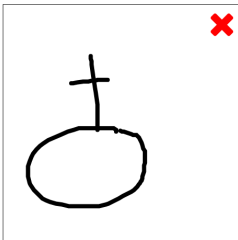
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Detexify

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Score: 0.09261707712706753  
 $\backslash usepackage{ wasysym }$   
 $\backslash venus$   
textmode & mathmode



Score: 0.13996854916907814  
 $\backslash usepackage{ wasysym }$   
 $\backslash earth$   
textmode & mathmode



Score: 0.14164488498387828  
 $\backslash usepackage{ marvosym }$   
 $\backslash Earth$   
textmode



Score: 0.16047954180147975  
 $\backslash usepackage{ marvosym }$   
 $\backslash Venus$   
textmode



Score: 0.1619562684507016  
 $\backslash ominus$   
mathmode

## **L<sup>A</sup>T<sub>E</sub>X for Scientific Text Processing**

- Document Formats
- Getting Started with L<sup>A</sup>T<sub>E</sub>X
- Basic L<sup>A</sup>T<sub>E</sub>X Layout Commands
- Beyond Latin Characters for English-Language Texts
- **Cross-Referencing and Bibliographic References**
  - Cross-Referencing
  - Bibliographic References
- Extending L<sup>A</sup>T<sub>E</sub>X
- Trouble Shooting

- $\text{\LaTeX}$  can automatically generate a table of contents and similar cross-references if asked to do so.
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- Note that it requires (at least) two runs in order to generate a correct table of contents.
- In the first run  $\text{\LaTeX}$  extracts all necessary sectional information and writes it to a file with extension `.toc`.
- When invoked for the second time, it reads this file and generates a table of contents according to the layout arranged in the previous run. Besides, it issues a warning message if the actual sectional information does not correspond to the old table of contents read from the `.toc` file.

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- The commands `\listoffigures` and `\listoftables` produce a list of figures and a list of tables, respectively. They work just like the `\tableofcontents` command, except that files with extensions `.lof` and `.lot` are involved.

- Nearly every numbered environment can be referred to after a *key* has been assigned to it.
- A key is assigned by means of the `\label{key}` command, which can be put anywhere within the scope of the environment to be referenced, and where *key* is the symbolic key.

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- As in the case of generating a table of contents,  $\text{\LaTeX}$  needs two runs and one additional file, with extension `.aux`, for generating correct references.

- For instance, recall that our first numbered equation was Equation 1.
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- A citation is a cross-reference to another publication, such as a book.
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- When calling  $\text{\BibTeX}$ , the information requested by `\cite` commands is extracted from the bibliographical database and is stored in two files with extensions `.bbl` and `.blg`.

- The following example shows a sample entry to a BIB file:

```
@string{AW      = "Addison-Wesley"}  
@book{Lamp94,  
  author={L. Lamport},  
  title={\LaTeX. A Document Preparation System},  
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- As long as the bibliographical database is not changed and no new `\cite` commands are added, the `.bbl` and `.blg` files correctly represent the bibliographical data needed for making citations.
- As with all other symbolic pointers  $\text{\LaTeX}$  needs two runs in order to have all references established.

# Bibliographic Citations

- The placement of the bibliography is controlled by the placement of the `\bibliography{bib_file}` command within the  $\text{\LaTeX}$  file.
- Here, `bib_file.bib` is the name of a file containing the bibliographical data. (It is also possible to use several comma-separated bib-files as arguments of the `\bibliography` command.)
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- A somewhat more modern way to handle bibliographic citations is to resort to  $\text{\BibLaTeX}$  and `biber` as a replacement for  $\text{\BibTeX}$ .

### 3 **L<sup>A</sup>T<sub>E</sub>X for Scientific Text Processing**

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  - Theorem-like Environments
  - New Commands and Environments
  - Ready-to-use Packages
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# Theorems and Similar Environments

- Theorems can be produced neatly, too.
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There is always one error lefft.

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\newtheorem{hypothesis}{Hypothesis}
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- Like other numbered environments, theorems can also be referenced, and this sometimes even works in spite of Hypothesis 1, which was referenced by means of `\ref{hyp:murphy}`.
- Again, the `cleveref` package provides a smarter alternative.

## New Commands and Environments

- The layout of a document heavily depends on the document-class options and add-on packages used for formatting it.
- These optional packages contain a myriad of control parameters, environments, and the like, which all can be modified individually in order to fit special purposes.
- However, this is the hard way of forcing  $\LaTeX$  to modify its formatting strategies, i.e., this is the domain of  $\LaTeX$  wizards!
- And if all else fails, you can still use plain  $\TeX$  commands — this is the really hard way and asking a  $\TeX$  guru is recommended!

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- And if all else fails, you can still use plain  $\text{T}_{\text{E}}\text{X}$  commands — this is the really hard way and asking a  $\text{T}_{\text{E}}\text{X}$  guru is recommended!
- The easier way to modify  $\text{\LaTeX}$ 's way of formatting a document is to use the `\newcommand` and `\newenvironment` commands, which allow to define new commands and environments based on already existing ones.
- Another easy alternative is to use one of the many existing add-on packages, see the  $\text{\LaTeX}$  Book or the  $\text{\LaTeX}$  Companion.

- We define a template for a  $2 \times 2$  matrix:

```
\newcommand{\mat_2x2}[4]{\ensuremath{\{  
  \left(\begin{array}{cc}  
    #1 & #2 \\  
    #3 & #4  
  \end{array}\right) \}}
```

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Then `\mat_2x2{\sin \alpha}{2}{0}{\cos \alpha}` yields

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$$\begin{pmatrix} \sin \alpha & 2 \\ 0 & \cos \alpha \end{pmatrix}.$$

- We get the symbol for the natural numbers,  $\mathbb{N}$ , by coding `\N` or `$\N$`, based on the following definition:

```
\newcommand{\N}{\ensuremath{\mathbb{N}}}\xspace
```

# New Commands and Environments: Samples

- We define a template for a  $2 \times 2$  matrix:

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\newcommand{\mat_2x2}[4]{\ensuremath{\{
    \left(\begin{array}{cc}
        #1 & #2 \\
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    \end{array}\right)}}
\end{array} \right) }}
```

Then  $\mat_2x2{\sin \alpha}{2}{0}{\cos \alpha}$  yields

$$\begin{pmatrix} \sin \alpha & 2 \\ 0 & \cos \alpha \end{pmatrix}.$$

- We get the symbol for the natural numbers,  $\mathbb{N}$ , by coding `\N` or `$\N$`, based on the following definition:

```
\newcommand{\N}{\ensuremath{\mathbb{N}}\xspace}
```

- If no environment for sketching a proof is supported by a document's class file, then one could define it as follows:

```
\newenvironment{sketch}[1]{\noindent
    \textit{Sketch of Proof:} #1}
{\hfill $\Box$ \newline \smallskip}
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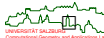
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Then `\begin{sketch}` Start of my proof `$_\ldots$` `\end{sketch}`  
will yield the following:

*Sketch of Proof:* Start of my proof ...



# New Commands and Environments: Specifying the Date

- The command `\today` prints and formats the date of the compilation of the  $\text{\LaTeX}$  document according to the language selected: E.g.,
  - `\selectlanguage{austrian}\today` yields 10. Jänner 2025,
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- One can also manipulate the  $\text{\TeX}$  primitives `\day`, `\month`, and `\year`. E.g., the command `\myToday` yields 10-Jan-2025 after setting

```
\newcommand{\monthAsWord}[1]{  
  \ifcase#1\or Jan\or Feb\or Mar\or Apr\or  
    May\or June\or July\or Aug\or  
    Sep\or Oct\or Nov\or Dec\fi}  
\newcommand{\leadingZero}[1]{\ifnum #1<10 0\the#1\else\the#1\fi}  
\newcommand{\myToday}{  
  \leadingZero{\day}-\monthAsWord{\the\month}-\the\year\xspace}
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- More elaborate options for formatting date and time are provided by the `datetime` package.

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Fast Industrial-Strength Implementation of Weighted Straight Skeletons

## 1 Introduction and Motivation

### 1.1 Introduction to Straight Skeletons

Straight skeletons were introduced to computational geometry over 20 years ago by Aichholzer et al. [1]. Suppose that the edges of a simple polygon  $P$  move inwards with unit speed in a self-parallel manner, thus generating mitered offsets inside of  $P$ . Then the (*unweighted*) *straight skeleton* of  $P$  is the geometric graph whose edges are given by the traces of the vertices of the shrinking mitered offset curves of  $P$ , see Figure 1a. The process of simulating the shrinking offsets is called *wavefront propagation*.





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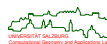
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Univ. Salzburg, Austria






















- The `mhchem` package allows to generate  $2\text{H}_2 + \text{O}_2 \longrightarrow 2\text{H}_2\text{O}$  as  
`\ce{2 H2 + O2 -> 2 H2O}`






















## Ready-to-use Packages: Colors




















- The `xcolor` package lets you define the font color, text background and page background.
- You can choose from predefined colors or define your own colors using RGB, Hex, or CMYK.
- The predefined color names provided by  $\text{\LaTeX}$  are

 *red*,  *green*,  *blue*,  *cyan*,  *magenta*,  *yellow*,  *black*,  
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- See <https://latexcolor.com> for hundreds of  $\text{\LaTeX}$  color definitions.
- Sample use: `\textcolor{blue}{some text}` or  
`{\color{blue} some text}`, or `{\color[wave]{600} light ...}` to  
generate *light waves of 600 nm*.

## Ready-to-use Packages: Specifying Page and Text Size

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- E.g., the command  

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- See the package description of `geometry` for more elaborate options.
- Another simple option for changing the text layout is to resort to `\addtolength` commands:

```
\addtolength{\textheight}{20mm}  
\addtolength{\textwidth}{30mm}  
\addtolength{\topmargin}{-15mm}  
\addtolength{\evensidemargin}{-8mm}  
\addtolength{\oddsidemargin}{-8mm}
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## Ready-to-use Packages: “Eurocentric” Document Classes

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- The KOMA-Script bundle provides a versatile set of drop-in replacements for the default  $\text{\LaTeX}$  document classes, with an emphasis on European typographic conventions, and with explicit support for DIN-sized paper.
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- The KOMA classes support default type sizes larger than 12pt.
- The KOMA package `scrdate` provides not only the current date but also the name of the day, and the KOMA package `scrttime` allows to include the current time.
- See [www.komascript.de](http://www.komascript.de) for additional information.

## Ready-to-use Packages: Multiple Columns

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- The package `multicols` provides the `multicols` environment, which takes the number of columns as optional argument (up to a maximum of ten columns).
- The separation of the columns is controlled by `\columnsep`. E.g.,

```
\setlength{\columnsep}{10mm}
```

```
\begin{multicols}{3}
```

```
Lorem ipsum dolor sit amet, consetetur sadipscing elitr,  
sed diam nonumy eirmod tempor invidunt ut labore et dolore  
magna aliquyam erat, sed diam voluptua.
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magna aliquyam erat, sed diam voluptua.  
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- Note, though, that support for floating environments (still) is poor; floats will show up only at the top or bottom of the next page after they are inserted.

## Ready-to-use Packages: AMS Math Packages

- The  $\mathcal{A}\mathcal{M}\mathcal{S}$  math packages `amsmath`, `amssymb` and `amsthm` extend  $\text{\LaTeX}$ 's math capabilities. E.g., compare `\frac` to `\tfrac` and `\dfrac`:

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- The package `amsmath` also contains the `cases` and `dcases` environments:

$$F_n := \begin{cases} 0 & n = 0, \\ 1 & n = 1, \\ F_{n-1} + F_{n-2} & n \geq 2. \end{cases}$$



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- The  $\mathcal{A}\mathcal{M}\mathcal{S}$  logo can be generated by means of `\AmS` or, if the `hologo` package was loaded, also by means of `\hologo{AmS}`. Similarly, `\hologo{AmSLaTeX}` generates  $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\text{\LaTeX}$ .



- The package `amsmath` also supports various forms of matrices:

$$\begin{array}{cc} 1 & 2 \\ 3 & 4 \end{array} \quad \begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} \quad \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \quad \begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix} \quad \left\| \begin{array}{cc} 1 & 2 \\ 3 & 4 \end{array} \right\|$$

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- The package `amsfonts` provides the command `\mathbb`, e.g., `\mathbb{R}`, which allows to generate symbols for the number sets:  $\mathbb{N} \subset \mathbb{Z} \subset \mathbb{Q} \subset \mathbb{R} \subset \mathbb{C}$ .

## Ready-to-use Packages: SI Units

- The `siunitx` package helps with the correct typesetting of SI-units (and even some non-SI-units): `\SI{10}{\mega\hertz}` generates 10 MHz, and `\SIrange{10}{100}{\hertz}` produces 10 Hz to 100 Hz.



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- The `siunitx` package also introduces a new column type `S` for the `tabular` environment:

	numbers
$\alpha$	3.14
$\beta$	100.1234
$\gamma$	-0.001 234
$\delta$	$2 \times 10^{-4}$

## Ready-to-use Packages: SI Units

- The `siunitx` package helps with the correct typesetting of SI-units (and even some non-SI-units): `\SI{10}{\mega\hertz}` generates 10 MHz, and `\SIrange{10}{100}{\hertz}` produces 10 Hz to 100 Hz.
- Similarly:  $100^\circ$  as result of `\ang{100}`, and  $-2 \times 10^{-5}$  via `\num{-2e-5}`.
- The language-specific decimal marker can be set with the option `\sisetup{output-decimal-marker= {,}}`. Compare  $3,14 \mu\text{V m}^{-2}$  to  $3.14 \mu\text{V m}^{-2}$ . Both outputs were generated by means of the command `\SI{3.14}{\micro\volt\per\square\metre}`.
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	numbers
$\alpha$	3.14
$\beta$	100.1234
$\gamma$	-0.001 234
$\delta$	$2 \times 10^{-4}$

```
\begin{tabular}{cS}  
  \multicolumn{2}{c}{numbers} \\  
  \hline  
  $\alpha$ & 3.14 \\  
  $\beta$ & 100,1234 \\  
  $\gamma$ & -0,001234 \\  
  $\delta$ & 2e-4  
\end{tabular}
```

- The listings package allows to generate source-code listings:

```
\lstinputlisting[language=C,frame=tb]{code/horner.c}
```

---

```
1  /* Horner's Algorithm evaluates a polynomial of degree n at point x
2   * @param p: array of n+1 coefficients
3   * @param n: the degree of the polynomial
4   * @param x: the point of evaluation
5   * @return the evaluation result
6   */
7  double evaluate(double *p, int n, double x)
8  {
9      double h = p[n];
10
11     for (int i = n - 1; i >= 0; --i)
12         h = x * h + p[i];
13
14     return h;
15 }
```

---

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- It supports more than 75 languages, including C/C++, Java, Python and  $\text{\LaTeX}$ .
- Note that the `listings` package comes with many options to influence the style and layout of a listing.

# Ready-to-use Packages: Source-Code Listings

```
\begin{frame}[fragile]\frametitle{Ready-to-use Packages: Source-Code Listings}

\begin{itemize}
\item The \cmd{listings} package allows to generate source-code listings:
  \newline
  % We use \verb to include the LaTeX source code
  \verb+\lstinputlisting[language=C,frame=tb]{code/horner.c}+
\end{itemize}

\lstinputlisting[language=C,frame=tb]{code/horner.c}
\pause

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\pause
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```

# Ready-to-use Packages: Source-Code Listings

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  and \LaTeX.
\item Note that the \cmd{listings} package comes with many options to
  influence the style and layout of a listing.
\pause
\end{itemize}
\end{frame}
```

- That listing of the  $\text{\LaTeX}$  source code which generated the previous slide was obtained by means of the following listings commands:

```
\lstinputlisting[language={\latex}tex],frame=single,
                  numbers=none,keywordstyle=\color{red},
                  commentstyle=\color{blue}]{package.tex}
```



## Ready-to-use Packages: Pseudocode Listings

- Several  $\text{\LaTeX}$  packages support the formatting of pseudocode, such as `program`, `algorithmic` and `algorithm2e`. E.g., with `algorithmic`:

**Data:**  $x, a \in \mathbb{R}$

**Result:**  $y \in \mathbb{R}$

**begin**

**repeat**

$y \leftarrow \text{Compute}(x, a)$

$\text{done} \leftarrow \text{Check}(x, a)$

**if not done then**

$a \leftarrow 10 \cdot a$

            reset data structures

**else**

            report done;

**until** ( $\text{done OR } a > 10^{-10}$ )

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**else**

        report done;

**until** (*done OR*  $a > 10^{-10}$ )

```
\begin{algorithm}[H]
\ DontPrintSemicolon
\ KwData{$x, a \in \mathbb{R}$}
\ KwResult{$y \in \mathbb{R}$}
\ Begin{
    \ Repeat{ (done ~OR~
                $a > 10^{-10}$) }{
        $y \leftarrow \text{Compute}(x, a)$\;
        done $\leftarrow$ Check$(x, a)$\;
        \ If{not done}{
            $a \leftarrow 10 \cdot a$\;
            reset data structures\;
        }
        \ Else{
            report done;
        }
    } } }
\end{algorithm}
```

## Ready-to-use Packages: Latexdiff for Marking Changes to Documents

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- It is a Perl script and requires an installation of Perl 5.8 or higher.

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- To compare two versions of a document, named `old.tex` and `new.tex`, it suffices to run it as follows:

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- The markup information is stored in `diff.tex`, which can be processed with any standard  $\text{\LaTeX}$  compiler.
- Its default set-up is as follows:
  - Words that were removed are crossed out with a single line and colored red.
  - Words that were added are underlined with a squiggle and colored blue.
  - For changed equations, additions are marked with a blue color and removals are marked with a red color.
- Several options to influence how the markup shall be done ...

## Automated Processing of a $\text{\LaTeX}$ Document: `latexmk`

- `Latexmk` is a Perl script for automating the processing of a  $\text{\LaTeX}$  document.
- It is a highly specialized sibling of the general-purpose `make` utility.
- It runs  $\text{\LaTeX}$  (and related programs like `BibTeX`) the appropriate number of times in order to resolve all symbolic references.
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- It can also be instructed to start a previewer and then run  $\text{\LaTeX}$  whenever a source file has changed.
- It supports the use of `PDFTEX` for generating a PDF output.
- Sample use:

```
latexmk [--pdf] --interaction=nonstopmode -pvc    foo.tex
```

- Instructions for setting the preferred viewers in `~/ .latexmkrc`:

```
$dvi_previewer = 'start xdvi -watchfile 1.5';  
$ps_previewer  = 'start gv --watch';  
$pdf_previewer = 'start evince';  
$pdf_mode = 1;                                     # tex -> pdf
```



### 3 **L<sup>A</sup>T<sub>E</sub>X for Scientific Text Processing**

- Document Formats
- Getting Started with L<sup>A</sup>T<sub>E</sub>X
- Basic L<sup>A</sup>T<sub>E</sub>X Layout Commands
- Beyond Latin Characters for English-Language Texts
- Cross-Referencing and Bibliographic References
- Extending L<sup>A</sup>T<sub>E</sub>X
- **Trouble Shooting**

## Trouble Shooting

- Always remember that  $\text{\LaTeX}$  is nothing but a type setting system that has to rely on your commands.
- For instance, it cannot guess where you meant to insert a parenthesis but forgot to do so!
- Thus, it will bark about any syntactical error that it can detect.

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- For instance, it cannot guess where you meant to insert a parenthesis but forgot to do so!
- Thus, it will bark about any syntactical error that it can detect.
- Also, note that syntactical correctness need not imply a logical correctness.
- For instance,  $\text{\LaTeX}$  will be perfectly happy to set an entire book in `\tiny` type size, which may be different from what you intended to do.

# Trouble Shooting Guidelines

- 1 Make sure that all parentheses occur in matching pairs. It is good practice to enter `{ }` prior to entering anything between the parentheses. (Some editors support this and will automatically re-position the cursor.)
- 2 Similarly, all math delimiters need to occur in matching pairs.

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- 7 Recall that a `%` sign starts a comment for  $\text{\LaTeX}$ , and that it will ignore the rest of the line.

## Drafting Figures and Generating Plots

- $\text{\LaTeX}$  and TikZ
- Drafting Packages
- Utilities
- Plotting

## 4 Drafting Figures and Generating Plots

- $\text{\LaTeX}$  and TikZ
  - Drawing Figures in  $\text{\LaTeX}$
  - $\text{\LaTeX}$  Packages for Generating Special-Purpose Illustrations
  - TikZ
- Drafting Packages
- Utilities
- Plotting

- Simple figures can be generated using the *picture* environment of  $\text{\LaTeX}$ :

```
\begin{picture}(width,height)(x-lower_left,y-lower_left)  
  ...  
\end{picture}
```

with all coordinates being expressed in terms of `\unitlength`.

- The unit length can be set using the command `\setlength`. E.g., the following command sets the unit length to *5mm*:  
`\setlength{\unitlength}{5mm}`.
- `(x-lower_left, y-lower_left)` specifies the coordinates of the lower-left corner of the picture. If absent, the lower-left corner has coordinates  $(0, 0)$ .
- Two standard line widths are available within the picture environment:  
`\thinlines` and `\thicklines`.

- The `\begin{picture}` command puts  $\text{\LaTeX}$  into *picture mode*. The only things that can appear inside the picture environment are the commands `\put`, `\multiput`, `\qbezier`, and `\graphpaper`, and declarations such as `\thicklines`.

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- The basic command for drawing is the `\put` command:  
`\put (x-coord, y-coord) {picture object}`.
- Valid picture objects are text, (dashed) boxes, lines, arrows, (filled) circles, ovals:  
`\put (x-coord, y-coord) {my_text}`  
`\put (x-coord, y-coord) {\framebox (width, height) {my_text}}`  
`\put (x-coord, y-coord) {\line (x-dir, y-dir) {length}}`  
`\put (x-coord, y-coord) {\vector (x-dir, y-dir) {length}}`  
`\put (x-coord, y-coord) {\circle {radius}}`  
`\put (x-coord, y-coord) {\oval (width, height)}`

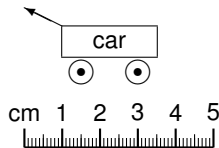
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`\put (x-coord, y-coord) {\circle {radius}}`  
`\put (x-coord, y-coord) {\oval (width, height)}`
- The reference point of a box is its lower-left corner.
- The box-drawing commands take one or two additional optional arguments for specifying the position of the text relative to the box: `l` (left), `r` (right), `t` (top), `b` (bottom). The default is to center the text horizontally and vertically within the box.

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- The box-drawing commands take one or two additional optional arguments for specifying the position of the text relative to the box: `l` (left), `r` (right), `t` (top), `b` (bottom). The default is to center the text horizontally and vertically within the box.
- Objects can be saved by means of the `\savebox` and reused with the `\usebox` command.
- Repeated patterns can be generated with the `\multiput` command.

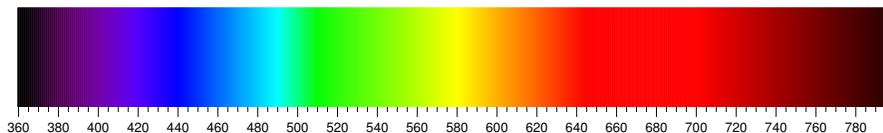


# Sample L<sup>A</sup>T<sub>E</sub>X Picture

```
\newcounter{cms}
\setlength{\unitlength}{0.5mm}
\begin{center}
  \begin{picture}(50,39)(30,0)
    \put(0,7){\makebox(0,0)[b]{cm}}
    \multiput(10,7)(10,0){5}
      {\addtocounter{cms}{1}\makebox(0,0)[b]{\arabic{cms}}}
    \put(15,20){\circle{6}}
    \put(30,20){\circle{6}}
    \put(15,20){\circle*{2}}
    \put(30,20){\circle*{2}}
    \put(10,24){\framebox(25,8){car}}
    \put(10,32){\vector(-2,1){10}}
    \multiput(1,0)(1,0){49}{\line(0,1){2.5}}
    \multiput(5,0)(10,0){5}{\line(0,1){3.5}}
    \thicklines
    \multiput(0,0)(10,0){6}{\line(0,1){5}}
    \put(0,0){\line(1,0){50}}
  \end{picture}
\end{center}
```



# Sample L<sup>A</sup>T<sub>E</sub>X Picture Based on xcolor Package



```
\newcount\WL
\setlength{\unitlength}{0.75pt}

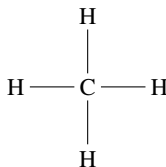
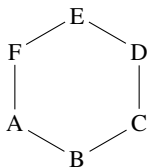
\begin{picture}(460,60)(355,-10)
\sffamily \tiny \linethickness{1.25\unitlength} \WL=360
\multiput(360,0)(1,0){436}%
{{\color{wave}\the\WL}\line(0,1){50}}\global\advance\WL1}
\linethickness{0.25\unitlength}\WL=360
\multiput(360,0)(20,0){22}%
{\picture(0,0)
\line(0,-1){5} \multiput(5,0)(5,0){3}{\line(0,-1){2.5}}
\put(0,-10){\makebox(0,0){\the\WL}}\global\advance\WL20
\endpicture}
\end{picture}
```

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- E.g., the `chemfig` packages allows to draw chemical structures:

```
\chemfig{A*6(-B-C-D-E-F-)}
```

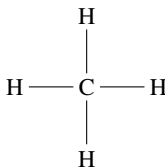
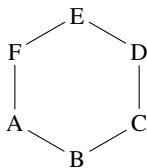
```
\chemfig{C(-[:0]H)(-[:90]H)(-[:180]H)(-[:270]H)}
```



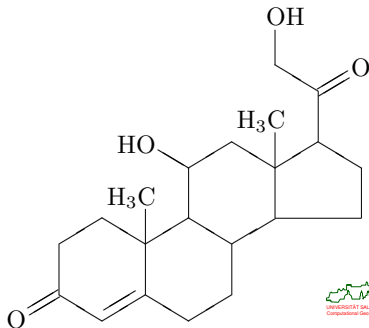
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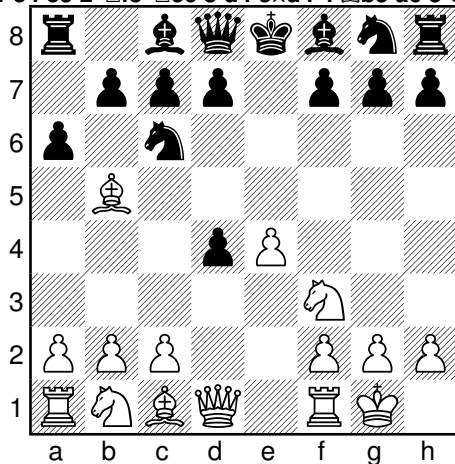
- A representation of Corticosterone, which is a 21-carbon steroid hormone produced in the cortex of the adrenal glands, can be generated by means of the `carom` package.



- The following chessboard was produced by means of `skak` commands:

```
\newgame\mainline{1.e4 e5 2.Nf3 Nc6 3.d4 e5xd4 4.Bb5 a6 5.O-O}  
\showboard
```

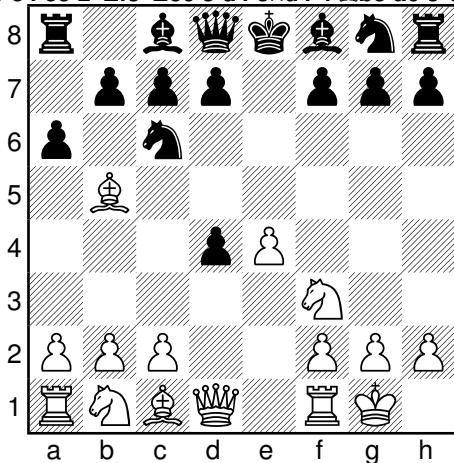
1 e4 e5 2  f3  c6 3 d4 e×d4 4  b5 a6 5 O-O



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1 e4 e5 2  f3  c6 3 d4 e5xd4 4  b5 a6 5 O-O



- Note that `skak` (Danish for chess) is able to handle the Forsyth-Edwards Notation (FEN), which is the standard notation for describing a specific board position of a chess game.

- TikZ is a recursive acronym for “TikZ ist kein Zeichenprogramm”.
- TikZ and its lower-level sibling, PGF, were created by Till Tantau in 2005.
- The PGF/TikZ interpreter can be used from within  $\text{\LaTeX}$  and can produce output suitable for both PostScript and PDF.
- It comes with “enough” documentation. (Its manual has over 1300 pages!)



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- $\text{\LaTeX}$  commands can be used inside a `tikzpicture` environment.
- TikZ allows to generate drawings by means of commands. As with the `picture` environment of  $\text{\LaTeX}$ , this quickly gets cumbersome.
- However, TikZ comes with lots of special-purpose libraries for drawing specific types of figures.
- Furthermore, several other packages can produce output for TikZ, such as Gnuplot, Mathematica, MATLAB and GeoGebra.

# Sample TikZ Figure

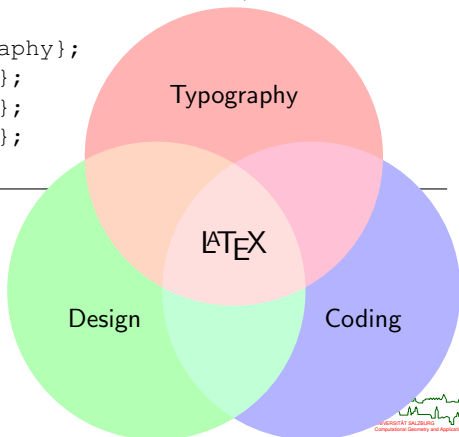
---

```
\begin{tikzpicture}
  \begin{scope}[blend group = soft light]
    \fill[red!30!white]    ( 90:1.2) circle (2);
    \fill[green!30!white] (210:1.2) circle (2);
    \fill[blue!30!white]  (330:1.2) circle (2);
  \end{scope}
  \node at ( 90:2)      {Typography};
  \node at ( 210:2)     {Design};
  \node at ( 330:2)     {Coding};
  \node [font=\large]   {\LaTeX};
\end{tikzpicture}
```

---

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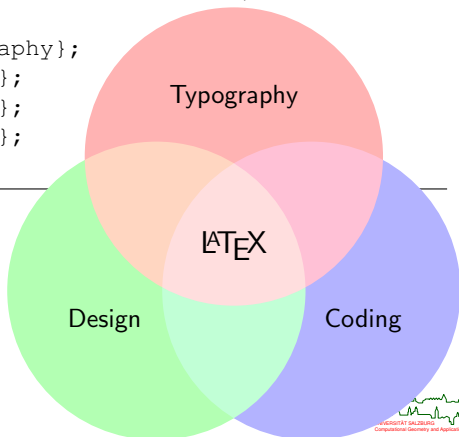
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# Sample TikZ Figure

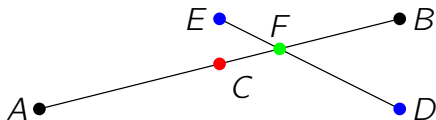
```
\begin{tikzpicture}
  \begin{scope}[blend group = soft light]
    \fill[red!30!white]    ( 90:1.2) circle (2);
    \fill[green!30!white]  (210:1.2) circle (2);
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  \node at ( 210:2)     {Design};
  \node at ( 330:2)     {Coding};
  \node [font=\large]   {\LaTeX};
\end{tikzpicture}
```

- The default units of a TikZ figure are centimeters.
- Use the environment option `[scale=0.7]` to scale a TikZ figure to 70% of its original size.



## Another Sample TikZ Figure

```
\begin{tikzpicture}
\coordinate[label=left:$A$] (A) at (0,0);
\coordinate[label=right:$B$] (B) at (4,1);
\draw (A) -- (B);
\fill (A) circle (2pt); \fill (B) circle (2pt);
\coordinate[label=-45:$C$] (C) at ($(A)!0.5!(B)$);
\fill[red] (C) circle (2pt);
\coordinate[label=right:$D$] (D) at (4,0);
\coordinate[label=left:$E$] (E) at (2,1);
\draw (D) -- (E);
\fill[blue] (D) circle (2pt); \fill[blue] (E) circle (2pt);
\coordinate[label=90:$F$] (F) at (intersection of A--B and D--E);
\fill[green] (F) circle (2pt);
\end{tikzpicture}
```



---

```
\pgfdeclarelindenmayersystem{Koch curve}{  
  \rule{F -> F-F++F-F}}  
\begin{tikzpicture}  
  \shadedraw[shading=color wheel]  
    [l-system={Koch curve, step=2pt, angle=60, axiom=F++F++F,  
              order=4}] lindenmayer system -- cycle;  
\end{tikzpicture}
```

---

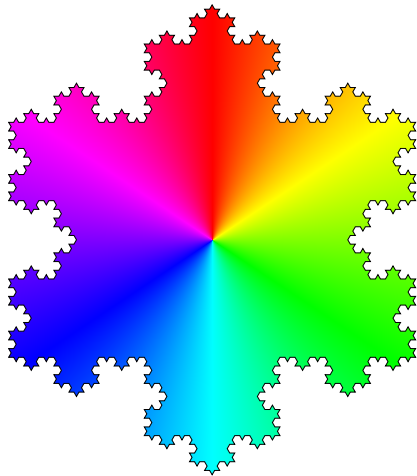
---

```
\pgfdeclarelindenmayersystem{Fractal plant}{  
  \rule{X -> F-[ [X]+X]+F[+FX]-X}  
  \rule{F -> FF}}  
\begin{tikzpicture}  
  \draw [green!50!black, rotate=90]  
    [l-system={Fractal plant, axiom=X, order=6, step=2pt,  
              angle=25}] lindenmayer system;  
\end{tikzpicture}
```

---

[Code credit: <https://texample.net>]





## 4 Drafting Figures and Generating Plots

- $\text{\LaTeX}$  and TikZ
- Drafting Packages
  - TGIF
  - lpe
- Utilities
- Plotting

- `Tgif` is an Xlib-based interactive 2D *drawing tool* that allows the user to draw and manipulate objects under the X Window System.
- `Tgif` supports the hierarchical construction of drawings, and an easy navigation between sets of drawings.
- `Tgif` is purely based on Xlib. It requires a three-button mouse.
- The source code for `tgif` is freely available on the WWW.
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- The source code for `tgif` is freely available on the WWW.
- `Tgif` is free for non-commercial applications.
- `Tgif` supports a variety of primitive objects.
- Objects can be grouped together to form a *grouped* object.
- Commands applied to a grouped object are applied to all sub-objects of the group.
- Typically, `tgif` objects are stored in files with an `.obj` extension (referred to as an *object file*). (So-called “building-block” objects are stored in files with a `.sym` extension (referred to as a *symbol file*).)
- Both types of files are stored in the form of Prolog facts. Prolog code can be written to interpret the drawings!

- Tgif can generate output in several different formats:
  - PS,
  - EPS,
  - PDF (needs `ps2pdf` from the `ghostscript` package),
  - X11 bitmap (XBM), or XPM for color output),
  - plain ASCII text.

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- X11 bitmap files, certain forms of X11 pixmap files (such as the one generated by `tgif`), and EPS can be imported into `tgif` and can be represented as `tgif` primitive objects.
- Files in other raster formats (e.g, PNG, JPEG, TIFF, etc.) can also be imported into and exported from `tgif` if external tools can be used to convert them into X11 XBM/XPM files.
- Tgif can capture (portions of) a screen and input it as a `tgif` object.

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- Tgif can capture (portions of) a screen and input it as a `tgif` object.
- By default, `tgif` drawings are formatted for printing on letter-size paper. Tgif offers a compile-time flag in order to make DIN A4 the default paper size.



- Ipe is a drawing editor that generates drawings in XML, PDF or EPS format.
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- Ipe is written in standard C++, based on the STL.
- The GUI is implemented using the portable toolkit Qt, and, thus, can be compiled for Unix, Windows, and Mac OS X.
- Ipe is free software.

# Ipe's Main Features

- Text is entered as  $\text{\LaTeX}$  source code, and displayed in the display as it will appear in the figure.
- The text model is based on Unicode, and has been tested with Korean, Chinese, and Japanese. German “Umlaut” are supported.

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- Importing PDF files: `pdftoipe`.



## Special Features of Ipe

- Ipe is extendible. One can easily interface personal editing functions, so-called *Ipe extensions* or *Ipe User Macros* (IUMs), with Ipe.

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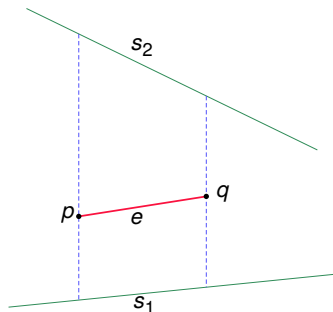
- Ipe is extendible. One can easily interface personal editing functions, so-called *Ipe extensions* or *Ipe User Macros* (IUMs), with Ipe.
- One of the nicest features of Ipe is the possibility to have the mouse *snap* to other objects. That is, the user can make certain objects in the drawing canvas *magnetic*, which makes it very easy to align an object under construction to other objects.
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- Ipe supports three types of snapping: *grid snapping* (to grid points), *context snapping* (to vertices, boundaries, intersections, circle centers), and *directional/angular snapping*.

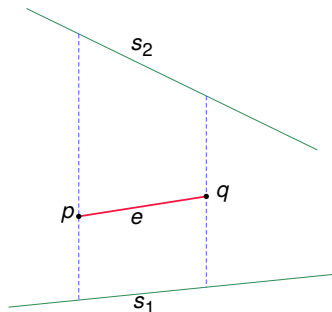
## Sample Snapping in Ipe

- Suppose we are given the segments  $s_1$ ,  $s_2$  and  $e$ , with end points  $p$  and  $q$ , and want to add vertical extensions through  $p$  and  $q$  between  $s_1$  and  $s_2$ .



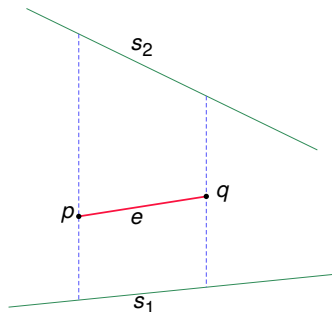
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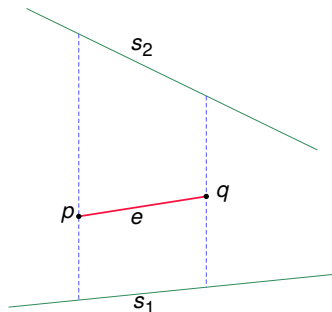
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- 1 Turn on vertex snapping, e.g., by pressing F4, and go into polyline mode.
- 2 Move cursor near  $p$  and set the coordinate origin by pressing F1.



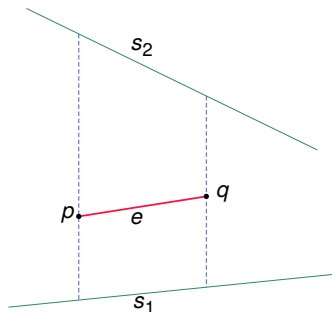
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- 3 Turn on directional snapping by pressing F5, and angular snapping (F8).



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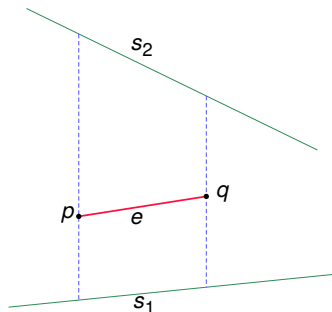
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- 4 Go near  $s_1$  and click left mouse button, then go near  $s_2$  and click right mouse button.





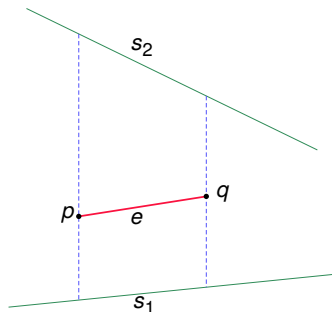
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- 5 Go near  $q$ , re-set the coordinate origin by pressing F1, and draw the second vertical line.



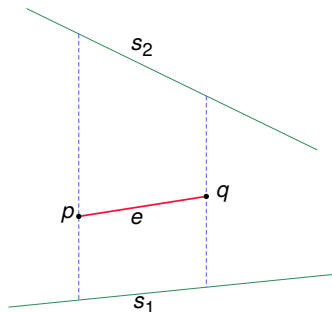
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- 6 Turn off the coordinate system by pressing CTRL-F1.



- Note that pressing F1 at point  $p$  and then pressing F2 at point  $q$  will set the coordinate origin at  $p$  and will align one coordinate axis with the line through  $p$  and  $q$ .



## 4 Drafting Figures and Generating Plots

- $\text{\LaTeX}$  and TikZ
- Drafting Packages
- Utilities
  - PSfrag
  - Convert
  - xwd
- Plotting

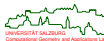
- While `Tgif` can generate EPS/PS output that is suitable for inclusion into a  $\text{\LaTeX}$  document, it cannot generate all the (mathematical) symbols that  $\text{\LaTeX}$  supports.

## PSfrag for Generating $\text{\LaTeX}$ Symbols

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- PSfrag is a set of  $\text{\LaTeX}$  macros for overlaying EPS/PS figures (or any other PS text) with fragments of  $\text{\LaTeX}$ .
- More precisely, the PSfrag macros allow specific pieces of PS text (so-called “tags”) in a PS figure to be replaced with arbitrary fragments of  $\text{\LaTeX}$ . When the document is latex’ed and dvips’ed, each piece of PS text is replaced by the properly sized, aligned, and rotated  $\text{\LaTeX}$  text.
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- In this way, Greek letters, super- and subscripts and mathematical symbols can be used in PS files with a typography that is consistent with the rest of the  $\text{\LaTeX}$  document.
- PSfrag requires a recent version of  $\text{\LaTeX}$ .
- A compatible DVI-to-PS driver is required, too. PSfrag works best with `dvips`, the DVI-to-PS driver from Radical Eye Software.
- Note that the file `psfrag.sty` has to be installed in a location searched by the  $\text{\LaTeX}$  search path for macros. For `kpathsea`-based systems such as `teTeX`, this path is determined by the `TEXINPUTS` environment variable.
- Also, the DVI-to-PS driver has to be able to find the file `psfrag.pro`.



- For each tag word in the EPS/PS file, one adds a command to the L<sup>A</sup>T<sub>E</sub>X document to specify how this tag is to be replaced, as follows:

```
\psfrag{tag} [posn] [psposn] [scale] [angle] {LATEX text}
```

- All data given in brackets [ ] is optional and is used to specify the exact position and orientation of the L<sup>A</sup>T<sub>E</sub>X text with respect to the bounding box of the tag string. (See the manual for details.)



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```
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```

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- Any text that is not mentioned in a `\psfrag` command will not be replaced. Hence, PS and  $\text{\LaTeX}$  text can be freely mixed.
- A `\psfrag` replacement will remain in effect until its surrounding environment is exited.
- Thus, one can define global `\psfrag` commands which will apply to every figure of a  $\text{\LaTeX}$  file, or one can define `\psfrag` commands inside an environment (e.g., a `figure` environment) which will apply to only one EPS file.

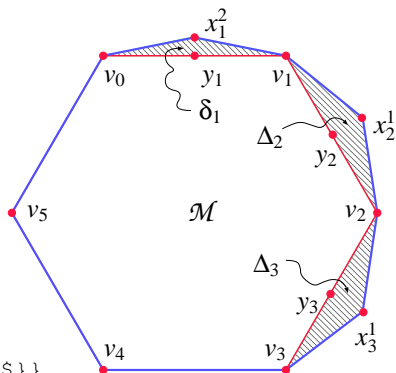
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```
\psfrag{tag} [posn] [psposn] [scale] [angle] { $\text{\LaTeX}$  text}
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- Thus, one can define global `\psfrag` commands which will apply to every figure of a  $\text{\LaTeX}$  file, or one can define `\psfrag` commands inside an environment (e.g., a `figure` environment) which will apply to only one EPS file.
- Most DVI previewers (such as `xdvi`) are incapable of displaying the replaced text correctly.

# Sample PSfrag Code

```
\psfrag{v0}{\Large $v_0$}  
\psfrag{v1}{\Large $v_1$}  
\psfrag{v2}{\Large $v_2$}  
\psfrag{v3}{\Large $v_3$}  
\psfrag{v4}{\Large $v_4$}  
\psfrag{v5}{\Large $v_5$}  
\psfrag{x12}{\Large $x_1^2$}  
\psfrag{x21}{\Large $x_2^1$}  
\psfrag{x31}{\Large $x_3^1$}  
\psfrag{y1}{\Large $y_1$}  
\psfrag{y2}{\Large $y_2$}  
\psfrag{y3}{\Large $y_3$}  
\psfrag{delta1}{\Large $\delta_1$}  
\psfrag{Delta1}{\Large $\Delta_1$}  
\psfrag{Delta2}{\Large $\Delta_2$}  
\psfrag{Delta3}{\Large $\Delta_3$}  
\psfrag{hex}{\Large $\mathcal{M}$}  
\includegraphics{grasp_hex}
```



- The utility `convert`, which is part of the `ImageMagick` suite of tools, lets you convert between image formats.
- It supports reading and/or writing more than 100 major image formats.
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`convert label.xwd label.png`
- But it is more than just a simple converter. The following example was taken from [www.imagemagick.org/script/command-line-processing.php](http://www.imagemagick.org/script/command-line-processing.php):

```
convert label.png +matte
\ ( +clone -shade 110x90 -normalize -negate +clone
    -compose Plus -composite \ )
\ ( -clone 0 -shade 110x50 -normalize -channel BG
    -fx 0 +channel -matte \ )
-delete 0 +swap -compose Multiply
-composite "button.png"
```

- This command transforms



to



## xwd – Making X11 Screen Dumps

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- `xwd` is part of the standard X11 distribution.
- Sample command sequence for dumping a window into a file `foo.xwd`, and for converting it into a PostScript file:

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xwd > foo.xwd
```

```
xpr -device ps -portrait -psfig foo.xwd > foo.ps
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```
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```

- Several packages for drafting and image manipulation also support capturing part or all of an X11 display.



## Drafting Figures and Generating Plots

- $\text{\LaTeX}$  and TikZ
- Drafting Packages
- Utilities
- Plotting
  - Gnuplot
  - Gnuplottex
  - PGFPlots
  - TikZ and Gnuplot

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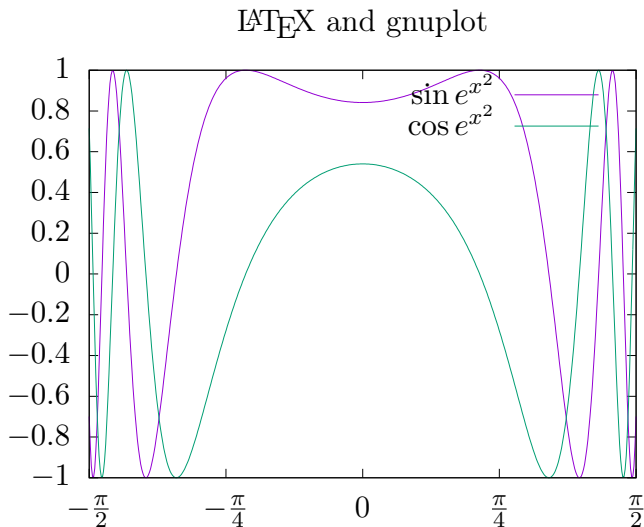
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- Advantages over other methods (discussed on the subsequent slides):
  - No data file needs to be shipped when distributing the  $\text{\LaTeX}$  document.
  - No computations are necessary when the  $\text{\LaTeX}$  document is processed.

# Sample Gnuplot Code

---

```
set terminal epslatex size 9cm,7cm color colortext standalone
set output 'gnuplot.tex'
set title '\LaTeX\ and gnuplot'
set xrange [-pi/2:pi/2]
set xtics ('$-\frac{\pi}{2}$' -pi/2, \
           '$-\frac{\pi}{4}$' -pi/4, '0' 0, \
           '$\frac{\pi}{4}$' pi/4, \
           '$\frac{\pi}{2}$' pi/2)
set samples 500
f(x)=sin(exp(x**2))
g(x)=cos(exp(x**2))
plot f(x) title '$\sin e^{x^2}$', \
      g(x) title '$\cos e^{x^2}$'
```

---



# Gnuplottex: Gnuplot Invoked within $\text{\LaTeX}$

- The package `gnuplottex` allows to call Gnuplot from within a  $\text{\LaTeX}$  document.
- It supports the use of  $\text{\LaTeX}$  commands for axis labeling, including the use of SI units via the `siunitx` package.
- `\usepackage{gnuplottex}` goes into the preamble.

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- `\usepackage{gnuplottex}` goes into the preamble.
- The Gnuplot code is extracted from the document and written to a Gnuplot file `.gnuplot`. Then this file is processed by Gnuplot and prepared for inclusion into the  $\text{\LaTeX}$  document.

# Gnuplottex: Gnuplot Invoked within $\text{\LaTeX}$

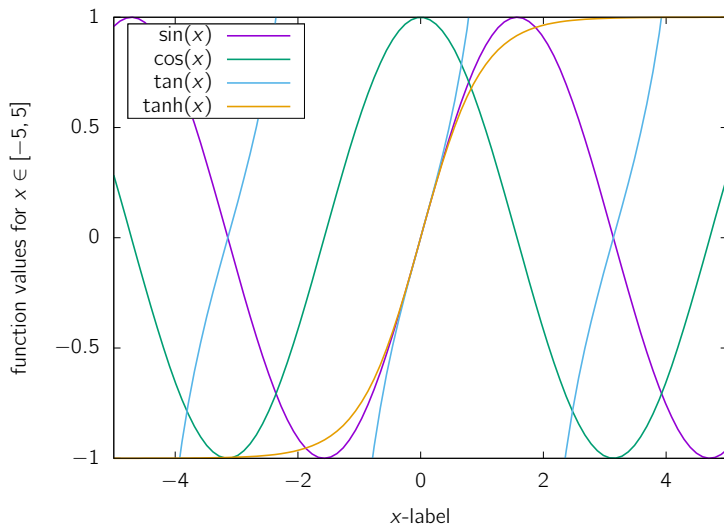
- The package `gnuplottex` allows to call Gnuplot from within a  $\text{\LaTeX}$  document.
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- `\usepackage{gnuplottex}` goes into the preamble.
- The Gnuplot code is extracted from the document and written to a Gnuplot file `.gnuplot`. Then this file is processed by Gnuplot and prepared for inclusion into the  $\text{\LaTeX}$  document.

## Caveats

- $\text{\LaTeX}$  needs to be allowed to call external programs!
- Use the run-time option `--shell-escape` or even `--shell-escape --enable-write18 -interaction=nonstopmode`.

```
\begin{gnuplot}[terminal=epslatex, terminaloptions=color]
set key box top left
set key width 2
set key opaque
set sample 100
set xr [-5:5]
set yr [-1:1]
set xlabel '$x$-label'
set ylabel 'function values for $x\text{\color{red}in}[-5,5]$\textcolor{red}'
plot sin(x) w l lc 1 lw 3 t '$\textcolor{red}{sin}(x)$', \
      cos(x) w l lc 2 lw 3 t '$\textcolor{red}{cos}(x)$', \
      tan(x) w l lc 3 lw 3 t '$\textcolor{red}{tan}(x)$', \
      tanh(x) w l lc 4 lw 3 t '$\textcolor{red}{tanh}(x)$'
\end{gnuplot}
```

# Gnuplottex: Gnuplot Invoked within $\text{\LaTeX}$



tbcolrgb1,1,1



- The PGFPLOTS package is a tool to produce diverse types of plots directly within  $\text{\LaTeX}$ .
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Documents that contain multiple complex figures generated by means of PGFPLOTS may take a considerably larger amount of time to compile!

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Documents that contain multiple complex figures generated by means of PGFPLOTS may take a considerably larger amount of time to compile!

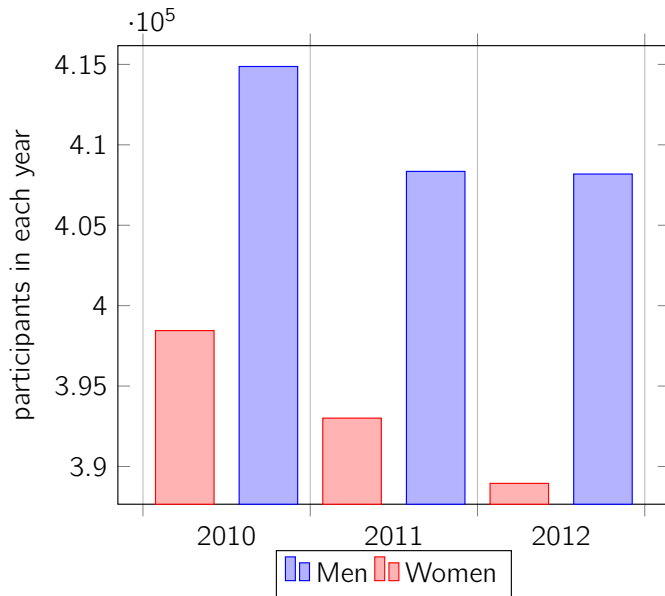
- Hence, in order to allow re-using figures that had already been generated, it is advisable to externalize those figures by putting the following two lines into the preamble:

```
\usepgfplotslibrary{external}  
\tikzexternalize
```

```
\begin{tikzpicture}
\begin{axis}[
  x tick label style={
    /pgf/number format/1000 sep=},
  ylabel=participants in each year,
  enlargelimits=0.05,
  legend style={at={(0.5,-0.1)},
    anchor=north,legend columns=-1},
  ybar interval=0.7,
]
\addplot
  coordinates {(2012,408184) (2011,408348)
    (2010,414870) (2009,412156)};
\addplot
  coordinates {(2012,388950) (2011,393007)
    (2010,398449) (2009,395972)};
\legend{Men,Women}
\end{axis}
\end{tikzpicture}
```

[Code credit: [de.overleaf.com](https://de.overleaf.com)]

## PGFPLOTS: Bar Graph

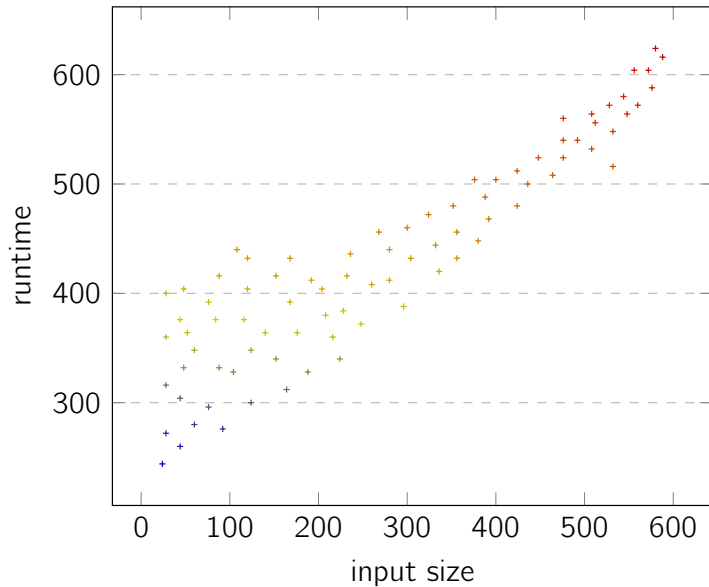


---

```
\begin{tikzpicture}
\begin{axis}[
    enlargelimits=true,
    xlabel={input size},
    ylabel={runtime},
    ymajorgrids=true,
    grid style=dashed,
]
\addplot+[
    only marks,
    scatter,
    mark=+,
    mark size=1pt]
table[meta=cputime]
{data/cputimes.txt};
\end{axis}
\end{tikzpicture}
```

---

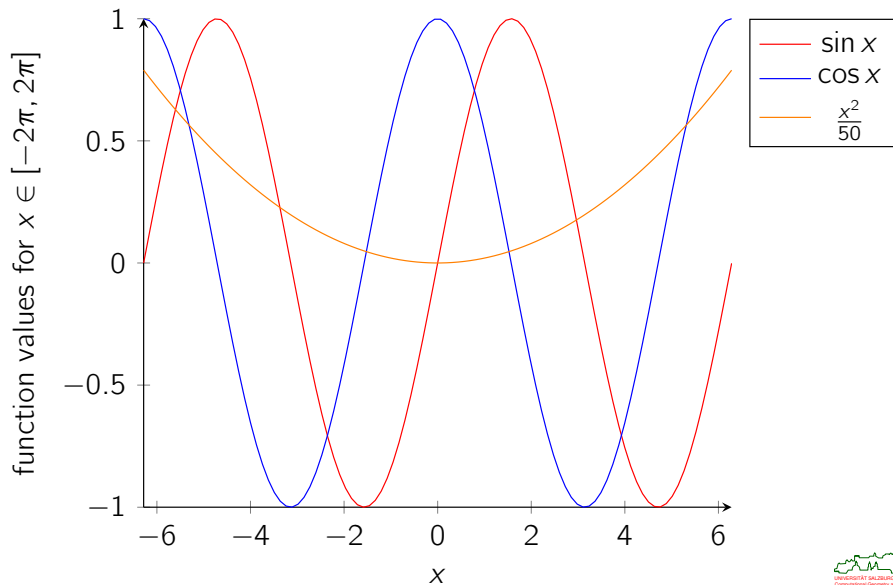
## PGFPLOTS: Scatter Plot



```
\begin{tikzpicture}
\begin{axis}[
    domain=-2*pi:2*pi,
    samples=100,
    axis lines = left,
    xlabel = {$x$},
    ylabel = {function values for $x\in[-2\pi,2\pi]$},
    legend pos=outer north east
]
\addplot[color=red]    {\sin(deg(x))}; \addlegendentry{$\sin x$}
\addplot[color=blue]  {\cos(deg(x))}; \addlegendentry{$\cos x$}
\addplot[color=orange]{x^2/50};        \addlegendentry{$\frac{x^2}{50}$}
\end{axis}
\end{tikzpicture}
```

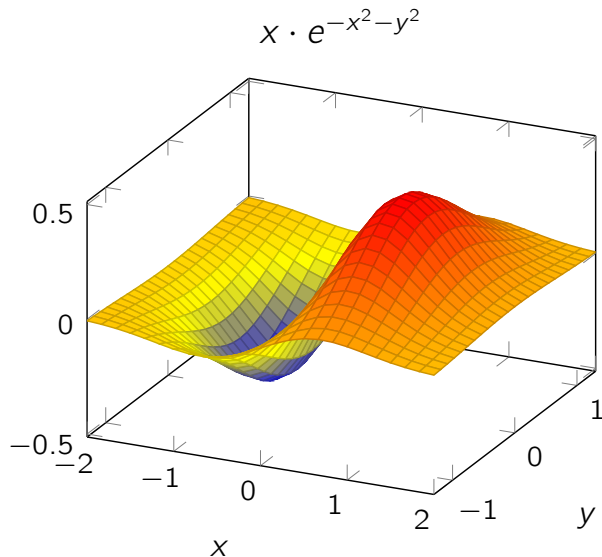


## PGFPLOTS: Graphs of Functions



```
\begin{tikzpicture}
\begin{axis}[
  title={$x \cdot e^{-x^2-y^2}$},
  xlabel=$x$, ylabel=$y$,
  small,
]
\addplot3[
  surf,
  domain=-2:2,
  domain y=-1.3:1.3,
]
{exp(-x^2-y^2)*x};
\end{axis}
\end{tikzpicture}
```

[Code credit: manual of PGFPLOTS at [ctan.org/pkg/pgfplots](https://ctan.org/pkg/pgfplots)]



---

```
\begin{tikzpicture}[x=1cm,y=0.5cm,domain=3:9,samples=100]
  \def\xmin{3}
  \def\ymin{2}

  \draw[dashed, ystep=2, xstep=1] (\xmin,\ymin) grid (9.2,12.5);

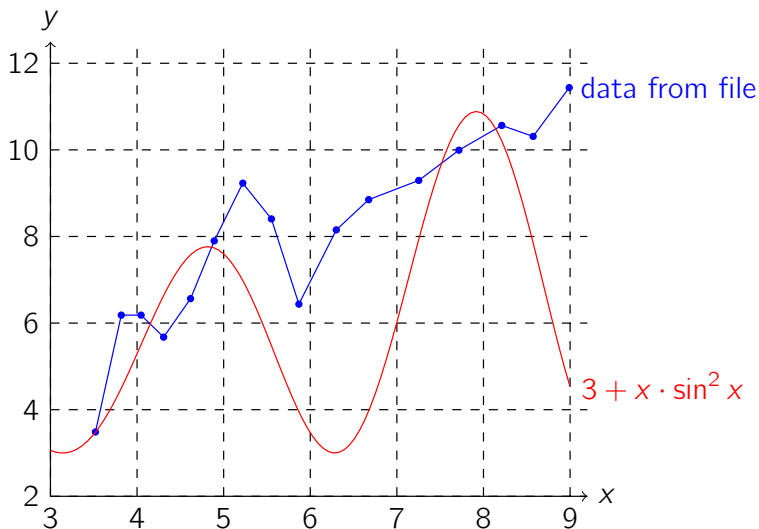
  \draw[->] (\xmin,\ymin) -- (9.2,\ymin) node[right] {$x$};
  \draw[->] (\xmin,\ymin) -- (\xmin,12.5) node[above] {$y$};

  \foreach \x in {3,4,...,9} \node at (\x,\ymin) [below] {\x};
  \foreach \y in {2,4,...,12} \node at (\xmin,\y) [left] {\y};

  \draw[color=blue] plot[mark=*,mark size=1pt] file {data/data.txt}
    node [right] {data from file};

  \draw[color=red] plot[id=xsinx]
    function{3+ x * sin(x) * sin(x)}
    node [right] {$3 + x \cdot \sin^2 x$};
\end{tikzpicture}
```

---



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- Hence it is advisable to include a TikZ picture into a  $\text{\LaTeX}$  document by
  - 1 generating that picture in a wrapper file of its own,
  - 2 loading the `standalone` package into the main document with the option `mode=buildnew`, and
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- This will compile all included standalone files automatically as graphics files and build these graphics if the source file is newer than the existing graphics file.
- Of course, you need `--shell-escape` to be enabled to allow the main  $\text{\LaTeX}$  run to invoke further LaTeX compilers.

```
% wrapper.tex
%
\documentclass[crop,tikz]{standalone}
% in theory, tikz package should be loaded by
% the 'tikz' option
\usepackage{tikz}

%\usetikzlibrary{...}

\begin{document}
  \begin{tikzfigure}
    \coordinate[label=left:$A$] (A) at (0,0);
    \coordinate[label=right:$B$] (B) at (4,1);
    \draw (A) -- (B);

    ...
  \end{tikzfigure}
\end{document}
```

# Main File for Standalone Run

---

```
% main.tex ----- requires --shell-escape!
%
\documentclass{article}
\usepackage[mode=buildnew]{standalone}
\usepackage{tikz}

\begin{document}

    \includestandalone[options]{wrapper}

\end{document}
```

---

## pdf $\text{\LaTeX}$ and Recent $\text{\LaTeX}$ Developments

- Basics of pdf $\text{\LaTeX}$
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*“The pdfT<sub>E</sub>X package is an extension of L<sup>A</sup>T<sub>E</sub>X/T<sub>E</sub>X that can create PDF directly from T<sub>E</sub>X/L<sup>A</sup>T<sub>E</sub>X source files and improve/enhance the result of T<sub>E</sub>X typesetting with the help of PDF.”*

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- The `pdftex` command uses the equivalent of the plain T<sub>E</sub>X format, and the `pdflatex` command uses the equivalent of the L<sub>A</sub>T<sub>E</sub>X format.



## Macro Packages Supported by pdfL<sup>A</sup>T<sub>E</sub>X

- The typical use of the pdfL<sup>A</sup>T<sub>E</sub>X-package is with pre-generated formats for which PDF output has been enabled.
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- For instance, the `hyperref` package has substantial support for pdfL<sup>A</sup>T<sub>E</sub>X. The user merely needs to load `hyperref` with the `pdftex` option, and all cross-references will be converted to PDF hypertext links.

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```
\usepackage[pdftex]{hyperref}
```

Bookmarks can be created to match the table of contents.

- Similarly, the L<sup>A</sup>T<sub>E</sub>X packages `graphicx` and `xcolor` have options for pdfL<sup>A</sup>T<sub>E</sub>X, which allow the use of the standard commands for color, text rotation, and graphics inclusion.
- PDF support can also be turned on globally:

```
\documentclass[... ,pdftex, ...]{...}
```

- Manual tagging for cross-referencing:

```
\hyperlink{myref}{Clicking here will take you to ...}  
\hypertarget{myref}{... this target}
```

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- Similarly, bookmarks can be set manually:

```
\pdfbookmark[level]{bookmark text}{myref}
```

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```
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```
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- Most PDF viewers support the handling of URLs: Clicking on an `href` construct will start a web browser and take you to the page specified:

```
\href{https://www.cosy.sbg.ac.at}{Departmental home page}  
\url{www.cosy.sbg.ac.at}
```

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- Similarly for other descriptors:

```
\href{ftp://...}  
\href{mailto:...}  
\href{run:...}
```

- Manual tagging for cross-referencing:

```
\hyperlink{myref}{Clicking here will take you to ...}  
\hypertarget{myref}{... this target}
```

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- Most PDF viewers support the handling of URLs: Clicking on an `href` construct will start a web browser and take you to the page specified:

```
\href{https://www.cosy.sbg.ac.at}{Departmental home page}  
\url{www.cosy.sbg.ac.at}
```

- Similarly for other descriptors:

```
\href{ftp://...}  
\href{mailto:...}  
\href{run:...}
```

- Menu functions of `acroread` can be accessed via links, e.g.:

```
\Acrobatmenu{Print}{print this document}
```



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```
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```
\usepackage[pdf]{pstricks}
```

- The standard `\psfrag` replacements can be used with the command

```
\usepackage{auto-pst-pdf}
```

provided that shell escapes are allowed: For T<sub>E</sub>X Live we use

```
pdfflatex --shell-escape ...
```

while the command-line option `--enable-write18` should work for MiK<sub>T</sub>E<sub>X</sub>.

## pdfL<sup>A</sup>T<sub>E</sub>X and Recent L<sup>A</sup>T<sub>E</sub>X Developments

- Basics of pdfL<sup>A</sup>T<sub>E</sub>X
- Generating PDF Slides: L<sup>A</sup>T<sub>E</sub>X Beamer Class
  - Structuring
  - Special Frames
  - Partial Builds and Overlays
  - Animations
  - Visual Appearance
- Current L<sup>A</sup>T<sub>E</sub>X-Related Projects
- Improving Text

- Created by Till Tantau in 2003, and distributed via the Comprehensive TeX Archive Network (CTAN, [ctan.org](https://ctan.org)).
- The L<sup>A</sup>T<sub>E</sub>X beamer class allows to create slides directly within L<sup>A</sup>T<sub>E</sub>X, with no need to resort to postprocessing by other software packages.
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- It can be used with `pdflatex`, but also with `dvips`.
- Professional layouts and sophisticated overlays can be achieved.
- These slides (and the corresponding handouts) were prepared using `pdflatex` and the L<sup>A</sup>T<sub>E</sub>X beamer class — based on one set of source files for all three PDF outputs.
- Note that the word “beamer” is a pseudo-anglicism.



## Tools for Viewing Beamer-Class Slides

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**pdfpc** — PDF presenter console — is a GTK-based viewer which uses multi-monitor output to provide meta information to the speaker during the presentation.

**BeamerPresenter** also offers dual-monitor output and is similar to `pdfpc`; it tries to implement all features available in the  $\text{\LaTeX}$  `beamer` class; in addition, it supports tools like pointer, highlighter, pen and eraser.

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**pympress**, **dspdfviewer**, **ipepresenter** are similar to **pdfpc**.

**There is theory, and there is practice ...**

I am yet to see a presentation tool that can deal with all slides generated by pdf $\text{\LaTeX}$ !

- Section:

```
\section{...}
```

- Section:

```
\section{...}
```

- Subsection:

```
\subsection{...}
```

```
\subsubsection{...}
```

- Section:

```
\section{...}
```

- Subsection:

```
\subsection{...}
```

```
\subsubsection{...}
```

- Slide:

```
\begin{frame} ... \end{frame}
```

- Section:

```
\section{...}
```

- Subsection:

```
\subsection{...}
```

```
\subsubsection{...}
```

- Slide:

```
\begin{frame} ... \end{frame}
```

- Block:

```
\begin{block} ... \end{block}
```

```
\begin{alertblock} ... \end{alertblock}
```

```
\begin{exampleblock} ... \end{exampleblock}
```



- Section:

```
\section{...}
```

- Subsection:

```
\subsection{...}
```

```
\subsubsection{...}
```

- Slide:

```
\begin{frame} ... \end{frame}
```

- Block:

```
\begin{block} ... \end{block}
```

```
\begin{alertblock} ... \end{alertblock}
```

```
\begin{exampleblock} ... \end{exampleblock}
```

- (Standard) L<sup>A</sup>T<sub>E</sub>X lists:

```
\begin{itemize} ... \end{itemize}
```

```
\begin{enumerate} ... \end{enumerate}
```

```
\begin{description} ... \end{description}
```

- Multiple columns:

## Block: Lorem ...

Lorem ipsum dolor  
sit amet, ...

## Warning: Pseudo Latin

Lorem ipsum dolor sit amet,  
consectetur adipisicing elit, sed eiusmod  
tempor incididunt ut labore et dolore  
magna aliqua. Ut enim ...

## Example

Lorem  
ipsum dolor  
sit amet, ...

- Multiple columns:

## Block: Lorem ...

Lorem ipsum dolor sit amet, ...

## Warning: Pseudo Latin

Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ...

## Example

Lorem ipsum dolor sit amet, ...

```
\begin{columns}[c]
  \column{0.25\textwidth}
  \begin{block}{Block: Lorem ...}
    Lorem ipsum dolor sit amet, ...
  \end{block}
  \column{0.45\textwidth}
  \begin{alertblock}{Warning: Pseudo Latin}
    Lorem ipsum dolor sit amet, ...
  \end{alertblock}
  \column{0.15\textwidth}
  \begin{exampleblock}{Example}
    Lorem ipsum dolor sit amet, ...
  \end{exampleblock}
\end{columns}
```

- Title page:

```
\begin{frame}[plain]  
  \titlepage  
\end{frame}
```

- Title page:

```
\begin{frame}[plain]
  \titlepage
\end{frame}
```

- Table of content:

```
\begin{frame}\frametitle{Contents} % or something else
                                     % as frame title
  \tableofcontents[subsectionstyle=hide,
                  subsubsectionstyle=hide]
\end{frame}
```

- Title page:

```
\begin{frame}[plain]
  \titlepage
\end{frame}
```

- Table of content:

```
\begin{frame}\frametitle{Contents} % or something else
                                     % as frame title
  \tableofcontents[subsectionstyle=hide,
                   subsubsectionstyle=hide]
\end{frame}
```

- At the begin of a section:

```
\AtBeginSection[] {
  \begin{frame}
    \tableofcontents[sectionstyle=show/hide,
                      hideothersubsections,
                      subsubsectionstyle=hide/hide/hide]
  \end{frame}
}
```

- The `\pause` command can be used for simple partial builds of a page.

- The `\pause` command can be used for simple partial builds of a page.

```
\begin{frame}[fragile]\frametitle{\LaTeX\ Beamer Class: ...}  
  
\begin{itemize}  
  \item The \verb#\pause# command can be used for simple ...  
  \pause  
  \item This will build a page from top to bottom ...  
  \pause  
  \item Using \verb#\verb# or the \verb#verbatim# ...  
\end{itemize}  
  
\end{frame}
```



- The `\pause` command can be used for simple partial builds of a page.
- This will build a page from top to bottom in sequential order.

```
\begin{frame}[fragile]\frametitle{\LaTeX\ Beamer Class: ...}  
  
\begin{itemize}  
  \item The \verb#\pause# command can be used for simple ...  
\pause  
  \item This will build a page from top to bottom ...  
\pause  
  \item Using \verb#\verb# or the \verb#verbatim# ...  
\end{itemize}  
  
\end{frame}
```

- The `\pause` command can be used for simple partial builds of a page.
- This will build a page from top to bottom in sequential order.
- Using the `\verb` command or the `verbatim` environment in conjunction with `\pause` requires to specify the option `[fragile]` after `\begin{frame}`!

```
\begin{frame}[fragile]\frametitle{\LaTeX\ Beamer Class: ...}  
  
\begin{itemize}  
  \item The \verb#\pause# command can be used for simple ...  
\pause  
  \item This will build a page from top to bottom ...  
\pause  
  \item Using \verb#\verb# or the \verb#verbatim# ...  
\end{itemize}  
  
\end{frame}
```

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\pause  
  \item Using \verb#\verb# or the \verb#verbatim# ...  
\end{itemize}  
  
\end{frame}
```

- The obvious advantage of this scheme is its simplicity. The obvious disadvantage is its rigidity.

## Overlay 1

- only on overlay 1
- blue text only on overlays 1–3
- on all overlays except 2

```
\begin{itemize}
  \item<1> only on overlay 1
  \item<1-> \color<1-3>{blue} blue text only on overlays 1--3}
  \item\alt<2>{only on overlay 2}{on all overlays except 2}
  \item<3-> on overlay 3 and all subsequent overlays
  \item<4-> The overlay specification ...
  \item<5-> There are four other commands ...
\end{itemize}
```

## Overlay 2

- blue text only on overlays 1–3
- only on overlay 2

```
\begin{itemize}
  \item<1> only on overlay 1
  \item<1-> \color<1-3>{blue} blue text only on overlays 1--3}
  \item\alt<2>{only on overlay 2}{on all overlays except 2}
  \item<3-> on overlay 3 and all subsequent overlays
  \item<4-> The overlay specification ...
  \item<5-> There are four other commands ...
\end{itemize}
```

## Overlay 3

- blue text only on overlays 1–3
- on all overlays except 2
- on overlay 3 and all subsequent overlays

```
\begin{itemize}
  \item<1> only on overlay 1
  \item<1-> \color<1-3>{blue} blue text only on overlays 1--3}
  \item\alt<2>{only on overlay 2}{on all overlays except 2}
  \item<3-> on overlay 3 and all subsequent overlays
  \item<4-> The overlay specification ...
  \item<5-> There are four other commands ...
\end{itemize}
```

## Overlay 4

- blue text only on overlays 1–3
- on all overlays except 2
- on overlay 3 and all subsequent overlays
- The overlay specification can be used with quite a few other L<sup>A</sup>T<sub>E</sub>X commands, too. E.g., `\includegraphics<1|handout:0>{...}`.

```
\begin{itemize}
  \item<1> only on overlay 1
  \item<1-> \color<1-3>{blue} blue text only on overlays 1--3}
  \item\alt<2>{only on overlay 2}{on all overlays except 2}
  \item<3-> on overlay 3 and all subsequent overlays
  \item<4-> The overlay specification ...
  \item<5-> There are four other commands ...
\end{itemize}
```

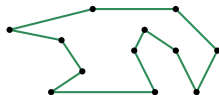


## Overlay 5

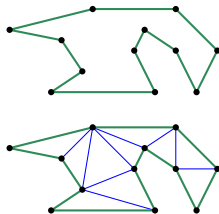
- blue text only on overlays 1–3
- on all overlays except 2
- on overlay 3 and all subsequent overlays
- The overlay specification can be used with quite a few other L<sup>A</sup>T<sub>E</sub>X commands, too. E.g., `\includegraphics<1|handout:0>{...}`.
- There are four other commands to switch material on and off: `\only`, `\onslide`, `\uncover`, `\visible`.

```
\begin{itemize}
  \item<1> only on overlay 1
  \item<1-> \color<1-3>{blue} blue text only on overlays 1--3}
  \item\alt<2>{only on overlay 2}{on all overlays except 2}
  \item<3-> on overlay 3 and all subsequent overlays
  \item<4-> The overlay specification ...
  \item<5-> There are four other commands ...
\end{itemize}
```

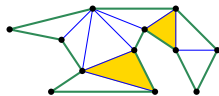
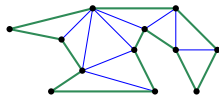
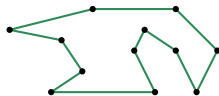




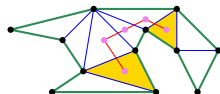
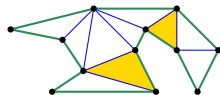
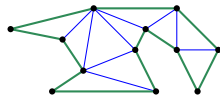
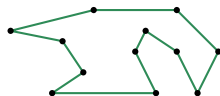
- Suppose that we want to explain a concept that requires to display similar figures repeatedly. E.g.,
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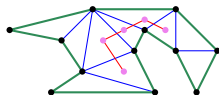
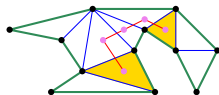
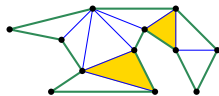
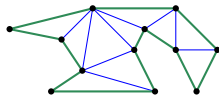
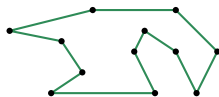
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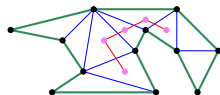
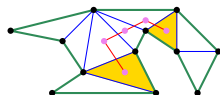
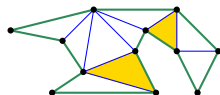
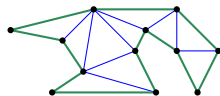
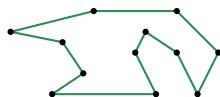
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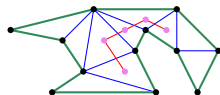
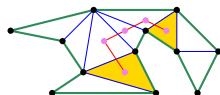
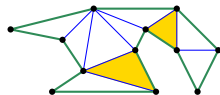
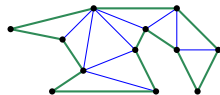
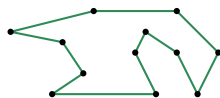
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  - 3 two specific triangles,
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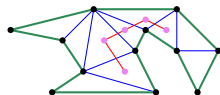
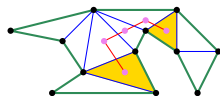
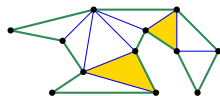
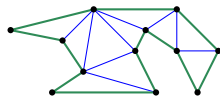
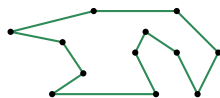
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  - 1 a polygon,
  - 2 its triangulation,
  - 3 two specific triangles,
  - 4 the triangles and a path between them, and
  - 5 only the path.



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  - 1 a polygon,
  - 2 its triangulation,
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  - 4 the triangles and a path between them, and
  - 5 only the path.
- Ipe allows to group contents of a figure into layers which can be turned on and off individually.



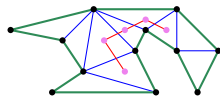
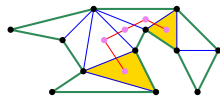
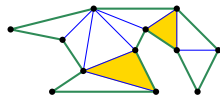
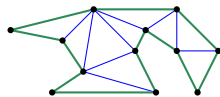
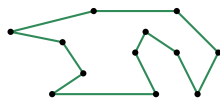
- Suppose that we want to explain a concept that requires to display similar figures repeatedly. E.g.,
  - 1 a polygon,
  - 2 its triangulation,
  - 3 two specific triangles,
  - 4 the triangles and a path between them, and
  - 5 only the path.
- Ipe allows to group contents of a figure into layers which can be turned on and off individually.
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```

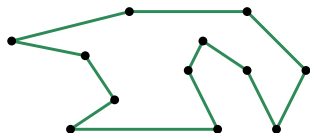




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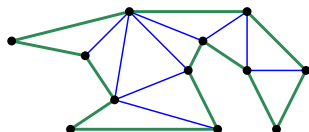
```
\includegraphics<1->[page=1,...]{views}  
\includegraphics<2->[page=2,...]{views}
```
- This makes it easy to “build” a figure or an animation, without (re-)drawing the figure multiple times.

```
\begin{columns}[c]
\column{0.4\textwidth}
\includegraphics<1|handout:0>[page=1]{views}%
\includegraphics<2|handout:0>[page=2]{views}%
\includegraphics<3|handout:0>[page=3]{views}%
\includegraphics<4|handout:1>[page=4]{views}%
\column{0.6\textwidth}
\begin{enumerate}
\item<1-> A polygon,
\item<2-> its triangulation,
\item<3-> two specific triangles, \only<4->{and}
\item<4-> the triangles and a path between them.
\end{enumerate}
\end{columns}
```



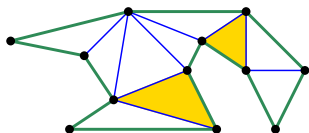
1 A polygon,

```
\begin{columns}[c]
  \column{0.4\textwidth}
    \includegraphics<1|handout:0>[page=1]{views}%
    \includegraphics<2|handout:0>[page=2]{views}%
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\end{columns}
```



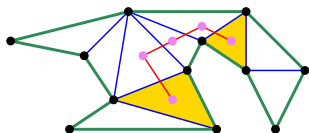
- ❶ A polygon,
- ❷ its triangulation,

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\begin{columns}[c]
  \column{0.4\textwidth}
    \includegraphics<1|handout:0>[page=1]{views}%
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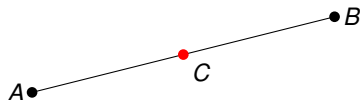
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\begin{columns}[c]
\column{0.4\textwidth}
\includegraphics<1|handout:0>[page=1]{views}%
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```
\begin{tikzpicture}
  \coordinate[label=left:$A$] (A) at (0,0);
  \coordinate[label=right:$B$] (B) at (4,1);
  \draw (A) -- (B);
  \fill (A) circle (2pt);
  \fill (B) circle (2pt);
  \onslide<2->{
    \coordinate[label=-45:$C$] (C) at ($(A)!0.5!(B)$);
    \fill[red] (C) circle (2pt);
  }
\end{tikzpicture}
```



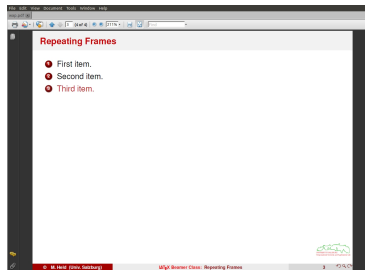
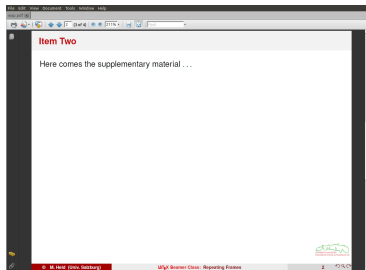
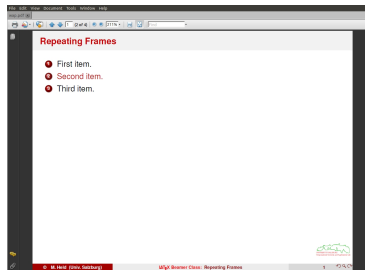
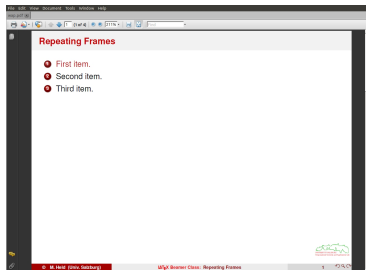
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```

# L<sup>A</sup>T<sub>E</sub>X Beamer Class: Repeating Frames



- The following L<sup>A</sup>T<sub>E</sub>X code produces the four slides shown on the previous slide:

```
\begin{frame}<1-2>[label=myframe]\frametitle{Repeating Frames}

\begin{enumerate}
  \item<alert@1> First item.
  \item<alert@2> Second item.
  \item<alert@3> Third item.
\end{enumerate}
\end{frame}

\begin{frame}\frametitle{Item Two}

  Here comes the supplementary material $\ldots$

\end{frame}

\againframe<3>\myframe
```



- For an  $n$ -page PDF file `foo.pdf`:

```
\animategraphics[autoplay,loop]{fps}{foo}{0}{n-1}
```

- For an  $n$ -page PDF file `foo.pdf`:

```
\animategraphics[autoplay,loop]{fps}{foo}{0}{n-1}
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`convert -coalesce foo.gif foo.png`

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- The use of `animategraphics` requires the `animate` package to be loaded in the preamble.



- For an  $n$ -page PDF file `foo.pdf`:

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```

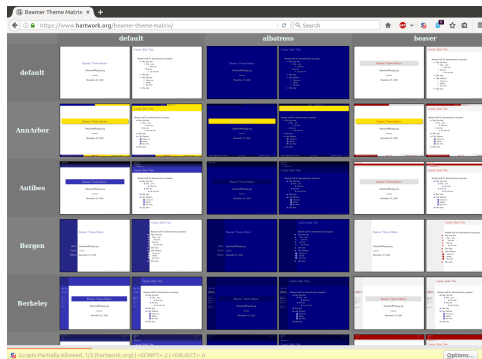
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```
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```

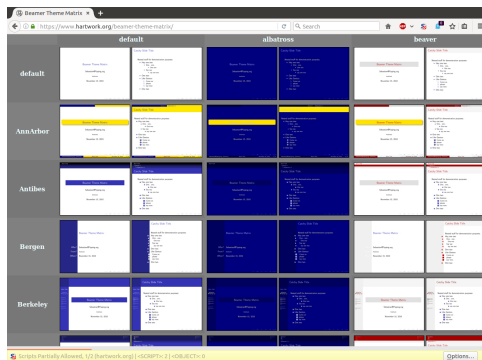
- The use of `animategraphics` requires the `animate` package to be loaded in the preamble.
- Unfortunately, `acroread` and `okular` seem to be the only PDF viewers that can display PDF slides correctly if `animategraphics` was used ...

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- A great survey of the basic combinations is provided by the **Beamer Theme Matrix**, <https://www.hartwork.org/beamer-theme-matrix>.



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- Combinations and personal customizations of the pre-defined options allow to create a virtually unlimited variety of layouts.

- These slides and handouts were generated with the following setting in `wap.tex`:

```
\ifdefined\ishandout
\documentclass[handout,...options...]{beamer}
\usetheme{default}
\usecolortheme{dove}
\usecolortheme[named=BrickRed]{structure}
% \usepackage{pgfpages}
% \pgfpagesuselayout{4 on 1}[border shrink=5mm,landscape]
\else \ifdefined\nopause
\documentclass[handout,...options...]{beamer}
\usetheme{Madrid}
\usecolortheme{beaver}
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\else
\documentclass[...options...]{beamer}
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```

- L<sup>A</sup>T<sub>E</sub>X command: `pdflatex "\def\ishandout{1} \input{wap}"`.

## 5 pdf $\text{\LaTeX}$ and Recent $\text{\LaTeX}$ Developments

- Basics of pdf $\text{\LaTeX}$
- Generating PDF Slides:  $\text{\LaTeX}$  Beamer Class
- Current  $\text{\LaTeX}$ -Related Projects
  - Future Developments
  - Collaborative  $\text{\LaTeX}$  Environments
- Improving Text

- Work on pdfL<sup>A</sup>T<sub>E</sub>X has mostly been finished, and future releases should be expected to contain only bug fixes.



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- Lua $\text{\TeX}$ /Lua $\text{\LaTeX}$ :
  - It has been adopted as the official successor of pdf $\text{\LaTeX}$ .
  - Based on the Lua scripting engine.
  - It supports multi-directional typesetting.
  - A variety of fonts can be accessed via a library based on FontForge.
  - It has pretty good dynamic memory management.
  - Logos obtained as `\LuaTeX` and `\LuaLaTeX`, as provided by the `metalogo` package.

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- Xe $\text{\TeX}$ /Xe $\text{\LaTeX}$ :
  - It is another development that supports Unicode in a native way and that can use any font installed on the system, with no extra configurations needed.
  - Its input files are assumed to be in UTF-8 encoding.
  - It also supports more advanced typographic features than pdf $\text{\LaTeX}$ .
  - It is included in the  $\text{\TeX}$  Live, MiK $\text{\TeX}$ , and Mac $\text{\TeX}$  bundles.
  - Logos obtained as `\XeTeX` and `\XeLaTeX`, as provided by the `metalogo` package.

- Overleaf, [www.overleaf.com](https://www.overleaf.com), is a cloud-based academic writing environment that supports collaborative work.
- It is based on  $\text{\LaTeX}$ , with  $\text{\LaTeX}$  being run in the background as one enters new text.
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- Overleaf also provides a decent Rich Text editor that can be used to enter text in a WYSIWYG environment, even if one knows no or only very little  $\text{\LaTeX}$ . Still, one can switch back to the actual  $\text{\LaTeX}$  code at any time.

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- The basic full version is free but it allows only one collaborator per project. Furthermore the free version imposes some limitations on the number of projects and on the storage provided.
- Premium (pay-per-month) plans allow more collaborators per project and come with additional features, such as a synchronization with DropBox or GitHub.

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  - an interactive spell checker,
  - an advanced build system that supports Latexmk and several  $\text{\LaTeX}$  systems, like  $\text{\TeX}$  Live and MiK $\text{\TeX}$ ,
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- TeXstudio is open source.
- It is available for Linux, Windows and Mac OS X.
- See [www.texstudio.org/](http://www.texstudio.org/).



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## Checking Orthography and Grammar

- Since  $\text{\LaTeX}$  contains markup instructions, standard tools for checking spelling and grammar are not readily applicable.
- Some editors (e.g., `emacs`), support spell checking of  $\text{\LaTeX}$  documents.
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- Similarly, some  $\text{\LaTeX}$  installations come with tools for spell checking.
- The tools `ispell`, `hunspell` and `aspell` understand  $\text{\LaTeX}$  and will skip  $\text{\LaTeX}$  commands.
- E.g.:

```
aspell --lang=en --mode=tex  
      --dont-tex-check-comments check foo.tex
```

- ChatGPT ([chatgpt.com](https://chatgpt.com)) can also be asked to assist with checking grammar and style. It can review a text for grammatical errors, suggest improvements, and offer style recommendations to enhance readability and coherence.
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- Schools have varied reactions to the use of ChatGPT or similar tools, reflecting a struggle between recognizing its educational benefits and addressing potential concerns.
- In particular, there are concerns that their advanced features, especially in premium versions, might cross into the realm of academic dishonesty if students use it to do more than just correct errors.

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- There also is an issue of accessibility: Not all students may have access to (pay-per-use) premium features, potentially creating inequities in the tools available to students.

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- It integrates with various platforms, including web browsers, word processors, and email clients, offering real-time suggestions and corrections.
- Grammarly supports several regional varieties of English, including British and American English, thus allowing users to tailor their writing to specific audiences. As of July 2024, Grammarly does not support text in German or other languages.

- LanguageTool ([languagetool.org/de](https://languagetool.org/de)) is an open-source proof-reading tool designed to check grammar, style, punctuation, and spelling in multiple languages.
- It supports over 20 languages, including English and German (and their regional varieties), Spanish, French, Portuguese, and many others, making it a versatile option for multilingual users.

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- Open-Source: Free to use with an active community contributing to its development and improvement.
- The package **TeXtidote** can remove markup from a  $\text{\LaTeX}$  file and send it to LanguageTool.

## Mathematica for Symbolic Computation

- Mathematica
- Lists, Vectors, and Matrices in Mathematica
- Symbolic Computation in Mathematica
- Calculus with Mathematica
- Symbolic Solution of Equations with Mathematica
- Numerical Mathematics in Mathematica
- Defining Functions in Mathematica
- Mathematica for Plotting
- Import and Export of Mathematica Data
- Sample Use of Mathematica
- Symbolic Computation – Caveats

## 6 **Mathematica for Symbolic Computation**

- **Mathematica**
  - **Basics**
  - **User Interface**
  - **Basic Computations**
- Lists, Vectors, and Matrices in Mathematica
- Symbolic Computation in Mathematica
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- Mathematica is a software package – “*computer algebra system*” (CAS) – for use in mathematical applications that require symbolic computation.
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- Mathematica is a commercial product, and it is available for a variety of platforms.
- A license for “WorkAtHome” can be obtained via the web page of PLUS ITServices: See <https://im.sbg.ac.at/display/ITInfo/Software> for more information.

## Other Packages for Symbolic Computation

- Maple: By MapleSoft, Waterloo (ON, Canada); [www.maplesoft.com](http://www.maplesoft.com)
- Maxima: Based on MIT's legendary Macsyma; [maxima.sourceforge.net](http://maxima.sourceforge.net)
- Axiom: By T. Daly, Pittsburgh (PA, USA); [axiom.axiom-developer.org](http://axiom.axiom-developer.org)
- Magma: By Computational Algebra Group, U. Sidney (Australia);  
[magma.maths.usyd.edu.au/magma](http://magma.maths.usyd.edu.au/magma)
- MATLAB: Via the MuPAD symbolic engine, by MathWorks, Natick (MA, USA);  
[www.mathworks.com/products/matlab.html](http://www.mathworks.com/products/matlab.html)
- SageMath: By W. Stein, U. Washington (WA, USA); [www.sagemath.org](http://www.sagemath.org)
- ...



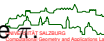
- Mathematica can run in an *ASCII terminal mode*, or it can display *notebooks* as an *X11 client*.
- To run Mathematica from an ASCII terminal, enter `math`. To run Mathematica as an X11 client, enter `mathematica`.
- Both display variants are front ends to Mathematica's *kernel*, which takes care of the actual computations.

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- Calculations that take too long can be aborted by typing `ALT ^`, (in a notebook environment), or `CTRL C` (in terminal mode).
- Mathematica offers several *palettes* for facilitating the input of characters and symbols.
- Functions can often be entered via *templates*, and `TAB` can be used for moving among *placeholders*.
- Many symbols can also be entered directly. E.g., `ESC p ESC` will generate  $\pi$ .



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- Mathematica labels its input and output as `In[n]` and `Out[n]`, where  $n$  is a counter that is stepped for every input/output pair.

```
In[1] := 3 + 5
```

```
Out[1] = 8
```

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```
In[1] := 3 + 5  
Out[1] = 8
```

- One can refer to the last output generated as `%`. A string of  $k$  percent signs refers to the  $k$ -th previous output, and `%n` refers to the output numbered  $n$ .

```
In[2] := % + 3^2  
Out[2] = 17
```

```
In[3] := % - 2 * %1  
Out[3] = 1
```



- Mathematica distinguishes between two types of values, *exact* and *approximate*.
  - Exact values may either be (a) integers or fractions, in which case Mathematica keeps as many digits as necessary to express the value exactly, or (b) symbolic names for constants such as  $e$ ,  $\pi$ ,  $\sqrt{2}$ , for which Mathematica knows how to find as many digits as necessary in any computation.

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  - Approximate values are most typically numeric expressions containing a decimal point.
- An exact value of  $x$  can be converted to an  $n$ -digit approximate value by calling the function  $N[x, n]$ .

```
In[4] := N[% +  $\pi$ , 20]
```

```
Out[4] = 4.1415926535897932385
```

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```
In[4] := N[% +  $\pi$ , 20]
```

```
Out[4] = 4.1415926535897932385
```

## Warning

Mathematica will apply inexact computation (and approximate all exact values) even if an expression contains just one approximate value!

- By convention, all names of built-in objects of Mathematica start with upper-case letters. Note that names can never start with a number.

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- Mathematica accepts some non-standard input forms for arithmetic. E.g., the multiplication operator  $*$  may be omitted so that the multiplication is implied.
- Note, however, that spaces are required if  $*$  is omitted:  $x\ 2$  is different from  $x2$ !

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- The expression `x = value` assigns *value* to *x*.



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- Note, however, that spaces are required if `*` is omitted: `x 2` is different from `x2`!
- The expression `x = value` assigns *value* to *x*.

### Warning

Note that this is a *permanent assignment*, and Mathematica will substitute *value* in all subsequent occurrences of *x*, until or unless explicitly told otherwise.

- Any value assigned to  $x$  can be removed via  $x = .$  or `Clear[x]`.

```
In[5] := x = 4
```

```
Out[5] = 4
```

```
In[6] := 3 *  $\sqrt{x}$ 
```

```
Out[6] = 6
```

```
In[7] := Clear[x]
```

```
In[8] := 3 *  $\sqrt{x}$ 
```

```
Out[8] = 3  $\sqrt{x}$ 
```

- Any value assigned to  $x$  can be removed via  $x = .$  or `Clear[x]`.

```
In[5] := x = 4
```

```
Out[5] = 4
```

```
In[6] := 3 *  $\sqrt{x}$ 
```

```
Out[6] = 6
```

```
In[7] := Clear[x]
```

```
In[8] := 3 *  $\sqrt{x}$ 
```

```
Out[8] = 3  $\sqrt{x}$ 
```

### Advice

In order to avoid mistakes, it is advisable to clear assignments as soon as they are no longer needed.

In[9] :=  $\sqrt[6]{64}$

Out[9] = 2

In[10] := 123456789123456789 + 987654321987654321

Out[10] = 1111111111111111110

In[11] := 40!

Out[11] = 815915283247897734345611269596115894272000000000

In[12] :=  $\pi^2 / 6$

Out[12] =  $\frac{\pi^2}{6}$

In[13] :=  $\pi^2 / 6.$

Out[13] = 1.64493

In[14] := Binomial[5, 2]

Out[14] = 10

In[15] := BaseForm[25, 2]

Out[15] = 11001<sub>2</sub>

In[16] := Sin[ $\pi$ ]

Out[16] = 0

In[17] :=  $x = N[\pi]$

Out[17] = 3.14159

In[18] := Sin[ $x$ ]

Out[18] =  $1.22465 \cdot 10^{-16}$

In[19] :=  $x = 1/3 + 1/5$

Out[19] =  $\frac{8}{15}$

In[20] := (15  $x$ ) / 8

Out[20] = 1

In[21] := Clear[ $x$ ]

## 6 Mathematica for Symbolic Computation

- Mathematica
- Lists, Vectors, and Matrices in Mathematica
  - Lists
  - Vectors and Matrices
  - Graphs
- Symbolic Computation in Mathematica
- Calculus with Mathematica
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# Lists as Mathematica Objects

- Many Mathematica objects are based on *lists*. Also, most operations can be applied to whole lists, which get treated as single objects.

In[22] :=  $x = \{2, 3, 4\}$

Out[22] =  $\{2, 3, 4\}$

In[23] :=  $x^2$

Out[23] =  $\{4, 9, 16\}$

- Many Mathematica objects are based on *lists*. Also, most operations can be applied to whole lists, which get treated as single objects.

```
In[22] := x = {2, 3, 4}
```

```
Out[22] = {2, 3, 4}
```

```
In[23] := x2
```

```
Out[23] = {4, 9, 16}
```

- The commands `Part[x, i]` and `x[[i]]` extract the *i*-th element of the list *x*.

```
In[24] := x
```

```
Out[24] = {2, 3, 4}
```

```
In[25] := x[[2]] = 10
```

```
Out[25] = 10
```



- The commands `Part[x, i]` and `x[[i]]` extract the  $i$ -th element of the list  $x$ .

```
In[26] := x
```

```
Out[26] = {2, 10, 4}
```

```
In[27] := x[[1]] + x[[2]] + x[[3]]
```

```
Out[27] = 16
```

```
In[28] := Clear[x]
```

- The commands `Part[x, i]` and `x[[i]]` extract the  $i$ -th element of the list  $x$ .

```
In[26] := x
```

```
Out[26] = {2, 10, 4}
```

```
In[27] := x[[1]] + x[[2]] + x[[3]]
```

```
Out[27] = 16
```

```
In[28] := Clear[x]
```

- Typical use of delimiters in Mathematica:
  - Parentheses `()` are used for grouping;
  - Brackets `[]` enclose function arguments;
  - Curly braces `{ }` delimit lists;
  - Double brackets `[[]]` are used for indexing.

- Vectors and matrices are lists and lists of lists, respectively.

```
In[29] := m[x_] := {{Cos[x], -Sin[x], 0}, {Sin[x], Cos[x], 0},  
                    {0, 0, 1}}
```

```
In[30] := MatrixForm[m[x]]  
Out[30] = 
$$\begin{pmatrix} \cos[x] & -\sin[x] & 0 \\ \sin[x] & \cos[x] & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

```

```
In[31] := Simplify[Det[m[x]]]  
Out[31] = 1
```

```
In[32] := Transpose[m[x]]  
Out[32] = {{Cos[x], Sin[x], 0}, {-Sin[x], Cos[x], 0}, {0, 0, 1}}
```

```
In[33] := Dimensions[m[x]]  
Out[33] = {3, 3}
```

- A dot or the Mathematica function Dot is used for products of Vectors and matrices.

```
In[34] := v = {1, 0, 1}
```

```
Out[34] = {1, 0, 1}
```

```
In[35] := w = m[ $\pi/2$ ] . v
```

```
Out[35] = {0, 1, 1}
```

```
In[36] := Cross[v, w]
```

```
Out[36] = {-1, -1, 1}
```

```
In[37] := v . w
```

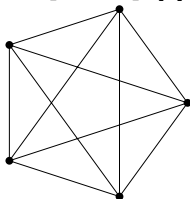
```
Out[37] = 1
```

```
In[38] := Dot[v, w]
```

```
Out[38] = 1
```

- Mathematica can also deal with graphs and similar combinatorial entities.

```
In[39] := CompleteGraph[5]
```



```
Out[39] =
```

```
In[40] := MatrixForm[AdjacencyMatrix[%]]
```

```
Out[40] = 
$$\begin{pmatrix} 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 \end{pmatrix}$$

```

## Mathematica for Symbolic Computation

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- Expand and Factor can be used for transforming algebraic expressions.

```
In[41] := 1 + x^2 - 2x
```

```
Out[41] = 1 - 2x + x^2
```

```
In[42] := % * (2 + x)
```

```
Out[42] = (2 + x) (1 - 2x + x^2)
```

```
In[43] := Expand[%]
```

```
Out[43] = 2 - 3x + x^3
```

```
In[44] := Factor[%]
```

```
Out[44] = (-1 + x)^2 (2 + x)
```

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```
Out[41] = 1 - 2 x + x^2
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In[42] := % * (2 + x)
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Out[42] = (2 + x) (1 - 2 x + x^2)
```

```
In[43] := Expand[%]
```

```
Out[43] = 2 - 3 x + x^3
```

```
In[44] := Factor[%]
```

```
Out[44] = (-1 + x)^2 (2 + x)
```

- In the sample below, the transformation rule  $x \rightarrow 1$  is applied, and “x goes to 1”. The replacement operator /. is typed as a pair of characters, with no space in between. Similarly,  $\rightarrow$  is typed as a pair of characters, with no space in between.

```
In[45] := % /. {x -> 1}
```

```
Out[45] = 0
```



- Getting expressions into a “simple” form sometimes is an art, and may require a bit of experimenting with `ExpandAll`, `Simplify` and similar commands.

In[46] := %%

Out[46] =  $(-1 + x)^2 (2 + x)$

In[47] := % \* x / ((x - 1)^3 \* (x + 1))

Out[47] =  $\frac{x (2+x)}{(-1+x) (1+x)}$

In[48] := Expand[%]

Out[48] =  $\frac{2 x}{(-1+x) (1+x)} + \frac{x^2}{(-1+x) (1+x)}$

In[49] := ExpandAll[%]

Out[49] =  $\frac{2 x}{-1+x^2} + \frac{x^2}{-1+x^2}$

In[50] := Simplify[%]

Out[50] =  $\frac{x (2+x)}{-1+x^2}$

## Mathematica for Symbolic Computation

- Mathematica
- Lists, Vectors, and Matrices in Mathematica
- Symbolic Computation in Mathematica
- **Calculus with Mathematica**
  - Differentiation and Integration
  - Sums and Products
  - Limits
  - Advanced Calculus
- Symbolic Solution of Equations with Mathematica
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- Mathematica can handle differentiation and integration symbolically.

In[51] := D[x (1 + x^4), x]

Out[51] = 1 + 5 x^4

In[52] := D[2x + x^2 + (2 x + x^2) y, y]

Out[52] = 2 x + x^2

In[53] := Integrate[% / (x + 1), x]

Out[53] = x +  $\frac{x^2}{2}$  - log[1 + x]

In[54] := D[%, x]

Out[54] = 1 + x -  $\frac{1}{1+x}$

In[55] := Factor[%]

Out[55] =  $\frac{x (2+x)}{1+x}$

- Mathematica can handle differentiation and integration symbolically.

In[56] := D[f[x] / x, x]

Out[56] =  $-\frac{f[x]}{x^2} + \frac{f'[x]}{x}$

In[57] := Integrate[%, x]

Out[57] =  $\frac{f[x]}{x}$

In[58] := D[x^y, x]

Out[58] =  $x^{-1+y} y$

In[59] := % /. {y -> x}

Out[59] =  $x^x$

- Of course, an integral need not always exist. Still, one may be able to get a numerical approximation of a corresponding definite integral.

```
In[60] := %  
Out[60] =  $x^x$ 
```

```
In[61] := Integrate[%, x]  
Out[61] =  $\int x^x dx$ 
```

```
In[62] := Integrate[%%, {x, 0, 1}]  
Out[62] =  $\int_0^1 x^x dx$ 
```

```
In[63] := N[%]  
Out[63] = 0.783431
```

```
In[64] := D[%%%, x]  
Out[64] =  $x^x$ 
```

- Mathematica can also handle sums and products.

```
In[65] := Sum[i, {i, 1, 5}]
```

```
Out[65] = 15
```

```
In[66] := Product[i, {i, 1, 5}]
```

```
Out[66] = 120
```

```
In[67] := Sum[Product[x + i, {i, 0, j}], {j, 0, 3}]
```

```
Out[67] = x + x (1 + x) + x (1 + x) (2 + x) + x (1 + x) (2 + x) (3 + x)
```

```
In[68] := Expand[%]
```

```
Out[68] = 10 x + 15 x2 + 7 x3 + x4
```

```
In[69] := Sum[1 / 2i, {i, 0, ∞}]
```

```
Out[69] = 2
```

```
In[70] := D[x Sum[1 / 2i, {i, 0, ∞}], x]
```

```
Out[70] = 2
```

- Mathematica can handle limits.

In[71] := Sin[x] / x

Out[71] =  $\frac{\text{Sin}[x]}{x}$

In[72] := % /. {x -> 0}

Out[72] = *Indeterminate*

In[73] := Limit[%%, x -> 0]

Out[73] = 1

- Mathematica can handle ordinary differential equations.

```
In[74] := DSolve[{y'[x] == a y[x] + 1, y[0] == 0}, y[x], x]
Out[74] = {{y[x] -> -1 + e^{a x}}}
```



- Mathematica can handle ordinary differential equations.

```
In[74] := DSolve[{y'[x] == a y[x] + 1, y[0] == 0}, y[x], x]
Out[74] = {{y[x] ->  $\frac{-1 + e^{a x}}{a}$ }}
```

- Mathematica can also handle multi-dimensional calculus.

```
In[75] := D[{Sin[α], Cos[α]}, α]
Out[75] = {Cos[α], -Sin[α]}
```

```
In[76] := ArcLength[{Sin[α], Cos[α]}, {α, 0, 2π}]
Out[76] = 2π
```

```
In[77] := Grad[x2 + y2 + z2, {x, y, z}]
Out[77] = {2x, 2y, 2z}
```

## Mathematica for Symbolic Computation

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  - Recurrence Relations
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- Mathematica provides the function `Solve` for computing symbolic solutions for equations.

```
In[78] := Solve[a x^2 + b x + c == 0, x]
```

```
Out[78] = {{x ->  $\frac{-b - \sqrt{b^2 - 4 a c}}{2 a}$ }, {x ->  $\frac{-b + \sqrt{b^2 - 4 a c}}{2 a}$ }}
```

- Mathematica provides the function `Solve` for computing symbolic solutions for equations.

```
In[78] := Solve[a x^2 + b x + c == 0, x]
```

```
Out[78] = {{x -> (-b - Sqrt[b^2 - 4 a c]) / (2 a)}, {x -> (-b + Sqrt[b^2 - 4 a c]) / (2 a)}}
```

- The Mathematica command `expr/.rules` applies a list of rules to the expression `expr`. The replacement operator `/.` is typed as a pair of characters, with no space in between.

```
In[79] := % /. {a -> 2, b -> 3, c -> 1 / 2}
```

```
Out[79] = {{x -> 1/4 (-3 - Sqrt[5])}, {x -> 1/4 (-3 + Sqrt[5])}}
```

```
In[80] := x /. %
```

```
Out[80] = {1/4 (-3 - Sqrt[5]), 1/4 (-3 + Sqrt[5])}
```

```
In[81] := %[[1]] * 4
```

```
Out[81] = -3 - Sqrt[5]
```

- Mathematica provides the `Solve` function for computing symbolic solutions for equations.

```
In[82] := Solve[{x - y == 2, x + y == 0}, {x, y}]
```

```
Out[82] = {{x -> 1, y -> -1}}
```

```
In[83] := Eliminate[{x - y == 2, x + y == 0}, y]
```

```
Out[83] = x == 1
```

```
In[84] := Solve[Sin[x]^2 == a, x]
```

```
Out[84] = {{x -> -ArcSin[Sqrt[a]], {x -> ArcSin[Sqrt[a]]}}
```

- We can use Mathematica to solve recurrence relations.

```
In[85] := RSolve[{a[n] == 2a[n - 1], a[1] == 1}, a[n], n]
```

```
Out[85] = {{a[n] -> 2^{-1+n}}}
```

```
In[86] := Table[a[n]/. First[%], {n, 12}]
```

```
Out[86] = {1, 2, 4, 8, 16, 32, 64, 128, 256, 512}
```

- We can use Mathematica to solve recurrence relations.

```
In[85] := RSolve[{a[n] == 2a[n - 1], a[1] == 1}, a[n], n]
Out[85] = {{a[n] -> 2^{-1+n}}}
```

```
In[86] := Table[a[n]/. First[%], {n, 12}]
Out[86] = {1, 2, 4, 8, 16, 32, 64, 128, 256, 512}
```

- We can also directly tabulate the first few Fibonacci numbers.

```
In[87] :=
RecurrenceTable[{a[n] == a[n - 1] + a[n - 2], a[1] == 1, a[2] == 1}, a, {n, 10}]
Out[87] = {1, 1, 2, 3, 5, 8, 13, 21, 34, 55}
```

```
In[88] := Table[Fibonacci[n], {n, 10}]
Out[88] = {1, 1, 2, 3, 5, 8, 13, 21, 34, 55}
```

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- Mathematica provides functions for computing numerical approximations of sums, products, and integrals.

```
In[89] := Sum[1 / i^2, {i, 1, ∞}]
```

```
Out[89] =  $\frac{\pi^2}{6}$ 
```

```
In[90] := N[%]
```

```
Out[90] = 1.64493
```

```
In[91] := NSum[1 / i^2, {i, 1, ∞}]
```

```
Out[91] = 1.64493
```

```
In[92] := NIntegrate[Sin[xy], {x, 0, 1}, {y, 0, x}]
```

```
Out[92] = 0.119906
```

- It can also solve a (system of) polynomial equation(s) numerically, or search for an approximate solution of an arbitrary equation.

```
In[93] := Solve[x^3 - Sqrt[Pi] x^2 == 0, x]
```

```
Out[93] = {{x -> 0}, {x -> 0}, {x -> Sqrt[Pi]}}
```

```
In[94] := NSolve[x^3 - Sqrt[Pi] x^2 == 0, x]
```

```
Out[94] = {{x -> 0.}, {x -> 0.}, {x -> 1.77245}}
```

```
In[95] := FindRoot[Sin[x] == x, {x, 0.001}]
```

```
Out[95] = {x -> 0.}
```

- It can also solve a (system of) polynomial equation(s) numerically, or search for an approximate solution of an arbitrary equation.

```
In[93] := Solve [  $x^3 - \sqrt{\pi}x^2 == 0$ , x]
```

```
Out[93] = {{x -> 0}, {x -> 0}, {x ->  $\sqrt{\pi}$ }}
```

```
In[94] := NSolve [  $x^3 - \sqrt{\pi}x^2 == 0$ , x]
```

```
Out[94] = {{x -> 0.}, {x -> 0.}, {x -> 1.77245}}
```

```
In[95] := FindRoot[ Sin[x] == x, {x, 0.001}]
```

```
Out[95] = {x -> 0.}
```

- Mathematica's function FindRoot has several options. In particular, it can be instructed to use a specific method for searching for a solution besides the (default) Newton's method, e.g., Brent's root bracketing.

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# Defining Functions in Mathematica

- Mathematica lets one define functions that can then be used similar to built-in functions.

```
In[96] := Expand[ Product[ x + i, {i, 1, 3}]]
```

```
Out[96] = 6 + 11 x + 6 x2 + x3
```

```
In[97] := exprod[n_] := Expand[ Product[ x + i, {i, 1, n}]]
```

```
In[98] := exprod[3]
```

```
Out[98] = 6 + 11 x + 6 x2 + x3
```

- Mathematica lets one define functions that can then be used similar to built-in functions.

```
In[96] := Expand[Product[x + i, {i, 1, 3}]]
```

```
Out[96] = 6 + 11 x + 6 x2 + x3
```

```
In[97] := exprod[n_] := Expand[Product[x + i, {i, 1, n}]]
```

```
In[98] := exprod[3]
```

```
Out[98] = 6 + 11 x + 6 x2 + x3
```

```
In[99] := D[exprod[3], x]
```

```
Out[99] = 11 + 12 x + 3 x2
```

- Mathematica lets one define functions that can then be used similar to built-in functions.

```
In[96] := Expand[ Product[ x + i, {i, 1, 3}]]
```

```
Out[96] = 6 + 11 x + 6 x2 + x3
```

```
In[97] := exprod[n_] := Expand[ Product[ x + i, {i, 1, n}]]
```

```
In[98] := exprod[3]
```

```
Out[98] = 6 + 11 x + 6 x2 + x3
```

```
In[99] := D[exprod[3], x]
```

```
Out[99] = 11 + 12 x + 3 x2
```

```
In[100] := cex[n_, i_] := ( t = exprod[n]; Coefficient[t, xi] )
```

```
In[101] := cex[3, 2]
```

```
Out[101] = 6
```

# Defining Functions in Mathematica

- Mathematica lets one define functions that can then be used similar to built-in functions.

```
In[102] := Clear[cex]
```

```
In[103] := t
```

```
Out[103] = 6 + 11 x + 6 x2 + x3
```



- Mathematica lets one define functions that can then be used similar to built-in functions.

```
In[102] := Clear[cex]
In[103] := t
Out[103] = 6 + 11 x + 6 x^2 + x^3
```

- This is not quite what we expected and want ...
- We resort to a module to encapsulate the local variable.

```
In[104] := Clear[t]
In[105] := cex[n_, i_] := Module[{t}, t = exprod[n]; Coefficient[t, x^i]]
In[106] := cex[3, 2]
Out[106] = 6

In[107] := t
Out[107] = t
```

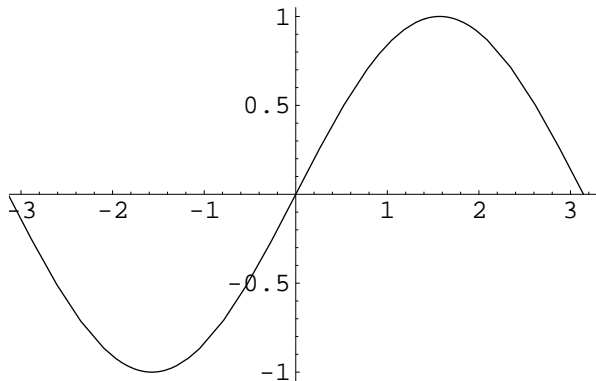
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## 2D Plots in Mathematica: Plotting Functions

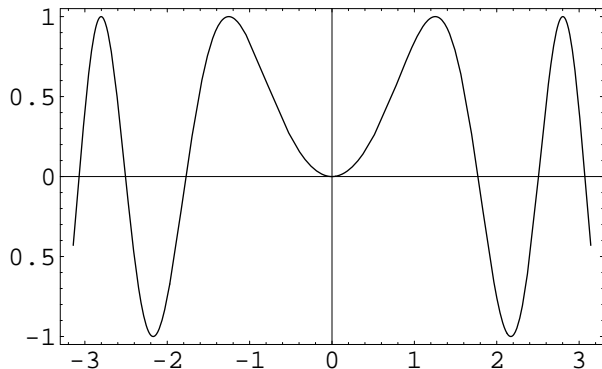
- Mathematica's function `Plot` offers many features for drawing 2D graphs.

```
In[108] := Plot[Sin[x], {x, -π, π}]
```



## 2D Plots in Mathematica: Plotting Functions

● In[109] := Plot[Sin[x^2], {x, - $\pi$ ,  $\pi$ }, Frame -> True]

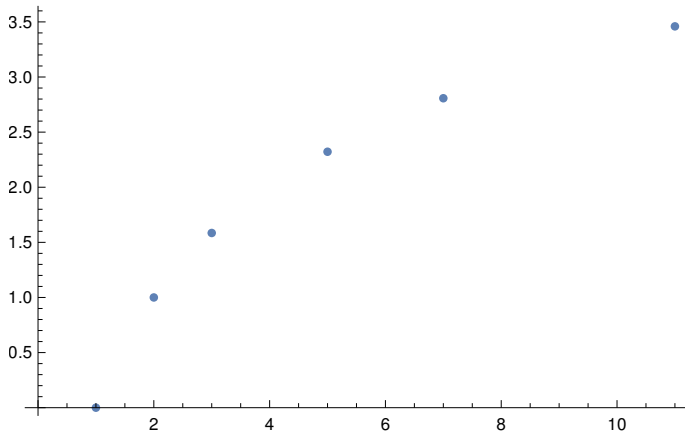


## 2D Plots in Mathematica: Scatter Plots

- Mathematica can plot pairs of points.

```
In[110] :=
```

```
ListPlot[{{1, 0}, {2, 1}, {3, Log2[3]}, {5, Log2[5]}, {7, Log2[7]}, {11, Log2[11]}}]
```

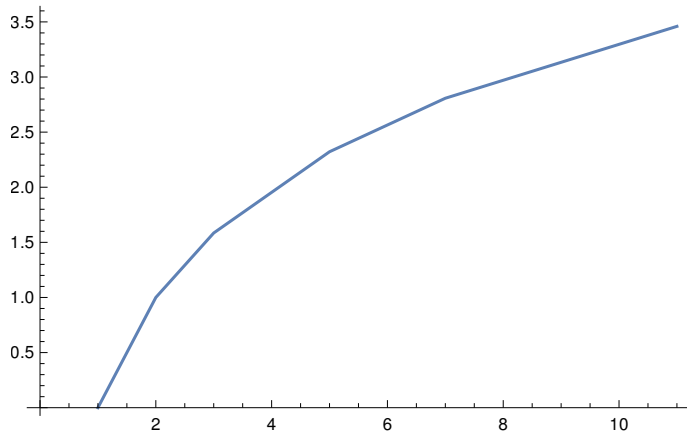


## 2D Plots in Mathematica: Line Plots

- Mathematica can plot polygonal curves defined by consecutive pairs of points.

```
In[111] :=
```

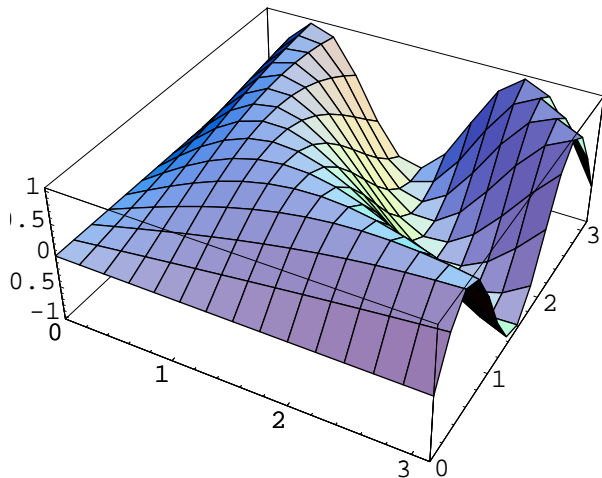
```
ListLinePlot[{{1, 0}, {2, 1}, {3, Log2[3]}, {5, Log2[5]}, {7, Log2[7]}, {11, Log2[11]}}]
```



## 3D Plots in Mathematica

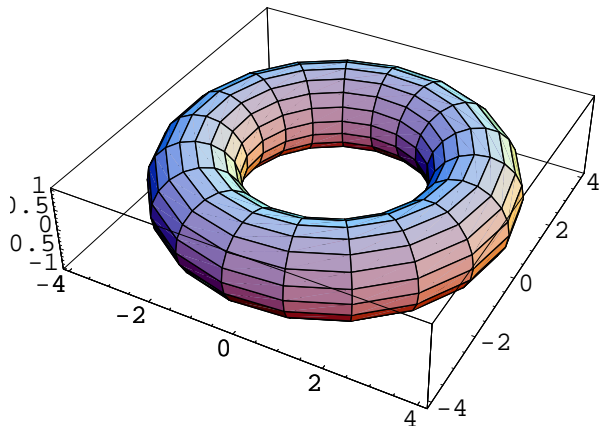
- Mathematica can also handle 3D plots.

```
In[112] := Plot3D[Sin[x y], {x, 0,  $\pi$ }, {y, 0,  $\pi$ }]
```



- Mathematica can also handle 3D plots.

```
torus = ParametricPlot3D[  
In[113] := {Cos[t] (3 + Cos[u]), Sin[t] (3 + Cos[u]), Sin[u]},  
            {t, 0, 2π}, {u, 0, 2π}]
```





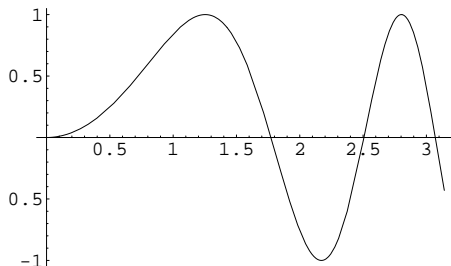
## 6 **Mathematica for Symbolic Computation**

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  - Export to Graphics File
  - Export to Programming Languages
  - Export to  $\text{\LaTeX}$
  - Interface to Other Programs
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# Exporting Mathematica Output

- Mathematica can export a plot as a graphics file. Supported formats include, among others, EPS, PDF, GIF, TIFF, PBM.

```
In[114] := Plot[Sin[x^2], {x, 0,  $\pi$ }]
```

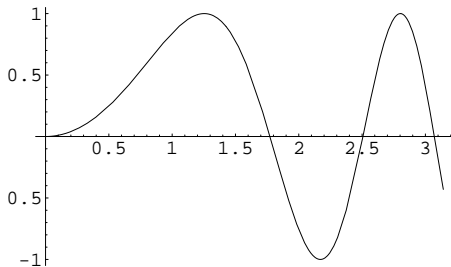


```
Out[114] =
```

```
In[115] := Export["foo.eps", %, "EPS"]
```

- Mathematica can export a plot as a graphics file. Supported formats include, among others, EPS, PDF, GIF, TIFF, PBM.

```
In[114] := Plot[Sin[x^2], {x, 0,  $\pi$ }]
```



```
Out[114] =
```

```
In[115] := Export["foo.eps", %, "EPS"]
```

- (Portions of) Mathematica notebooks can also be printed as PostScript files. See Mathematica's `print` menu.

- Mathematica can export expressions in C or Fortran format. (C macros are defined in Mathematica's file `mdefs.h`.)

In[116] :=  $t = (x^2 - 1) / \sqrt{x - 1}$

Out[116] =  $\frac{-1+x^2}{\sqrt{-1+x}}$

In[117] := `CForm[t]`

Out[117] = `(-1 + Power(x,2))/Sqrt(-1 + x)`

In[118] := `FortranForm[t]`

Out[118] = `(-1 + x**2)/Sqrt(-1 + x)`

- Mathematica can export expressions in  $\text{T}_{\text{E}}\text{X}$ -format, too.

```
In[119] := t
```

```
Out[119] =  $\frac{-1+x^2}{\sqrt{-1+x}}$ 
```

```
In[120] := TeXForm[t]
```

```
Out[120] = \frac{-1 + x^2}{\sqrt{-1 + x}}
```

```
In[121] := Clear[t]
```

- Mathematica can export expressions in  $\text{\LaTeX}$ -format, too.

```
In[119] := t
```

```
Out[119] =  $\frac{-1+x^2}{\sqrt{-1+x}}$ 
```

```
In[120] := TeXForm[t]
```

```
Out[120] = \frac{-1 + x^2}{\sqrt{-1 + x}}
```

```
In[121] := Clear[t]
```

- Mathematica can export a notebook (or portions thereof) as a  $\text{\LaTeX}$  file, too. Such a  $\text{\LaTeX}$  file makes use of macros defined in Mathematica's style file `notebook.sty`. See the `TeXSave` command for details.

- Mathematica can export expressions in  $\text{\LaTeX}$ -format, too.

```
In[119] := t
Out[119] =  $\frac{-1+x^2}{\sqrt{-1+x}}$ 
```

```
In[120] := TeXForm[t]
Out[120] = \frac{-1 + x^2}{\sqrt{-1 + x}}
```

```
In[121] := Clear[t]
```

- Mathematica can export a notebook (or portions thereof) as a  $\text{\LaTeX}$  file, too. Such a  $\text{\LaTeX}$  file makes use of macros defined in Mathematica's style file `notebook.sty`. See the `TeXSave` command for details.
- This is the way all the Mathematica expressions of this document were generated. Personal experience tells me that the  $\text{\LaTeX}$  output generated by Mathematica needs a bit of manual polishing in order for  $\text{\LaTeX}$  to digest it, and to format it neatly.

# Interfacing Mathematica with Other Programs

- Bi-directional communication between Mathematica and an application program is supported by the *MathLink* standard. See the manual for details.



- Bi-directional communication between Mathematica and an application program is supported by the *MathLink* standard. See the manual for details.
- Mathematica can be instructed to generate output suitable for display by Geomview. (The file `OOGL.m` is provided by Geomview.)

```
In[122] := << OOGL.m
```

```
In[123] := WriteOOGL["m_torus.off", torus]
```

- One can also use Geomview directly for displaying Mathematica graphics. The `Geomview` command invokes Geomview and sends the graphics to Geomview as an OOGL object. (For some reason, this does not work in our environment!)

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- **Sample Use of Mathematica**
  - Image Processing
  - Drawing a Bézier Curve
- Symbolic Computation – Caveats

# Sample Use of Mathematica: Image Processing

- Mathematica supports image processing.

```
In[124] := img = ColorConvert[ Import["kitten.jpg"], "RGB"]
```



```
Out[124] =
```

```
In[125] := {w, h} = ImageDimensions[img]
```

```
Out[125] = {250, 250}
```

```
In[126] := data = ImageDate[img]
```

```
In[127] := data[[125, 125]]
```

```
Out[127] = {0.427451, 0.392157, 0.356863}
```

# Sample Use of Mathematica: Image Processing

- Mathematica supports image processing.

```
In[128] := imgGray = ColorConvert[img, "Grayscale"]
```



```
Out[128] =
```

```
In[129] := Export["kitten_gray.png", imgGray]
```

```
Out[129] = kitten_gray.png
```

```
In[130] := Clear["Global`*"]
```

## Sample Use of Mathematica: Bézier Curve

- We use Mathematica for plotting a Bézier curve.

```
In[131] := pts =  
{ {0, 0}, {0, 1}, {1, 3}, {3, 3}, {5, 0}, {7, 1}, {8, 2}, {7, 3}, {5, 4}, {4, 4}, {4, 3} }
```

```
Out[131] =  
{ {0, 0}, {0, 1}, {1, 3}, {3, 3}, {5, 0}, {7, 1}, {8, 2}, {7, 3}, {5, 4}, {4, 4}, {4, 3} }
```

```
In[132] :=  
Bezier[n_, pts_, x_] := Sum[pts[[k + 1]] * BernsteinBasis[n, k, x], {k, 0, n}]
```

## Sample Use of Mathematica: Bézier Curve

- We use Mathematica for plotting a Bézier curve.

```
In[131] := pnts =  
{{0, 0}, {0, 1}, {1, 3}, {3, 3}, {5, 0}, {7, 1}, {8, 2}, {7, 3}, {5, 4}, {4, 4}, {4, 3}}
```

```
Out[131] =  
{{0, 0}, {0, 1}, {1, 3}, {3, 3}, {5, 0}, {7, 1}, {8, 2}, {7, 3}, {5, 4}, {4, 4}, {4, 3}}
```

```
In[132] :=  
Bezier[n_, pnts_, x_] := Sum[pnts[[k + 1]] * BernsteinBasis[n, k, x], {k, 0, n}]
```

```
In[133] := ParametricPlot[Bezier[10, pnts, x], {x, 0, 1}, Axes → False]
```

```
Out[133] =
```



```
In[134] := Export["sample_bezier.pdf", %, "PDF"]
```

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- **Symbolic Computation – Caveats**

- Consider the class of terms generated from one variable  $x$ , constants for the rationals,  $\pi$ , and the function symbols  $+$ ,  $*$ ,  $\sin$ ,  $\text{abs}$ . Caviness (1967) proved that the simplification problem with respect to functional equivalence is undecidable for this class of terms.



- Consider the class of terms generated from one variable  $x$ , constants for the rationals,  $\pi$ , and the function symbols  $+$ ,  $*$ ,  $\sin$ ,  $\text{abs}$ . Caviness (1967) proved that the simplification problem with respect to functional equivalence is undecidable for this class of terms.
- Similarly, Risch proved that the problem of integration in finite terms is undecidable for transcendental functions. In 1968–1969, Risch also described the first complete integration algorithm for algebraic and elementary transcendental functions.

- Consider the class of terms generated from one variable  $x$ , constants for the rationals,  $\pi$ , and the function symbols  $+$ ,  $*$ ,  $\sin$ ,  $\text{abs}$ . Caviness (1967) proved that the simplification problem with respect to functional equivalence is undecidable for this class of terms.
- Similarly, Risch proved that the problem of integration in finite terms is undecidable for transcendental functions. In 1968–1969, Risch also described the first complete integration algorithm for algebraic and elementary transcendental functions.
- Several important algorithms of computer algebra have an exponential complexity, e.g., Collins' cylindrical algebraic decomposition for quantifier elimination.

- Consider the class of terms generated from one variable  $x$ , constants for the rationals,  $\pi$ , and the function symbols  $+$ ,  $*$ ,  $\sin$ ,  $\text{abs}$ . Caviness (1967) proved that the simplification problem with respect to functional equivalence is undecidable for this class of terms.
- Similarly, Risch proved that the problem of integration in finite terms is undecidable for transcendental functions. In 1968–1969, Risch also described the first complete integration algorithm for algebraic and elementary transcendental functions.
- Several important algorithms of computer algebra have an exponential complexity, e.g., Collins' cylindrical algebraic decomposition for quantifier elimination.
- The bit complexity may grow substantially during a computation, thus potentially requiring a large main memory. In particular, the bit complexity of intermediate results may be significantly larger than the complexity of the input and the output. Some algorithms are well-known to be memory hoggers — consult textbooks prior to waiting for hours/days just in order to see the system crash due to lack of memory.

## 7 Graphics and Visualization

- Basics of Geomview
- Manipulation and Appearance of Geomview Objects
- Geomview I/O
- Geomview and External Applications

## 7 Graphics and Visualization

- Basics of Geomview
- Manipulation and Appearance of Geomview Objects
- Geomview I/O
- Geomview and External Applications

# Basics of Geomview

- Geomview is an interactive program for *viewing and manipulating 3D geometric objects*.
- Geomview was written by staff members of the Geometry Center (UMN).

# Basics of Geomview

- Geomview is an interactive program for *viewing and manipulating 3D geometric objects*.
- Geomview was written by staff members of the Geometry Center (UMN).
- Unfortunately, in an attempt to save money, the US administration scrapped the Geometry Center in 1998, and development efforts for Geomview have been hampered.
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- Geomview is in a mature and stable state, though! And it is still used widely and continues to evolve, see [www.geomview.org](http://www.geomview.org)
- Geomview is free software, released under a GNU license.
- It runs on a variety of systems using generic OpenGL or X11 graphics and a Motif interface.
- It builds on Mac OS X, and it can also run under MS Windows using Cygwin.



- The simplest way to use Geomview is as a *standalone viewer* to see and manipulate objects. It can display objects described in a variety of file formats.
- Geomview supports the following simple data types: polyhedra with shared vertices, quadrilaterals, rectangular meshes, vectors, and Bézier surface patches of arbitrary degree including rational patches.
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- Objects can be manipulated through direct mouse manipulation, control panels, and keyboard shortcuts.
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- Geomview allows multiple independently controllable objects and cameras. It provides interactive control for motion, appearances (including lighting, shading, and materials), picking on an object, edge or vertex level, snapshots, and adding or deleting objects.
- One can also use Geomview to handle the display of data coming from another program (*external module*) that is running simultaneously. As the other program changes the data, the Geomview image reflects the changes.
- Geomview can also display 3D graphics output from Mathematica and Maple.

## 7 Graphics and Visualization

- Basics of Geomview
- Manipulation and Appearance of Geomview Objects
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# Object Manipulations

- Objects can be selected by clicking at the name of the object in the `Targets` browser of the `Main` panel. If `world` is selected, then any motion/transformation is applied to all objects currently drawn.
- The object selected is called the *target object*.
- Geomview lets you manipulate objects with the mouse. There are six different mouse motion modes: Rotate, Translate, Cam Fly, Cam Zoom, Geom Scale, and Cam Orbit. The `Tools` panel has a button for each of these modes; to switch modes, click on the corresponding button.

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- Most of the motion modes have *inertia*, which means that if one lets go of the button while moving the mouse, the motion will continue.
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- Generally, the left mouse button controls motion in the screen plane, while the middle mouse controls motion along or around the forward direction.
- The `Center` button undoes the target object's transformation, moving it back to its home position, which is where it was when it was originally loaded into Geomview.





# Object Manipulations

- Geomview uses the *glass sphere model* for mouse-based rotations. Think of the object as being inside an invisible sphere, and regard the mouse cursor as a gripper outside the sphere. When one presses the left mouse button, the gripper grabs the sphere; when one releases the left mouse button, the gripper releases the sphere.
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- One can pick any point on an object (not just its origin) as the center of motion by holding down the shift key while clicking the right mouse button; this chooses a point of interest.
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- `Cam Fly` is a crude flight simulator that lets one fly around the scene. It works by moving the camera.

# Object Manipulations

- `Cam Orbit` mode lets one rotate the current camera around the current center.
- `Cam Zoom` lets one change the current camera's field of view with the mouse.
- `Geom Scale` mode lets one enlarge or shrink an object.
- The `Stop` button causes all motion to stop.
- The `Look At` button causes the current camera to be moved to a position such that it is looking at the target object, and such that the target object more or less fills the window.
- The `Reset` button stops all motion and causes all objects to move back to their home positions.

# Modifying the Appearance of Objects

- Geomview uses a hierarchy of appearances to control the way things look. An *appearance* is a specification of information about how something should be drawn.
- There is an appearance associated with "World", which serves as the parent of each individual object's appearance. Also, there is a global "base" appearance, which is the parent of the World appearance.

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- Appearances work in a hierarchical manner: if a certain appearance property, for example a face color, is not specified in a particular object's appearance, that object is drawn using that property from the parent appearance. If both the parent and the child appearance specify a property, the child's setting takes precedence unless the parent appearance is set to override.



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- The `Lighting` panel controls the number, position, and color of the light sources used in shading.
- The `Cameras` panel controls certain aspects of the target camera (such as its field of view). The use of multiple cameras is supported.
- The *Geomview command language* (gcl) provides complete control of all appearance data, including data that cannot be changed via the panels.

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- The `Save` panel offers several possibilities for storing Geomview objects and other information in files.
- One can store gcl commands, geometric data, input data for RenderMan, PPM (software) snapshots, snapshots in PostScript format, and data for restoring all windows and panels in a subsequent session of Geomview.
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- Commands in gcl format, which uses the syntax of lisp, can be entered via the `Commands` panel.
- Most panel interaction can be replaced by commands that have keyboard shortcuts. For instance, the keyboard shortcut for switching to `Rotate` mode is `r`.
- Some keyboard shortcuts consist of more than one key. In these cases one types the keys one after the other, with no `RET` afterwards. For instance, `glae` toggles the edge drawing for object ("geom") `gl`.



- Geomview reads objects in the format of the *Object Oriented Graphics Library* (OOGL).
- Examples for many OOGL objects can be found in Geomview's `data/geom` directory.
- Most OOGL files are are free-format ASCII. (Binary formats are also defined for several objects types.)
- Typical OOGL objects begin with a key word designating the object type, possibly with modifiers indicating the presence of additional data (such as color).
- Most key words are case sensitive.
- When OOGL objects are input, the OOGL library uses the file suffix to guess at the file type.

- Geomview supports inhomogeneous and homogeneous coordinates.
- Transformation matrices are given in a  $4 \times 4$  row-vector representation, for multiplication on the right of vectors. That is, a row vector  $p$  (of a point in homogeneous coordinates) is transformed by a matrix  $\mathbf{M}$  to a point  $p'$  as follows:  
$$p' = p\mathbf{M}.$$
- Appearances and texture maps can be specified; see the manual for details.

- QUAD:** a collection of quadrilaterals. The default file suffix is `.quad`.
- MESH:** a rectangularly-connected mesh of dimension  $n \times m$ . The default file suffix is `.mesh`.
- Bézier:** a Bézier surface. The default file suffix is `.bez`.
- OFF:** an object in *object file format*. It is used for representing collections of planar polygons, possibly with shared vertices. This is a convenient way to describe polyhedra. The polygons may be concave but polygons with holes are not supported. The default file suffix is `.off`.
- VECT:** strings of connected line segments, possibly closed. The default file suffix is `.vect`.
- SKEL:** collections of points and polylines, possibly with shared vertices. The default file suffix is `.skel`.
- SPHERE:** a sphere, drawn as a collection of rational Bézier patches. The default file suffix is `.sph`.
- INST:** a  $4 \times 4$  transformation, to be applied to another OOGL object. The default file suffix is `.inst`.
- LIST:** a list of OOGL objects. The default file suffix is `.list`.
- TLIST:** a list of  $4 \times 4$  transformations. The default file suffix is `.grp`.

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- An *external module* is a program that interacts with Geomview. It communicates with Geomview through gcl commands and can control any aspect of Geomview that one can control through Geomview's user interface. Typically, Geomview acts as a *display engine* for the external module.

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- External modules known to Geomview are listed in the `Modules` browser in Geomview's `Main` panel. An external module can be invoked by clicking on its entry in the browser.
- In order to make an external module `foo` known to Geomview, include the following line in your local initialization file, `.geomview`:

```
(emodule-define "Foo" "./foo")
```

Here, `Foo` is the name of the external module that will appear in the `Modules` browser of Geomview. One can also execute this command on-line from the `Commands` panel.

- When starting an external module, Geomview creates *pipes* connected to the module's standard input and output.
- Geomview interprets everything that the module writes to its standard output as a gcl command. Likewise, if the external module requests any data from Geomview, Geomview writes that data to the module's standard input.

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- Geomview interprets everything that the module writes to its standard output as a `gcl` command. Likewise, if the external module requests any data from Geomview, Geomview writes that data to the module's standard input.
- Note that this implies that the module cannot use standard I/O for communicating with the user!
- Sample external modules (`example*.c`) are available in Geomview's subdirectory `/geomview/doc`.



# Using Geomview as an External Display Engine

- It is also possible to invoke Geomview from an application program, and to direct graphics output produced by the application to Geomview, thus using Geomview as an external display engine.
- Communication between the application program and Geomview is again carried out via *pipes*.

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- Communication between the application program and Geomview is again carried out via *pipes*.
- In a C environment, an input file `geomview_in` for Geomview is opened by the application program as follows:

```
geomview_in = popen("togeomview", "w");
```

- Then, the application writes any input for Geomview to `geomview_in`.
- Since pipes may be buffered, it is advisable to flush the pipe after data has been written to the pipe: `fflush(geomview_in)`.

# Using Geomview as an External Display Engine

- Typically, we will want Geomview to create objects that can later on be modified (e.g., translated or rotated). The `gcl` command

```
(geometry Foo { : foo })
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instructs Geomview to create an object (“geom”) named `Foo` as an instance of the *handle* `foo`, where `Foo` is the name of the object as it will appear in the object browser of Geomview, and `foo` is the internal reference for Geomview.

- Handles allow one to name a piece of geometry whose value can be specified elsewhere, and which can be updated repeatedly. See the manual for details.

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- Handles allow one to name a piece of geometry whose value can be specified elsewhere, and which can be updated repeatedly. See the manual for details.
- If multiple objects are to be passed to Geomview, it is a good idea to turn off any scaling of the individual objects:

```
(normalization Foo none)
```

# The End!

I hope that you enjoyed this course, and I wish you all the best for your future studies.

