

MASTERING FUNCTIONAL PROGRAMMING, ALGORITHMS AND DATA STRUCTURES IN OCAML, AT YOUR DISPOSAL

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Trends in Functional Programming in Education, January 2023

Part I

WHAT THIS IS ABOUT

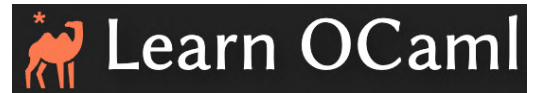
THE COURSEWARE

- ▶ **Public** courseware based on the **open source** platform LEARN-OCAML



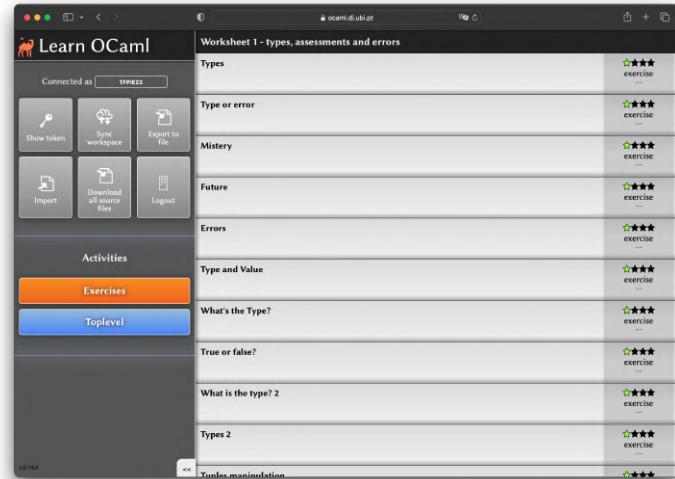
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- ▶ **Public** courseware based on the **open source** platform LEARN-OCAML
 - Monitored mode
 - Self-learning Mode



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THE COURSEWARE

The screenshot shows the Learn OCaml web interface. The left pane contains a code editor with the following OCaml code:

```
1 let rec hhq r s n =
2   if s < 2 || r >= s then raise (Failure "hhq")
3   else if ! <= n && n <= s then
4     else if n > s then
5       hhq r s (n - hhq r s (n - r)) + hhq r s (n - hhq r s (n - s))
6     else raise (Failure "hhq")
7
```

The right pane displays the problem description for "The Hofstadter-Huber $Q_{r,s}(n)$ sequences".

Introduction

Consider r and s to be two natural positive integers, where $s \geq 2$ and $r < s$. The Hofstadter-Huber sequence of family (r, s) is the sequence determined by the following formula:

$$Q_{r,s}(n) = \begin{cases} 1 & \text{if } 1 \leq n \leq s \\ Q_{r,s}(n - Q_{r,s}(n - r)) + Q_{r,s}(n - Q_{r,s}(n - s)) & \text{if } n > s \end{cases}$$

where n is a positive integer.

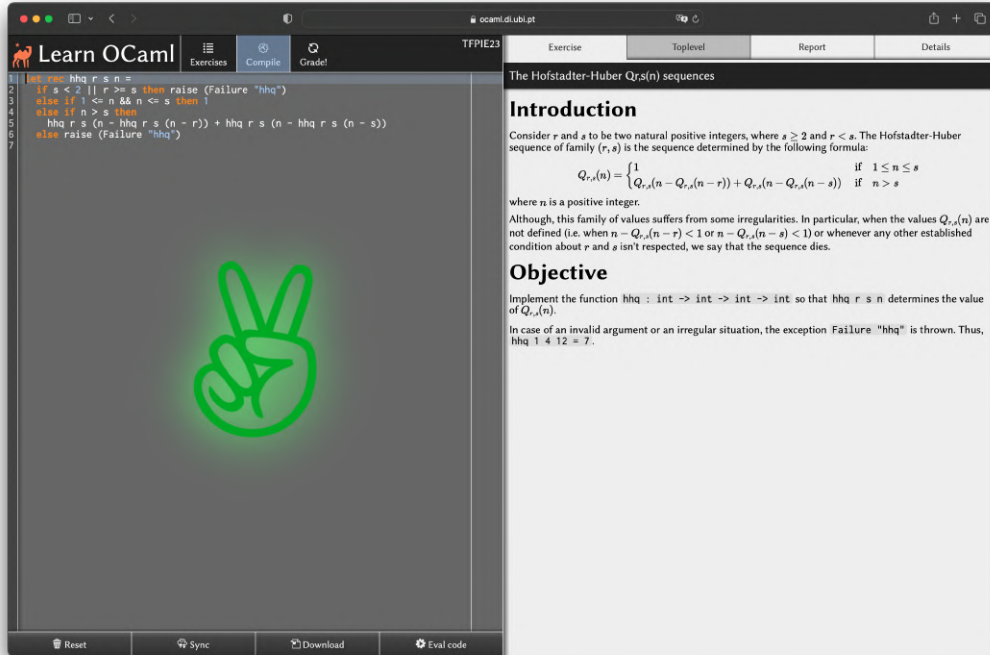
Although, this family of values suffers from some irregularities. In particular, when the values $Q_{r,s}(n)$ are not defined (i.e. when $n - Q_{r,s}(n - r) < 1$ or $n - Q_{r,s}(n - s) < 1$) or whenever any other established condition about r and s isn't respected, we say that the sequence dies.

Objective

Implement the function `hhq : int -> int -> int -> int` so that `hhq r s n` determines the value of $Q_{r,s}(n)$.

In case of an invalid argument or an irregular situation, the exception `Failure "hhq"` is thrown. Thus, `hhq 1 4 12 = 7`.

THE COURSEWARE



The screenshot shows the Learn OCaml IDE interface. The code editor on the left contains the following OCaml code:

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  else raise (Failure "hhq")
```

The right-hand panel displays the documentation for the Hofstadter-Huber sequence, titled "The Hofstadter-Huber $Q_{r,s}(n)$ sequences".

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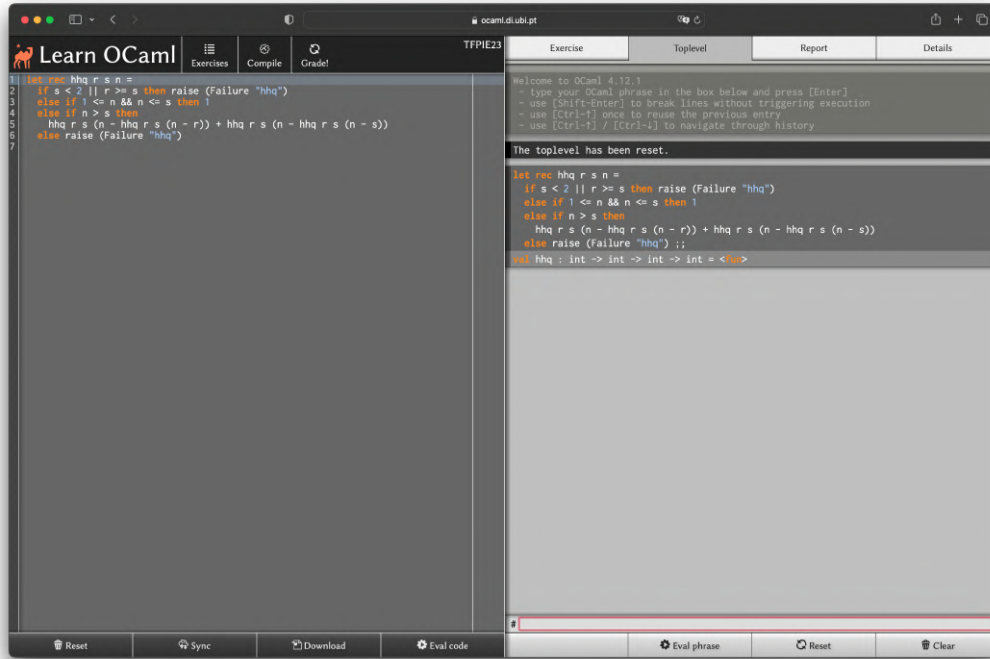
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```

The right pane shows the test results for the exercise "v Testing function hhq", which is completed with 17 points. The results are as follows:

Test Case	Result	Points
Found hhq with compatible type.	Success	
Computing hhq 2 5 10	Success	1 pt
Correct value 8	Success	1 pt
Computing hhq 1 4 12	Success	1 pt
Correct value 7	Success	1 pt
Computing hhq 2 2 20	Success	1 pt
Correct exception (Failure "hhq")	Success	1 pt
Computing hhq 1 4 15	Success	1 pt
Correct value 9	Success	1 pt
Computing hhq 2 4 17	Success	1 pt
Correct value 9	Success	1 pt
Computing hhq 0 1 10	Success	1 pt
Correct exception (Failure "hhq")	Success	1 pt
Computing hhq 5 2 10	Success	1 pt
Correct exception (Failure "hhq")	Success	1 pt
Computing hhq 1 7 10	Success	1 pt
Correct value 4	Success	1 pt
Computing hhq 2 7 8	Success	1 pt
Correct value 2	Success	1 pt
Computing hhq 1 4 9	Success	1 pt
Correct value 5	Success	1 pt
Computing hhq 1 6 10	Success	1 pt
Correct value 5	Success	1 pt
Computing hhq 1 6 13	Success	1 pt
Correct value 7	Success	1 pt
Computing hhq 1 1 1	Success	1 pt
Correct exception (Failure "hhq")	Success	1 pt
Computing hhq 2 5 5	Success	1 pt
Correct value 1	Success	1 pt
Computing hhq 1 1 14	Success	1 pt
Correct exception (Failure "hhq")	Success	1 pt
Computing hhq 3 1 9	Success	1 pt
Correct exception (Failure "hhq")	Success	1 pt
Computing hhq 2 4 13	Success	1 pt
Correct value 9	Success	1 pt

Part II

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This initiative responds to some needs felt in the OCAML functional programming community as well as in the education community:

- ▶ OCAML is a mature, principled, evolving and modern programming language
- ▶ There are good books about programming in OCAML, but...
- ▶ Scarcity of pedagogical materials in algorithms and data structures in OCAML (even worse in Portuguese)
- ▶ We have been teaching OCAML programming for years and the community outside our university is regularly interacting with us

Part III

THE OPPORTUNITY

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- ▶ A new curriculum focused on data structures and algorithms

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- ▶ Large classes, heterogeneous levels and modest size teaching teams: challenging **logistics**

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- ▶ Large classes, heterogeneous levels and modest size teaching teams: challenging **logistics**
- ▶ A sad reality, the pandemic

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- ▶ Support for real-time or deferred interaction
- ▶ Mechanisms for fine-tuning the progress of each student's learning process

Part V

THE FUNCTION

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THEORETICAL EXPOSITION SUPPORT

The platform includes lecture notes that consist of the Portuguese translation of the excellent book of Sylvain Conchon and Jean-Christophe Filliâtre. (english translation is ongoing)



THE FUNCTION

PRACTICAL COMPONENT SUPPORT

As of today, the practical lessons covers half of the book (enough for a one semester course), the full coverage is on going

The assignment of exercises to each student works as follows:

- ▶ first-year students: 3 basic level exercises, 2 intermediate level exercises;
- ▶ second-year students: 1 or 2 basic level exercises, 2 or 3 intermediate level exercises, 1 experienced level exercise;
- ▶ third-year students: 2 or 3 intermediate level exercises, 2 or 3 experienced level exercises.

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SUPPORT AND CONTROL OF STUDENT PROGRESS



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https://join.slack.com/t/azizos/shared_invite/zt-1mrkozpqf-EYEsVBEUocfVreUqCHBM9Q

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HELPS THE TEACHER TO FOLLOW THE STUDENT'S PROGRESS

The platform allows to track and customize student's learning process

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HELPS THE TEACHER TO FOLLOW THE STUDENT'S PROGRESS

The platform allows to track and customize student's learning process

- ▶ Tracking of which exercises students have completed
- ▶ Assigning, if needed, additional exercises
- ▶ The feedback on the student's performance is detailed

DEMO

The screenshot shows the 'Learn OCaml' web application interface. The top navigation bar includes 'Exercises', 'Compile', and 'Grade!' buttons. The main content area is split into two panes. The left pane is a code editor with the following OCaml code:

```
1 let babbage () = failwith "Replace with your solution"
2
3 let p4 = replace_with_your_solution
4
```

The right pane displays the 'Number searching' exercise. It has tabs for 'Exercise', 'Toplevel', 'Report', and 'Details'. The 'Introduction' section contains the following text:

Charles Babbage proposed a simple arithmetic challenge that he thought could be solved easily with machines if these existed. In particular, if he had the means to construct them.

What is the smallest positive integer whose square ends in the digits 269,269?

(Babbage, letter to Lord Bowden, 1837)

He thought the answer could be 99,736, which squared gives 9,947,269,696; although he wasn't sure.

He obviously solved the problem without a computer program, but using one is so **much** more practical.

The right pane also shows a C code snippet for solving the problem:

```
#include <stdio.h>
#include <stdlib.h>
#include <limits.h>

int main() {
    int current = 0,
        square;

    while (((square=current*current) % 1000000 != 269696) && (square<INT_
        current++;
    }

    if (square > INT_MAX)
        printf("Condition not satisfied before INT_MAX reached.");
    else
        printf("The smallest number whose square ends in 269696 is %d\n",
        return 0;
}
```

The 'Objectives' section states: 'This is a solution written in C (taken from the amazing website *rosetta code*). Unfortunately, this code has some hidden issues.'

At the bottom of the interface, there are four buttons: 'Reset', 'Sync', 'Download', and 'Eval code'.

Part VI

TODAY

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Current perspectives:

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- ▶ Platform stability and scalability: the computation is on the client side

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- ▶ Fine-tuned mechanism of graders

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Current perspectives:

- ▶ Platform stability and scalability: the computation is on the client side
- ▶ Fine-tuned mechanism of graders
- ▶ The English version is still evolving

Part VII

TOMORROW

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The next steps for the current teaching team are:

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- ▶ Videos

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- ▶ Videos
- ▶ Improved control center

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The next steps for the current teaching team are:

- ▶ Videos
- ▶ Improved control center
- ▶ More contents
- ▶ And...

TOMORROW

More research

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- ▶ Automatic program transformation

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- ▶ Mechanisms that allow the student to specify pre-/post-annotations and invariant and graders to verify/test them

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More research

- ▶ Automatic program transformation
- ▶ Mechanisms that allow the student to specify pre-/post-annotations and invariant and graders to verify/test them
- ▶ Algorithmic complexity checking
- ▶ Extend platforms like LEARN-OCAML to the teaching of other areas of computer science (see OFlat, OCAML workshop 2022, for a formal language course)

Thank You!

Questions?

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