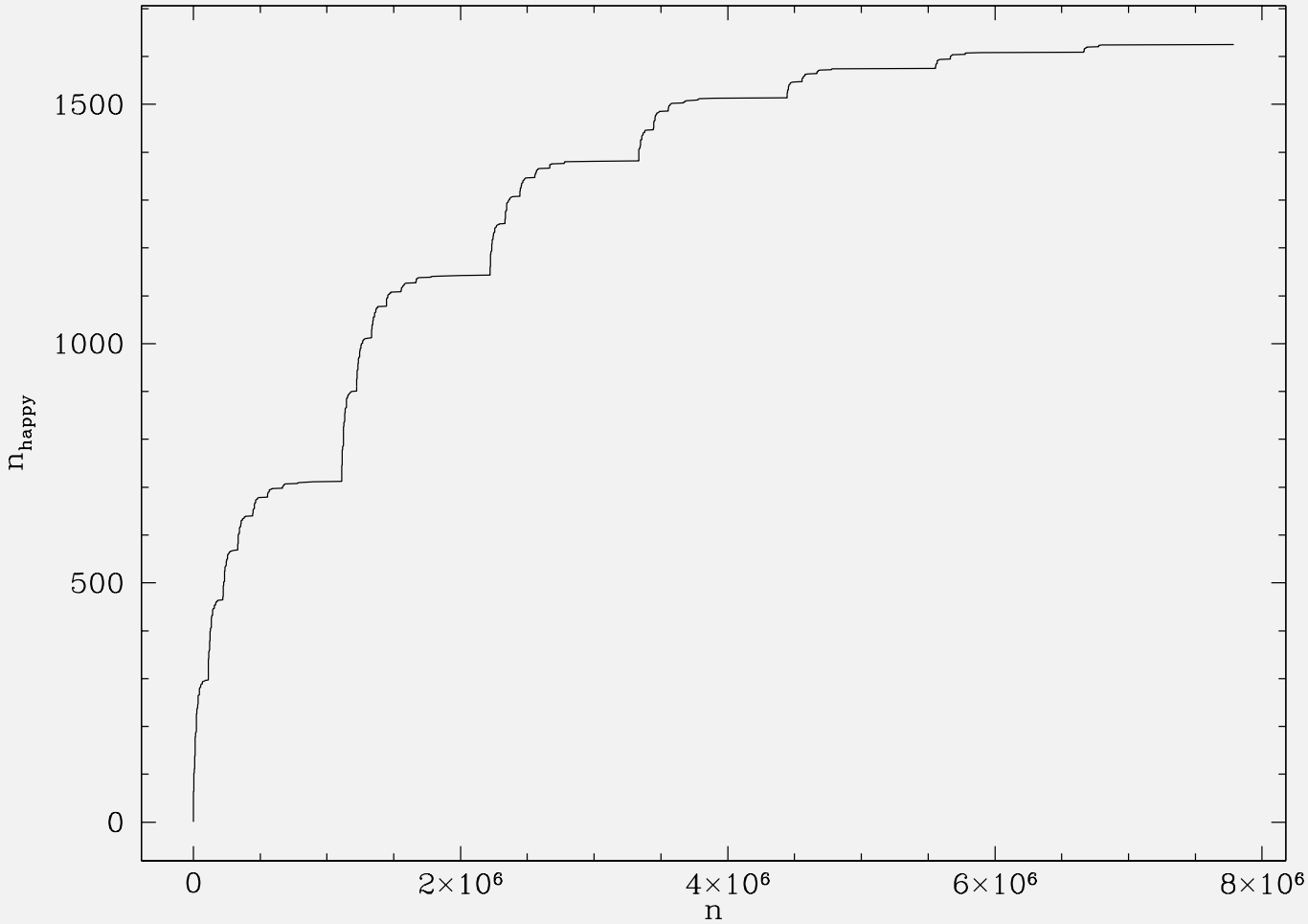
Mini-projects in Level 5 Programming



Ralf Napiwotzki

School of Physics, Astronomy and Mathematics (UH)

Typical programming assignment

- Students have been shown a programming method, sets of commands or functions.
- The assignment asks students to apply these to a well defined problem.
- Learning outcome: students are trained to apply a programming method . . .
- . . . but with not much room for creativity or independent thinking.

Typical research or real life problem

- A function is fitted to a data set.
- **Problem:** Small number of objects cause statistical uncertainties. How much can I trust the fitted parameters?
- Which **method** can I use to address this problem?
- A good method for this problem is a Monte Carlo simulation: produce randomised simulated samples and fit the function to the simulated sample.
- Repeat this many times and measure the spread of simulated results.

Typical research or real life problem

- Then think about a **program** to carry out the simulations: structure, programming methods to use.
- Carry out the **calculations**.
- Think about the best way to **display** results: plots, tables.
- **Analyse and interpret** the results. Draw **conclusions**.
- Based on the outcome potentially redesign your experiment.

Programming mini-projects

Students are given a taster of the research method.

- Students are given a selection of problems from mathematics, physics or astrophysics.
- Some guidelines are given concerning which method to use.
- Student have almost complete **freedom to implement this in a program**.
- Students are asked to find a good way to display their results.
- The final step is interpretation of the results.
- Work is done in **teams**.

Programming mini-projects

Mini-projects offered this year

1. Happy numbers (pure maths)
2. Option pricing (financial maths)
3. Water flow through soil (applied maths problem from civil engineering)
4. Air pollution modelling (atmospheric physics)
5. Initial mass function of stellar clusters (astrophysics)

Happy numbers mini-project

A happy number is defined by the following process:

- Take the decimal representation of an integer number. Do the sum over the squares of the digits.
- Repeat this process on the result until . . .
- . . . either the result is 1 and the process comes to a standstill. Then you have found a happy number.
- . . . or you end up with a number repeating itself and thus ending up with an endless sequence.

Happy numbers mini-project

Testing 19:

$$\begin{aligned} 1^2 + 9^2 &= 82 \\ 8^2 + 2^2 &= 68 \\ 6^2 + 8^2 &= 100 \\ 1^2 + 0^2 + 0^2 &= 1 \end{aligned}$$

19 is a happy number.

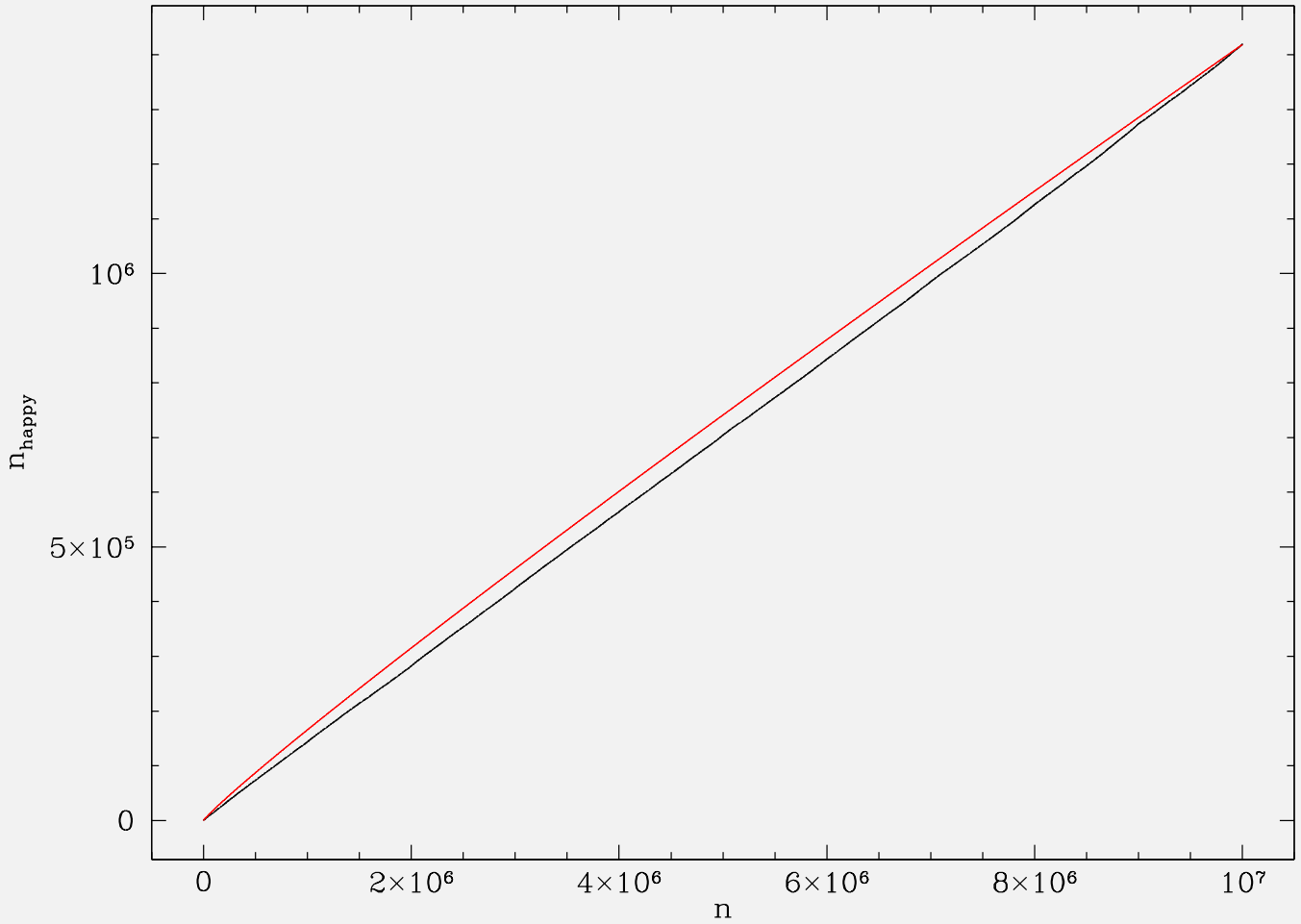
Testing 22 produces the sequence:

$$22, 8, 64, 52, 29, 85, 89, 145, 42, 20, 4, 16, 37, 58, 89, \ldots$$

89 appeared previously in the sequence. The sequence will cycle endlessly through the past 8 numbers and 22 is not a happy number (a sad number).

Happy numbers mini-project

Cumulative distribution of happy numbers.



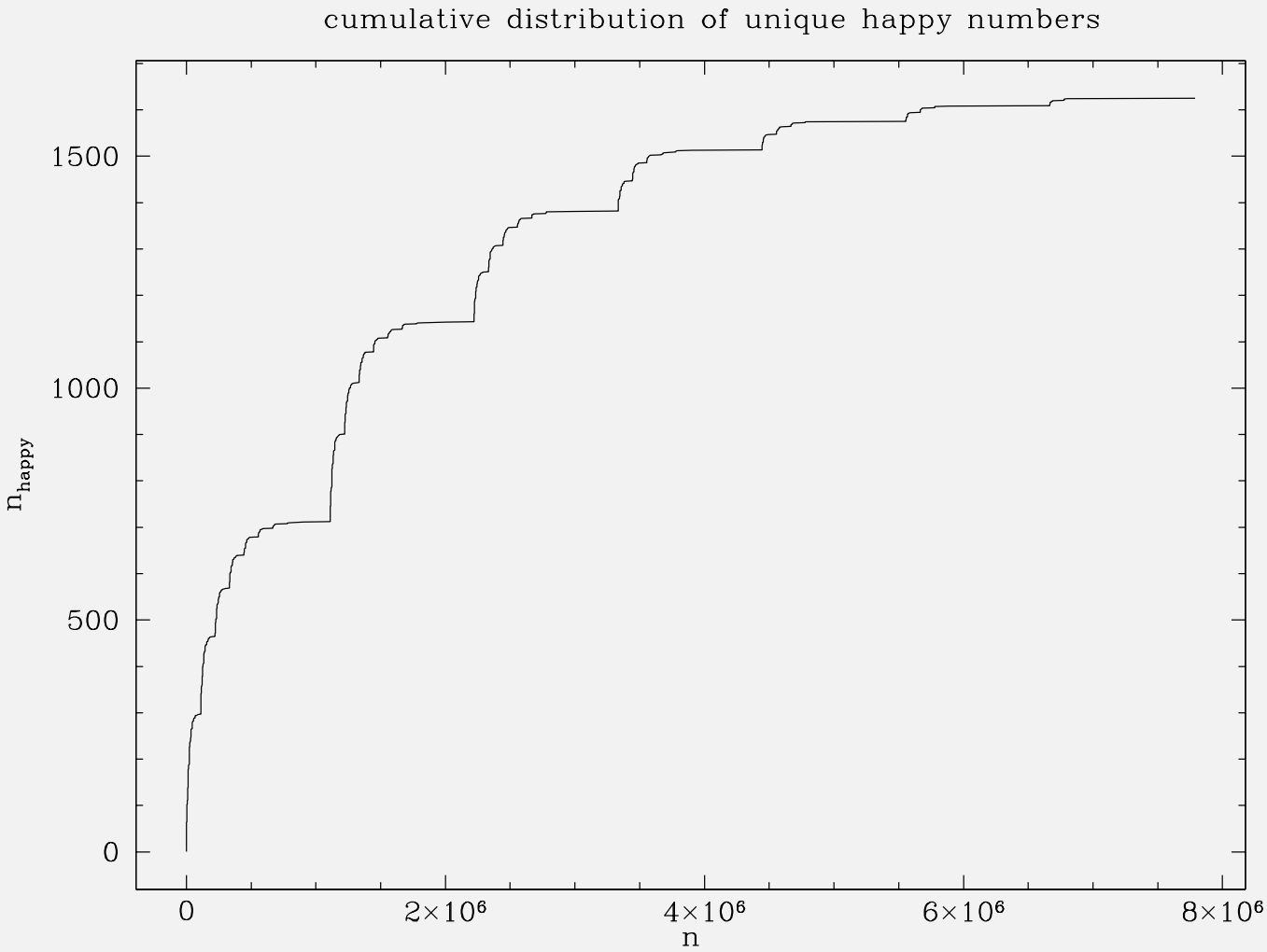
Happy numbers mini-project

Unique happy numbers

- Every permutation of the digits of a happy number produces another happy number.
- E.g. 19 and 91 are both happy numbers.
- A **unique** happy number is the smallest happy number with the same set of digits.
- 19 is a unique happy number, 91 is not.

Happy numbers mini-project

Cumulative distribution of unique happy numbers.



Happy numbers mini-project

Explanation for the structure of cumulative distribution.
(For those who want to know).

- Numbers starting with a 1 (e.g. 1,000,000 to 1,999,999) can form many new happy numbers, which are not just a simple permutation of one already known.

- Numbers starting with a 2 (e.g. 2,000,000 to 2,999,999) will find some new unique ones, but some will be permutations of happy numbers with a leading 1.

- The higher the value of the leading digit, the more likely it is that any happy number is a simple permutation of one already known. Think 19 and 91.

Mini-project: side effects

Marking: Students came up with many different approaches to solve the problems, some of them ingenious.

Intended, but it makes marking more time consuming than marking a standard assignment.

Student feedback indicated that they felt **anxious** working on a large piece of coursework without intermediate feedback.

Have a first part submission earlier giving students feedback whether they are on the right track, what needs to be corrected,.....

10. . . 20% of mini-project marks. Full marks if a serious attempt up to a certain stage has been tried.

Mini-project: Conclusions

- Mini-projects were worth doing and they will be offered again.
- Students got a research taster.
- Students were challenged to develop new skills.