

# Some Enhancements to the Prolog Playground and ALD Notebooks for the Modern Prolog Classroom\*

Jose F. Morales<sup>1,2</sup>, Daniela Ferreiro<sup>1,2</sup>, Marco Pérez<sup>1,2</sup> and Manuel V. Hermenegildo<sup>1,2</sup>

<sup>1</sup>Universidad Politécnica de Madrid (UPM), Madrid, Spain

<sup>2</sup>IMDEA Software Institute, Madrid, Spain

## Abstract

One of the main objectives of the Prolog Playground and ALD-style notebooks (Active Logic Documents) is to facilitate the task of teaching and learning Prolog. The Playground allows teachers and students to develop, run, debug, verify, and test Prolog programs directly on the browser, without needing a Prolog installation. It also greatly facilitates the sharing of Prolog code and adding click-to-run capabilities to any kind of teaching materials. ALD-style notebooks further facilitate the generation of web-based materials with embedded running examples and exercises. Fundamental to these tools is that they run locally on the student's browser, with no need for a server infrastructure. We will report on (and demo) some recent important extensions which include a) being able to develop the notebooks with embedded running examples and quizzes now directly within the Playground, b) also being able to develop *slides* with such examples and quizzes as well as doing presentations within the Playground, c) a fully reactive mode where feedback and results are given on-the-fly, as the student types, d) new facilities for interactive collaboration in the classroom, and e) integration with the LPTP theorem prover. We hope these facilities will be of interest to teachers and students of the Prolog language.

## Keywords

Active Logic Documents, Prolog Playground, Prolog Notebooks, Teaching Prolog, Prolog, Ciao Prolog, Logic Programming, WebAssembly.

## 1. Introduction

The Prolog Playground [1, 2]<sup>1</sup> and ALD-style notebooks (Active Logic Documents) [3] constitute a toolset designed to facilitate the task of teaching and learning Prolog, both online and in the classroom. An important characteristic of these tools, is that everything (editors, queries, applications, etc.) runs locally on the student's browser, with no need for a server infrastructure. This is based on the use of the *ciaowasm* build grade of Ciao Prolog (i.e., using WebAssembly [4] compiled with Emscripten [5]). This is in contrast to other tools which are generally server-based.<sup>2</sup> After providing a brief overview of the previous characteristics of this toolset in Section 2, our purpose herein is to report on (and demo) some recent extensions to these tools, presented in Section 3.

## 2. Previous Playground and ALD Characteristics

**The Prolog Playground:** Since its first versions, the first component of the toolset, the *Prolog Playground*, allows teachers and students to perform a number of tasks directly within the browser, providing essentially a full IDE, without any need for a Prolog installation or being connected to a server. These include:

- Code can be loaded from the user's local files or the web, edited, run and debugged using the classic and familiar top-level interaction model (see Fig. 1), and saved, all locally on the user's web

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<sup>1</sup><http://ciao-lang.org/playground>

<sup>2</sup>See [3] for a more complete discussion and references.

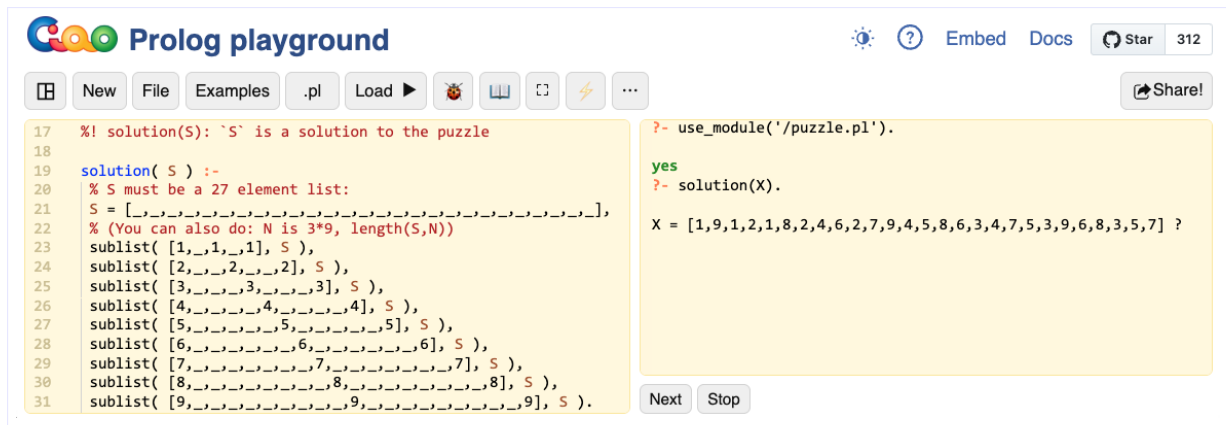


Figure 1: Editing and running code ( New File Examples .pl Load ▶ ).

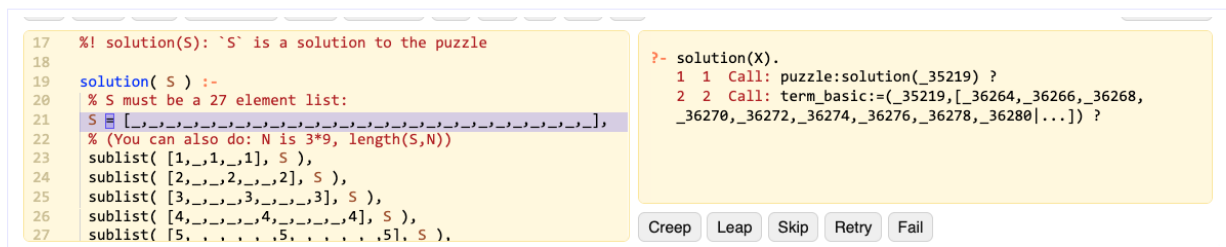


Figure 2: Source-level debugging ( 🐛 ).

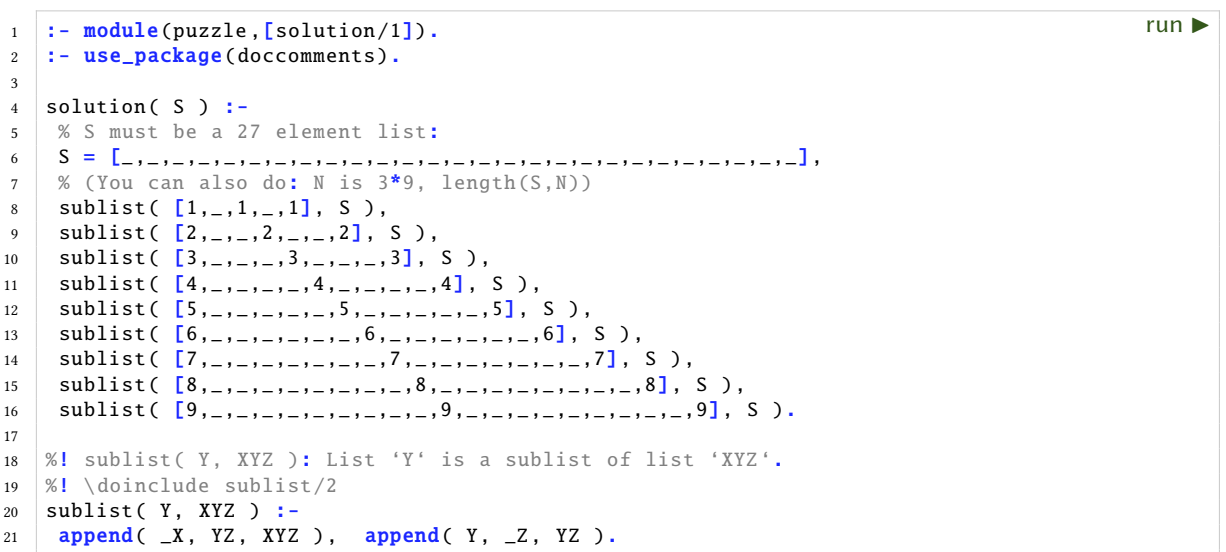





Figure 3: An example with an embedded link to the Playground (obtained via [Share](#)).

browser. The debugger allows stepping through the code in the traditional way, with the position (as well as errors, etc.) being marked on the source in the editor window (Fig. 2). Solutions to goals can be portrayed in ways other than just printing them out, allowing output of graphical and user-interface components. An example is giving explanations in the s(CASP) Playground (see later).

- Code sharing: clicking on the [Share](#) button, a link is generated that opens a Playground with the contents of the editor window (see [this link](#) and Fig. 3 for a LaTeX example; note that the link with the code is stored within this document and has not been uploaded to any server). This link can be mailed or pasted into applications or documents. This allows very easily embedding “click-to-run” links to runnable code examples in any kind of teaching materials, including tutorials, manuals, slides, exercises, technical papers, notebooks, etc., developed with any tool.

The screenshot shows the Prolog playground interface. On the left, a code editor displays a Prolog program for a puzzle. The program includes comments in Prolog format (starting with `%!`) that describe the puzzle and the documentation to be generated. The code defines a `sublist` predicate and a `solution` predicate. On the right, the generated documentation is shown, including a title "Example - A simple puzzle", a description of the puzzle, and the usage of the `library` and `exports`. The documentation also includes a section for "Documentation on exports" showing the `PREDICATE solution/1` and its usage.

Figure 4: Generating program documentation ()

- Developing Prolog code documentation: the LPdoc documentation generator [6, 7] is also embedded within the Playground. This allows generating and previewing documentation obtained from the source code itself and any machine-readable comments and/or assertions, also locally within the browser ( button; Fig. 4).
- Advanced features () include running any unit tests [8] that may be present in the program; analyzing and verifying properties such as modes, types, determinacy, non-failure, etc. [9, 10]; partial evaluation and code specialization; etc., again all running locally within the browser.

The Playground can be easily specialized for particular applications, an example of which is the s(CASP) Playground [2] <sup>3</sup> or the LPTP Playground (see later). More information on the implementation of the Ciao WebAssembly back-end and the Playground architecture can be found in [2].

**Active Logic Documents:** The other main component of the toolset is *Active Logic Documents* (ALDs) [3]. ALDs are notebooks which incorporate *embedded* Prolog engines. For example, [this document](https://cliplab.org/logalg/doc/99problemsALD.html)<sup>4</sup> is an ALD containing Werner Hett's 99 Prolog problems encoded as executable exercises. ALDs are composed from simple .md (markdown) files, where examples and queries can be marked as **runnable**. These are then included in the document in embedded Prolog mini-Playground cells, so that interaction with these examples is possible within the documents produced. The actual generation of the html files is performed by LPdoc (Fig. 5). Runnable cells can also contain interactive exercises with hints (to help students find a solution) and solutions, tests (for self-evaluation of the student-provided solutions), non-visible parts, etc. (as in the 99 Prolog problems example). There is also an escape mechanism to javascript that allows easily implementing additional functionality, graphical output, etc. (jseval) and ALD fragments can be dynamically generated from programs (dynpreview). ALDs can

<sup>3</sup><https://ciao-lang.org/playground/scasp.html>

<sup>4</sup><https://cliplab.org/logalg/doc/99problemsALD.html/>

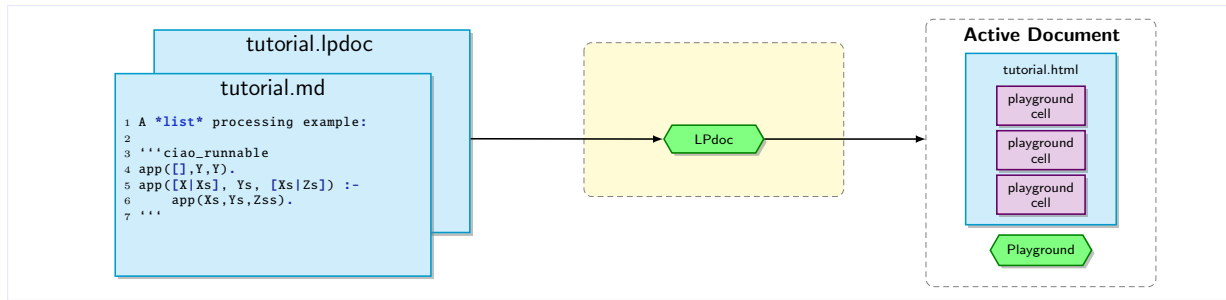


Figure 5: Generating Active Logic Documents.

**Prolog playground**

New File Examples .md .pl

```

1 \title Example - A simple puzzle
2
3 Write a Prolog program that generates (as a list) a sequence tha
4
5 - includes three 1's, three 2's, . . . , and three 9's,
6
7 - and between each digit i and the next i there are exactly i
8 elements.
9
10 E.g.:
11
12 `[1,9,1,2,1,8,2,4,6,2,7,9,4,5,8,6,3,4,7,5,3,9,6,8,3,5,7]`
13
14 '''ciao_runnable
15 % Headers (hidden):
16 :- module(_).
17 :- use_package([assertions,nativeprops]).
18 :- use_module(library(unittest/unittest_props)).
19
20
21 % Testing code (hidden):
22 :- test solution(S)
23 => member(S,[[1,9,1,2,1,8,2,4,6,2,7,9,4,5,8,6,3,4,7,5,3,9,6,8
24 [1,8,1,9,1,5,2,6,7,2,8,5,2,9,6,4,7,5,3,8,4,6,3,9
25 [1,9,1,6,1,8,2,5,7,2,6,9,2,5,8,4,7,6,3,5,4,9,3,8
26 [3,4,7,8,3,9,4,5,3,6,7,4,8,5,2,9,6,2,7,5,2,8,1,6
27 [3,4,7,9,3,6,4,8,3,5,7,4,6,9,2,5,8,2,7,6,2,5,1,9
28 [7,5,3,8,6,9,3,5,7,4,3,6,8,5,4,9,7,2,6,4,2,8,1,2
29 + (try_sols(8),num_solutions(6))).
  
```

**Example - A simple puzzle** run ►

Write a Prolog program that generates (as a list) a sequence that:

- includes three 1's, three 2's, . . . , and three 9's,
- and between each digit i and the next i there are exactly i elements.

E.g.:

```
[1,9,1,2,1,8,2,4,6,2,7,9,4,5,8,6,3,4,7,5,3,9,6,8,3,5,7]
```

```

1 % Write the solution as the following predicate, such that S is a
2 % solution to the puzzle:
3
4 solution(S) :-
  
```

★ Show solution

- To test your solution, press the 'thinking face'.
- To run your solution load it by pressing the question mark above, and use the following query:

```
?- solution(S).
```

Alternatively, you can try and debug your solution in the playground by pressing the arrow.

Figure 6: Creating and Editing an Active Logic Document in the Playground. Click on 'run ►' above to open in Playground (the link was also obtained via [Share](#)).

be used to very easily create editable and runnable educational resources for teaching Prolog and logic programming, such as on-line tutorials, slides, activities, runnable examples, programming exercises, web sites, manuals, etc. It is also possible to develop tutorials for advanced features, such as analyzers and verifiers [11].

In comparison with other approaches to notebooks [12, 13, 14, 15], a fundamental aspect of the ALD approach is that all the reactive parts run locally on the user's web browser without any dependency on a central server or a local Prolog installation. Also, output can be generated from and stored in simple source files that can be developed with any editor. Arguably, the ALD approach has advantages from the point of view of scalability, low maintenance cost, security, privacy, ease of packaging and distribution, etc.

### 3. Some New Features


We now turn to describing some new extensions and improvements to the Prolog Playground and ALD-style notebooks since the first versions of [2, 3] that we described in the previous section:

**In-Playground creation and editing of Active Logic Documents.** One of the main improvements since the early versions has been to better support *within the Playground* the process of developing ALD notebooks with embedded running examples and quizzes. To this end the Playground has two distinct modes, *code mode* and *document mode* (see Figure 6). The current mode is identified by the `.md` or `.pl` button shown in the button bar, which also allows changing the mode (Figure 6). You can see an example by clicking on 'run ►' in Figure 6. The ALD can then be edited by clicking on the pencil icon on the top right. The link was obtained as usual with the [Share](#) button. These two modes

## A traditional example - family relations.

open slides ►

```
1 mother_of(susan, mary).
2 mother_of(susan, john).
3 mother_of(mary, michael).
4
5 father_of(john, david).
6
7 grandmother_of(X,Y) :-
8   mother_of(X,Z), mother_of(Z,Y).
9 grandmother_of(X,Y) :-
10  mother_of(X,Z), father_of(Z,Y).
```

We can load (clicking on ) and get answers to questions in different modes:

?- mother\_of(susan,Y).

?- mother\_of(X,mary).




?- grandmother\_of(X,Y).



**All these queries will return the correct solution and terminate using standard Prolog.**

All is good! However, things can quickly get more complicated...

**Figure 7:** An example ALD slide from a presentation. Click on 'open slides ►' above to open in the Playground for viewing and editing the full set of slides.

enable a flexible and integrated workflow: in code mode one can write and test code snippets, and also annotate them with documentation and explanations, and in document mode one can incorporate these examples into documents as exercises, notes, etc., all fully within the browser.

**Presentation mode.** The mode in which the ALD notebook appears when clicking on 'run ►' in Figure 6 is another improvement: *presentation mode*. Presentation mode provides the traditional full view of ALD notebooks but within the Playground. I.e., in presentation mode, only the document panel (the right panel in Figure 6) is visible, without buttons or menus, similarly to a statically generated ALD. However, in contrast to statically generated ALDs, by clicking on the pencil icon  on the top right, one can enter (or return to) the normal Playground to view and edit the ALD notebook. Presentation mode can also be entered from the editing view via the  button. Links obtained with the  Share button in document mode will open by default in presentation mode so that they can be used directly as notes, exercises, etc. For example, instructors can prepare exercises and notes in the editor view, and then send the links to students (or include them in an exercise sheet, slides, etc.), and the students see the presentation view when they click on these links.

**ALD slides.** A further improvement is the possibility of creating ALDs as slides for presentations (still with embedded examples and quizzes), and of delivering the presentations directly with the Playground. An example is 'these slides' (a subset of the presentation of [16]; see Figure 7). Any ALD can be presented in slides form by clicking on the rectangular icon top right , which switches modes. By default in slides mode the ALD is split into separate slides at section boundaries (other mechanisms exist, but this one is the simplest and has proved useful in practice). Slides mode also uses presentation-friendly fonts and layout. Slides mode can be exited using the escape key and then the pencil icon can be used to edit the slides in the standard way. And again the  Share button can be used to share the slides. These presentations are full ALDs, written with the same markdown-style syntax and allowing the inclusion of interactive components, such as code editors, query boxes, etc.. This has proven particularly useful for class lectures including live demonstrations, and also workshops, etc.



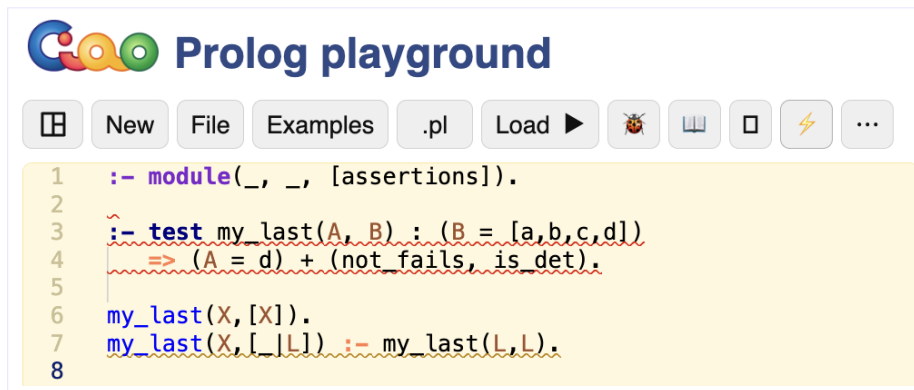


Figure 8: Errors from tests appearing dynamically in on-the-fly mode (⚡).

**Reactive (on-the-fly) mode.** A fully reactive mode is now available (toggled via the ⚡ button), in which feedback and results are shown on-the-fly as the student types. This includes real-time syntax checking, incremental goal evaluation, incremental testing, incremental analysis/verification, incremental documentation, and in general dynamic result previews. As a result, errors and warnings (from compilation, testing, static analysis/verification, etc.) are immediately highlighted on the source, and partial solutions and hints displayed, as the code is typed. As a simple example, Figure 8 shows a situation in which an error is introduced (in line 7), the tests are automatically triggered, and a failing test is underlined in red, indicating on the fly that the change causes that test to not pass. Figure 9 is a snapshot of how analysis results are also generated dynamically as the program is typed. Also, documentation is generated and the preview pane updated dynamically as the comments or assertions are typed in the code pane. The same applies to ALD notebooks, which are generated and visualized incrementally in the visualization pane. Figure 10 shows a snapshot of an ALD being generated dynamically in on-the-fly mode as the markdown source is being typed.

**Interactive collaboration.** New facilities have been added for this purpose (👥 button). In particular, Prolog Playground and ALD notebook instances can now be shared among several users and worked on concurrently. This is particularly useful for collaboration between the lecturer and students in the classroom (both in person and remote), and for collaborative work among students.



Figure 9: Errors from static analysis appearing dynamically in on-the-fly mode (⚡).

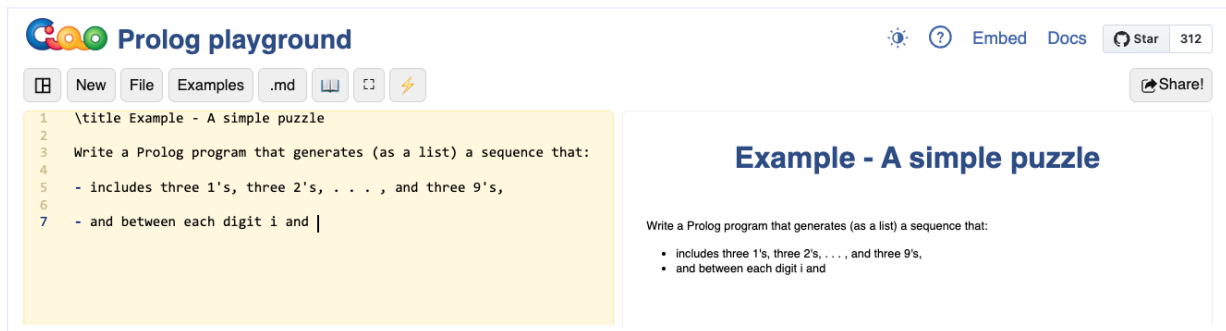


Figure 10: ALDs being rendered incrementally in on-the-fly mode.

**Integration of the LPTP prover.** A recent extension is the integration of the LPTP theorem prover for Prolog [17] within the Playground, which has been completed in collaboration with Fred Mesnard and colleagues. Figure 12 shows an example program and part of a lemma and its proof, as well as the menu with entries for checking the proofs, choosing tactics, etc. It is also possible to include programs with proofs and run the prover within runnable cells in ALD notebooks. Space limitations do not allow us to go into more details about this very interesting topic, but this integration opens the door to teaching within the Playground and ALDs how to carry out theorem proving tasks for Prolog programs, and develop active materials, exercises, assignments, etc.

## 4. Conclusions: The Tools in Classroom Practice

We conclude with some comments on the use of these tools in practice in and for the classroom.

Regarding teaching materials, some lecturers and course creators often prefer to develop (or have already developed) these with their favorite tools (LaTeX, Word, PowerPoint, Keynote, Pages, etc.), and may be reluctant to use a new platform. The Playground “click-to-run” functionality is ideal here: examples in course materials can be loaded into the Playground and links generated which can then be included in these materials next to the examples, independently of the tools used or the generated format (pdf, html, etc.). Code remains in the teaching materials themselves with no dependencies on any code server. Examples of this approach can be found in the pdfs labeled “slides with embedded code” from our (C)LP courses.<sup>5</sup> However, for new materials or for renewing existing materials, ALDs are

<sup>5</sup>See <https://cliplab.org/logalg>.

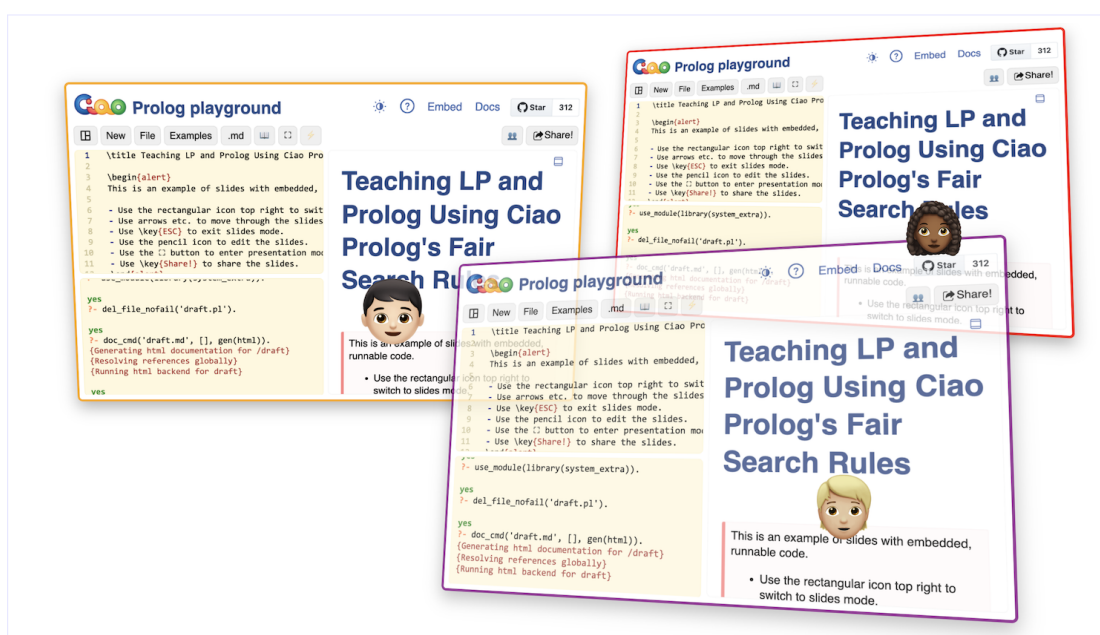
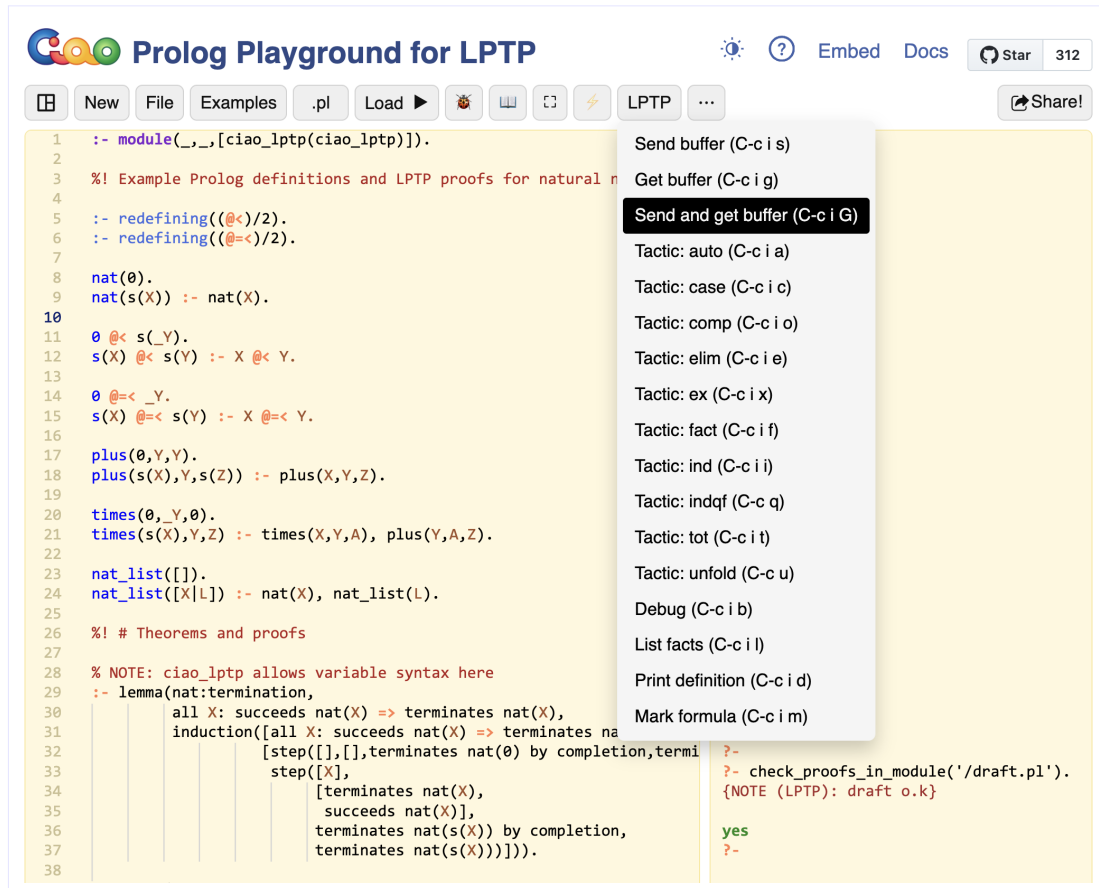


Figure 11: Collaboration mode: several playgrounds connected.



**Figure 12:** Integration of the LPTP prover in the Playground.

very useful, since they allow developing engaging, interactive exercises and assignments, class notes, tutorials, etc. with built-in self-assessment. The new ALD slides are also instrumental for developing material for lectures containing runnable examples. Finally, the new interactive collaboration facilities greatly facilitate involving students during lectures, keeping them engaged.

Regarding the personal work of students, we have observed that some of our (college-level, CS) students<sup>6</sup> still do install the Prolog system in their laptops and use VSC or Emacs, as we actually suggest, since this is always closer to how a programming language is used in application development. But the majority of students prefer the Playground, because it saves them installation time and hassle. Also, the Playground is clearly preferable in other contexts such as younger, non CS, no laptop, etc. students. The Playground and the runnable cells in ALDs offer performance that is competitive with native Prolog implementations (around 50% of Ciao Prolog native speed) and provide access to most of Ciao Prolog's functionality, including Pure LP (with several search rules), ISO-Prolog, higher-order, functional syntax, constraints, imperative syntax, ASP/s(CASP), etc. Fair search rules in particular are very useful in the early stages of LP instruction for running examples under a pure, declarative view. This avoids having to face non-termination prematurely and force introducing operational aspects too early, which can hamper the first learning steps (see [16] and [18] for arguments in favor of this approach).

The new features that we have presented are aimed at further lowering the barrier to creating and delivering interactive, browser-based, server-independent Prolog material. At the same time, they help improve the student learning experience by making it more active, responsive, and self-directed. We believe these developments make the Playground+ALDs toolset particularly well-suited for modern logic programming education. We hope these new additions to the Playground and ALDs, as well as our reflections, will be of interest to the PEG audience and in general to all those interested in Prolog Education.

<sup>6</sup>We teach a full semester of Prolog/(C)LP to upwards of 400 CS undergraduate and graduate students every year.



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**Declaration on Generative AI:** The authors have not employed any GenAI tools for this paper.