Computer tools for secondary school

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Attività di laboratorio

Preface

This book was created with the goal of making the world of computer science a powerful and accessible ally in secondary school education.

You won't find magic formulas or digital spells here (though the results may sometimes feel that way), but rather a reliable toolbox, field-tested and refined through years of hands-on experience by the author.

The main audience is curious teachers and students, those already convinced that a programming language can become a lens through which to view the world, and that computer science is not just a school subject, but a bridge to understanding real-world phenomena.

The PhD in Physics who signs these pages didn't stop at theory: every resource has been tested in real classrooms, with real students, and optimized to meet the needs of a school system often resistant to innovation. Whether your goal is to enrich a science lesson, simulate physical phenomena, or simply bring some excitement into a teaching unit, you'll find here ready-to-use ideas or ones easily adaptable to your context.

There's more. This book goes beyond secondary schools: many of the proposed activities are also well-suited to university settings, demonstrating that the boundary between school and research is often thinner than it seems.

I would like to thank all those who contributed to my education in computer science, in particular: Prof. Mario Capitelli and Dr. Gianpiero Colonna, both from the IMIP Institute of the CNR, and Prof. Giuseppe Pascazio from the Polytechnic University of Bari.

And now, dear readers, get comfortable in front of your digital device (or your sheet of paper, for those who enjoy contrasts), and get ready to discover how technology can turn teaching into an adventure.

Enjoy the read and happy coding!

Michele Tuttafesta

Introduction

The "Computer tools" considered in this book are represented by software of significant educational and technological relevance.

The first chapter is dedicated to "Gnuplot" [1], a software that allows students to develop programming skills while simultaneously acquiring abilities in graphical data representation.

The second chapter explains the use of the software "Tracker" [2], designed to acquire and analyze trajectories (or generic space-time evolutions) of moving systems starting from video files.

The main focus of the third chapter is the software "LTSpice" [3], a system that can be used to design and simulate electrical circuits, from the simplest to the most complex ones. It also provides the ability to analyze the characteristics (voltages, currents, power) of a circuit, both in the time domain and in the frequency domain. It is a particularly useful tool for teaching Physics in the final years of secondary school or at the university level.

The fourth chapter is dedicated to "Python", a programming language that probably needs no introduction for those who have made it this far. In the following pages, significant examples will be provided demonstrating the application of this language to data analysis and graphical representation.

The fifth chapter contains an introduction to the amazing LaTeX, a typesetting system of unparalleled elegance and power, designed for advanced typographic composition and universally acclaimed for its ability to produce documents of impeccable publishing quality. Created in 1984 by Leslie Lamport as an extension of the TeX typesetting system developed by Donald Knuth, LaTeX has become the de facto standard for writing scientific papers. Its importance in the mathematical and scientific community is unmatched, thanks to its ability to handle complex mathematical formulas with unsurpassed clarity and precision. In an age

[1] http://www.gnuplot.info
[2] https://physlets.org/tracker
[3] https://ltspice.it.softonic.com

dominated by simplification and standardized digital aesthetics, LaTeX remains a beacon of intellectual rigor and typographic beauty.

At the end of almost every section, significant examples related to the topic are provided, along with worksheets—often with data that can be freely chosen—followed by explanatory solutions.

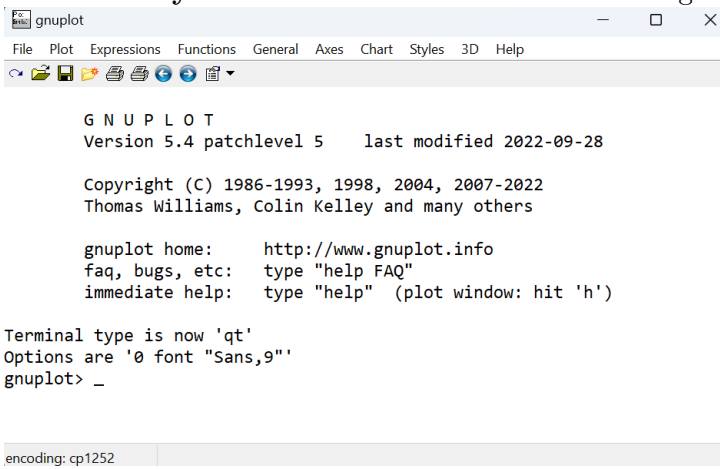
Any clarifications on certain mathematical algorithms proposed in the following pages can be found in the author's text "Mathematical tools for secondary school" ([1]) or in the excellent books by Domenico D'Ortenzi ([2], [3], [4]).

Chapter 1

Gnuplot

We report below what is described on the official software page http://www.gnuplot.info: "Gnuplot is a portable command-line driven graphing utility for Linux, OS/2, MS Windows, OSX, VMS, and many other platforms. The source code is copyrighted but freely distributed (that is, you don't have to pay for it). It was originally created to allow scientists and students to visualize mathematical functions and data interactively, but has grown to support many non-interactive uses such as web scripting. It is also used as a plotting engine by third-party applications like Octave. Gnuplot has been supported and actively developed since 1986."

On Windows systems the software shows the following interface

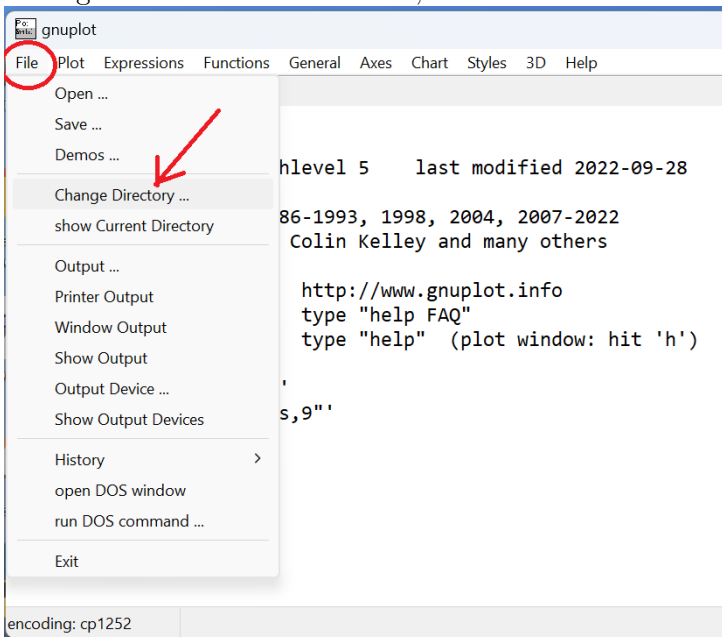


One way to use it is by entering commands directly at the command line. For example, by typing:

```
plot sin(x)
```

and pressing [Enter], a simple plot of the function y = sin(x) is displayed.

Another method, in many respects more effective, is to write the commands in a text file, using for example Notepad, one instruction per line. Then, from the 'File' menu, choose the directory where the text file containing the commands is located, as shown in the following figure:



and load the file, for example named 'script.txt', from the command line with the instruction:

```
load 'script.txt'
```

On Linux systems, using the terminal, simply move to the directory where the script (e.g., 'script.txt') is located and type:

```
$ gnuplot script.txt
```

We now present some significant examples, partly taken from the author's Moodle website ([5]), available by logging in as a "Guest" at https://www.a049.it and then accessing the course "Geometricamente", where additional documentation about the software can also be found.

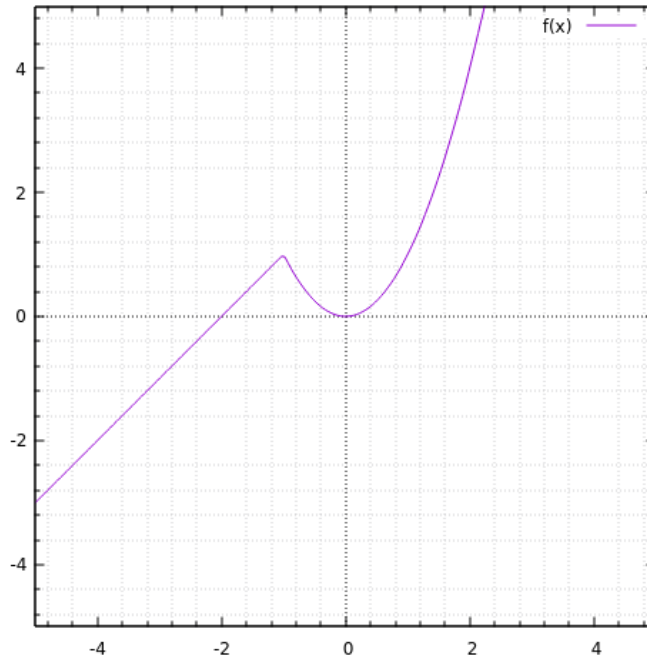
1.1 Plots of piecewise-defined functions

By running the following script

```
set size ratio 1
set zeroaxis
set grid mxtics mytics
```

```
set mxtics 5
set mytics 5
set xrange [-5:5]
set yrange [-5:5]
set samples 200
f(x) = x<-1 ? x+2 : x**2
plot f(x)
pause -1
```

we obtain



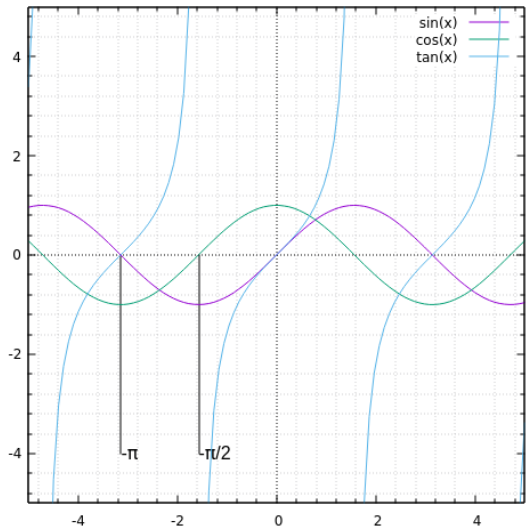
1.2 Graphs of Multiple Functions on the Same Plane

By executing the following script

```
set size ratio 1
set zeroaxis
set grid mxtics mytics
set mxtics 5
set mytics 5
set xrange [-5:5]
```

```
set yrange [-5:5]
set arrow 1 nohead from -pi,-4 to -pi,0
set arrow 2 nohead from -pi/2,-4 to -pi/2,0
set label 1 "-{/Symbol p}" at -pi,-4 font "Arial,12"
set label 2 "-{/Symbol p}/2" at -pi/2,-4 font "Arial,12"
plot sin(x),cos(x),tan(x)
pause -1
```

you obtain

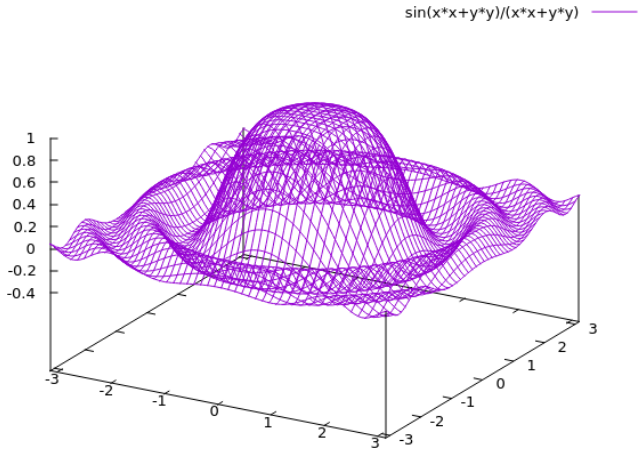


1.3 Surfaces in Space

Surfaces in space can be defined by functions of two variables. By executing the following script

```
set xrange [-pi:pi]
set yrange [-pi:pi]
set isosamples 50,50
splot sin(x*x+y*y)/(x*x+y*y)
pause -1
```

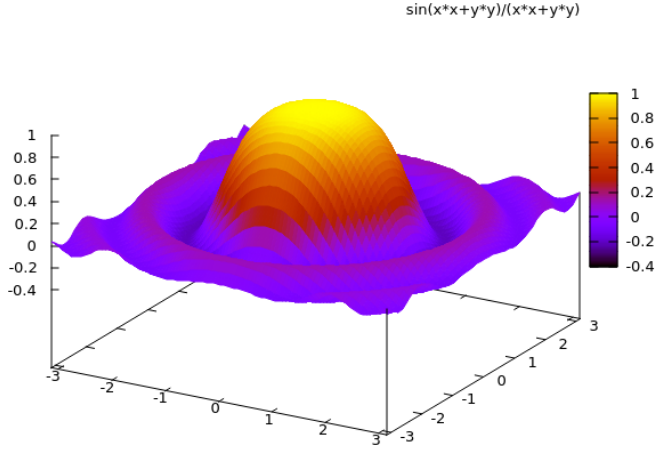
you obtain



or, using the "pm3d" option

```
set xrange [-pi:pi]
set yrange [-pi:pi]
set isosamples 50,50
splot sin(x*x+y*y)/(x*x+y*y) w pm3d
pause -1
```

you obtain



Chapter 3

LTspice

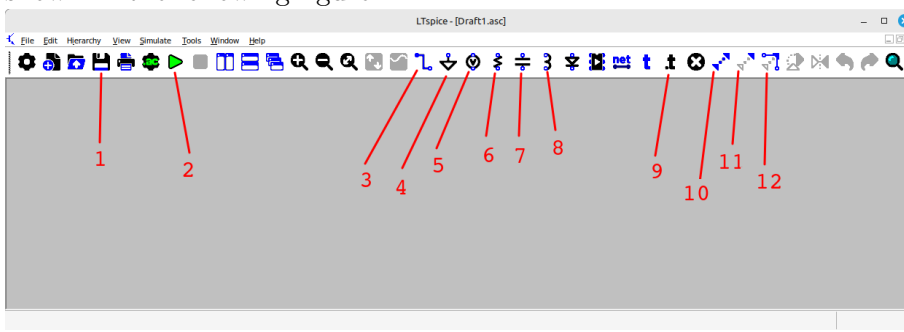
Here is the description taken from the distribution website:

https://ltspice.it.softonic.com:

"LTspice is a free graphical design software that allows you to create circuit designs. Developed by Analog Devices [1], this program is a SPICE-based analog circuit simulator capable of analyzing the performance of circuit designs before prototyping. It offers various features appreciated by both beginners and advanced users. Moreover, it provides extensive online documentation. ...

SPICE or "Simulation Program with Integrated Circuit Emphasis" is an open-source analog electronic circuit simulator used in integrated circuit design. Its purpose is to verify the integrity of designs and predict their behavior before physical implementation. The program became popular due to its stability, speed, and ease of use. Among the many SPICE-based programs, **LTspice** includes enhancements over the original tool."

The program interface, from the menu: File→New Schematic, is shown in the following figure.



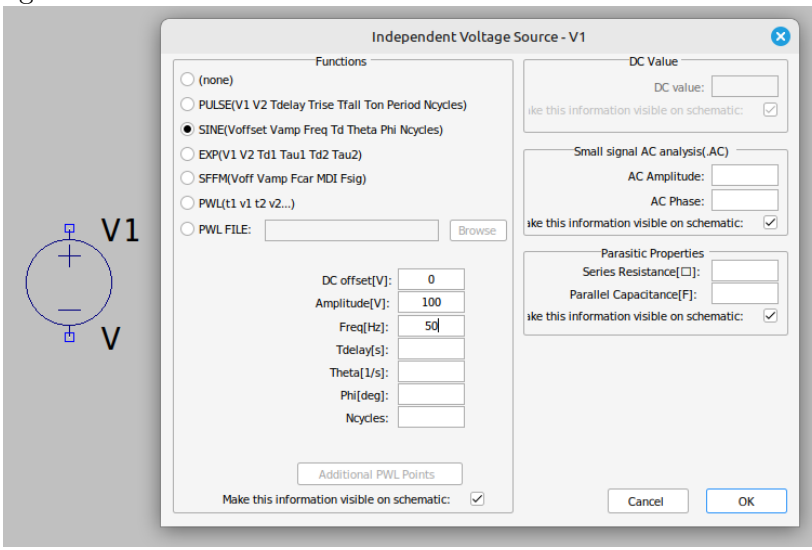
[1] https://www.analog.com/en/resources/design-tools-and-calculators/ltspice-simulator.html

We illustrate its basic usage through a few examples.

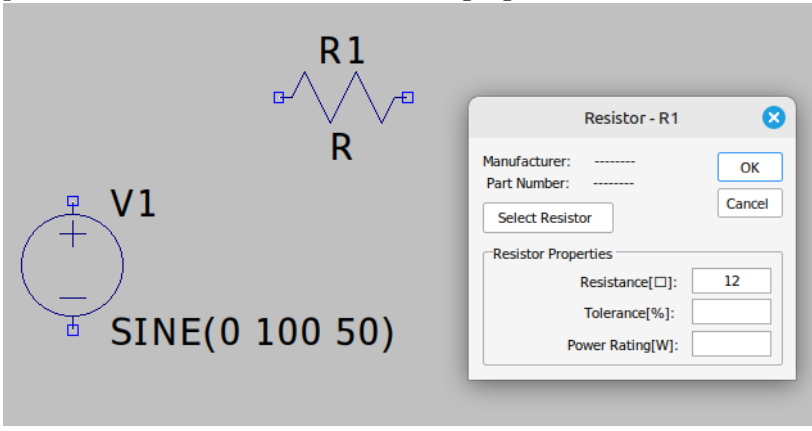
3.1 RLC Circuit: Time-Domain Analysis

First, we draw a series RLC circuit with an alternating voltage generator.

From the toolbar, select the voltage source (5) and place it in the drawing area using the left mouse button; then press [Esc] to cancel the automatic duplication of the component. Next, right-click on it, then select [Advanced], and enter its characteristics as shown in the following figure.



Now select a resistor (6) and, before placing it with the left mouse button, rotate it using Ctrl+r. Then, right-click on it and enter its parameters as shown in the following figure.



Repeat the same procedure for an inductor (8) and a capacitor (7), entering the parameters as shown in the following figures.