



UNIVERSIDAD DE MÁLAGA

UNIVERSITY OF MÁLAGA
SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

SyntaxTutor

Developer Manual

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Chapter 1

SyntaxTutor: An interactive Tool for Learning Syntax Analysis

[SyntaxTutor](#) is an educational application designed to help compiler students understand LL(1) and SLR(1) parsing algorithms. Through a visual and interactive interface, it guides users step-by-step through the computation of FIRST, FOLLOW, CLOSURE, GOTO, predictive parsing tables, and LR automata, offering real-time pedagogical feedback.

Rather than acting as a mere calculator, [SyntaxTutor](#) functions as a learning companion. It explains the reasoning behind each step, highlights common mistakes, and encourages students to engage with the theory behind the algorithms.

1.1 Academic Context

[SyntaxTutor](#) is part of a Final Degree Project (TFG) developed at the University of Málaga (UMA), in the Computer Engineering program. Its main goal is to offer an educational companion for students learning syntax analysis, going beyond traditional calculators by incorporating guided feedback, visualization, and gamified learning.

1.2 Key Features

- **Educational Focus:** built to teach, not just compute.
 - **Visualization:** derivation trees, intermediate steps, sets, and tables.
 - **Exportable Results:** useful for reports or coursework.
-

1.3 Interface Screenshots

1.3.1 Main Menu

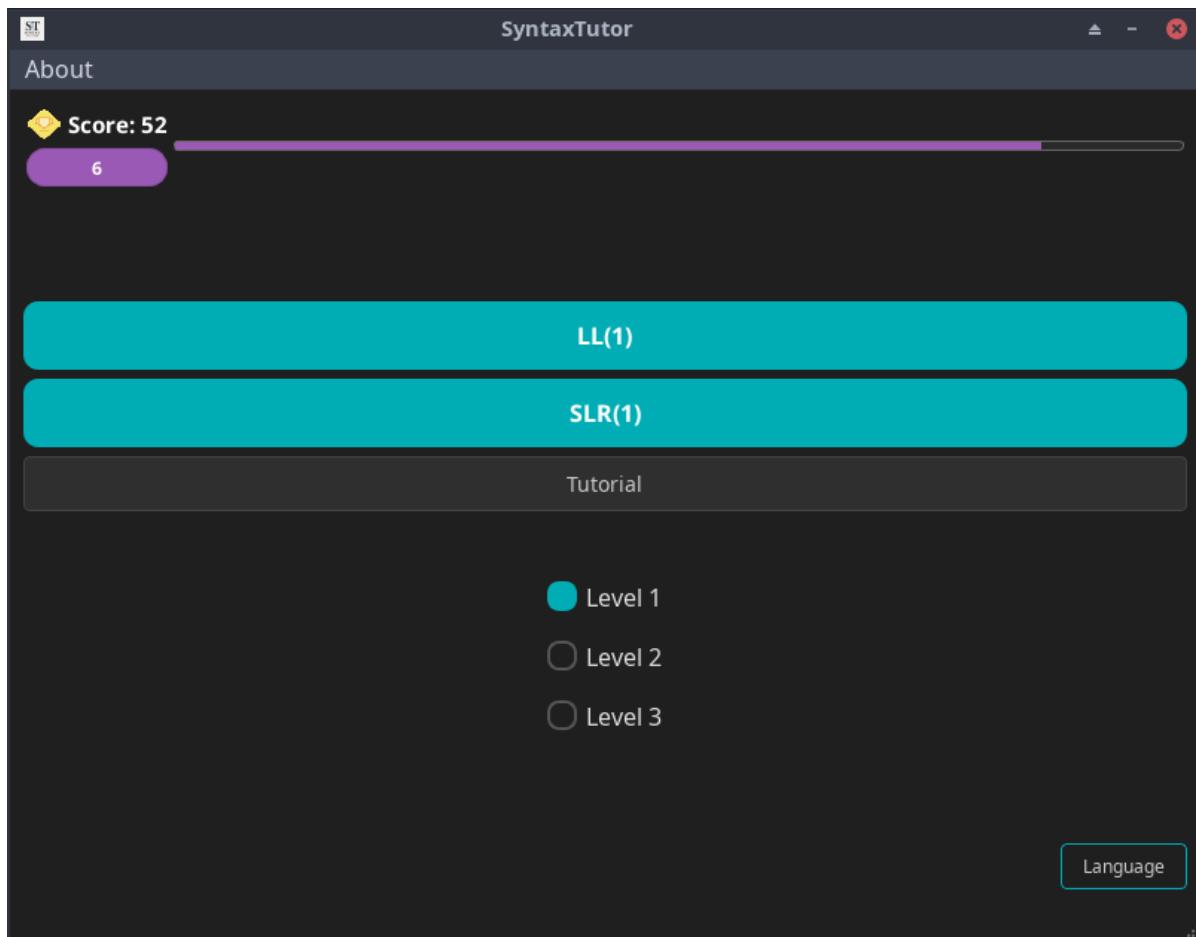


Figure 1.1 Main window

Home screen with gamification, levels, and language options.

1.3.2 LL(1) Learning Mode

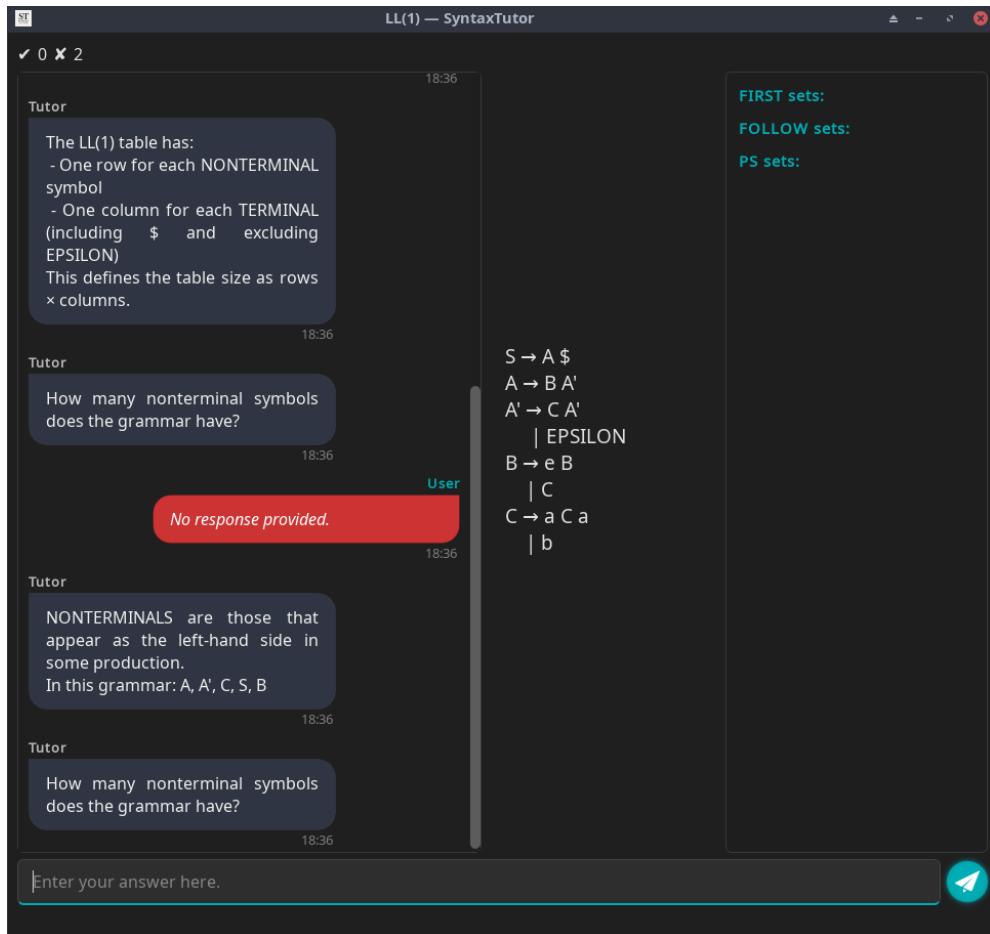


Figure 1.2 LL(1) dialog view

Interactive LL(1) tutor asks questions and provides feedback.

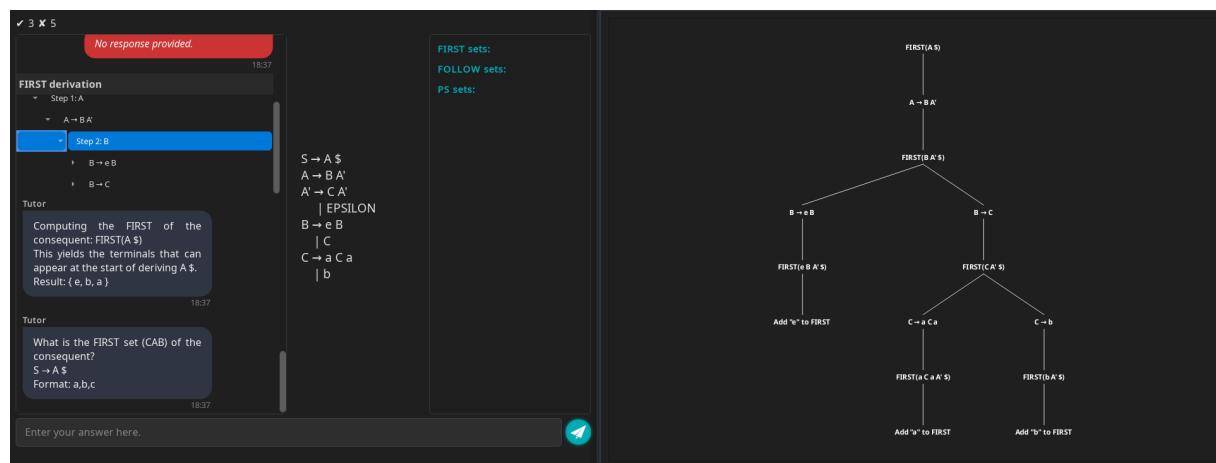


Figure 1.3 LL(1) derivation tree

Derivation tree view showing how FIRST sets are built step-by-step.

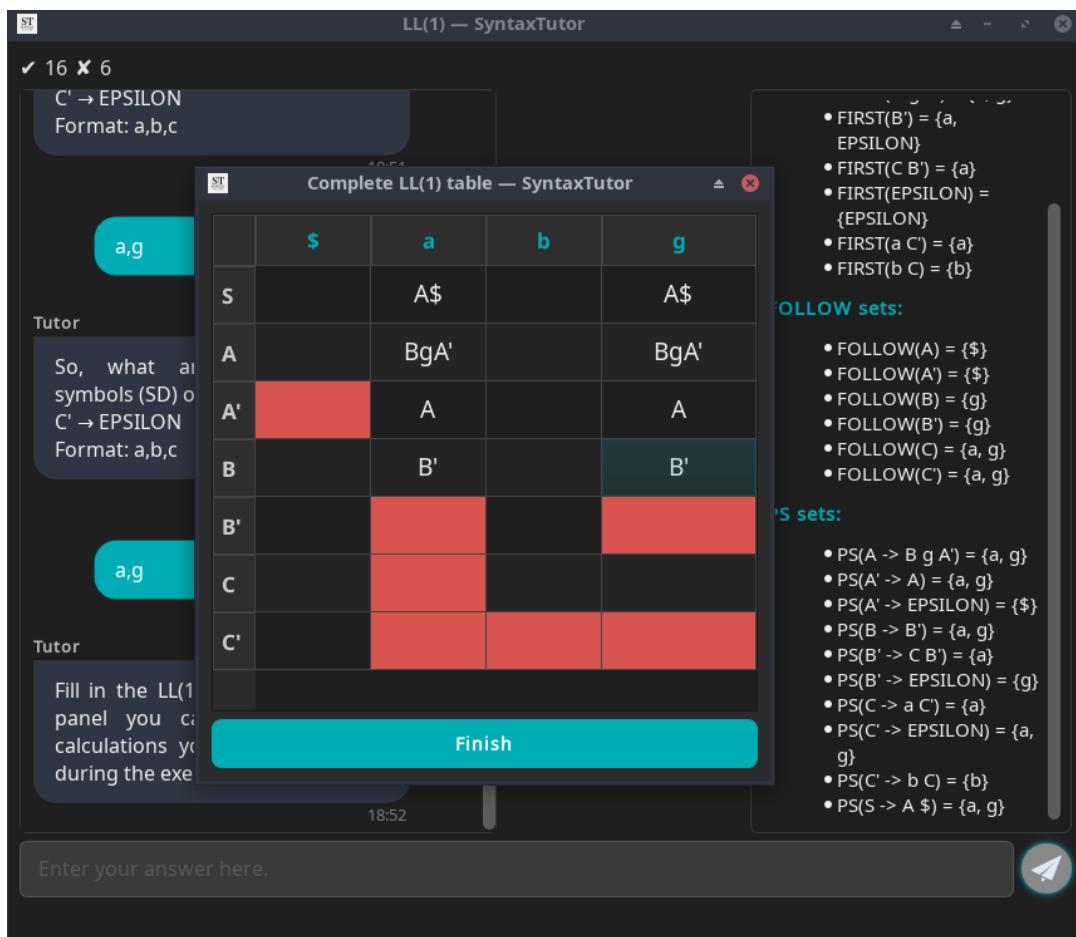


Figure 1.4 LL(1) table task

Completion of the LL(1) predictive table with visual guidance.

1.3.3 SLR(1) Learning Mode

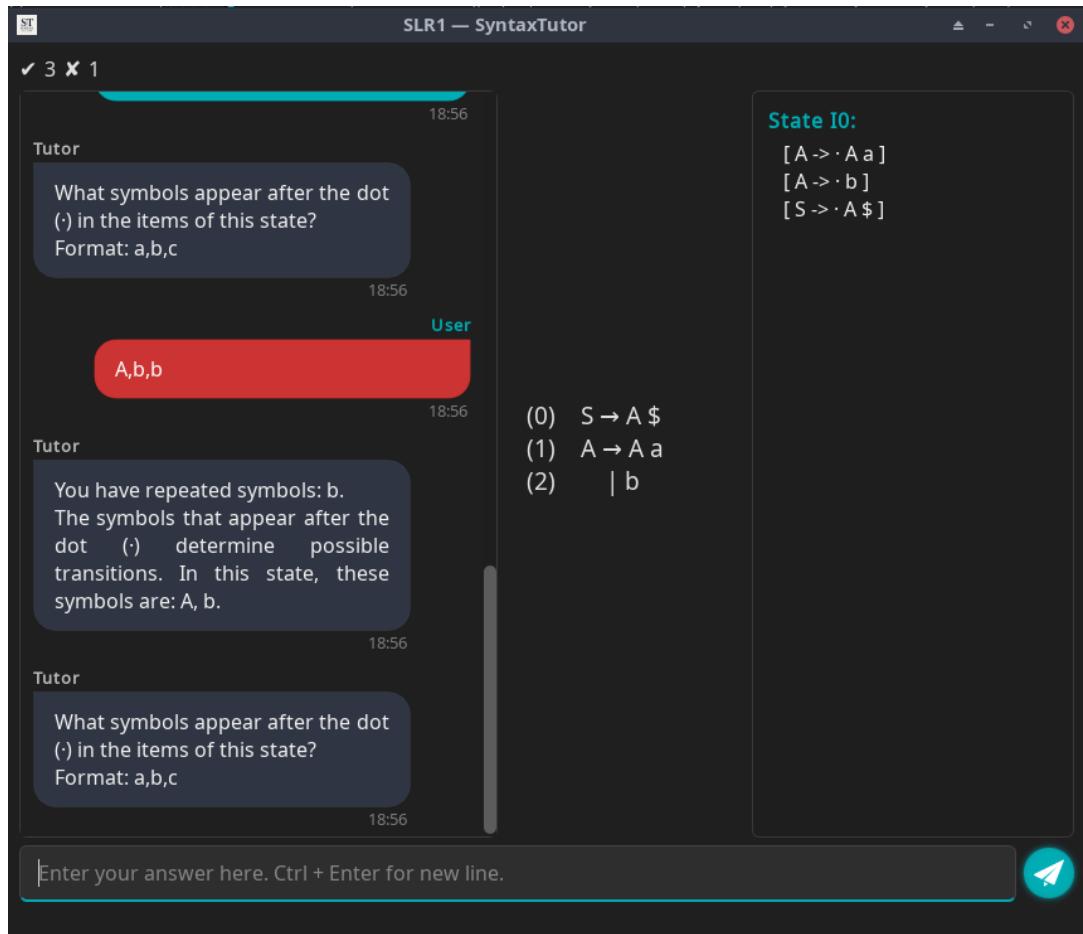


Figure 1.5 SLR(1) item view

User is asked to identify symbols after the dot in an LR(0) item.

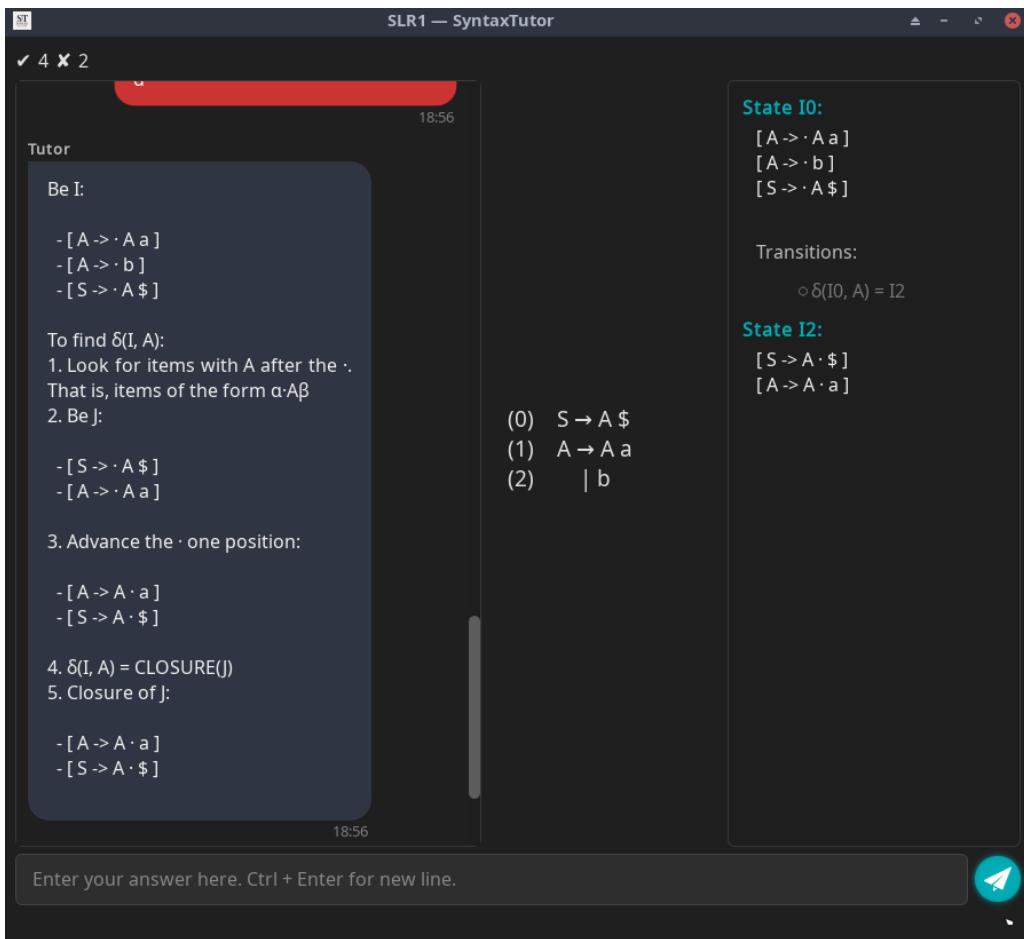


Figure 1.6 SLR(1) automaton construction

Step-by-step explanation of the GOTO/closure construction.

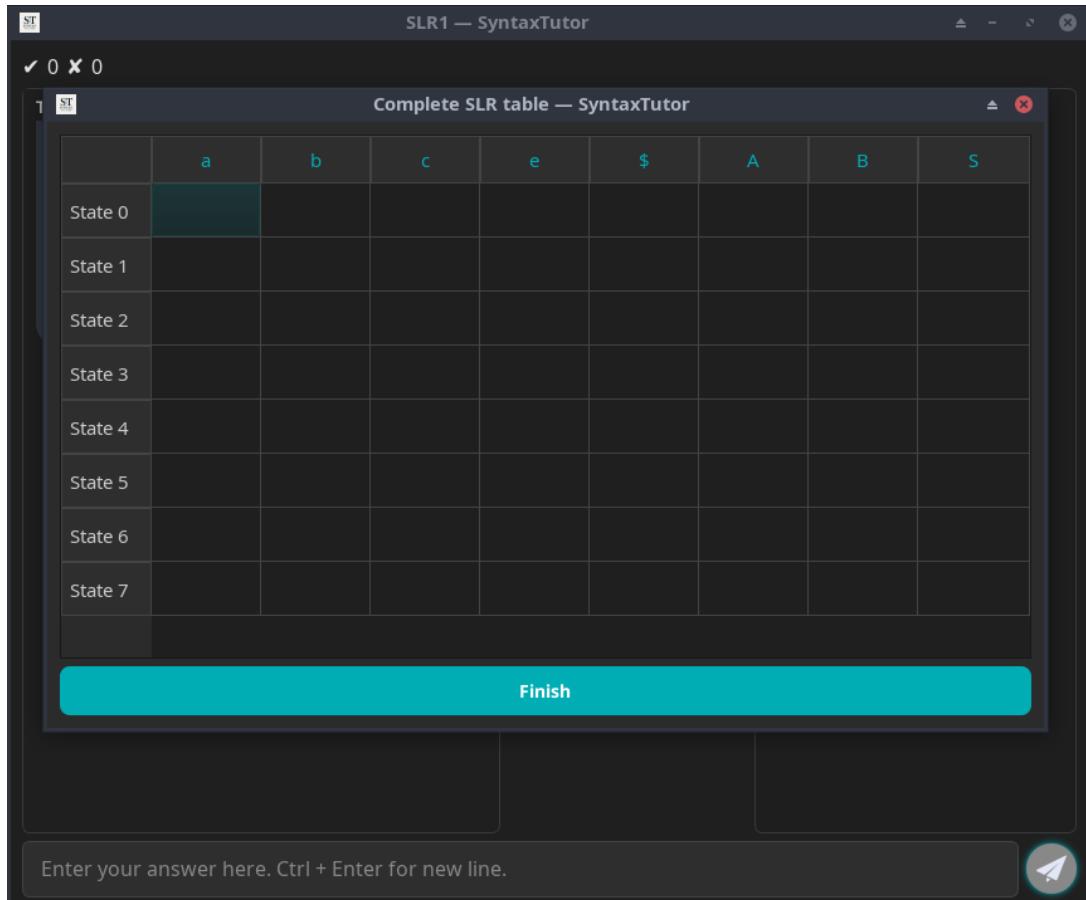


Figure 1.7 SLR(1) table fill-in

Interactive SLR(1) table to complete, with states and terminals/non-terminals.

1.3.4 Assisted Mode: Guided Table Completion

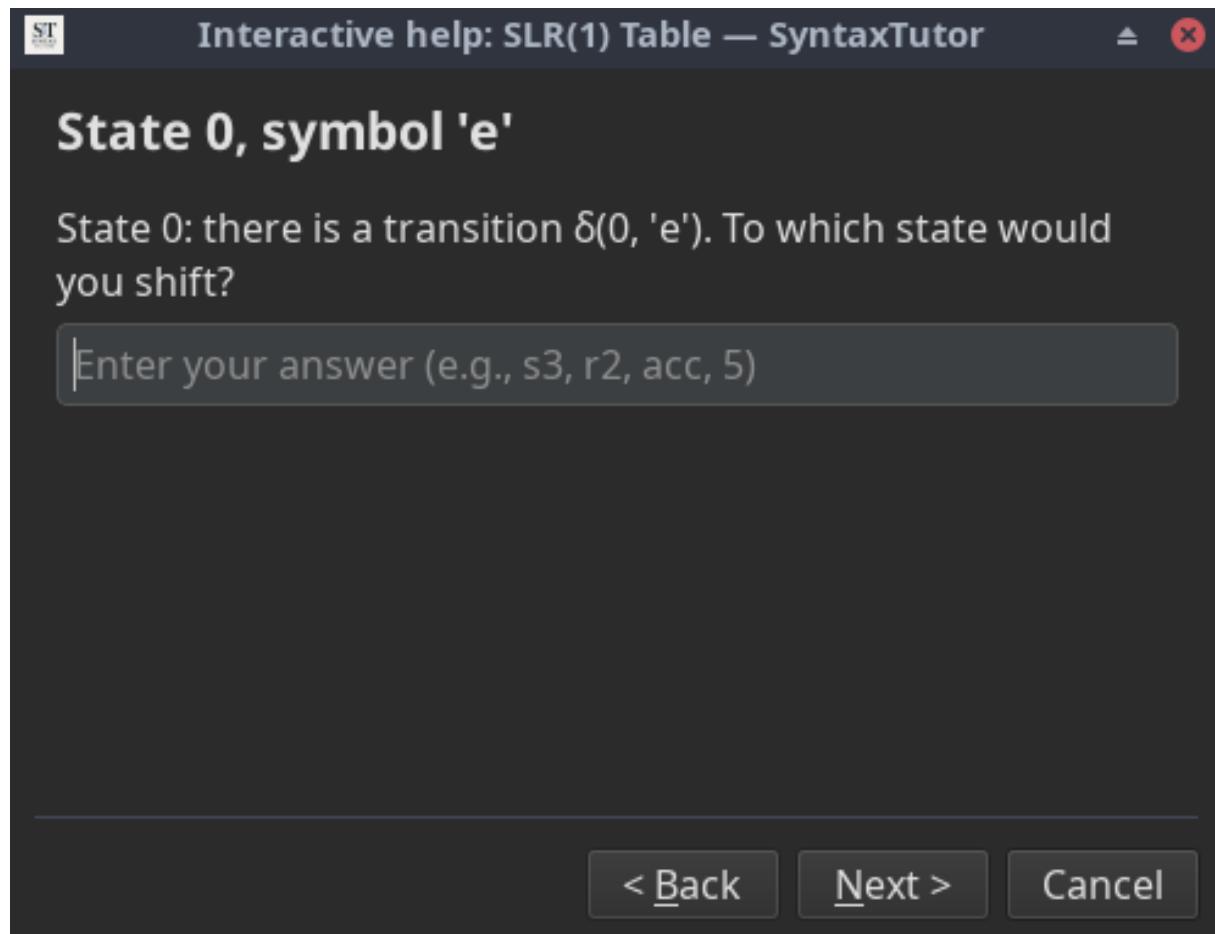


Figure 1.8 SLR(1) guided mode

SyntaxTutor walks the student through each cell in the parsing table with hints and context.

1.4 Technologies Used

- **C++:** efficient implementation of parsing algorithms
 - **Qt6:** modern, cross-platform graphical user interface.
 - **Modular architecture:** clean separation between logic and UI, designed for easy extensibility.
-

1.5 Downloads

Precompiled builds of SyntaxTutor are available in the Releases tab:

- Linux (X11): executable AppImage
- Windows: ZIP archive with the .exe
- macOS: .app bundles for both Apple Silicon (ARM) and Intel

Warning

The Windows and macOS versions are not digitally signed. Your operating system may display a warning when running the application. You can bypass it manually if you trust the source.

1.6 Building from Source

To build [SyntaxTutor](#) from source, you just need:

- Qt6 (including `qmake6`)
- A C++20-compliant compiler

```
qmake6  
make
```

1.6.1 Documentation

Full documentation for the source code is available via Doxygen:

- **Online HTML Documentation:** <https://jose-rzm.github.io/SyntaxTutor/>
- **PDF Reference Manual:** [refman.pdf](#) (in the `docs/latex/` folder)

The documentation includes:

- Detailed class and function reference
- Graphs of dependencies and inheritance
- Descriptions of parsing algorithms and internal logic

To regenerate it locally, install [Doxygen](#) and run:

```
doxygen
```

This will update the contents of the `docs/` folder with both HTML and LaTeX output.

Chapter 2

Changelog

All notable changes to this project will be documented in this file.

2.1 [1.0.4] - 2025-11-07

Minor usability improvements in user input handling and enhancements to the pre-release workflow to simlify future releases.

2.1.1 Added

- Tutorial hint explaining the expected format used in SLR table question (H)

2.1.2 Fixed

- Remove all spaces in LL/SLR table questions (C-C' and H steps)

2.2 [1.0.3] - 2025-11-04

Minor usability improvements in user input handling.

2.2.1 Added

- Allow the user to write A → . instead of A → EPSILON .

2.2.2 Fixed

- Accept input containing spaces in responses such as x, y

2.3 [1.0.2] - 2025-07-16

2.3.1 Added

- User manual in Spanish ([manual/SyntaxTutor-Manual-ES.pdf](#))
- User manual in English ([manual/SyntaxTutor-Manual-EN.pdf](#))
- Developer manual ([manual/SyntaxTutor-Developer-Manual.pdf](#))
- Script to customize titlepage ([manual/patch_refman_title.sh](#))

2.3.2 Fixed

- Fixed issue when exporting PDF in SLR mode.
- Fixed some feedback in SLR mode

2.4 [1.0.1] - 2025-06-17

2.4.1 Added

- Added `Doxyfile` for automatic documentation generation with Doxygen.
- Completed missing translations for multilingual support (English/Spanish).

2.4.2 Fixed

- Corrected a typo in the SLR(1) Quick Reference view.
- EPSILON is no longer shown when exporting LL(1) parse tables to PDF.
- Improved feedback message for the FA question in the SLR module.

2.4.3 Quality

- All changes successfully passed CI (GitHub Actions).
- Test suite: 158 tests passed (100% success rate).
- Maintained high test coverage across modules (most above 90%).

2.5 [1.0.0] - 2025-06-15

2.5.1 Initial Release

- First public version of [SyntaxTutor](#).
- Includes LL(1) and SLR(1) modules with guided exercises.
- Features interactive tutoring, automatic grammar generation, feedback system, and performance tracking.

Chapter 3

Directory Hierarchy

3.1 Directories

backend	23
grammar.cpp	116
grammar.hpp	116
grammar_factory.cpp	118
grammar_factory.hpp	118
ll1_parser.cpp	121
ll1_parser.hpp	121
lr0_item.cpp	123
lr0_item.hpp	123
slr1_parser.cpp	125
slr1_parser.hpp	125
state.hpp	127
symbol_table.cpp	129
symbol_table.hpp	129

Chapter 4

Namespace Index

4.1 Namespace List

Here is a list of all namespaces with brief descriptions:

SyntaxTutor	25
SyntaxTutor::Version	25

Chapter 5

Hierarchical Index

5.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

GrammarFactory::FactoryItem	29
Grammar	30
GrammarFactory	34
LL1Parser	49
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QDialog	
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QMainWindow	
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SLR1Parser::s_action	75
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SymbolTable	104
LLTutorWindow::TreeNode	107
TutorialStep	112
UniqueQueue< T >	113

Chapter 6

Class Index

6.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

CenterAlignDelegate	27
CustomTextEdit	28
GrammarFactory::FactoryItem	
Represents an individual grammar item with its associated symbol table	29
Grammar	
Represents a context-free grammar, including its rules, symbol table, and starting symbol	30
GrammarFactory	
Responsible for creating and managing grammar items and performing checks on grammars	34
LL1Parser	49
LLTableDialog	
Dialog for filling and submitting an LL(1) parsing table	55
LLTutorWindow	
Main window for the LL(1) interactive tutoring mode in SyntaxTutor	57
Lr0Item	
Represents an LR(0) item used in LR automata construction	68
MainWindow	
Main application window of SyntaxTutor , managing levels, exercises, and UI state	71
SLR1Parser::s_action	75
SLR1Parser	
Implements an SLR(1) parser for context-free grammars	75
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Dialog window for completing and submitting an SLR(1) parsing table	85
SLRTutorWindow	
Main window for the SLR(1) interactive tutoring mode in SyntaxTutor	87
SLRWizard	
Interactive assistant that guides the student step-by-step through the SLR(1) parsing table	100
SLRWizardPage	
A single step in the SLR(1) guided assistant for table construction	102
state	
Represents a state in the LR(0) automaton	103
SymbolTable	
Stores and manages grammar symbols, including their classification and special markers	104
LLTutorWindow::TreeNode	
TreeNode structure used to build derivation trees	107
TutorialManager	
Manages interactive tutorials by highlighting UI elements and guiding the user	107
TutorialStep	
Represents a single step in the tutorial sequence	112
UniqueQueue< T >	
A queue that ensures each element is inserted only once	113

Chapter 7

File Index

7.1 File List

Here is a list of all files with brief descriptions:

appversion.h	115
customtextedit.cpp	130
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backend/symbol_table.hpp	129

Chapter 8

Directory Documentation

8.1 backend Directory Reference

Files

- file [grammar.cpp](#)
- file [grammar.hpp](#)
- file [grammar_factory.cpp](#)
- file [grammar_factory.hpp](#)
- file [ll1_parser.cpp](#)
- file [ll1_parser.hpp](#)
- file [lr0_item.cpp](#)
- file [lr0_item.hpp](#)
- file [slr1_parser.cpp](#)
- file [slr1_parser.hpp](#)
- file [state.hpp](#)
- file [symbol_table.cpp](#)
- file [symbol_table.hpp](#)

Chapter 9

Namespace Documentation

9.1 SyntaxTutor Namespace Reference

Namespaces

- namespace [Version](#)

9.2 SyntaxTutor::Version Namespace Reference

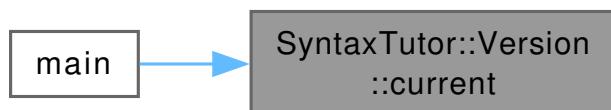
Functions

- `QString current ()`
- `const char * raw ()`

9.2.1 Function Documentation

9.2.1.1 `current()`

```
QString SyntaxTutor::Version::current () [inline]  
Here is the caller graph for this function:
```



9.2.1.2 `raw()`

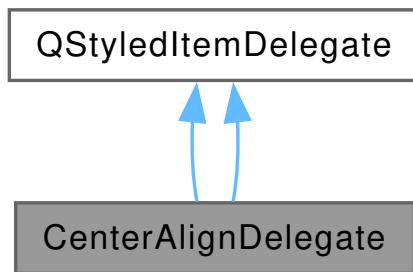
```
const char * SyntaxTutor::Version::raw () [inline]
```


Chapter 10

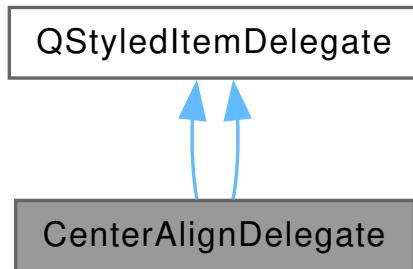
Class Documentation

10.1 CenterAlignDelegate Class Reference

Inheritance diagram for CenterAlignDelegate:



Collaboration diagram for CenterAlignDelegate:



Public Member Functions

- void [initStyleOption](#) (QStyleOptionViewItem *opt, const QModelIndex &idx) const override
- void [initStyleOption](#) (QStyleOptionViewItem *opt, const QModelIndex &idx) const override

10.1.1 Member Function Documentation

10.1.1.1 [initStyleOption\(\)](#) [1/2]

```
void CenterAlignDelegate::initStyleOption (
    QStyleOptionViewItem * opt,
    const QModelIndex & idx) const [inline], [override]
```

10.1.1.2 `initStyleOption()` [2/2]

```
void CenterAlignDelegate::initStyleOption (
    QStyleOptionViewItem * opt,
    const QModelIndex & idx) const [inline], [override]
```

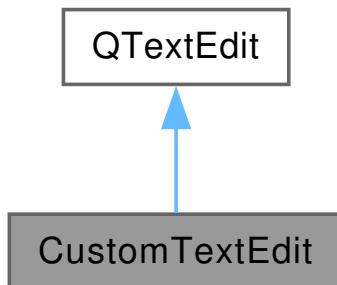
The documentation for this class was generated from the following files:

- [litabledialog.cpp](#)
- [slrtabledialog.cpp](#)

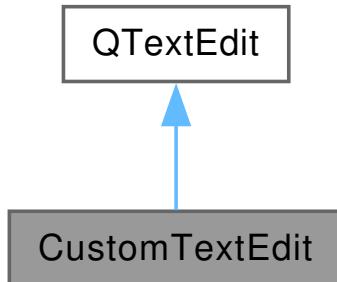
10.2 CustomTextEdit Class Reference

```
#include <customtextedit.h>
```

Inheritance diagram for CustomTextEdit:



Collaboration diagram for CustomTextEdit:



Signals

- void [sendRequested \(\)](#)

Public Member Functions

- [CustomTextEdit \(QWidget *parent=nullptr\)](#)

Protected Member Functions

- void [keyPressEvent \(QKeyEvent *event\)](#) override

10.2.1 Constructor & Destructor Documentation

10.2.1.1 CustomTextEdit()

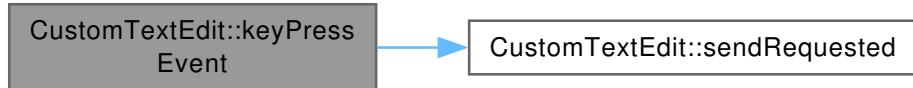
```
CustomTextEdit::CustomTextEdit (
    QWidget * parent = nullptr) [explicit]
```

10.2.2 Member Function Documentation

10.2.2.1 keyPressEvent()

```
void CustomTextEdit::keyPressEvent (
    QKeyEvent * event) [override], [protected]
```

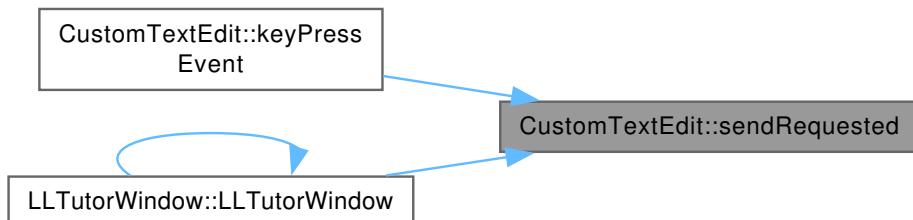
Here is the call graph for this function:



10.2.2.2 sendRequested

```
void CustomTextEdit::sendRequested () [signal]
```

Here is the caller graph for this function:



The documentation for this class was generated from the following files:

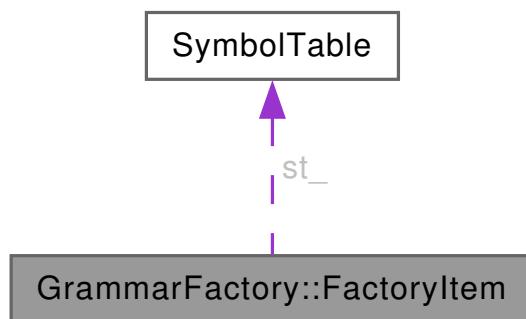
- [customtextedit.h](#)
- [customtextedit.cpp](#)

10.3 GrammarFactory::FactoryItem Struct Reference

Represents an individual grammar item with its associated symbol table.

```
#include <grammar_factory.hpp>
```

Collaboration diagram for GrammarFactory::FactoryItem:



Public Member Functions

- [FactoryItem](#) (const std::unordered_map< std::string, std::vector< production > > &grammar)

Constructor that initializes a [FactoryItem](#) with the provided grammar.

Public Attributes

- std::unordered_map< std::string, std::vector< [production](#) > > [g_](#)
Stores the grammar rules where each key is a non-terminal symbol and each value is a vector of production rules.
- [SymbolTable st_](#)
Symbol table associated with this grammar item.

10.3.1 Detailed Description

Represents an individual grammar item with its associated symbol table.

10.3.2 Constructor & Destructor Documentation

10.3.2.1 [FactoryItem\(\)](#)

```
GrammarFactory::FactoryItem::FactoryItem (
    const std::unordered_map< std::string, std::vector< production > > & grammar)
[explicit]
```

Constructor that initializes a [FactoryItem](#) with the provided grammar.

Parameters

<i>grammar</i>	The grammar to initialize the FactoryItem with.
----------------	---

10.3.3 Member Data Documentation

10.3.3.1 [g_](#)

```
std::unordered_map<std::string, std::vector<production> > GrammarFactory::FactoryItem::g_
Stores the grammar rules where each key is a non-terminal symbol and each value is a vector of production rules.
```

10.3.3.2 [st_](#)

```
SymbolTable GrammarFactory::FactoryItem::st_
```

Symbol table associated with this grammar item.

The documentation for this struct was generated from the following files:

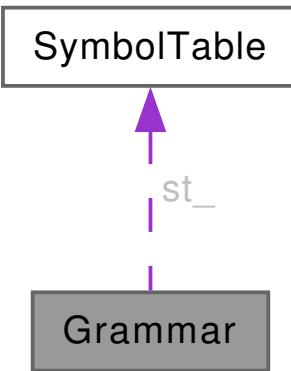
- backend/[grammar_factory.hpp](#)
- backend/[grammar_factory.cpp](#)

10.4 Grammar Struct Reference

Represents a context-free grammar, including its rules, symbol table, and starting symbol.

```
#include <grammar.hpp>
```

Collaboration diagram for Grammar:



Public Member Functions

- `Grammar ()`
- `Grammar (const std::unordered_map< std::string, std::vector< production > > &grammar)`
- `void SetAxiom (const std::string &axiom)`
Sets the axiom (entry point) of the grammar.
- `bool HasEmptyProduction (const std::string &antecedent) const`
Checks if a given antecedent has an empty production.
- `std::vector< std::pair< const std::string, production > > FilterRulesByConsequent (const std::string &arg) const`
Filters grammar rules that contain a specific token in their consequent.
- `void Debug () const`
Prints the current grammar structure to standard output.
- `void AddProduction (const std::string &antecedent, const std::vector< std::string > &consequent)`
Adds a production rule to the grammar and updates the symbol table.
- `std::vector< std::string > Split (const std::string &s)`
Splits a string into grammar symbols using the current symbol table.

Public Attributes

- `std::unordered_map< std::string, std::vector< production > > g_`
Stores the grammar rules with each antecedent mapped to a list of productions.
- `std::string axiom_`
The axiom or entry point of the grammar.
- `SymbolTable st_`
Symbol table of the grammar.

10.4.1 Detailed Description

Represents a context-free grammar, including its rules, symbol table, and starting symbol. This structure encapsulates all components required to define and manipulate a grammar, including production rules, the associated symbol table, and metadata such as the start symbol. It supports construction, transformation, and analysis of grammars.

10.4.2 Constructor & Destructor Documentation

10.4.2.1 Grammar() [1/2]

```
Grammar::Grammar () [default]
```

10.4.2.2 Grammar() [2/2]

```
Grammar::Grammar (
    const std::unordered_map< std::string, std::vector< production > > & grammar)
[explicit]
```

10.4.3 Member Function Documentation

10.4.3.1 AddProduction()

```
void Grammar::AddProduction (
    const std::string & antecedent,
    const std::vector< std::string > & consequent)
```

Adds a production rule to the grammar and updates the symbol table.

This function inserts a new production of the form $A \rightarrow$ into the grammar, where `antecedent` is the non-terminal `A` and `consequent` is the sequence . It also updates the internal symbol table to reflect any new symbols introduced.

Parameters

<code>antecedent</code>	The left-hand side non-terminal of the production.
<code>consequent</code>	The right-hand side sequence of grammar symbols.

10.4.3.2 Debug()

```
void Grammar::Debug () const
```

Prints the current grammar structure to standard output.

This function provides a debug view of the grammar by printing out all rules, the axiom, and other relevant details.

10.4.3.3 FilterRulesByConsequent()

```
std::vector< std::pair< const std::string, production > > Grammar::FilterRulesByConsequent (
    const std::string & arg) const
```

Filters grammar rules that contain a specific token in their consequent.

Parameters

<code>arg</code>	The token to search for within the consequents of the rules.
------------------	--

Returns

`std::vector` of pairs where each pair contains an antecedent and its respective production that includes the specified token.

Searches for rules in which the specified token is part of the consequent and returns those rules.

10.4.3.4 HasEmptyProduction()

```
bool Grammar::HasEmptyProduction (
    const std::string & antecedent) const
```

Checks if a given antecedent has an empty production.

Parameters

<code>antecedent</code>	The left-hand side (LHS) symbol to check.
-------------------------	---

Returns

true if there exists an empty production for the antecedent, otherwise false.

An empty production is represented as `<antecedent> -> ;`, indicating that the antecedent can produce an empty string.

10.4.3.5 SetAxiom()

```
void Grammar::SetAxiom (
    const std::string & axiom)
```

Sets the axiom (entry point) of the grammar.

Parameters

<code>axiom</code>	The entry point or start symbol of the grammar.
--------------------	---

Defines the starting point for the grammar, which is used in parsing algorithms and must be a non-terminal symbol present in the grammar.

10.4.3.6 Split()

```
std::vector< std::string > Grammar::Split (
    const std::string & s)
```

Splits a string into grammar symbols using the current symbol table.

This function tokenizes the input string `s` into a sequence of grammar symbols based on the known entries in the symbol table. It uses a greedy approach, matching the longest valid symbol at each step.

Parameters

<code>s</code>	The input string to split.
----------------	----------------------------

Returns

A vector of grammar symbols extracted from the string.

10.4.4 Member Data Documentation**10.4.4.1 axiom_**

```
std::string Grammar::axiom_
```

The axiom or entry point of the grammar.

10.4.4.2 g_

```
std::unordered_map<std::string, std::vector<production> > Grammar::g_
```

Stores the grammar rules with each antecedent mapped to a list of productions.

10.4.4.3 st_

```
SymbolTable Grammar::st_
```

Symbol table of the grammar.

The documentation for this struct was generated from the following files:

- backend/grammar.hpp
- backend/grammar.cpp

10.5 GrammarFactory Struct Reference

Responsible for creating and managing grammar items and performing checks on grammars.

```
#include <grammar_factory.hpp>
```

Classes

- struct [FactoryItem](#)

Represents an individual grammar item with its associated symbol table.

Public Member Functions

- void [Init \(\)](#)
Initializes the [GrammarFactory](#) and populates the items vector with initial grammar items.
- [Grammar PickOne \(int level\)](#)
Picks a random grammar based on the specified difficulty level (1, 2, or 3).
- [Grammar GenLL1Grammar \(int level\)](#)
Generates a LL(1) random grammar based on the specified difficulty level.
- [Grammar GenSLR1Grammar \(int level\)](#)
Generates a SLR(1) random grammar based on the specified difficulty level.
- [Grammar Lv1 \(\)](#)
Generates a Level 1 grammar.
- [Grammar Lv2 \(\)](#)
Generates a Level 2 grammar by combining Level 1 items.
- [Grammar Lv3 \(\)](#)
Generates a Level 3 grammar by combining a Level 2 item and a Level 1 item.
- [Grammar Lv4 \(\)](#)
Generates a Level 4 grammar by combining Level 3 and Level 1 items.
- [Grammar Lv5 \(\)](#)
Generates a Level 5 grammar by combining Level 4 and Level 1 items.
- [Grammar Lv6 \(\)](#)
Generates a Level 6 grammar by combining Level 5 and Level 1 items.
- [Grammar Lv7 \(\)](#)
Generates a Level 7 grammar by combining Level 6 and Level 1 items.
- FactoryItem [CreateLv2Item \(\)](#)
Creates a Level 2 grammar item for use in grammar generation.
- bool [HasUnreachableSymbols \(Grammar &grammar\) const](#)
Checks if a grammar contains unreachable symbols (non-terminals that cannot be derived from the start symbol).
- bool [IsInfinite \(Grammar &grammar\) const](#)
Checks if a grammar is infinite, meaning there are non-terminal symbols that can never derive a terminal string. This happens when a production leads to an infinite recursion or an endless derivation without reaching terminal symbols. For example, a production like:
 • bool [HasDirectLeftRecursion \(const Grammar &grammar\) const](#)
 Checks if a grammar contains direct left recursion (a non-terminal can produce itself on the left side of a production in one step).
- bool [HasIndirectLeftRecursion \(const Grammar &grammar\) const](#)
Checks if a grammar contains indirect left recursion.
- bool [HasCycle \(const std::unordered_map< std::string, std::unordered_set< std::string > > &graph\) const](#)
Checks if directed graph has a cycle using topological sort.
- std::unordered_set< std::string > [NullableSymbols \(const Grammar &grammar\) const](#)
Find nullable symbols in a grammar.
- void [RemoveLeftRecursion \(Grammar &grammar\)](#)
Removes direct left recursion in a grammar. A grammar has direct left recursion when one of its productions is.

- void [LeftFactorize \(Grammar &grammar\)](#)
Performs left factorization. A grammar can be left factorized if it has productions with the same prefix for one non-terminal. For example:
- std::vector< std::string > [LongestCommonPrefix \(const std::vector< production > &productions\)](#)
Finds the longest common prefix among a set of productions.
- bool [StartsWith \(const production &prod, const std::vector< std::string > &prefix\)](#)
Checks if a production starts with a given prefix.
- std::string [GenerateNewNonTerminal \(Grammar &grammar, const std::string &base\)](#)
Generates a new non-terminal symbol that is unique in the grammar.
- void [NormalizeNonTerminals \(FactoryItem &item, const std::string &nt\) const](#)
Replaces all non-terminal symbols in a grammar item with a single target non-terminal.
- void [AdjustTerminals \(FactoryItem &base, const FactoryItem &cmb, const std::string &target_nt\) const](#)
Adjusts the terminal symbols between two grammar items.
- std::unordered_map< std::string, std::vector< production > > [Merge \(const FactoryItem &base, const FactoryItem &cmb\) const](#)
Merges the grammar rules of two grammar items into a single grammar.

Public Attributes

- std::vector< [FactoryItem](#) > [items](#)
A vector of [FactoryItem](#) objects representing different level 1 grammar items created by the [Init](#) method.
- std::vector< std::string > [terminal_alphabet_](#)
A vector of terminal symbols (alphabet) used in the grammar.
- std::vector< std::string > [non_terminal_alphabet_](#)
A vector of non-terminal symbols (alphabet) used in the grammar.

10.5.1 Detailed Description

Responsible for creating and managing grammar items and performing checks on grammars.

10.5.2 Member Function Documentation

10.5.2.1 AdjustTerminals()

```
void GrammarFactory::AdjustTerminals (
    FactoryItem & base,
    const FactoryItem & cmb,
    const std::string & target_nt) const
```

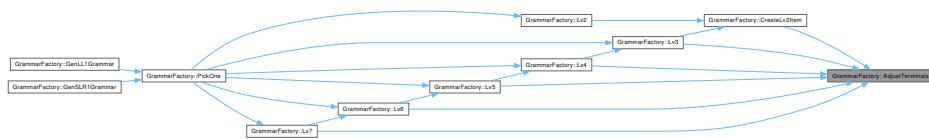
Adjusts the terminal symbols between two grammar items.

This function modifies the terminal symbols of a base grammar item so that they do not conflict with those of the item being combined. It also renames terminals to ensure consistency and inserts the target non-terminal where appropriate.

Parameters

<i>base</i>	The base grammar item to adjust.
<i>cmb</i>	The grammar item being combined with the base.
<i>target_nt</i>	The target non-terminal symbol used for replacement.

Here is the caller graph for this function:



10.5.2.2 CreateLv2Item()

`GrammarFactory::FactoryItem GrammarFactory::CreateLv2Item ()`

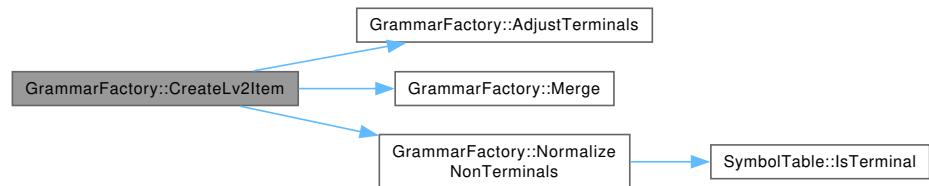
Creates a Level 2 grammar item for use in grammar generation.

This function generates a Level 2 grammar item, which can be used as a building block for creating more complex grammars.

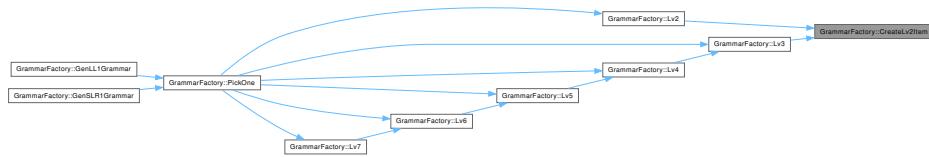
Returns

A `FactoryItem` representing a Level 2 grammar.

Here is the call graph for this function:



Here is the caller graph for this function:



10.5.2.3 GenerateNewNonTerminal()

```
std::string GrammarFactory::GenerateNewNonTerminal (
    Grammar & grammar,
    const std::string & base)
```

Generates a new non-terminal symbol that is unique in the grammar.

This function creates a new non-terminal symbol by appending a prime symbol ('') to the base name until the resulting symbol is not already present in the grammar's symbol table. It is used during left factorization to introduce new non-terminals for factored productions.

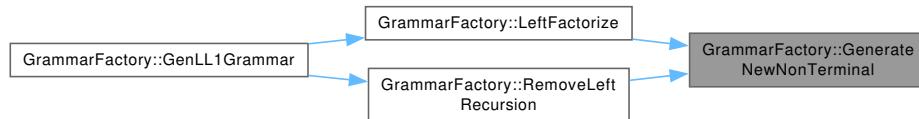
Parameters

<code>grammar</code>	The grammar in which the new non-terminal will be added.
<code>base</code>	The base name for the new non-terminal.

Returns

A unique non-terminal symbol derived from the base name.

Here is the caller graph for this function:

**10.5.2.4 GenLL1Grammar()**

```
Grammar GrammarFactory::GenLL1Grammar (
    int level)
```

Generates a LL(1) random grammar based on the specified difficulty level.

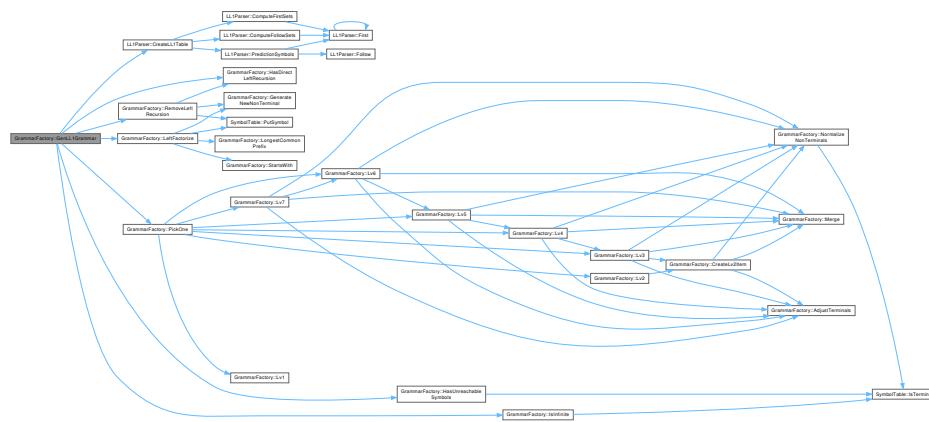
Parameters

<i>level</i>	The difficulty level (1, 2, or 3)
--------------	-----------------------------------

Returns

A random LL(1) grammar.

Here is the call graph for this function:

**10.5.2.5 GenSLR1Grammar()**

```
Grammar GrammarFactory::GenSLR1Grammar (
    int level)
```

Generates a SLR(1) random grammar based on the specified difficulty level.

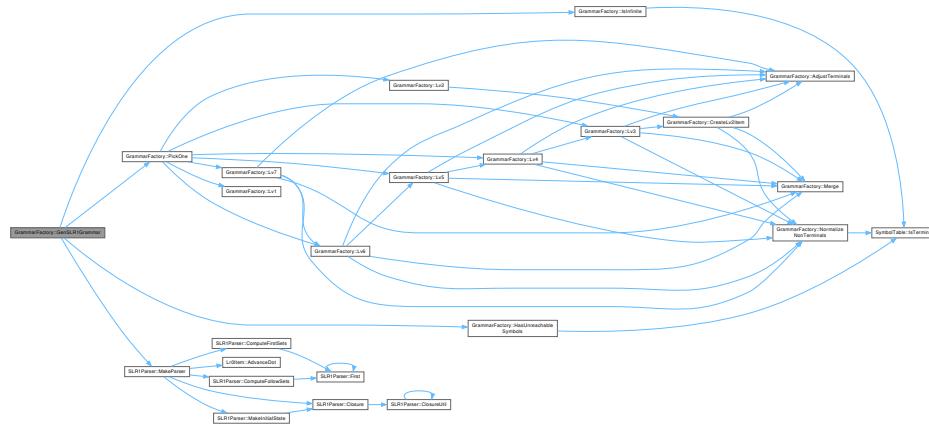
Parameters

<i>level</i>	The difficulty level (1, 2, or 3)
--------------	-----------------------------------

Returns

A random SLR(1) grammar.

Here is the call graph for this function:

**10.5.2.6 HasCycle()**

```
bool GrammarFactory::HasCycle (
    const std::unordered_map< std::string, std::unordered_set< std::string > > &
graph) const
Checks if directed graph has a cycle using topological sort.
```

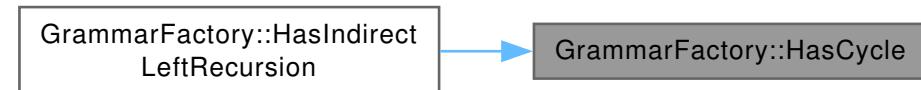
Parameters

<code>graph</code>	The directed graph.
--------------------	---------------------

Returns

true if grammar has cycle.

Here is the caller graph for this function:

**10.5.2.7 HasDirectLeftRecursion()**

```
bool GrammarFactory::HasDirectLeftRecursion (
    const Grammar & grammar) const
```

Checks if a grammar contains direct left recursion (a non-terminal can produce itself on the left side of a production in one step).

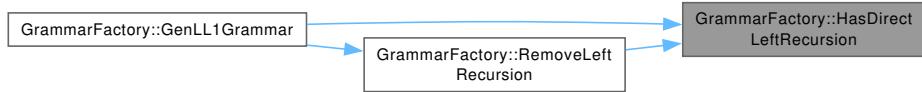
Parameters

<code>grammar</code>	The grammar to check.
----------------------	-----------------------

Returns

true if there is direct left recursion, false otherwise.

Here is the caller graph for this function:

**10.5.2.8 HasIndirectLeftRecursion()**

```
bool GrammarFactory::HasIndirectLeftRecursion (
    const Grammar & grammar) const
```

Checks if a grammar contains indirect left recursion.

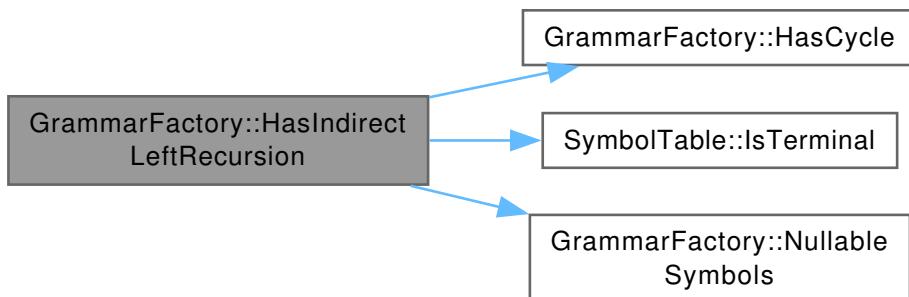
Parameters

<i>grammar</i>	The grammar to check.
----------------	-----------------------

Returns

true if there is direct left recursion, false otherwise.

Here is the call graph for this function:

**10.5.2.9 HasUnreachableSymbols()**

```
bool GrammarFactory::HasUnreachableSymbols (
    Grammar & grammar) const
```

Checks if a grammar contains unreachable symbols (non-terminals that cannot be derived from the start symbol).

Parameters

<i>grammar</i>	The grammar to check.
----------------	-----------------------

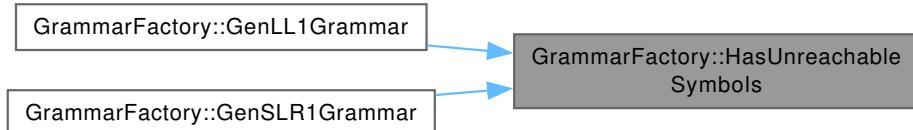
Returns

true if there are unreachable symbols, false otherwise.

Here is the call graph for this function:



Here is the caller graph for this function:

**10.5.2.10 Init()**

```
void GrammarFactory::Init ()
```

Initializes the [GrammarFactory](#) and populates the items vector with initial grammar items.

10.5.2.11 IsInfinite()

```
bool GrammarFactory::IsInfinite (
    Grammar & grammar) const
```

Checks if a grammar is infinite, meaning there are non-terminal symbols that can never derive a terminal string. This happens when a production leads to an infinite recursion or an endless derivation without reaching terminal symbols. For example, a production like:

```
S -> A
A -> a A | B
B -> c B
```

could lead to an infinite derivation of non-terminals.

Parameters

<i>grammar</i>	The grammar to check.
----------------	-----------------------

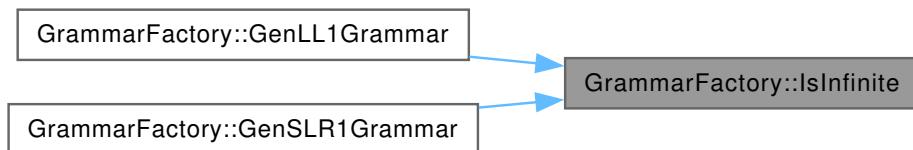
Returns

true if the grammar has infinite derivations, false otherwise.

Here is the call graph for this function:



Here is the caller graph for this function:



10.5.2.12 LeftFactorize()

```
void GrammarFactory::LeftFactorize (
    Grammar & grammar)
```

Performs left factorization. A grammar can be left factorized if it has productions with the same prefix for one non-terminal. For example:

$A \rightarrow a x \mid a y$

could be left factorized because it has "a" as the common prefix. The left factorization is done by adding a new non-terminal symbol that contains the uncommon part, and by unifying the common prefix in one production. So:

$A \rightarrow a x \mid a y$

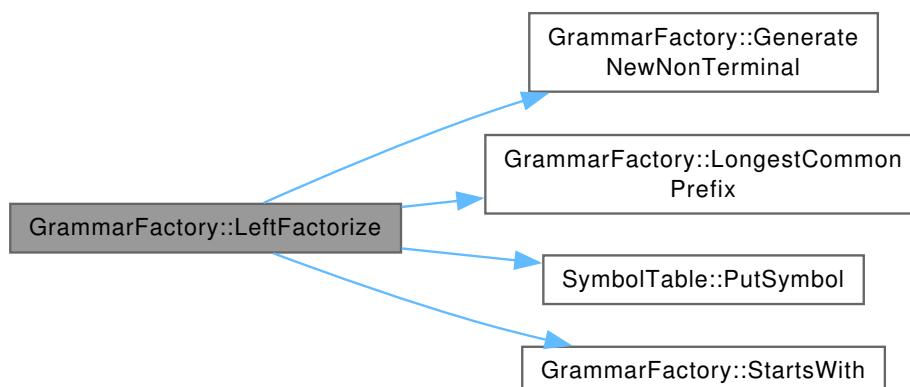
would become:

```
A   -> a A'
A' -> x | y
```

Parameters

<i>grammar</i>	The grammar to be left factorized.
----------------	------------------------------------

Here is the call graph for this function:



Here is the caller graph for this function:



10.5.2.13 LongestCommonPrefix()

```
std::vector< std::string > GrammarFactory::LongestCommonPrefix (
    const std::vector< production > & productions)
```

Finds the longest common prefix among a set of productions.

This function computes the longest sequence of symbols that is common to the beginning of all productions in the given vector. It is used during left factorization to identify common prefixes that can be factored out.

Parameters

<i>productions</i>	A vector of productions to analyze.
--------------------	-------------------------------------

Returns

A vector of strings representing the longest common prefix. If no common prefix exists, an empty vector is returned.

Here is the caller graph for this function:

**10.5.2.14 Lv1()**

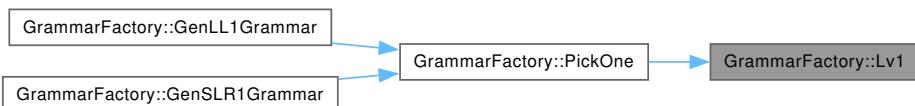
`Grammar GrammarFactory::Lv1 ()`

Generates a Level 1 grammar.

Returns

A Level 1 grammar.

Here is the caller graph for this function:

**10.5.2.15 Lv2()**

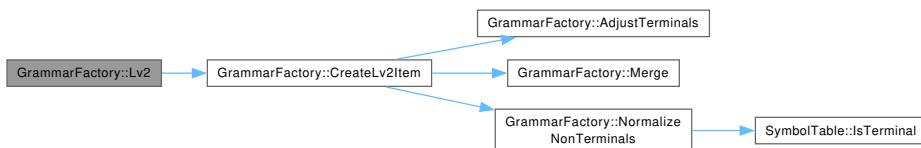
`Grammar GrammarFactory::Lv2 ()`

Generates a Level 2 grammar by combining Level 1 items.

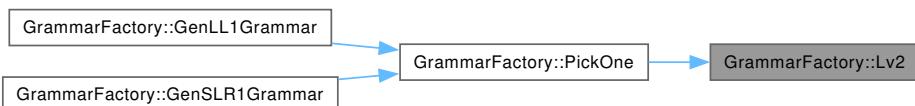
Returns

A Level 2 grammar.

Here is the call graph for this function:



Here is the caller graph for this function:

**10.5.2.16 Lv3()**

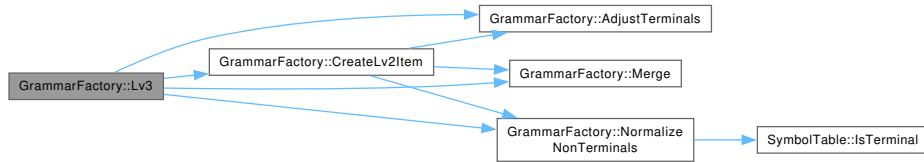
`Grammar GrammarFactory::Lv3 ()`

Generates a Level 3 grammar by combining a Level 2 item and a Level 1 item.

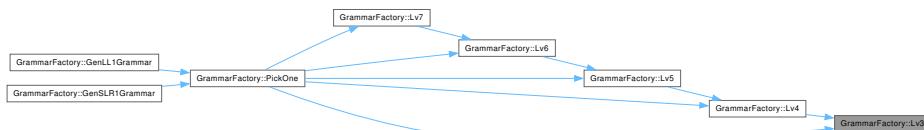
Returns

A Level 3 grammar.

Here is the call graph for this function:



Here is the caller graph for this function:

**10.5.2.17 Lv4()**

`Grammar GrammarFactory::Lv4 ()`

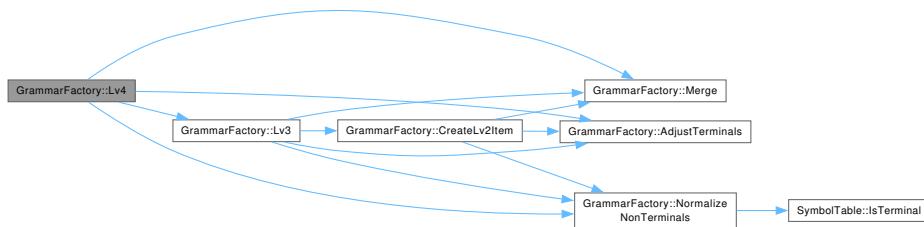
Generates a Level 4 grammar by combining Level 3 and Level 1 items.

This function creates a more complex grammar by combining elements from Level 3 and Level 1 grammars. It is used to generate grammars with increased complexity for testing or parsing purposes.

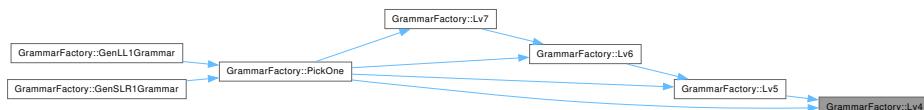
Returns

A Level 4 grammar.

Here is the call graph for this function:



Here is the caller graph for this function:

**10.5.2.18 Lv5()**

`Grammar GrammarFactory::Lv5 ()`

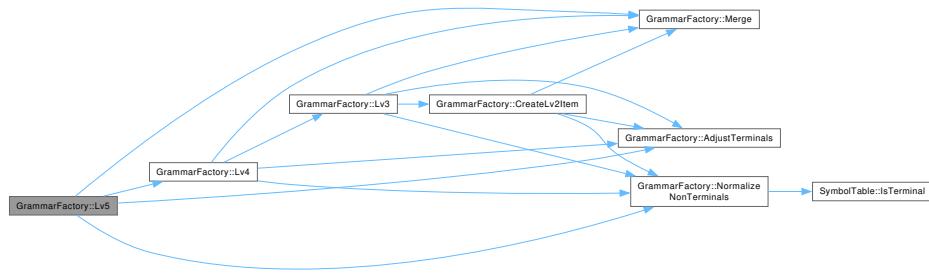
Generates a Level 5 grammar by combining Level 4 and Level 1 items.

This function creates a more advanced grammar by combining elements from Level 4 and Level 1 grammars. It is used to generate grammars with higher complexity for testing or parsing purposes.

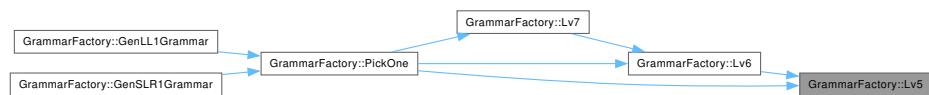
Returns

A Level 5 grammar.

Here is the call graph for this function:



Here is the caller graph for this function:

**10.5.2.19 Lv6()**

`Grammar GrammarFactory::Lv6 ()`

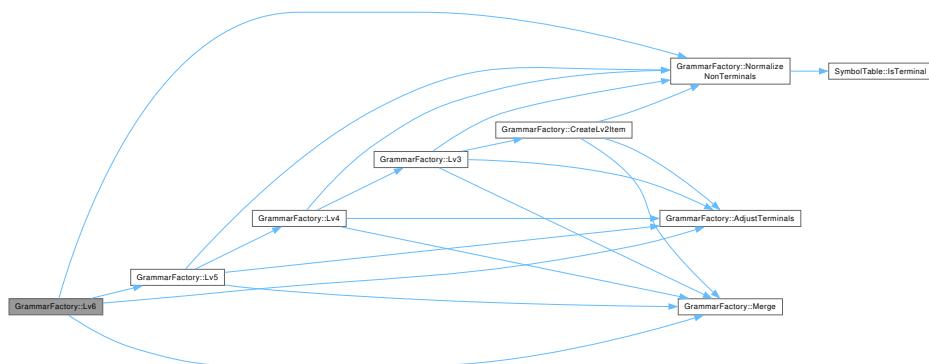
Generates a Level 6 grammar by combining Level 5 and Level 1 items.

This function creates a highly complex grammar by combining elements from Level 5 and Level 1 grammars. It is used to generate grammars with advanced structures for testing or parsing purposes.

Returns

A Level 6 grammar.

Here is the call graph for this function:



Here is the caller graph for this function:



10.5.2.20 Lv7()

```
Grammar GrammarFactory::Lv7 ()
```

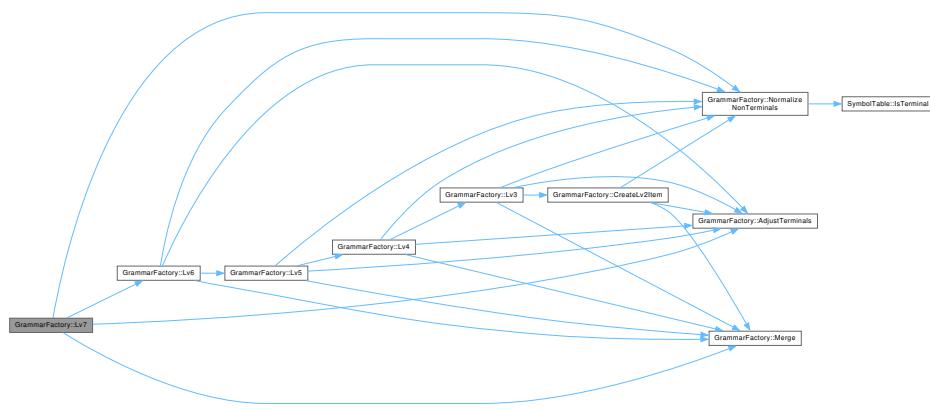
Generates a Level 7 grammar by combining Level 6 and Level 1 items.

This function creates a very complex grammar by combining elements from Level 6 and Level 1 grammars. It is used to generate grammars with highly advanced structures for testing or parsing purposes.

Returns

A Level 7 grammar.

Here is the call graph for this function:



Here is the caller graph for this function:



10.5.2.21 Merge()

```
std::unordered_map< std::string, std::vector< production > > GrammarFactory::Merge (
    const FactoryItem & base,
    const FactoryItem & cmb) const
```

Merges the grammar rules of two grammar items into a single grammar.

This function performs a raw combination of the production rules from both grammar items, resulting in a single grammar map that contains all productions.

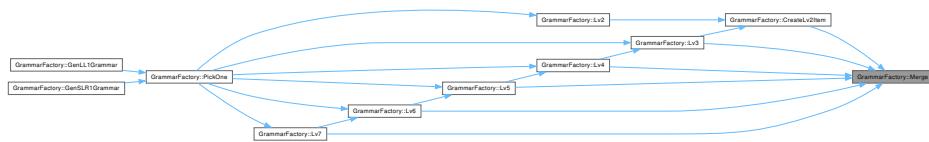
Parameters

<i>base</i>	The first grammar item.
<i>cmb</i>	The second grammar item.

Returns

A merged grammar map containing all production rules from both inputs.

Here is the caller graph for this function:

**10.5.2.22 NormalizeNonTerminals()**

```
void GrammarFactory::NormalizeNonTerminals (
    FactoryItem & item,
    const std::string & nt) const
```

Replaces all non-terminal symbols in a grammar item with a single target non-terminal.

This function is used during grammar combination to normalize the non-terminal symbols in a given [FactoryItem](#), so that they are consistent and compatible with another item.

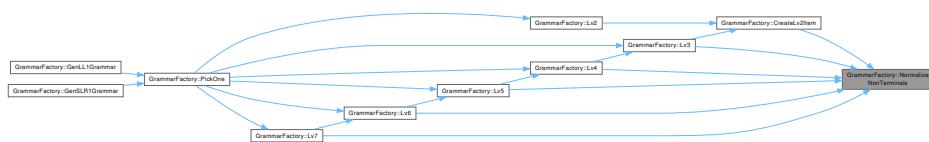
Parameters

<i>item</i>	The grammar item whose non-terminals will be renamed.
<i>nt</i>	The new non-terminal symbol that will replace all existing ones.

Here is the call graph for this function:



Here is the caller graph for this function:

**10.5.2.23 NullableSymbols()**

```
std::unordered_set< std::string > GrammarFactory::NullableSymbols (
    const Grammar & grammar) const
```

Find nullable symbols in a grammar.

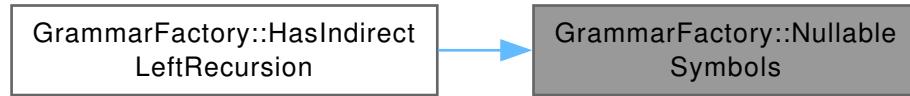
Parameters

<i>grammar</i>	The grammar to check.
----------------	-----------------------

Returns

set of nullable symbols.

Here is the caller graph for this function:

**10.5.2.24 PickOne()**

```
Grammar GrammarFactory::PickOne (
    int level)
```

Picks a random grammar based on the specified difficulty level (1, 2, or 3).

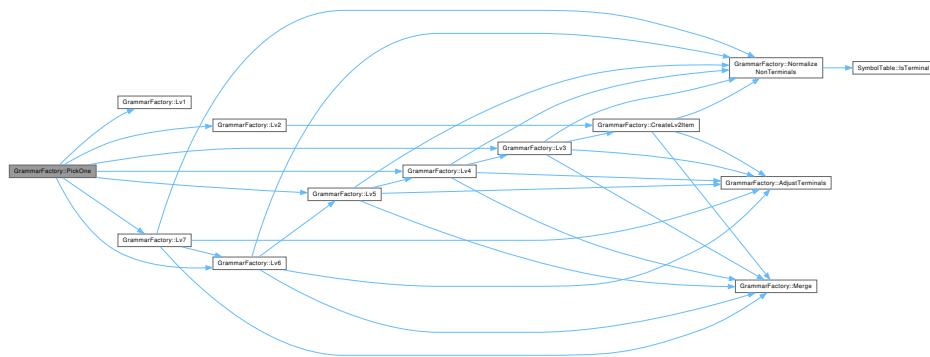
Parameters

<i>level</i>	The difficulty level (1, 2, or 3).
--------------	------------------------------------

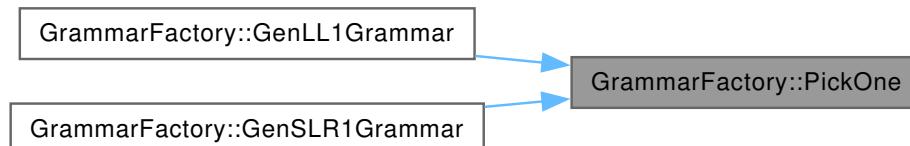
Returns

A randomly picked grammar.

Here is the call graph for this function:



Here is the caller graph for this function:

**10.5.2.25 RemoveLeftRecursion()**

```
void GrammarFactory::RemoveLeftRecursion (
    Grammar & grammar)
```

Removes direct left recursion in a grammar. A grammar has direct left recursion when one of its productions is.

$A \rightarrow A \alpha$

where A is a non-terminal symbol and "a" the rest of the production. The procedure removes direct left recursion by adding a new non-terminal. So, if the productions with left recursion are:

$A \rightarrow A \ a \mid b$

the result would be:

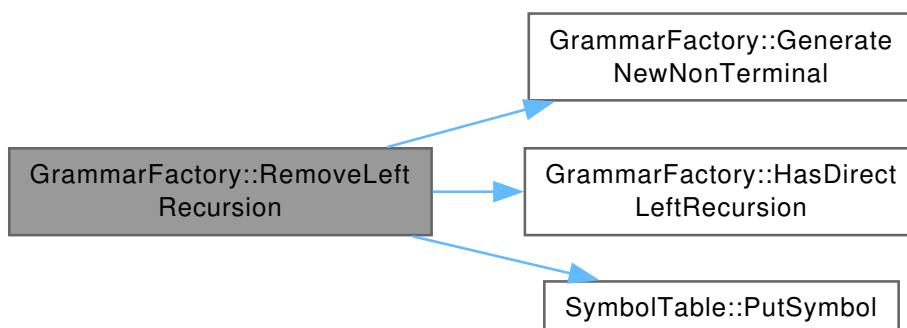
$A \rightarrow b \ A'$

$A' \rightarrow a \ A' \mid \text{epsilon}$

Parameters

<code>grammar</code>	The grammar to remove left recursion.
----------------------	---------------------------------------

Here is the call graph for this function:



Here is the caller graph for this function:



10.5.2.26 StartsWith()

```
bool GrammarFactory::StartsWith (
    const production & prod,
    const std::vector< std::string > & prefix)
```

Checks if a production starts with a given prefix.

This function determines whether the symbols in a production match the provided prefix sequence at the beginning. It is used during left factorization to identify productions that share a common prefix.

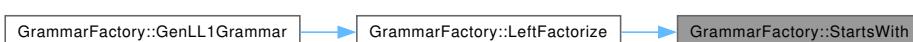
Parameters

<code>prod</code>	The production to check.
<code>prefix</code>	The sequence of symbols to compare against the beginning of the production.

Returns

`true` if the production starts with the prefix, `false` otherwise.

Here is the caller graph for this function:



10.5.3 Member Data Documentation

10.5.3.1 items

```
std::vector<FactoryItem> GrammarFactory::items
```

A vector of [FactoryItem](#) objects representing different level 1 grammar items created by the Init method.

10.5.3.2 non_terminal_alphabet_

```
std::vector<std::string> GrammarFactory::non_terminal_alphabet_
```

Initial value:

```
{"A", "B", "C", "D",
     "E", "F", "G"}
```

A vector of non-terminal symbols (alphabet) used in the grammar.

10.5.3.3 terminal_alphabet_

```
std::vector<std::string> GrammarFactory::terminal_alphabet_
```

Initial value:

```
{"a", "b", "c", "d", "e", "f",
     "g", "h", "i", "j", "k", "l"}
```

A vector of terminal symbols (alphabet) used in the grammar.

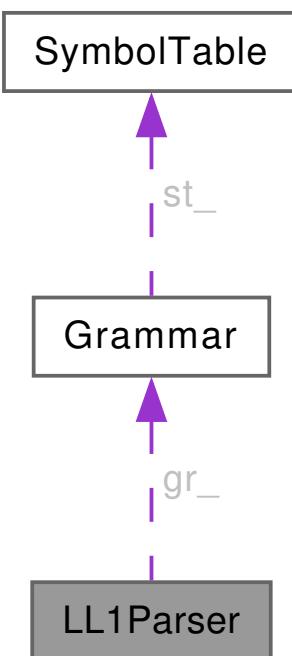
The documentation for this struct was generated from the following files:

- backend/[grammar_factory.hpp](#)
- backend/[grammar_factory.cpp](#)

10.6 LL1Parser Class Reference

```
#include <ll1_parser.hpp>
```

Collaboration diagram for LL1Parser:



Public Member Functions

- [LL1Parser \(\)=default](#)
- [LL1Parser \(Grammar gr\)](#)

- Constructs an [LL1Parser](#) with a grammar object and an input file.
- bool [CreateLL1Table \(\)](#)
Creates the LL(1) parsing table for the grammar.
- void [First \(std::span< const std::string > rule, std::unordered_set< std::string > &result\)](#)
Calculates the FIRST set for a given production rule in a grammar.
- void [ComputeFirstSets \(\)](#)
Computes the FIRST sets for all non-terminal symbols in the grammar.
- void [ComputeFollowSets \(\)](#)
Computes the FOLLOW sets for all non-terminal symbols in the grammar. The FOLLOW set of a non-terminal symbol A contains all terminal symbols that can appear immediately after A in any sentential form derived from the grammar's start symbol. Additionally, if A can be the last symbol in a derivation, the end-of-input marker (\\$) is included in its FOLLOW set. This function computes the FOLLOW sets using the following rules:
 - std::unordered_set< std::string > [Follow \(const std::string &arg\)](#)
Computes the FOLLOW set for a given non-terminal symbol in the grammar.
 - std::unordered_set< std::string > [PredictionSymbols \(const std::string &antecedent, const std::vector< std::string > &consequent\)](#)
Computes the prediction symbols for a given production rule.

Public Attributes

- [ll1_table ll1_t](#)
The LL(1) parsing table, mapping non-terminals and terminals to productions.
- [Grammar gr_](#)
Grammar object associated with this parser.
- std::unordered_map< std::string, std::unordered_set< std::string > > [first_sets_](#)
FIRST sets for each non-terminal in the grammar.
- std::unordered_map< std::string, std::unordered_set< std::string > > [follow_sets_](#)
FOLLOW sets for each non-terminal in the grammar.

10.6.1 Constructor & Destructor Documentation

10.6.1.1 LL1Parser() [1/2]

```
LL1Parser::LL1Parser () [default]
```

10.6.1.2 LL1Parser() [2/2]

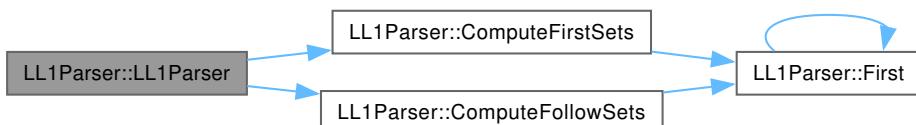
```
LL1Parser::LL1Parser (
    Grammar gr) [explicit]
```

Constructs an [LL1Parser](#) with a grammar object and an input file.

Parameters

<i>gr</i>	Grammar object to parse with
-----------	--

Here is the call graph for this function:



10.6.2 Member Function Documentation

10.6.2.1 ComputeFirstSets()

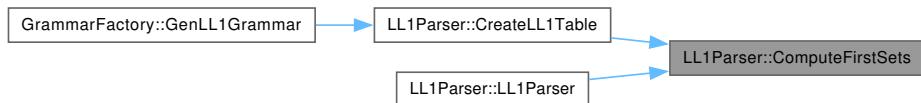
```
void LL1Parser::ComputeFirstSets ()
```

Computes the FIRST sets for all non-terminal symbols in the grammar.

This function calculates the FIRST set for each non-terminal symbol in the grammar by iteratively applying a least fixed-point algorithm. This approach ensures that the FIRST sets are fully populated by repeatedly expanding and updating the sets until no further changes occur (i.e., a fixed-point is reached). Here is the call graph for this function:



Here is the caller graph for this function:



10.6.2.2 ComputeFollowSets()

```
void LL1Parser::ComputeFollowSets ()
```

Computes the FOLLOW sets for all non-terminal symbols in the grammar. The FOLLOW set of a non-terminal symbol A contains all terminal symbols that can appear immediately after A in any sentential form derived from the grammar's start symbol. Additionally, if A can be the last symbol in a derivation, the end-of-input marker (`\$`) is included in its FOLLOW set. This function computes the FOLLOW sets using the following rules:

1. Initialize $\text{FOLLOW}(S) = \{\$\}$, where S is the start symbol.
2. For each production rule of the form $A \rightarrow \alpha B \beta$:
 - Add $\text{FIRST}(\beta) \setminus \{\epsilon\}$ to $\text{FOLLOW}(B)$.
 - If $\epsilon \in \text{FIRST}(\beta)$, add $\text{FOLLOW}(A)$ to $\text{FOLLOW}(B)$.
3. Repeat step 2 until no changes occur in any FOLLOW set. The computed FOLLOW sets are cached in the `follow_sets_` member variable for later use by the parser.

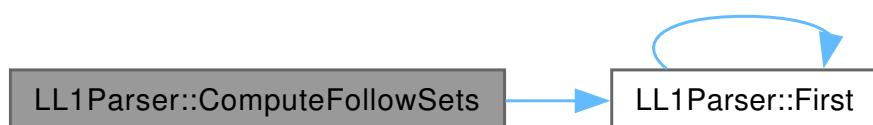
Note

This function assumes that the FIRST sets for all symbols have already been computed and are available in the `first_sets_` member variable.

See also

[First](#)
[follow_sets_](#)

Here is the call graph for this function:



Here is the caller graph for this function:



10.6.2.3 CreateLL1Table()

```
bool LL1Parser::CreateLL1Table ()
```

Creates the LL(1) parsing table for the grammar.

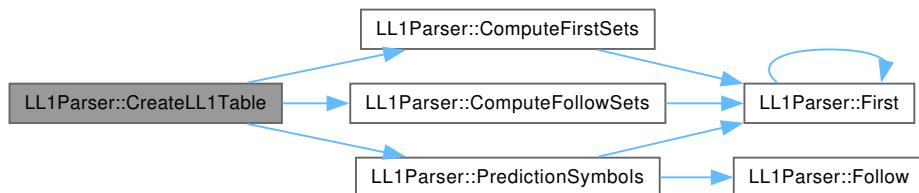
This function constructs the LL(1) parsing table by iterating over each production in the grammar and determining the appropriate cells for each non-terminal and director symbol (prediction symbol) combination. If the grammar is LL(1) compatible, each cell will contain at most one production, indicating no conflicts. If conflicts are found, the function will return `false`, signaling that the grammar is not LL(1).

- For each production rule $A \rightarrow \alpha$, the function calculates the prediction symbols using the [PredictionSymbols](#) function.
- It then fills the parsing table at the cell corresponding to the non-terminal A and each prediction symbol in the set.
- If a cell already contains a production, this indicates a conflict, meaning the grammar is not LL(1).

Returns

`true` if the table is created successfully, indicating the grammar is LL(1) compatible; `false` if any conflicts are detected, showing that the grammar does not meet LL(1) requirements.

Here is the call graph for this function:



Here is the caller graph for this function:



10.6.2.4 First()

```
void LL1Parser::First (
    std::span< const std::string > rule,
    std::unordered_set< std::string > & result)
```

Calculates the FIRST set for a given production rule in a grammar.

The FIRST set of a production rule contains all terminal symbols that can appear at the beginning of any string derived from that rule. If the rule can derive the empty string (`epsilon`), `epsilon` is included in the FIRST set.

This function computes the FIRST set by examining each symbol in the production rule:

- If a terminal symbol is encountered, it is added directly to the FIRST set, as it is the starting symbol of some derivation.

- If a non-terminal symbol is encountered, its FIRST set is recursively computed and added to the result, excluding epsilon unless it is followed by another symbol that could also lead to epsilon.
- If the entire rule could derive epsilon (i.e., each symbol in the rule can derive epsilon), then epsilon is added to the FIRST set.

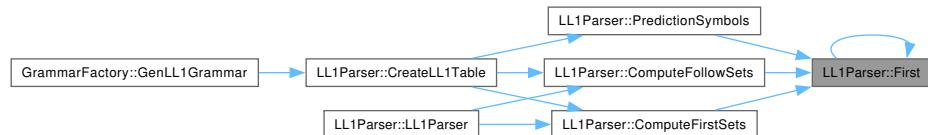
Parameters

<i>rule</i>	A span of strings representing the production rule for which to compute the FIRST set. Each string in the span is a symbol (either terminal or non-terminal).
<i>result</i>	A reference to an unordered set of strings where the computed FIRST set will be stored. The set will contain all terminal symbols that can start derivations of the rule, and possibly epsilon if the rule can derive an empty string.

Here is the call graph for this function:



Here is the caller graph for this function:



10.6.2.5 Follow()

```
std::unordered_set< std::string > LL1Parser::Follow (
    const std::string & arg)
```

Computes the FOLLOW set for a given non-terminal symbol in the grammar.

The FOLLOW set for a non-terminal symbol includes all symbols that can appear immediately to the right of that symbol in any derivation, as well as any end-of-input markers if the symbol can appear at the end of derivations. FOLLOW sets are used in LL(1) parsing table construction to determine possible continuations after a non-terminal.

Parameters

<i>arg</i>	Non-terminal symbol for which to compute the FOLLOW set.
------------	--

Returns

An unordered set of strings containing symbols that form the FOLLOW set for `arg`.

Here is the caller graph for this function:



10.6.2.6 PredictionSymbols()

```
std::unordered_set< std::string > LL1Parser::PredictionSymbols (
    const std::string & antecedent,
    const std::vector< std::string > & consequent)
```

Computes the prediction symbols for a given production rule.

- The prediction symbols for a rule determine the set of input symbols that can trigger this rule in the parsing table. This function calculates the prediction symbols based on the FIRST set of the consequent and, if epsilon (the empty symbol) is in the FIRST set, also includes the FOLLOW set of the antecedent.
- If the FIRST set of the consequent does not contain epsilon, the prediction symbols are simply the FIRST symbols of the consequent.

If the FIRST set of the consequent contains epsilon, the prediction symbols are computed as $\text{FIRST}(\text{consequent}) \setminus \{\epsilon\} \cup \text{FOLLOW}(\text{antecedent})$.

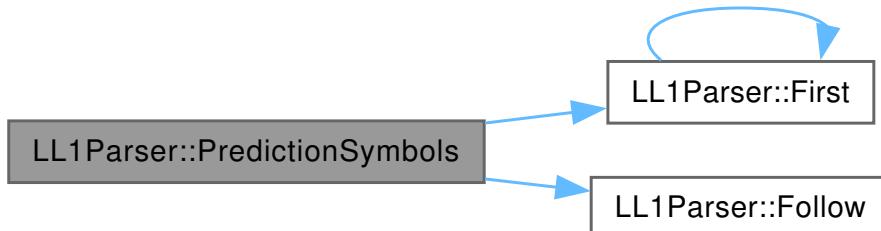
- Parameters**

<i>antecedent</i>	The left-hand side non-terminal symbol of the rule.
<i>consequent</i>	A vector of symbols on the right-hand side of the rule (production body).

Returns

An unordered set of strings containing the prediction symbols for the specified rule.

Here is the call graph for this function:



Here is the caller graph for this function:



10.6.3 Member Data Documentation

10.6.3.1 first_sets_

```
std::unordered_map<std::string, std::unordered_set<std::string> > LL1Parser::first_sets_
FIRST sets for each non-terminal in the grammar.
```

10.6.3.2 follow_sets_

```
std::unordered_map<std::string, std::unordered_set<std::string> > LL1Parser::follow_sets_
FOLLOW sets for each non-terminal in the grammar.
```

10.6.3.3 gr_

`Grammar LLLParser::gr_`

`Grammar` object associated with this parser.

10.6.3.4 ll1_t_

`ll1_table LLLParser::ll1_t_`

The LL(1) parsing table, mapping non-terminals and terminals to productions.

The documentation for this class was generated from the following files:

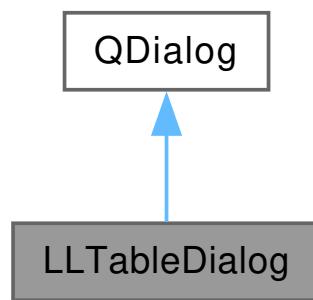
- `backend/ll1_parser.hpp`
- `backend/ll1_parser.cpp`

10.7 LLTableDialog Class Reference

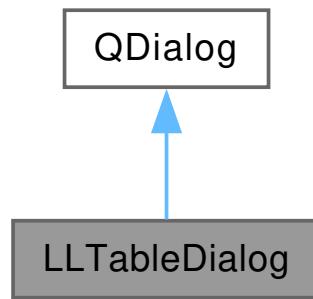
Dialog for filling and submitting an LL(1) parsing table.

`#include <lltabledialog.h>`

Inheritance diagram for LLTableDialog:



Collaboration diagram for LLTableDialog:



Signals

- void `submitted` (const QVector< QVector< QString > > &data)

Signal emitted when the user submits the table.

Public Member Functions

- `LLTableDialog` (const QStringList &rowHeaders, const QStringList &colHeaders, QWidget *parent, QVector< QVector< QString > > *initialData=nullptr)

Constructs the LL(1) table dialog with given headers and optional initial data.

- `QVector< QVector< QString > > getTableData () const`

Returns the contents of the table filled by the user.

- void `setInitialData` (const QVector< QVector< QString > > &data)
Pre-fills the table with existing user data.
- void `highlightIncorrectCells` (const QList< QPair< int, int > > &coords)
Highlights cells that are incorrect based on provided coordinates.

10.7.1 Detailed Description

Dialog for filling and submitting an LL(1) parsing table.

This class represents a dialog window that displays a table for users to complete the LL(1) parsing matrix. It provides functionality to initialize the table with data, retrieve the user's input, and highlight incorrect answers.

10.7.2 Constructor & Destructor Documentation

10.7.2.1 LLTableDialog()

```
LLTableDialog::LLTableDialog (
    const QStringList & rowHeaders,
    const QStringList & colHeaders,
    QWidget * parent,
    QVector< QVector< QString > > * initialData = nullptr)
```

Constructs the LL(1) table dialog with given headers and optional initial data.

Parameters

<code>rowHeaders</code>	Row labels (non-terminal symbols).
<code>colHeaders</code>	Column labels (terminal symbols).
<code>parent</code>	Parent widget.
<code>initialData</code>	Optional initial table data to pre-fill cells.

10.7.3 Member Function Documentation

10.7.3.1 getTableData()

```
QVector< QVector< QString > > LLTableDialog::getTableData () const
```

Returns the contents of the table filled by the user.

Returns

A 2D vector representing the LL(1) table.

10.7.3.2 highlightIncorrectCells()

```
void LLTableDialog::highlightIncorrectCells (
    const QList< QPair< int, int > > & coords)
```

Highlights cells that are incorrect based on provided coordinates.

Parameters

<code>coords</code>	A list of (row, column) pairs to highlight as incorrect.
---------------------	--

10.7.3.3 setInitialData()

```
void LLTableDialog::setInitialData (
    const QVector< QVector< QString > > & data)
```

Pre-fills the table with existing user data.

This is used to populate the table with a previous (possibly incorrect) answer when retrying a task or providing feedback.

Parameters

<i>data</i>	A 2D vector of strings representing the initial cell values.
-------------	--

10.7.3.4 submitted

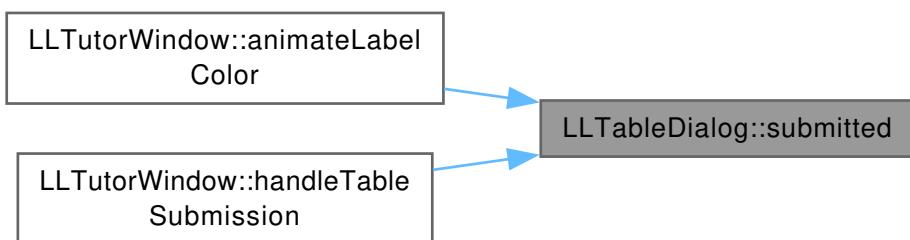
```
void LLTableDialog::submitted (
    const QVector< QVector< QString > > & data) [signal]
```

Signal emitted when the user submits the table.

Parameters

<i>data</i>	The filled table data submitted by the user.
-------------	--

Here is the caller graph for this function:



The documentation for this class was generated from the following files:

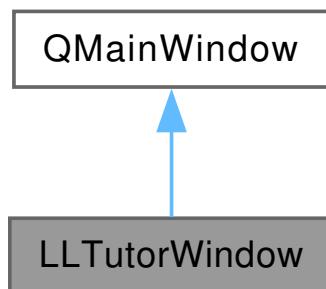
- [lltabledialog.h](#)
- [lltabledialog.cpp](#)

10.8 LLTutorWindow Class Reference

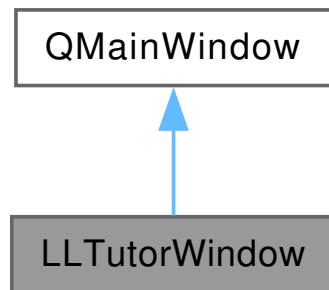
Main window for the LL(1) interactive tutoring mode in [SyntaxTutor](#).

```
#include <lltutorwindow.h>
```

Inheritance diagram for LLTutorWindow:



Collaboration diagram for LLTutorWindow:



Classes

- struct [TreeNode](#)

TreeNode structure used to build derivation trees.

Signals

- void [sessionFinished](#) (int cntRight, int cntWrong)

Public Member Functions

- [LLTutorWindow](#) (const [Grammar](#) &grammar, [TutorialManager](#) *tm=nullptr, [QWidget](#) *parent=nullptr)
Constructs the LL(1) tutor window with a given grammar.
- [~LLTutorWindow](#) ()
- [QString generateQuestion](#) ()
Generates a question for the current state of the tutor.
- void [updateState](#) (bool isCorrect)
Updates the tutor state after verifying user response.
- [QString FormatGrammar](#) (const [Grammar](#) &grammar)
Formats a grammar for display in the chat interface.
- void [addMessage](#) (const [QString](#) &text, bool isUser)
- void [addWidgetMessage](#) ([QWidget](#) *widget)
< Add text message to chat
- void [exportConversationToPdf](#) (const [QString](#) &filePath)
< Add widget (e.g., table, tree)
- void [showTable](#) ()
< Export chat to PDF
- void [showTableForCPrime](#) ()
Display the full LL(1) table in C' ex.
- void [updateProgressPanel](#) ()
- void [animateLabelPop](#) ([QLabel](#) *label)
- void [animateLabelColor](#) ([QLabel](#) *label, const [QColor](#) &flashColor)
- void [wrongAnimation](#) ()
Visual shake/flash for incorrect answer.
- void [wrongUserResponseAnimation](#) ()
Animation specific to user chat input.
- void [markLastUserIncorrect](#) ()
Marks last message as incorrect.
- void [TeachFirstTree](#) (const std::vector< std::string > &symbols, std::unordered_set< std::string > &first_set, int depth, std::unordered_set< std::string > &processing, [QTreeWidgetItem](#) *parent)

- std::unique_ptr< `TreeNode` > `buildTreeNode` (const std::vector< std::string > &symbols, std::unordered_set< std::string > &first_set, int depth, std::vector< std::pair< std::string, std::vector< std::string > > > &active_derivations)
- int `computeSubtreeWidth` (const std::unique_ptr< `TreeNode` > &node, int hSpacing)
- void `drawTree` (const std::unique_ptr< `TreeNode` > &root, QGraphicsScene *scene, QPointF pos, int hSpacing, int vSpacing)
- void `showTreeGraphics` (std::unique_ptr< `TreeNode` > root)
- bool `verifyResponse` (const QString &userResponse)
- bool `verifyResponseForA` (const QString &userResponse)
- bool `verifyResponseForA1` (const QString &userResponse)
- bool `verifyResponseForA2` (const QString &userResponse)
- bool `verifyResponseForB` (const QString &userResponse)
- bool `verifyResponseForB1` (const QString &userResponse)
- bool `verifyResponseForB2` (const QString &userResponse)
- bool `verifyResponseForC` ()
- QString `solution` (const std::string &`state`)
- QStringList `solutionForA` ()
- QString `solutionForA1` ()
- QString `solutionForA2` ()
- QSet< QString > `solutionForB` ()
- QSet< QString > `solutionForB1` ()
- QSet< QString > `solutionForB2` ()
- QString `feedback` ()
- QString `feedbackForA` ()
- QString `feedbackForA1` ()
- QString `feedbackForA2` ()
- QString `feedbackForAPrime` ()
- QString `feedbackForB` ()
- QString `feedbackForB1` ()
- QString `feedbackForB2` ()
- QString `feedbackForBPrime` ()
- QString `feedbackForC` ()
- QString `feedbackForCPrime` ()
- void `feedbackForB1TreeWidget` ()
- void `feedbackForB1TreeGraphics` ()
- QString `TeachFollow` (const QString &`nt`)
- QString `TeachPredictionSymbols` (const QString &`ant`, const `production` &`conseq`)
- QString `TeachLL1Table` ()
- void `handleTableSubmission` (const QVector< QVector< QString > > &`raw`, const QStringList &`colHeaders`)

Protected Member Functions

- void `closeEvent` (QCloseEvent *event) override
- bool `eventFilter` (QObject *obj, QEvent *event) override

10.8.1 Detailed Description

Main window for the LL(1) interactive tutoring mode in [SyntaxTutor](#).

This class guides students through the construction and analysis of LL(1) parsing tables. It uses a finite-state sequence to present progressively more complex tasks, verifies user responses, provides corrective feedback, and supports visualizations like derivation trees.

The tutor is designed to teach the student *how* the LL(1) table is built, not just test it — including interactive tasks, animated feedback, and hints.

Key features include:

- Interactive question flow based on grammar analysis.

- Derivation tree generation (`TeachFirst`).
- Step-by-step verification of FIRST, FOLLOW, prediction symbols, and table entries.
- Exportable conversation log for grading or review.

10.8.2 Constructor & Destructor Documentation

10.8.2.1 LLTutorWindow()

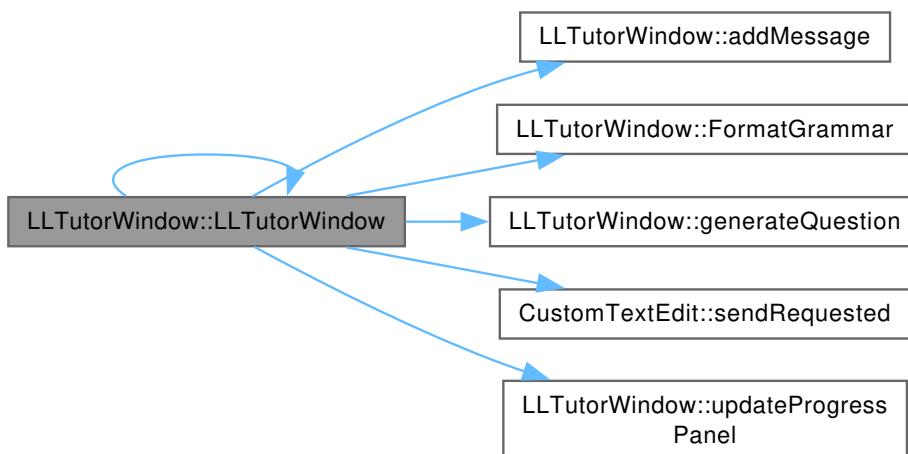
```
LLTutorWindow::LLTutorWindow (
    const Grammar & grammar,
    TutorialManager * tm = nullptr,
    QWidget * parent = nullptr) [explicit]
```

Constructs the LL(1) tutor window with a given grammar.

Parameters

<i>grammar</i>	The grammar to use during the session.
<i>tm</i>	Optional pointer to the tutorial manager (for help overlays).
<i>parent</i>	Parent widget.

Here is the call graph for this function:



Here is the caller graph for this function:



10.8.2.2 ~LLTutorWindow()

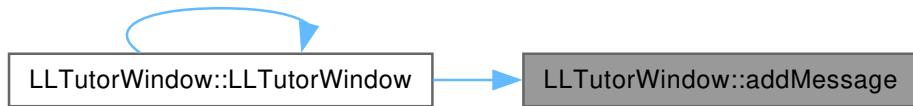
```
LLTutorWindow::~LLTutorWindow ()
```

10.8.3 Member Function Documentation

10.8.3.1 addMessage()

```
void LLTutorWindow::addMessage (
    const QString & text,
    bool isUser)
```

Here is the caller graph for this function:



10.8.3.2 addWidgetMessage()

```
void LLTutorWindow::addWidgetMessage (
    QWidget * widget)
< Add text message to chat
```

10.8.3.3 animateLabelColor()

```
void LLTutorWindow::animateLabelColor (
    QLabel * label,
    const QColor & flashColor)
```

Here is the call graph for this function:



10.8.3.4 animateLabelPop()

```
void LLTutorWindow::animateLabelPop (
    QLabel * label)
```

10.8.3.5 buildTreeNode()

```
std::unique_ptr< LLTutorWindow::TreeNode > LLTutorWindow::buildTreeNode (
    const std::vector< std::string > & symbols,
    std::unordered_set< std::string > & first_set,
    int depth,
    std::vector< std::pair< std::string, std::vector< std::string > > > & active_derivations)
```

10.8.3.6 closeEvent()

```
void LLTutorWindow::closeEvent (
    QCloseEvent * event) [inline], [override], [protected]
```

Here is the call graph for this function:



10.8.3.7 computeSubtreeWidth()

```
int LLTutorWindow::computeSubtreeWidth (
    const std::unique_ptr< TreeNode > & node,
    int hSpacing)
```

10.8.3.8 drawTree()

```
void LLTutorWindow::drawTree (
    const std::unique_ptr< TreeNode > & root,
    QGraphicsScene * scene,
    QPointF pos,
    int hSpacing,
    int vSpacing)
```

10.8.3.9 eventFilter()

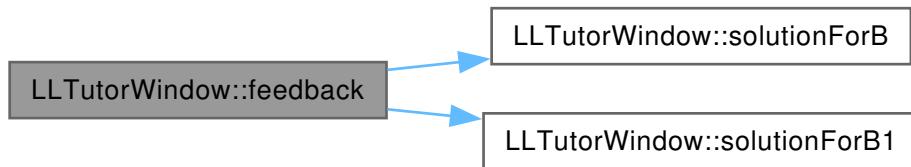
```
bool LLTutorWindow::eventFilter (
    QObject * obj,
    QEvent * event) [override], [protected]
```

10.8.3.10 exportConversationToPdf()

```
void LLTutorWindow::exportConversationToPdf (
    const QString & filePath)
< Add widget (e.g., table, tree)
```

10.8.3.11 feedback()

QString LLTutorWindow::feedback ()
Here is the call graph for this function:



10.8.3.12 feedbackForA()

```
QString LLTutorWindow::feedbackForA ()
```

10.8.3.13 feedbackForA1()

```
QString LLTutorWindow::feedbackForA1 ()
```

10.8.3.14 feedbackForA2()

```
QString LLTutorWindow::feedbackForA2 ()
```

10.8.3.15 feedbackForAPrime()

```
QString LLTutorWindow::feedbackForAPrime ()
```

10.8.3.16 feedbackForB()

```
QString LLTutorWindow::feedbackForB ()
```

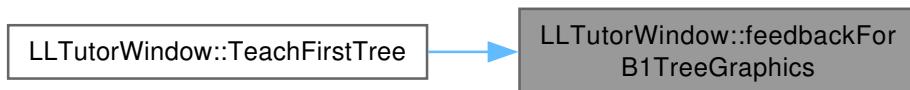
10.8.3.17 feedbackForB1()

```
QString LLTutorWindow::feedbackForB1 ()
```

10.8.3.18 feedbackForB1TreeGraphics()

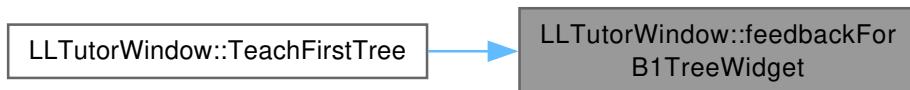
```
void LLTutorWindow::feedbackForB1TreeGraphics ()
```

Here is the caller graph for this function:

**10.8.3.19 feedbackForB1TreeWidget()**

```
void LLTutorWindow::feedbackForB1TreeWidget ()
```

Here is the caller graph for this function:

**10.8.3.20 feedbackForB2()**

```
QString LLTutorWindow::feedbackForB2 ()
```

10.8.3.21 feedbackForBPrime()

```
QString LLTutorWindow::feedbackForBPrime ()
```

10.8.3.22 feedbackForC()

```
QString LLTutorWindow::feedbackForC ()
```

10.8.3.23 feedbackForCPrime()

```
QString LLTutorWindow::feedbackForCPrime ()
```

10.8.3.24 FormatGrammar()

```
QString LLTutorWindow::FormatGrammar (
    const Grammar & grammar)
```

Formats a grammar for display in the chat interface.

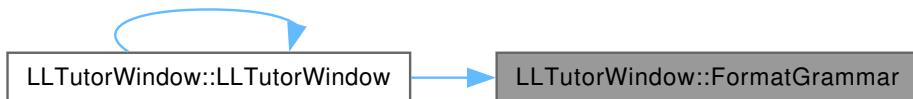
Parameters

<i>grammar</i>	The grammar to format.
----------------	------------------------

Returns

A QString representation.

Here is the caller graph for this function:

**10.8.3.25 generateQuestion()**

```
QString LLTutorWindow::generateQuestion ()
```

Generates a question for the current state of the tutor.

Returns

A formatted question string.

Here is the caller graph for this function:

**10.8.3.26 handleTableSubmission()**

```
void LLTutorWindow::handleTableSubmission (
    const QVector< QVector< QString > > & raw,
    const QStringList & colHeaders)
```

Here is the call graph for this function:

**10.8.3.27 markLastUserIncorrect()**

```
void LLTutorWindow::markLastUserIncorrect ()
```

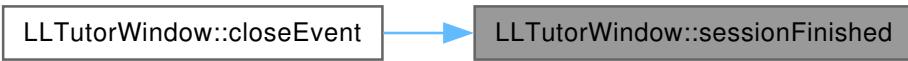
Marks last message as incorrect.

Here is the call graph for this function:

**10.8.3.28 sessionFinished**

```
void LLTutorWindow::sessionFinished (
    int cntRight,
    int cntWrong) [signal]
```

Here is the caller graph for this function:



10.8.3.29 showTable()

```
void LLTutorWindow::showTable ()  
< Export chat to PDF
```

Display the full LL(1) table in C ex. Here is the caller graph for this function:



10.8.3.30 showTableForCPrime()

```
void LLTutorWindow::showTableForCPrime ()  
Display the full LL(1) table in C' ex.
```

10.8.3.31 showTreeGraphics()

```
void LLTutorWindow::showTreeGraphics (  
    std::unique_ptr< TreeNode > root)
```

10.8.3.32 solution()

```
QString LLTutorWindow::solution (  
    const std::string & state)
```

10.8.3.33 solutionForA()

```
QStringList LLTutorWindow::solutionForA ()
```

10.8.3.34 solutionForA1()

```
QString LLTutorWindow::solutionForA1 ()
```

10.8.3.35 solutionForA2()

```
QString LLTutorWindow::solutionForA2 ()
```

10.8.3.36 solutionForB()

```
QSet< QString > LLTutorWindow::solutionForB ()
```

Here is the caller graph for this function:



10.8.3.37 solutionForB1()

```
QSet< QString > LLTutorWindow::solutionForB1 ()  
Here is the caller graph for this function:
```



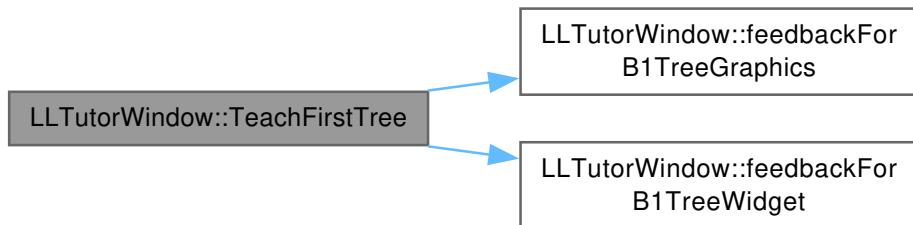
10.8.3.38 solutionForB2()

```
QSet< QString > LLTutorWindow::solutionForB2 ()
```

10.8.3.39 TeachFirstTree()

```
void LLTutorWindow::TeachFirstTree (  
    const std::vector< std::string > & symbols,  
    std::unordered_set< std::string > & first_set,  
    int depth,  
    std::unordered_set< std::string > & processing,  
    QTreeWidgetItem * parent)
```

Here is the call graph for this function:



10.8.3.40 TeachFollow()

```
QString LLTutorWindow::TeachFollow (  
    const QString & nt)
```

10.8.3.41 TeachLL1Table()

```
QString LLTutorWindow::TeachLL1Table ()
```

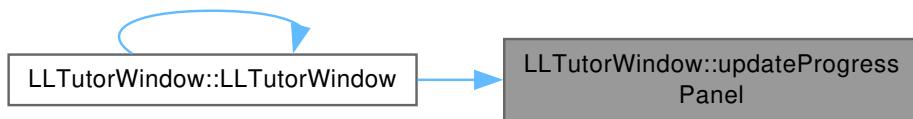
10.8.3.42 TeachPredictionSymbols()

```
QString LLTutorWindow::TeachPredictionSymbols (  
    const QString & ant,  
    const production & conseq)
```

10.8.3.43 updateProgressPanel()

```
void LLTutorWindow::updateProgressPanel ()
```

Here is the caller graph for this function:



10.8.3.44 updateState()

```
void LLTutorWindow::updateState (
    bool isCorrect)
```

Updates the tutor state after verifying user response.

Parameters

<i>isCorrect</i>	Whether the user answered correctly.
------------------	--------------------------------------

10.8.3.45 verifyResponse()

```
bool LLTutorWindow::verifyResponse (
    const QString & userResponse)
```

10.8.3.46 verifyResponseForA()

```
bool LLTutorWindow::verifyResponseForA (
    const QString & userResponse)
```

10.8.3.47 verifyResponseForA1()

```
bool LLTutorWindow::verifyResponseForA1 (
    const QString & userResponse)
```

10.8.3.48 verifyResponseForA2()

```
bool LLTutorWindow::verifyResponseForA2 (
    const QString & userResponse)
```

10.8.3.49 verifyResponseForB()

```
bool LLTutorWindow::verifyResponseForB (
    const QString & userResponse)
```

10.8.3.50 verifyResponseForB1()

```
bool LLTutorWindow::verifyResponseForB1 (
    const QString & userResponse)
```

10.8.3.51 verifyResponseForB2()

```
bool LLTutorWindow::verifyResponseForB2 (
    const QString & userResponse)
```

10.8.3.52 verifyResponseForC()

```
bool LLTutorWindow::verifyResponseForC ()
```

10.8.3.53 wrongAnimation()

```
void LLTutorWindow::wrongAnimation ()
```

Visual shake/flash for incorrect answer.

10.8.3.54 wrongUserResponseAnimation()

```
void LLTutorWindow::wrongUserResponseAnimation ()
Animation specific to user chat input.
```

The documentation for this class was generated from the following files:

- [lltutorwindow.h](#)
- [lltutorwindow.cpp](#)

10.9 Lr0Item Struct Reference

Represents an LR(0) item used in LR automata construction.

```
#include <lr0_item.hpp>
```

Public Member Functions

- [`Lr0Item`](#) (std::string antecedent, std::vector< std::string > consequent, std::string epsilon, std::string eol)

Constructs an LR(0) item with the dot at position 0.
- [`Lr0Item`](#) (std::string antecedent, std::vector< std::string > consequent, unsigned int dot, std::string epsilon, std::string eol)

Constructs an LR(0) item with a custom dot position.
- std::string [`NextToDot`](#) () const

Returns the symbol immediately after the dot, or empty if the dot is at the end.
- void [`PrintItem`](#) () const

Prints the LR(0) item to the standard output in a human-readable format.
- std::string [`ToString`](#) () const

Converts the item to a string representation, including the dot position.
- void [`AdvanceDot`](#) ()

Advances the dot one position to the right.
- bool [`IsComplete`](#) () const

Checks whether the dot has reached the end of the production.
- bool [`operator==`](#) (const [`Lr0Item`](#) &other) const

Equality operator for comparing two LR(0) items.

Public Attributes

- std::string [`antecedent_`](#)

The non-terminal on the left-hand side of the production.
- std::vector< std::string > [`consequent_`](#)

The sequence of symbols on the right-hand side of the production.
- std::string [`epsilon_`](#)

The symbol representing the empty string (ε).
- std::string [`eol_`](#)

The symbol representing end-of-line or end-of-input (\$).
- unsigned int [`dot_`](#) = 0

The position of the dot (.) in the production.

10.9.1 Detailed Description

Represents an LR(0) item used in LR automata construction.

An LR(0) item has a production of the form $A \rightarrow \alpha \bullet \beta$, where the dot indicates the current parsing position. This structure tracks the antecedent (left-hand side), consequent (right-hand side), the dot position, and special symbols like EPSILON and end-of-line (\$).

10.9.2 Constructor & Destructor Documentation

10.9.2.1 Lr0Item() [1/2]

```
Lr0Item::Lr0Item (
    std::string antecedent,
    std::vector< std::string > consequent,
    std::string epsilon,
    std::string eol)
```

Constructs an LR(0) item with the dot at position 0.

Parameters

<i>antecedent</i>	The left-hand side non-terminal.
<i>consequent</i>	The right-hand side of the production.
<i>epsilon</i>	The EPSILON symbol.
<i>eol</i>	The end-of-line symbol.

Here is the caller graph for this function:



10.9.2.2 Lr0Item() [2/2]

```
Lr0Item::Lr0Item (
    std::string antecedent,
    std::vector< std::string > consequent,
    unsigned int dot,
    std::string epsilon,
    std::string eol)
```

Constructs an LR(0) item with a custom dot position.

Parameters

<i>antecedent</i>	The left-hand side non-terminal.
<i>consequent</i>	The right-hand side of the production.
<i>dot</i>	The position of the dot.
<i>epsilon</i>	The EPSILON symbol.
<i>eol</i>	The end-of-line symbol.

10.9.3 Member Function Documentation

10.9.3.1 AdvanceDot()

```
void Lr0Item::AdvanceDot ()
```

Advances the dot one position to the right.

Here is the caller graph for this function:



10.9.3.2 IsComplete()

```
bool Lr0Item::IsComplete () const
Checks whether the dot has reached the end of the production.
```

Returns

true if the item is complete; false otherwise.

Here is the caller graph for this function:



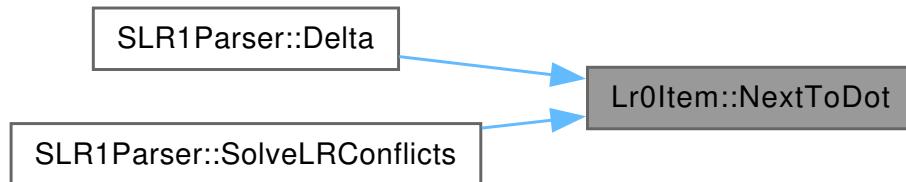
10.9.3.3 NextToDot()

```
std::string Lr0Item::NextToDot () const
Returns the symbol immediately after the dot, or empty if the dot is at the end.
```

Returns

The symbol after the dot, or an empty string.

Here is the caller graph for this function:



10.9.3.4 operator==()

```
bool Lr0Item::operator== (
    const Lr0Item & other) const
Equality operator for comparing two LR(0) items.
```

Parameters

<i>other</i>	The item to compare with.
--------------	---------------------------

Returns

true if both items are equal; false otherwise.

Here is the call graph for this function:



10.9.3.5 PrintItem()

```
void Lr0Item::PrintItem () const
Prints the LR(0) item to the standard output in a human-readable format.
```

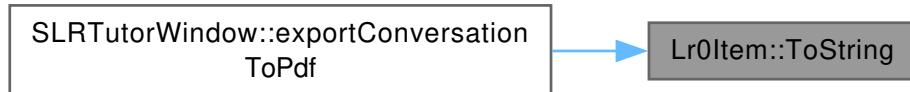
10.9.3.6 ToString()

```
std::string Lr0Item::ToString () const
Converts the item to a string representation, including the dot position.
```

Returns

A string representation of the item.

Here is the caller graph for this function:



10.9.4 Member Data Documentation

10.9.4.1 antecedent_

```
std::string Lr0Item::antecedent_
The non-terminal on the left-hand side of the production.
```

10.9.4.2 consequent_

```
std::vector<std::string> Lr0Item::consequent_
The sequence of symbols on the right-hand side of the production.
```

10.9.4.3 dot_

```
unsigned int Lr0Item::dot_ = 0
The position of the dot (·) in the production.
```

10.9.4.4 eol_

```
std::string Lr0Item::eol_
The symbol representing end-of-line or end-of-input ($).
```

10.9.4.5 epsilon_

```
std::string Lr0Item::epsilon_
The symbol representing the empty string (ε).
The documentation for this struct was generated from the following files:
```

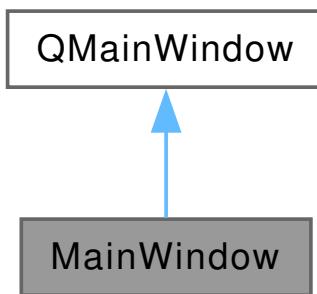
- backend/lr0_item.hpp
- backend/lr0_item.cpp

10.10 MainWindow Class Reference

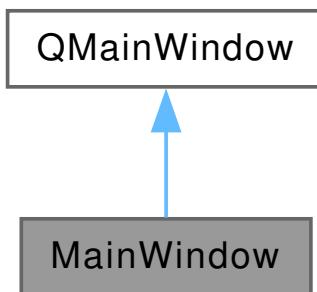
Main application window of [SyntaxTutor](#), managing levels, exercises, and UI state.

```
#include <mainwindow.h>
```

Inheritance diagram for MainWindow:



Collaboration diagram for MainWindow:



Signals

- void [userLevelChanged](#) (unsigned lvl)
Emitted when the user's level changes.
- void [userLevelUp](#) (unsigned newLevel)
Emitted when the user levels up.

Public Member Functions

- [MainWindow](#) (QWidget *parent=nullptr)
Constructs the main window.
- [~MainWindow](#) ()
Destructor.
- unsigned [thresholdFor](#) (unsigned level)
Returns the required score threshold to unlock a level.
- unsigned [userLevel](#) () const
Returns the current user level.
- void [setUserLevel](#) (unsigned lvl)
Sets the user level, clamping it to the allowed maximum.

Properties

- unsigned [userLevel](#)

10.10.1 Detailed Description

Main application window of [SyntaxTutor](#), managing levels, exercises, and UI state.

This class serves as the central hub of the application. It handles level selection, navigation to LL(1) and SLR(1) exercises, tutorial management, settings persistence, and emits signals for user progress. It also includes UI logic for dynamic behavior like unlocking levels and changing language.

10.10.2 Constructor & Destructor Documentation

10.10.2.1 MainWindow()

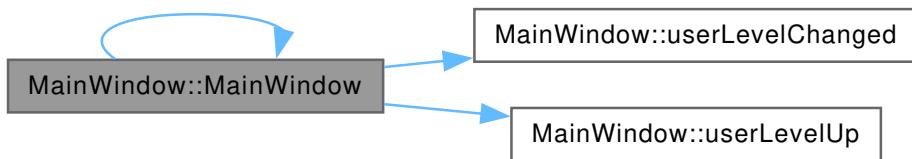
```
MainWindow::MainWindow (
    QWidget * parent = nullptr)
```

Constructs the main window.

Parameters

<i>parent</i>	Parent widget.
---------------	----------------

Here is the call graph for this function:



Here is the caller graph for this function:



10.10.2.2 ~MainWindow()

```
MainWindow::~MainWindow ()
```

Destructor.

10.10.3 Member Function Documentation

10.10.3.1 setUserLevel()

```
void MainWindow::setUserLevel (
    unsigned lvl) [inline]
```

Sets the user level, clamping it to the allowed maximum.

Parameters

<i>lvl</i>	New level to assign.
------------	----------------------

Here is the call graph for this function:



10.10.3.2 thresholdFor()

```
unsigned MainWindow::thresholdFor (
    unsigned level) [inline]
```

Returns the required score threshold to unlock a level.

Parameters

<i>level</i>	The level number.
--------------	-------------------

Returns

The score needed to unlock the given level.

10.10.3.3 userLevel()

```
unsigned MainWindow::userLevel () const [inline]
```

Returns the current user level.

10.10.3.4 userLevelChanged

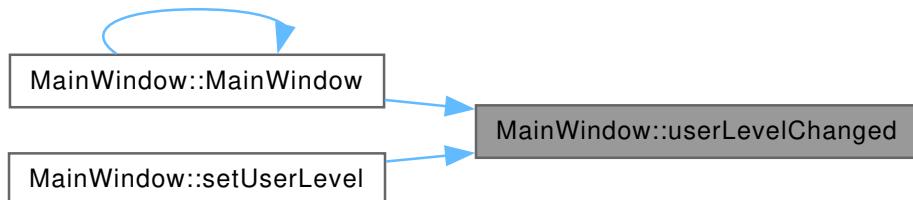
```
void MainWindow::userLevelChanged (
    unsigned lvl) [signal]
```

Emitted when the user's level changes.

Parameters

<i>lvl</i>	New user level.
------------	-----------------

Here is the caller graph for this function:



10.10.3.5 userLevelUp

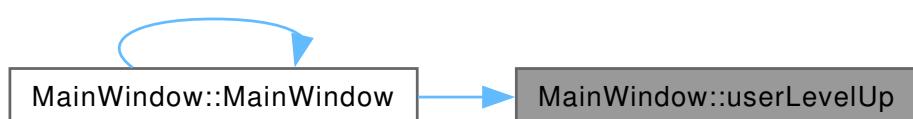
```
void MainWindow::userLevelUp (
    unsigned newLevel) [signal]
```

Emitted when the user levels up.

Parameters

<i>newLevel</i>	The new level achieved.
-----------------	-------------------------

Here is the caller graph for this function:



10.10.4 Property Documentation

10.10.4.1 userLevel

```
unsigned MainWindow::userLevel [read], [write]
```

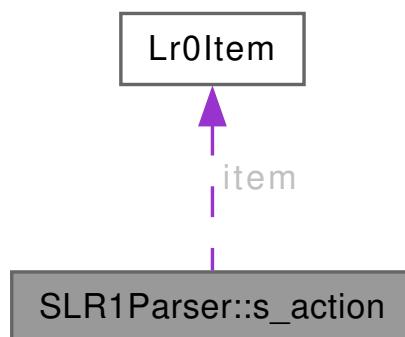
The documentation for this class was generated from the following files:

- [mainwindow.h](#)
- [mainwindow.cpp](#)

10.11 SLR1Parser::s_action Struct Reference

```
#include <slr1_parser.hpp>
```

Collaboration diagram for SLR1Parser::s_action:



Public Attributes

- const [Lr0Item](#) * item
- [Action](#) action

10.11.1 Member Data Documentation

10.11.1.1 action

```
Action SLR1Parser::s_action::action
```

10.11.1.2 item

```
const Lr0Item* SLR1Parser::s_action::item
```

The documentation for this struct was generated from the following file:

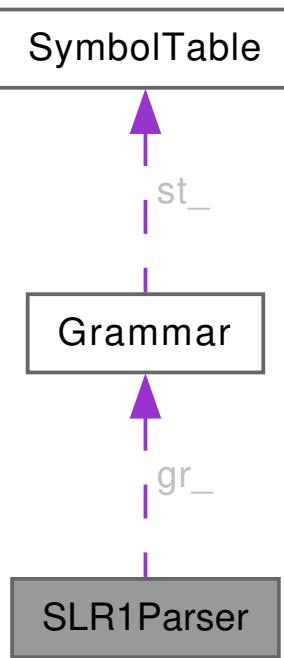
- backend/[slr1_parser.hpp](#)

10.12 SLR1Parser Class Reference

Implements an SLR(1) parser for context-free grammars.

```
#include <slr1_parser.hpp>
```

Collaboration diagram for SLR1Parser:



Classes

- struct [s_action](#)

Public Types

- enum class [Action](#) { Shift , Reduce , Accept , Empty }
Represents the possible actions in the SLR(1) parsing table.
- using [action_table](#)
Represents the action table for the SLR(1) parser.
- using [transition_table](#)
Represents the transition table for the SLR(1) parser.

Public Member Functions

- [SLR1Parser \(\)=default](#)
- [SLR1Parser \(Grammar gr\)](#)
- std::unordered_set< [Lr0Item](#) > [AllItems \(\) const](#)
Retrieves all LR(0) items in the grammar. This function returns a set of all LR(0) items derived from the grammar's productions. Each LR(0) item represents a production with a marker indicating the current position in the production (e.g., $A \rightarrow \alpha \bullet \beta$).
- void [Closure \(std::unordered_set< \[Lr0Item\]\(#\) > &items\)](#)
Computes the closure of a set of LR(0) items.
- void [ClosureUtil \(std::unordered_set< \[Lr0Item\]\(#\) > &items, unsigned int size, std::unordered_set< std::string > &visited\)](#)
Helper function for computing the closure of LR(0) items.
- std::unordered_set< [Lr0Item](#) > [Delta \(const std::unordered_set< \[Lr0Item\]\(#\) > &items, const std::string &str\)](#)
Computes the GOTO transition (δ) for a given set of LR(0) items and a symbol. This function is equivalent to the $\delta(I, X)$ function in LR parsing, where it computes the set of items reached from a state I via symbol X .
- bool [SolveLRConflicts \(const state &st\)](#)
Resolves LR conflicts in a given state.

- void [First](#) (std::span< const std::string > rule, std::unordered_set< std::string > &result)
Calculates the FIRST set for a given production rule in a grammar.
- void [ComputeFirstSets](#) ()
Computes the FIRST sets for all non-terminal symbols in the grammar.
- void [ComputeFollowSets](#) ()
Computes the FOLLOW sets for all non-terminal symbols in the grammar. The FOLLOW set of a non-terminal symbol A contains all terminal symbols that can appear immediately after A in any sentential form derived from the grammar's start symbol. Additionally, if A can be the last symbol in a derivation, the end-of-input marker ('\$') is included in its FOLLOW set. This function computes the FOLLOW sets using the following rules:
 - std::unordered_set< std::string > [Follow](#) (const std::string &arg)
Computes the FOLLOW set for a given non-terminal symbol in the grammar.
 - void [MakeInitialState](#) ()
Creates the initial state of the parser's state machine.
 - bool [MakeParser](#) ()
Constructs the SLR(1) parsing tables (action and transition tables).
 - std::string [PrintItems](#) (const std::unordered_set< Lr0Item > &items) const
Returns a string representation of a set of LR(0) items.

Public Attributes

- [Grammar gr_](#)
The grammar being processed by the parser.
- std::unordered_map< std::string, std::unordered_set< std::string > > [first_sets_](#)
Cached FIRST sets for all symbols in the grammar.
- std::unordered_map< std::string, std::unordered_set< std::string > > [follow_sets_](#)
Cached FOLLOW sets for all non-terminal symbols in the grammar.
- [action_table actions_](#)
The action table used by the parser to determine shift/reduce actions.
- [transition_table transitions_](#)
The transition table used by the parser to determine state transitions.
- std::unordered_set< [state](#) > [states_](#)
The set of states in the parser's state machine.

10.12.1 Detailed Description

Implements an SLR(1) parser for context-free grammars.

This class builds an SLR(1) parsing table and LR(0) automaton from a given grammar. It provides methods for computing closure sets, GOTO transitions, constructing states, and performing syntax analysis using the generated table.

10.12.2 Member Typedef Documentation

10.12.2.1 [action_table](#)

```
using SLR1Parser::action\_table
```

Initial value:

```
std::map<unsigned int, std::map<std::string, SLR1Parser::s\_action>>
```

Represents the action table for the SLR(1) parser.

The action table is a map that associates each state and input symbol with a specific action (Shift, Reduce, Accept, or Empty). It is used to determine the parser's behavior during the parsing process.

The table is structured as:

- Outer map: Keys are state IDs (unsigned int).
- Inner map: Keys are input symbols (std::string), and values are [s_action](#) structs representing the action to take.

10.12.2.2 transition_table

```
using SLR1Parser::transition_table
```

Initial value:

```
std::map<unsigned int, std::map<std::string, unsigned int>>
```

Represents the transition table for the SLR(1) parser.

The transition table is a map that associates each state and symbol with the next state to transition to. It is used to guide the parser's state transitions during the parsing process.

The table is structured as:

- Outer map: Keys are state IDs (unsigned int).
- Inner map: Keys are symbols (std::string), and values are the next state IDs (unsigned int).

10.12.3 Member Enumeration Documentation

10.12.3.1 Action

```
enum class SLR1Parser::Action [strong]
```

Represents the possible actions in the SLR(1) parsing table.

This enumeration defines the types of actions that can be taken by the parser during the parsing process:

- Shift: Shift the input symbol onto the stack and transition to a new state.
- Reduce: Reduce a production rule and pop symbols from the stack.
- Accept: Accept the input as a valid string in the grammar.
- Empty: No action is defined for the current state and input symbol.

Enumerator

Shift	
Reduce	
Accept	
Empty	

10.12.4 Constructor & Destructor Documentation

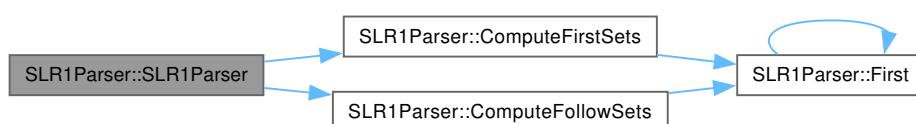
10.12.4.1 SLR1Parser() [1/2]

```
SLR1Parser::SLR1Parser () [default]
```

10.12.4.2 SLR1Parser() [2/2]

```
SLR1Parser::SLR1Parser (
    Grammar gr) [explicit]
```

Here is the call graph for this function:



10.12.5 Member Function Documentation

10.12.5.1 AllItems()

```
std::unordered_set< Lr0Item > SLR1Parser::AllItems () const
```

Retrieves all LR(0) items in the grammar. This function returns a set of all LR(0) items derived from the grammar's productions. Each LR(0) item represents a production with a marker indicating the current position in the production (e.g., $A \rightarrow \alpha \bullet \beta$).

Returns

A set of all LR(0) items in the grammar.

10.12.5.2 Closure()

```
void SLR1Parser::Closure (
    std::unordered_set< Lr0Item > & items)
```

Computes the closure of a set of LR(0) items.

This function computes the closure of a given set of LR(0) items by adding all items that can be derived from the current items using the grammar's productions. The closure operation ensures that all possible derivations are considered when constructing the parser's states.

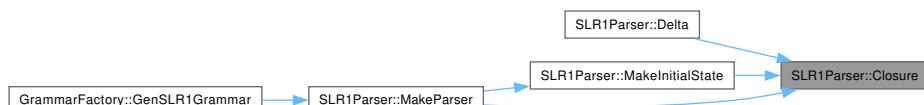
Parameters

<i>items</i>	The set of LR(0) items for which to compute the closure.
--------------	--

Here is the call graph for this function:



Here is the caller graph for this function:



10.12.5.3 ClosureUtil()

```
void SLR1Parser::ClosureUtil (
    std::unordered_set< Lr0Item > & items,
    unsigned int size,
    std::unordered_set< std::string > & visited)
```

Helper function for computing the closure of LR(0) items.

This function recursively computes the closure of a set of LR(0) items by adding items derived from non-terminal symbols. It avoids redundant work by tracking visited non-terminals and stopping when no new items are added.

Parameters

<i>items</i>	The set of LR(0) items being processed.
<i>size</i>	The size of the items set at the start of the current iteration.

<i>visited</i>	A set of non-terminals that have already been processed.
----------------	--

Here is the call graph for this function:



Here is the caller graph for this function:



10.12.5.4 ComputeFirstSets()

```
void SLR1Parser::ComputeFirstSets ()
```

Computes the FIRST sets for all non-terminal symbols in the grammar.

This function calculates the FIRST set for each non-terminal symbol in the grammar by iteratively applying a least fixed-point algorithm. This approach ensures that the FIRST sets are fully populated by repeatedly expanding and updating the sets until no further changes occur (i.e., a fixed-point is reached). Here is the call graph for this function:



Here is the caller graph for this function:



10.12.5.5 ComputeFollowSets()

```
void SLR1Parser::ComputeFollowSets ()
```

Computes the FOLLOW sets for all non-terminal symbols in the grammar. The FOLLOW set of a non-terminal symbol A contains all terminal symbols that can appear immediately after A in any sentential form derived from the grammar's start symbol. Additionally, if A can be the last symbol in a derivation, the end-of-input marker (`\$`) is included in its FOLLOW set. This function computes the FOLLOW sets using the following rules:

1. Initialize $\text{FOLLOW}(S) = \{\$\}$, where S is the start symbol.
2. For each production rule of the form $A \rightarrow \alpha B \beta$:
 - Add $\text{FIRST}(\beta) \setminus \{\epsilon\}$ to $\text{FOLLOW}(B)$.
 - If $\epsilon \in \text{FIRST}(\beta)$, add $\text{FOLLOW}(A)$ to $\text{FOLLOW}(B)$.
3. Repeat step 2 until no changes occur in any FOLLOW set. The computed FOLLOW sets are cached in the `follow_sets_` member variable for later use by the parser.

Note

This function assumes that the FIRST sets for all symbols have already been computed and are available in the `first_sets_` member variable.

See also

[First](#)
[follow_sets_](#)

Here is the call graph for this function:



Here is the caller graph for this function:

**10.12.5.6 Delta()**

```
std::unordered_set< Lr0Item > SLR1Parser::Delta (
    const std::unordered_set< Lr0Item > & items,
    const std::string & str)
```

Computes the GOTO transition (δ) for a given set of LR(0) items and a symbol. This function is equivalent to the $\delta(I, X)$ function in LR parsing, where it computes the set of items reached from a state I via symbol X .

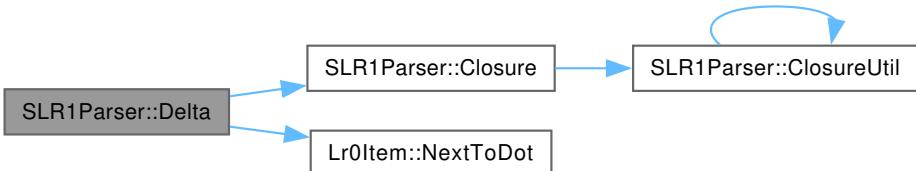
Parameters

<code>items</code>	The current set of LR(0) items (state).
<code>str</code>	The grammar symbol used for the transition.

Returns

The resulting item set after the GOTO transition.

Here is the call graph for this function:

**10.12.5.7 First()**

```
void SLR1Parser::First (
    std::span< const std::string > rule,
    std::unordered_set< std::string > & result)
```

Calculates the FIRST set for a given production rule in a grammar.

The FIRST set of a production rule contains all terminal symbols that can appear at the beginning of any string derived from that rule. If the rule can derive the empty string (epsilon), epsilon is included in the FIRST set.

This function computes the FIRST set by examining each symbol in the production rule:

- If a terminal symbol is encountered, it is added directly to the FIRST set, as it is the starting symbol of some derivation.
- If a non-terminal symbol is encountered, its FIRST set is recursively computed and added to the result, excluding epsilon unless it is followed by another symbol that could also lead to epsilon.
- If the entire rule could derive epsilon (i.e., each symbol in the rule can derive epsilon), then epsilon is added to the FIRST set.

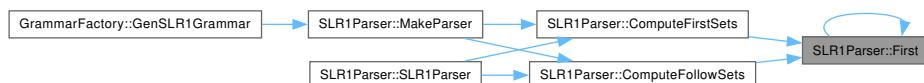
Parameters

<code>rule</code>	A span of strings representing the production rule for which to compute the FIRST set. Each string in the span is a symbol (either terminal or non-terminal).
<code>result</code>	A reference to an unordered set of strings where the computed FIRST set will be stored. The set will contain all terminal symbols that can start derivations of the rule, and possibly epsilon if the rule can derive an empty string.

Here is the call graph for this function:



Here is the caller graph for this function:



10.12.5.8 Follow()

```
std::unordered_set< std::string > SLR1Parser::Follow (
    const std::string & arg)
```

Computes the FOLLOW set for a given non-terminal symbol in the grammar.

The FOLLOW set for a non-terminal symbol includes all symbols that can appear immediately to the right of that symbol in any derivation, as well as any end-of-input markers if the symbol can appear at the end of derivations. FOLLOW sets are used in LL(1) parsing table construction to determine possible continuations after a non-terminal.

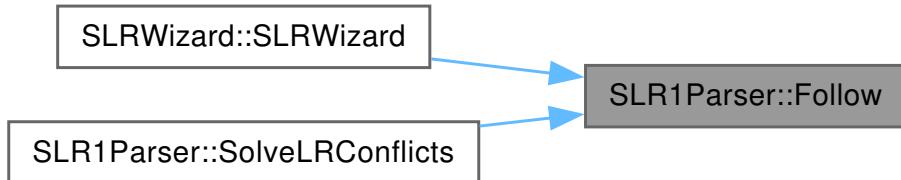
Parameters

<code>arg</code>	Non-terminal symbol for which to compute the FOLLOW set.
------------------	--

Returns

An unordered set of strings containing symbols that form the FOLLOW set for `arg`.

Here is the caller graph for this function:

**10.12.5.9 MakeInitialState()**

```
void SLR1Parser::MakeInitialState ()
```

Creates the initial state of the parser's state machine.

This function initializes the starting state of the parser by computing the closure of the initial set of LR(0) items derived from the grammar's start symbol. The initial state is added to the `states_` set, and its transitions are prepared for further processing in the parser construction.

See also

[states_](#)

[transitions_](#)

Here is the call graph for this function:



Here is the caller graph for this function:

**10.12.5.10 MakeParser()**

```
bool SLR1Parser::MakeParser ()
```

Constructs the SLR(1) parsing tables (action and transition tables).

This function builds the SLR(1) parsing tables by computing the canonical collection of LR(0) items, generating the action and transition tables, and resolving conflicts (if any). It returns `true` if the grammar is SLR(1) and the tables are successfully constructed, or `false` if a conflict is detected that cannot be resolved.

Returns

`true` if the parsing tables are successfully constructed, `false` if the grammar is not SLR(1) or a conflict is encountered.

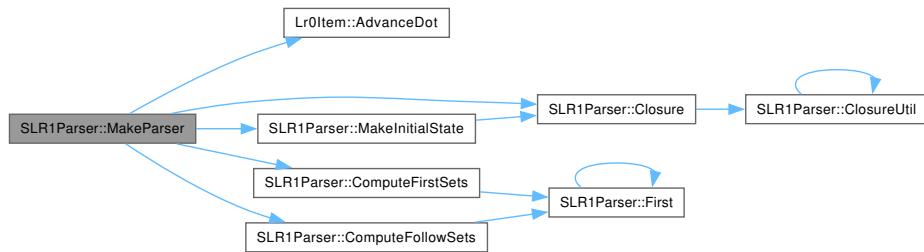
See also

[actions_](#)

[transitions_](#)

[states_](#)

Here is the call graph for this function:



Here is the caller graph for this function:



10.12.5.11 PrintItems()

```
std::string SLR1Parser::PrintItems (
    const std::unordered_set< Lr0Item > & items) const
```

Returns a string representation of a set of LR(0) items.

This function converts a set of LR(0) items into a human-readable string, including dot positions, to help visualize parser states.

Parameters

<code>items</code>	The set of LR(0) items to print.
--------------------	----------------------------------

Returns

A formatted string representation of the items.

10.12.5.12 SolveLRConflicts()

```
bool SLR1Parser::SolveLRConflicts (
    const state & st)
```

Resolves LR conflicts in a given state.

This function attempts to resolve shift/reduce or reduce/reduce conflicts in a given state using SLR(1) parsing rules. It checks the FOLLOW sets of non-terminals to determine the correct action and updates the action table accordingly.

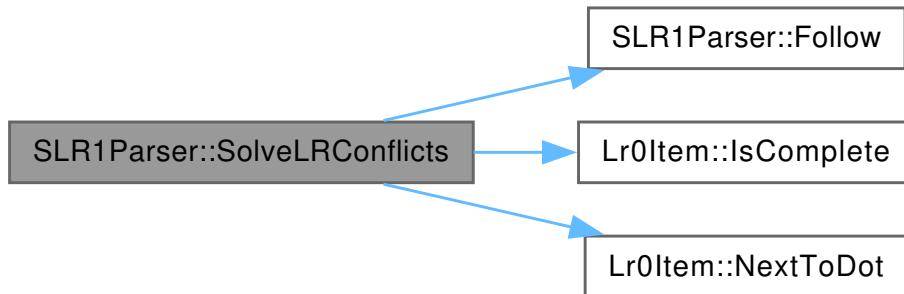
Parameters

<code>st</code>	The state in which to resolve conflicts.
-----------------	--

Returns

`true` if all conflicts are resolved, `false` if an unresolvable conflict is detected.

Here is the call graph for this function:



10.12.6 Member Data Documentation

10.12.6.1 `actions_`

`action_table` `SLR1Parser::actions_`

The action table used by the parser to determine shift/reduce actions.

10.12.6.2 `first_sets_`

`std::unordered_map<std::string, std::unordered_set<std::string> >` `SLR1Parser::first_sets_`
Cached FIRST sets for all symbols in the grammar.

10.12.6.3 `follow_sets_`

`std::unordered_map<std::string, std::unordered_set<std::string> >` `SLR1Parser::follow_sets_`
Cached FOLLOW sets for all non-terminal symbols in the grammar.

10.12.6.4 `gr_`

`Grammar` `SLR1Parser::gr_`

The grammar being processed by the parser.

10.12.6.5 `states_`

`std::unordered_set<state>` `SLR1Parser::states_`

The set of states in the parser's state machine.

10.12.6.6 `transitions_`

`transition_table` `SLR1Parser::transitions_`

The transition table used by the parser to determine state transitions.

The documentation for this class was generated from the following files:

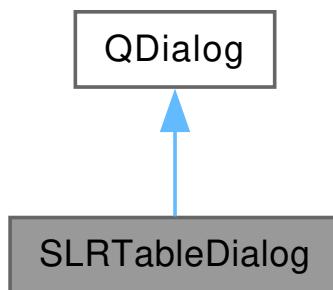
- backend/[slr1_parser.hpp](#)
- backend/[slr1_parser.cpp](#)

10.13 SLRTableDialog Class Reference

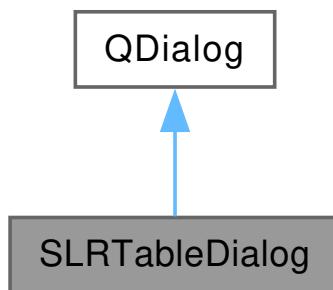
Dialog window for completing and submitting an SLR(1) parsing table.

```
#include <slrtabledialog.h>
```

Inheritance diagram for SLRTableDialog:



Collaboration diagram for SLRTableDialog:



Public Member Functions

- `SLRTableDialog (int rowCount, int colCount, const QStringList &colHeaders, QWidget *parent=nullptr, QVector< QVector< QString > > *initialData=nullptr)`
Constructs the SLR(1) table dialog.
- `QVector< QVector< QString > > getTableData () const`
Retrieves the content of the table after user interaction.
- `void setInitialData (const QVector< QVector< QString > > &data)`
Fills the table with existing data.

10.13.1 Detailed Description

Dialog window for completing and submitting an SLR(1) parsing table.

This class displays a table-based UI for students to fill in the ACTION and GOTO parts of the SLR(1) parsing table. It supports initializing the table with data, retrieving user input, and integrating with correction logic in tutorial or challenge mode.

10.13.2 Constructor & Destructor Documentation

10.13.2.1 SLRTableDialog()

```
SLRTableDialog::SLRTableDialog (
    int rowCount,
    int colCount,
    const QStringList & colHeaders,
    QWidget * parent = nullptr,
    QVector< QVector< QString > > * initialData = nullptr)
```

Constructs the SLR(1) table dialog.

Parameters

<i>rowCount</i>	Number of rows (usually equal to number of LR(0) states).
<i>colCount</i>	Number of columns (symbols = terminals + non-terminals).
<i>colHeaders</i>	Header labels for the columns.
<i>parent</i>	Parent widget.
<i>initialData</i>	Optional initial data to pre-fill the table.

10.13.3 Member Function Documentation**10.13.3.1 getTableData()**

```
QVector< QVector< QString > > SLRTableDialog::getTableData () const
Retrieves the content of the table after user interaction.
```

Returns

A 2D vector representing the current table values.

10.13.3.2 setInitialData()

```
void SLRTableDialog::setInitialData (
    const QVector< QVector< QString > > & data)
```

Fills the table with existing data.

This method is used to show a previous user submission (e.g., during retries or feedback).

Parameters

<i>data</i>	2D vector containing the table data to display.
-------------	---

The documentation for this class was generated from the following files:

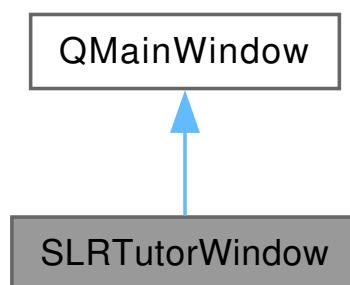
- [slrtabledialog.h](#)
- [slrtabledialog.cpp](#)

10.14 SLRTutorWindow Class Reference

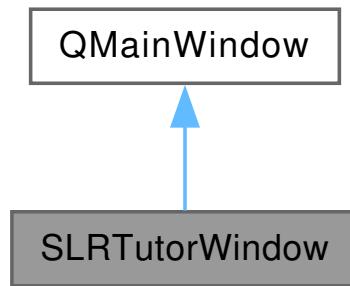
Main window for the SLR(1) interactive tutoring mode in [SyntaxTutor](#).

```
#include <slrtutorwindow.h>
```

Inheritance diagram for SLRTutorWindow:



Collaboration diagram for SLRTutorWindow:



Signals

- void `sessionFinished` (int cntRight, int cntWrong)

Public Member Functions

- `SLRTutorWindow` (const `Grammar` &g, `TutorialManager` *tm=nullptr, `QWidget` *parent=nullptr)
Constructs the SLR(1) tutor window with a given grammar.
- `~SLRTutorWindow` ()
- `QString generateQuestion` ()
Generates a new question for the current tutor state.
- void `updateState` (bool isCorrect)
Updates tutor state based on whether the last answer was correct.
- `QString FormatGrammar` (const `Grammar` &grammar)
- void `fillSortedGrammar` ()
< Utility for displaying grammar
- void `addMessage` (const `QString` &text, bool isUser)
< Prepares grammar in display-friendly format
- void `exportConversationToPdf` (const `QString` &filePath)
< Add message to chat
- void `showTable` ()
< Export full interaction
- void `launchSLRWizard` ()
< Render SLR(1) table
- void `updateProgressPanel` ()
- void `addUserState` (unsigned id)
< Refresh visual progress
- void `addUserTransition` (unsigned fromId, const std::string &symbol, unsigned told)
< Register a user-created state
- void `animateLabelPop` (`QLabel` *label)
- void `animateLabelColor` (`QLabel` *label, const `QColor` &flashColor)
- void `wrongAnimation` ()
- void `wrongUserResponseAnimation` ()
- void `markLastUserIncorrect` ()
- bool `verifyResponse` (const `QString` &userResponse)
- bool `verifyResponseForA` (const `QString` &userResponse)
- bool `verifyResponseForA1` (const `QString` &userResponse)
- bool `verifyResponseForA2` (const `QString` &userResponse)
- bool `verifyResponseForA3` (const `QString` &userResponse)
- bool `verifyResponseForA4` (const `QString` &userResponse)
- bool `verifyResponseForB` (const `QString` &userResponse)

- bool `verifyResponseForC` (const QString &userResponse)
- bool `verifyResponseForCA` (const QString &userResponse)
- bool `verifyResponseForCB` (const QString &userResponse)
- bool `verifyResponseForD` (const QString &userResponse)
- bool `verifyResponseForD1` (const QString &userResponse)
- bool `verifyResponseForD2` (const QString &userResponse)
- bool `verifyResponseForE` (const QString &userResponse)
- bool `verifyResponseForE1` (const QString &userResponse)
- bool `verifyResponseForE2` (const QString &userResponse)
- bool `verifyResponseForF` (const QString &userResponse)
- bool `verifyResponseForFA` (const QString &userResponse)
- bool `verifyResponseForG` (const QString &userResponse)
- bool `verifyResponseForH` ()
- QString `solution` (const std::string &`state`)
- std::unordered_set< `Lr0Item` > `solutionForA` ()
- QString `solutionForA1` ()
- QString `solutionForA2` ()
- std::vector< std::pair< std::string, std::vector< std::string > > > `solutionForA3` ()
- std::unordered_set< `Lr0Item` > `solutionForA4` ()
- unsigned `solutionForB` ()
- unsigned `solutionForC` ()
- QStringList `solutionForCA` ()
- std::unordered_set< `Lr0Item` > `solutionForCB` ()
- QStringList `solutionForD` ()
- QString `solutionForD1` ()
- QString `solutionForD2` ()
- std::ptrdiff_t `solutionForE` ()
- QSet< unsigned > `solutionForE1` ()
- QMap< unsigned, unsigned > `solutionForE2` ()
- QSet< unsigned > `solutionForF` ()
- QSet< QString > `solutionForFA` ()
- QSet< QString > `solutionForG` ()
- QString `feedback` ()
- QString `feedbackForA` ()
- QString `feedbackForA1` ()
- QString `feedbackForA2` ()
- QString `feedbackForA3` ()
- QString `feedbackForA4` ()
- QString `feedbackForAPrime` ()
- QString `feedbackForB` ()
- QString `feedbackForB1` ()
- QString `feedbackForB2` ()
- QString `feedbackForBPrime` ()
- QString `feedbackForC` ()
- QString `feedbackForCA` ()
- QString `feedbackForCB` ()
- QString `feedbackForD` ()
- QString `feedbackForD1` ()
- QString `feedbackForD2` ()
- QString `feedbackForDPrime` ()
- QString `feedbackForE` ()
- QString `feedbackForE1` ()
- QString `feedbackForE2` ()
- QString `feedbackForF` ()
- QString `feedbackForFA` ()

- `QString feedbackForG ()`
- `QString TeachDeltaFunction (const std::unordered_set< Lr0Item > &items, const QString &symbol)`
- `void TeachClosureStep (std::unordered_set< Lr0Item > &items, unsigned int size, std::unordered_set< std::string > &visited, int depth, QString &output)`
- `QString TeachClosure (const std::unordered_set< Lr0Item > &initialItems)`

Protected Member Functions

- void `closeEvent (QCloseEvent *event) override`

10.14.1 Detailed Description

Main window for the SLR(1) interactive tutoring mode in [SyntaxTutor](#).

This class implements an interactive, step-by-step tutorial to teach students how to construct SLR(1) parsing tables, including closure, GOTO, automaton construction, FOLLOW sets, and the final table. It supports animated feedback, pedagogical guidance, error correction, and export of the tutoring session. The tutor follows a finite-state flow ([StateSlr](#)) to structure learning, with corrective explanations and automatic evaluation at each step.

10.14.2 Constructor & Destructor Documentation

10.14.2.1 SLRTutorWindow()

```
SLRTutorWindow::SLRTutorWindow (
    const Grammar & g,
    TutorialManager * tm = nullptr,
    QWidget * parent = nullptr) [explicit]
```

Constructs the SLR(1) tutor window with a given grammar.

Parameters

<code>g</code>	The grammar used for the session.
<code>tm</code>	Optional pointer to the tutorial manager (for guided tour).
<code>parent</code>	Parent widget.

Here is the call graph for this function:



Here is the caller graph for this function:



10.14.2.2 ~SLRTutorWindow()

```
SLRTutorWindow::~SLRTutorWindow ()
```

10.14.3 Member Function Documentation**10.14.3.1 addMessage()**

```
void SLRTutorWindow::addMessage (
    const QString & text,
    bool isUser)
```

< Prepares grammar in display-friendly format

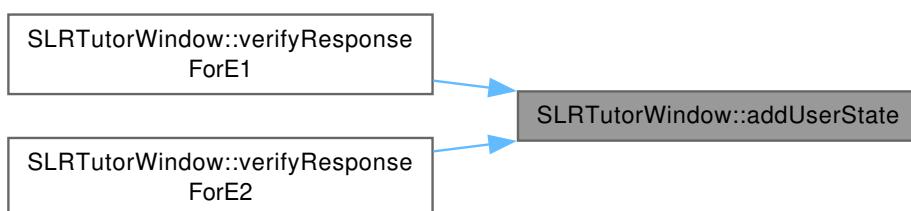
Here is the caller graph for this function:

**10.14.3.2 addUserState()**

```
void SLRTutorWindow::addUserState (
    unsigned id)
```

< Refresh visual progress

Here is the caller graph for this function:

**10.14.3.3 addUserTransition()**

```
void SLRTutorWindow::addUserTransition (
    unsigned fromId,
    const std::string & symbol,
    unsigned toId)
```

< Register a user-created state

10.14.3.4 animateLabelColor()

```
void SLRTutorWindow::animateLabelColor (
    QLabel * label,
    const QColor & flashColor)
```

10.14.3.5 animateLabelPop()

```
void SLRTutorWindow::animateLabelPop (
    QLabel * label)
```

10.14.3.6 closeEvent()

```
void SLRTutorWindow::closeEvent (
    QCloseEvent * event) [inline], [override], [protected]
```

Here is the call graph for this function:

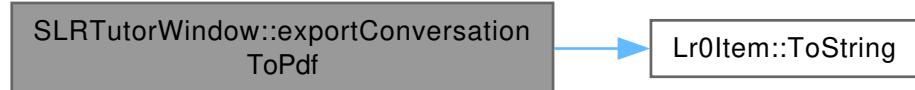


10.14.3.7 exportConversationToPdf()

```
void SLRTutorWindow::exportConversationToPdf (
    const QString & filePath)
```

< Add message to chat

Here is the call graph for this function:



10.14.3.8 feedback()

```
QString SLRTutorWindow::feedback ()
```

10.14.3.9 feedbackForA()

```
QString SLRTutorWindow::feedbackForA ()
```

10.14.3.10 feedbackForA1()

```
QString SLRTutorWindow::feedbackForA1 ()
```

10.14.3.11 feedbackForA2()

```
QString SLRTutorWindow::feedbackForA2 ()
```

10.14.3.12 feedbackForA3()

```
QString SLRTutorWindow::feedbackForA3 ()
```

10.14.3.13 feedbackForA4()

```
QString SLRTutorWindow::feedbackForA4 ()
```

10.14.3.14 feedbackForAPrime()

```
QString SLRTutorWindow::feedbackForAPrime ()
```

10.14.3.15 feedbackForB()

```
QString SLRTutorWindow::feedbackForB ()
```

10.14.3.16 feedbackForB1()

```
QString SLRTutorWindow::feedbackForB1 ()
```

10.14.3.17 feedbackForB2()

```
QString SLRTutorWindow::feedbackForB2 ()
```

10.14.3.18 feedbackForBPrime()

```
QString SLRTutorWindow::feedbackForBPrime ()
```

10.14.3.19 feedbackForC()

```
QString SLRTutorWindow::feedbackForC ()
```

10.14.3.20 feedbackForCA()

```
QString SLRTutorWindow::feedbackForCA ()
```

10.14.3.21 feedbackForCB()

```
QString SLRTutorWindow::feedbackForCB ()
```

10.14.3.22 feedbackForD()

```
QString SLRTutorWindow::feedbackForD ()
```

10.14.3.23 feedbackForD1()

```
QString SLRTutorWindow::feedbackForD1 ()
```

10.14.3.24 feedbackForD2()

```
QString SLRTutorWindow::feedbackForD2 ()
```

10.14.3.25 feedbackForDPrime()

```
QString SLRTutorWindow::feedbackForDPrime ()
```

10.14.3.26 feedbackForE()

```
QString SLRTutorWindow::feedbackForE ()
```

10.14.3.27 feedbackForE1()

```
QString SLRTutorWindow::feedbackForE1 ()
```

10.14.3.28 feedbackForE2()

```
QString SLRTutorWindow::feedbackForE2 ()
```

10.14.3.29 feedbackForF()

```
QString SLRTutorWindow::feedbackForF ()
```

10.14.3.30 feedbackForFA()

```
QString SLRTutorWindow::feedbackForFA ()
```

10.14.3.31 feedbackForG()

```
QString SLRTutorWindow::feedbackForG ()
```

10.14.3.32 fillSortedGrammar()

```
void SLRTutorWindow::fillSortedGrammar ()
```

```
< Utility for displaying grammar
```

10.14.3.33 FormatGrammar()

```
QString SLRTutorWindow::FormatGrammar (
    const Grammar & grammar)
```

10.14.3.34 generateQuestion()

```
QString SLRTutorWindow::generateQuestion ()
Generates a new question for the current tutor state.
```

Returns

The formatted question string.

10.14.3.35 launchSLRWizard()

```
void SLRTutorWindow::launchSLRWizard ()
< Render SLR(1) table
```

10.14.3.36 markLastUserIncorrect()

```
void SLRTutorWindow::markLastUserIncorrect ()
```

10.14.3.37 sessionFinished

```
void SLRTutorWindow::sessionFinished (
    int cntRight,
    int cntWrong) [signal]
```

Here is the caller graph for this function:



10.14.3.38 showTable()

```
void SLRTutorWindow::showTable ()
< Export full interaction
```

Here is the caller graph for this function:



10.14.3.39 solution()

```
QString SLRTutorWindow::solution (
    const std::string & state)
```

10.14.3.40 solutionForA()

```
std::unordered_set< Lr0Item > SLRTutorWindow::solutionForA ()
```

10.14.3.41 solutionForA1()

```
QString SLRTutorWindow::solutionForA1 ()
```

10.14.3.42 solutionForA2()

```
QString SLRTutorWindow::solutionForA2 ()
```

10.14.3.43 solutionForA3()

```
std::vector< std::pair< std::string, std::vector< std::string > > > SLRTutorWindow::solutionForA3 ()
```

10.14.3.44 solutionForA4()

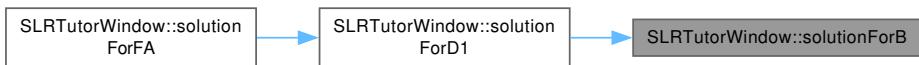
```
std::unordered_set< Lr0Item > SLRTutorWindow::solutionForA4 ()
```

Here is the caller graph for this function:

**10.14.3.45 solutionForB()**

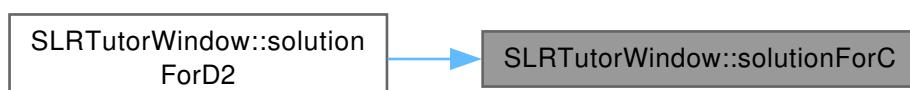
```
unsigned SLRTutorWindow::solutionForB ()
```

Here is the caller graph for this function:

**10.14.3.46 solutionForC()**

```
unsigned SLRTutorWindow::solutionForC ()
```

Here is the caller graph for this function:

**10.14.3.47 solutionForCA()**

```
QStringList SLRTutorWindow::solutionForCA ()
```

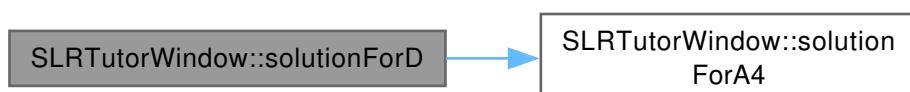
10.14.3.48 solutionForCB()

```
std::unordered_set< Lr0Item > SLRTutorWindow::solutionForCB ()
```

10.14.3.49 solutionForD()

```
QStringList SLRTutorWindow::solutionForD ()
```

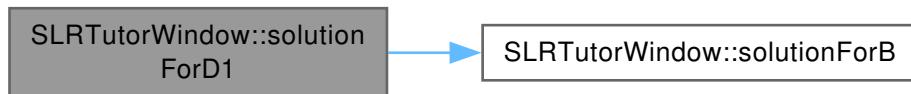
Here is the call graph for this function:



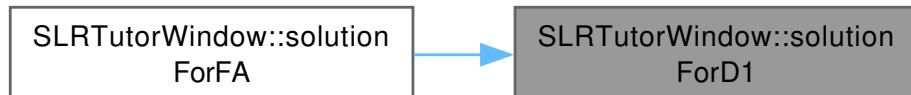
10.14.3.50 solutionForD1()

```
QString SLRTutorWindow::solutionForD1 ()
```

Here is the call graph for this function:



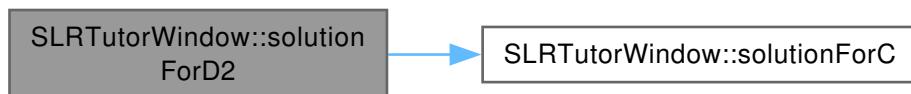
Here is the caller graph for this function:



10.14.3.51 solutionForD2()

```
QString SLRTutorWindow::solutionForD2 ()
```

Here is the call graph for this function:



10.14.3.52 solutionForE()

```
std::ptrdiff_t SLRTutorWindow::solutionForE ()
```

10.14.3.53 solutionForE1()

```
QSet< unsigned > SLRTutorWindow::solutionForE1 ()
```

10.14.3.54 solutionForE2()

```
QMap< unsigned, unsigned > SLRTutorWindow::solutionForE2 ()
```

10.14.3.55 solutionForF()

```
QSet< unsigned > SLRTutorWindow::solutionForF ()
```

10.14.3.56 solutionForFA()

```
QSet< QString > SLRTutorWindow::solutionForFA ()
```

Here is the call graph for this function:



10.14.3.57 solutionForG()

```
QSet< QString > SLRTutorWindow::solutionForG ()
```

10.14.3.58 TeachClosure()

```
QString SLRTutorWindow::TeachClosure (
    const std::unordered_set< Lr0Item > & initialItems)
```

10.14.3.59 TeachClosureStep()

```
void SLRTutorWindow::TeachClosureStep (
    std::unordered_set< Lr0Item > & items,
    unsigned int size,
    std::unordered_set< std::string > & visited,
    int depth,
    QString & output)
```

10.14.3.60 TeachDeltaFunction()

```
QString SLRTutorWindow::TeachDeltaFunction (
    const std::unordered_set< Lr0Item > & items,
    const QString & symbol)
```

10.14.3.61 updateProgressPanel()

```
void SLRTutorWindow::updateProgressPanel ()
```

10.14.3.62 updateState()

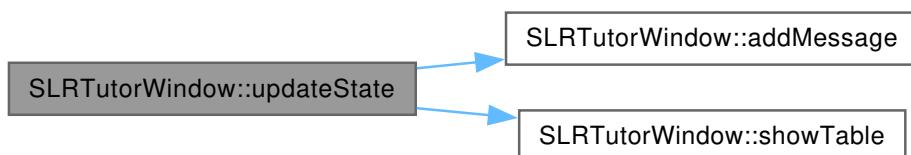
```
void SLRTutorWindow::updateState (
    bool isCorrect)
```

Updates tutor state based on whether the last answer was correct.

Parameters

<i>isCorrect</i>	Whether the user's answer was correct.
------------------	--

Here is the call graph for this function:

**10.14.3.63 verifyResponse()**

```
bool SLRTutorWindow::verifyResponse (
    const QString & userResponse)
```

10.14.3.64 verifyResponseForA()

```
bool SLRTutorWindow::verifyResponseForA (
    const QString & userResponse)
```

10.14.3.65 verifyResponseForA1()

```
bool SLRTutorWindow::verifyResponseForA1 (
    const QString & userResponse)
```

10.14.3.66 verifyResponseForA2()

```
bool SLRTutorWindow::verifyResponseForA2 (const QString & userResponse)
```

10.14.3.67 verifyResponseForA3()

```
bool SLRTutorWindow::verifyResponseForA3 (const QString & userResponse)
```

10.14.3.68 verifyResponseForA4()

```
bool SLRTutorWindow::verifyResponseForA4 (const QString & userResponse)
```

10.14.3.69 verifyResponseForB()

```
bool SLRTutorWindow::verifyResponseForB (const QString & userResponse)
```

10.14.3.70 verifyResponseForC()

```
bool SLRTutorWindow::verifyResponseForC (const QString & userResponse)
```

10.14.3.71 verifyResponseForCA()

```
bool SLRTutorWindow::verifyResponseForCA (const QString & userResponse)
```

10.14.3.72 verifyResponseForCB()

```
bool SLRTutorWindow::verifyResponseForCB (const QString & userResponse)
```

10.14.3.73 verifyResponseForD()

```
bool SLRTutorWindow::verifyResponseForD (const QString & userResponse)
```

10.14.3.74 verifyResponseForD1()

```
bool SLRTutorWindow::verifyResponseForD1 (const QString & userResponse)
```

10.14.3.75 verifyResponseForD2()

```
bool SLRTutorWindow::verifyResponseForD2 (const QString & userResponse)
```

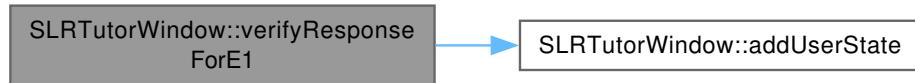
10.14.3.76 verifyResponseForE()

```
bool SLRTutorWindow::verifyResponseForE (const QString & userResponse)
```

10.14.3.77 verifyResponseForE1()

```
bool SLRTutorWindow::verifyResponseForE1 (const QString & userResponse)
```

Here is the call graph for this function:

**10.14.3.78 verifyResponseForE2()**

```
bool SLRTutorWindow::verifyResponseForE2 (const QString & userResponse)
```

Here is the call graph for this function:

**10.14.3.79 verifyResponseForF()**

```
bool SLRTutorWindow::verifyResponseForF (const QString & userResponse)
```

10.14.3.80 verifyResponseForFA()

```
bool SLRTutorWindow::verifyResponseForFA (const QString & userResponse)
```

10.14.3.81 verifyResponseForG()

```
bool SLRTutorWindow::verifyResponseForG (const QString & userResponse)
```

10.14.3.82 verifyResponseForH()

```
bool SLRTutorWindow::verifyResponseForH ()
```

10.14.3.83 wrongAnimation()

```
void SLRTutorWindow::wrongAnimation ()
```

10.14.3.84 wrongUserResponseAnimation()

```
void SLRTutorWindow::wrongUserResponseAnimation ()
```

The documentation for this class was generated from the following files:

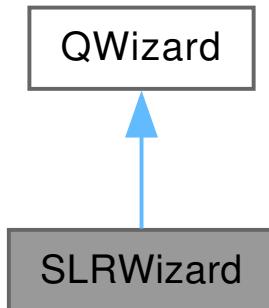
- [slrtutorwindow.h](#)
- [slrtutorwindow.cpp](#)

10.15 SLRWizard Class Reference

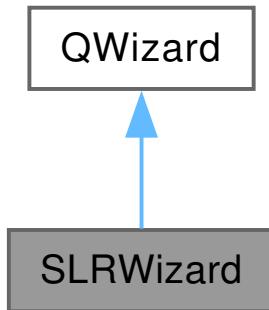
Interactive assistant that guides the student step-by-step through the SLR(1) parsing table.

```
#include <slrwizard.h>
```

Inheritance diagram for SLRWizard:



Collaboration diagram for SLRWizard:



Public Member Functions

- [SLRWizard \(SLR1Parser &parser, const QVector< QVector< QString > > &rawTable, const QString &list, const QVector< QPair< QString, QVector< QString > > > &sortedGrammar, QWidget *parent=nullptr\)](#)
Constructs the SLR(1) wizard with all necessary parsing context.
- [QVector< QString > stdVectorToQVector \(const std::vector< std::string > &vec\)](#)
Converts a std::vector< std::string > to QVector< QString > for UI compatibility.

10.15.1 Detailed Description

Interactive assistant that guides the student step-by-step through the SLR(1) parsing table.

This wizard-based dialog presents the user with one cell of the SLR(1) parsing table at a time, asking them to deduce the correct ACTION or GOTO entry based on the LR(0) automaton and FOLLOW sets. It is designed as an educational aid to explain the reasoning behind each parsing decision.

Each page includes:

- The current state and symbol (terminal or non-terminal).
- A guided explanation based on the grammar and LR(0) state.
- The expected entry (e.g., s3, r1, acc, or a state number).

10.15.2 Constructor & Destructor Documentation

10.15.2.1 SLRWizard()

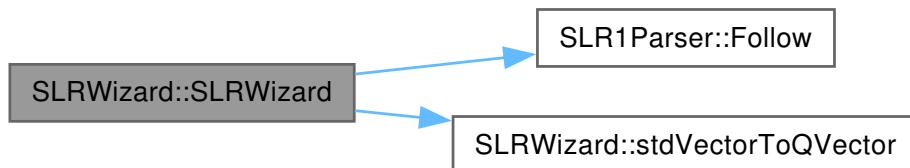
```
SLRWizard::SLRWizard (
    SLR1Parser & parser,
    const QVector< QVector< QString > > & rawTable,
    const QStringList & colHeaders,
    const QVector< QPair< QString, QVector< QString > > > & sortedGrammar,
    QWidget * parent = nullptr) [inline]
```

Constructs the SLR(1) wizard with all necessary parsing context.

Parameters

<i>parser</i>	The SLR(1) parser instance containing the LR(0) states and transitions.
<i>rawTable</i>	The target parsing table (student version or reference).
<i>colHeaders</i>	Header symbols (terminals and non-terminals).
<i>sortedGrammar</i>	Ordered list of grammar rules for reduce explanations.
<i>parent</i>	Parent widget.

Here is the call graph for this function:



10.15.3 Member Function Documentation

10.15.3.1 stdVectorToQVector()

```
QVector< QString > SLRWizard::stdVectorToQVector (
    const std::vector< std::string > & vec) [inline]
```

Converts a `std::vector<std::string>` to `QVector<QString>` for UI compatibility.

Parameters

<i>vec</i>	The input vector of strings.
------------	------------------------------

Returns

A `QVector` of `QString`s.

Here is the caller graph for this function:



The documentation for this class was generated from the following file:

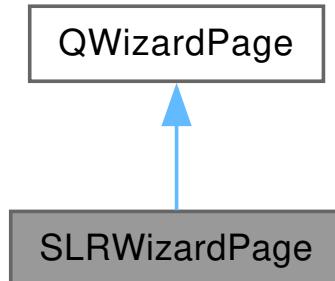
- [slrwizard.h](#)

10.16 SLRWizardPage Class Reference

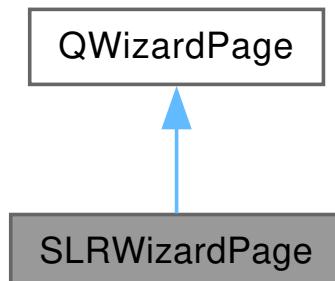
A single step in the SLR(1) guided assistant for table construction.

```
#include <slrwizardpage.h>
```

Inheritance diagram for SLRWizardPage:



Collaboration diagram for SLRWizardPage:



Public Member Functions

- [SLRWizardPage](#) (int `state`, const QString &`symbol`, const QString &`explanation`, const QString &`expected`, QWidget *`parent`=nullptr)

Constructs a page for a specific cell in the SLR(1) table.

10.16.1 Detailed Description

A single step in the SLR(1) guided assistant for table construction.

This wizard page presents a specific (state, symbol) cell in the SLR(1) parsing table, and prompts the student to enter the correct ACTION or GOTO value.

The page checks the user's input against the expected answer and provides immediate feedback, disabling the "Next" button until the correct response is entered.

10.16.2 Constructor & Destructor Documentation

10.16.2.1 SLRWizardPage()

```
SLRWizardPage::SLRWizardPage (
    int state,
    const QString & symbol,
    const QString & explanation,
    const QString & expected,
    QWidget * parent = nullptr) [inline]
```

Constructs a page for a specific cell in the SLR(1) table.

Parameters

<i>state</i>	The state ID (row index in the table).
<i>symbol</i>	The grammar symbol (column header).
<i>explanation</i>	A pedagogical explanation shown to the user.
<i>expected</i>	The expected answer (e.g., "s2", "r1", "acc", or a state number).
<i>parent</i>	The parent widget.

The documentation for this class was generated from the following file:

- [slrwizardpage.h](#)

10.17 state Struct Reference

Represents a state in the LR(0) automaton.

```
#include <state.hpp>
```

Public Member Functions

- `bool operator==(const state &other) const`
Equality operator for comparing states based on their items.

Public Attributes

- `std::unordered_set<Lr0Item> items_`
The set of LR(0) items that make up this state.
- `unsigned int id_`
Unique identifier of the state.

10.17.1 Detailed Description

Represents a state in the LR(0) automaton.

Each state consists of a unique identifier and a set of LR(0) items that define its core. States are used to build the SLR(1) parsing table.

10.17.2 Member Function Documentation

10.17.2.1 operator==()

```
bool state::operator== (
    const state & other) const [inline]
Equality operator for comparing states based on their items.
```

Parameters

<i>other</i>	The state to compare with.
--------------	----------------------------

Returns

true if both states have the same item set; false otherwise.

10.17.3 Member Data Documentation

10.17.3.1 id_

`unsigned int state::id_`

Unique identifier of the state.

10.17.3.2 items_

`std::unordered_set<Lr0Item> state::items_`

The set of LR(0) items that make up this state.

The documentation for this struct was generated from the following file:

- backend/[state.hpp](#)

10.18 SymbolTable Struct Reference

Stores and manages grammar symbols, including their classification and special markers.

#include <symbol_table.hpp>

Public Member Functions

- void [PutSymbol](#) (const std::string &identifier, bool isTerminal)

Adds a non-terminal symbol to the symbol table.
- bool [In](#) (const std::string &s) const

Checks if a symbol exists in the symbol table.
- bool [IsTerminal](#) (const std::string &s) const

Checks if a symbol is a terminal.
- bool [IsTerminalWthoEol](#) (const std::string &s) const

Checks if a symbol is a terminal excluding EOL.

Public Attributes

- std::string [EOL_](#) {"\$"}

End-of-line symbol used in parsing, initialized as "\$".
- std::string [EPSILON_](#) {"EPSILON"}

Epsilon symbol, representing empty transitions, initialized as "EPSILON".
- std::unordered_map< std::string, [symbol_type](#) > [st_](#)

Main symbol table, mapping identifiers to a pair of symbol type and its regex.
- std::unordered_set< std::string > [terminals_{EOL_}](#)

Set of all terminal symbols (including EOL).
- std::unordered_set< std::string > [terminals_wtho_eol_](#) {}

Set of terminal symbols excluding the EOL symbol (\$).
- std::unordered_set< std::string > [non_terminals_](#)

Set of all non-terminal symbols.

10.18.1 Detailed Description

Stores and manages grammar symbols, including their classification and special markers.

This structure holds information about all terminals and non-terminals used in a grammar, as well as special symbols such as EPSILON and the end-of-line marker (\$). It supports symbol classification, membership checks, and filtered views such as terminals excluding \$.

10.18.2 Member Function Documentation

10.18.2.1 In()

`bool SymbolTable::In (`
 `const std::string & s) const`

Checks if a symbol exists in the symbol table.

Parameters

s Symbol identifier to search.

Returns

true if the symbol is present, otherwise false.

10.18.2.2 IsTerminal()

```
bool SymbolTable::IsTerminal (
    const std::string & s) const
```

Checks if a symbol is a terminal.

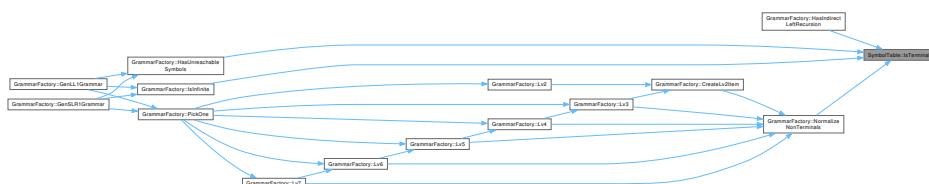
Parameters

s Symbol identifier to check.

Returns

true if the symbol is terminal, otherwise false.

Here is the caller graph for this function:



10.18.2.3 IsTerminalWthoEol()

`bool SymbolTable::IsTerminalWthoEol (`
 `const std::string & s)` const
Checks if a symbol is a terminal excluding EOL.

Parameters

s Symbol identifier to check.

Returns

true if the symbol is terminal, otherwise false.

10.18.2.4 PutSymbol()

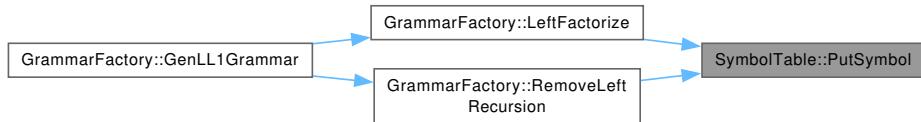
```
void SymbolTable::PutSymbol (
    const std::string & identifier,
    bool isTerminal)
```

Adds a non-terminal symbol to the symbol table.

Parameters

<i>identifier</i>	Name of the symbol.
<i>isTerminal</i>	True if the identifier is a terminal symbol

Here is the caller graph for this function:



10.18.3 Member Data Documentation

10.18.3.1 EOL_

```
std::string SymbolTable::EOL_ {"$"}  
End-of-line symbol used in parsing, initialized as "$".
```

10.18.3.2 EPSILON_

```
std::string SymbolTable::EPSILON_ {"EPSILON"}  
Epsilon symbol, representing empty transitions, initialized as "EPSILON".
```

10.18.3.3 non_terminals_

```
std::unordered_set<std::string> SymbolTable::non_terminals_  
Set of all non-terminal symbols.
```

10.18.3.4 st_

```
std::unordered_map<std::string, symbol_type> SymbolTable::st_  
Initial value:
```

```
{  
    {EOL_, symbol_type::TERMINAL}, {EPSILON_, symbol_type::TERMINAL}}}
```

Main symbol table, mapping identifiers to a pair of symbol type and its regex.

10.18.3.5 terminals_

```
std::unordered_set<std::string> SymbolTable::terminals_ {EOL_}  
Set of all terminal symbols (including EOL).
```

10.18.3.6 terminals_wtho_eol_

```
std::unordered_set<std::string> SymbolTable::terminals_wtho_eol_ {}  
Set of terminal symbols excluding the EOL symbol ($).
```

The documentation for this struct was generated from the following files:

- backend/[symbol_table.hpp](#)
- backend/[symbol_table.cpp](#)

10.19 LLTutorWindow::TreeNode Struct Reference

`TreeNode` structure used to build derivation trees.

```
#include <lltutorwindow.h>
```

Public Attributes

- `QString label`
- `std::vector< std::unique_ptr< TreeNode > > children`

10.19.1 Detailed Description

`TreeNode` structure used to build derivation trees.

10.19.2 Member Data Documentation

10.19.2.1 children

```
std::vector<std::unique_ptr<TreeNode>> LLTutorWindow::TreeNode::children
```

10.19.2.2 label

`QString LLTutorWindow::TreeNode::label`

The documentation for this struct was generated from the following file:

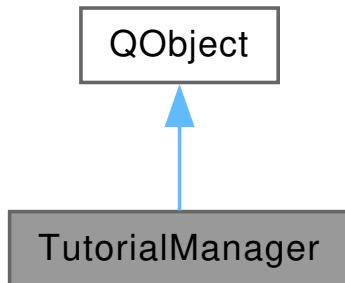
- `lltutorwindow.h`

10.20 TutorialManager Class Reference

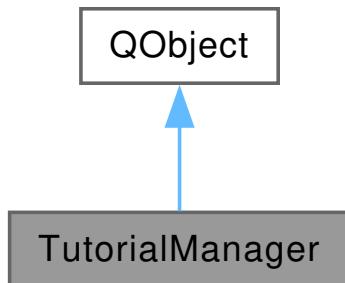
Manages interactive tutorials by highlighting UI elements and guiding the user.

```
#include <tutorialmanager.h>
```

Inheritance diagram for TutorialManager:



Collaboration diagram for TutorialManager:



Public Slots

- void `nextStep ()`
Advances to the next tutorial step.

Signals

- void `stepStarted (int index)`
Emitted when a new tutorial step starts.
- void `tutorialFinished ()`
Emitted when the full tutorial is finished.
- void `ll1Finished ()`
Emitted when the LL(1) tutorial ends.
- void `slr1Finished ()`
Emitted when the SLR(1) tutorial ends.

Public Member Functions

- `TutorialManager (QWidget *rootWindow)`
Constructs a `TutorialManager` for a given window.
- void `addStep (QWidget *target, const QString &htmlText)`
Adds a new step to the tutorial sequence.
- void `start ()`
Starts the tutorial from the beginning.
- void `setRootWindow (QWidget *newRoot)`
Sets the root window (used for repositioning the overlay).
- void `clearSteps ()`
Clears all steps in the tutorial.
- void `hideOverlay ()`
Hides the tutorial overlay immediately.
- void `finishLL1 ()`
Ends the LL(1) tutorial sequence and emits its corresponding signal.
- void `finishSLR1 ()`
Ends the SLR(1) tutorial sequence and emits its corresponding signal.

Protected Member Functions

- bool `eventFilter (QObject *obj, QEvent *ev) override`
Intercepts UI events to handle overlay behavior.

10.20.1 Detailed Description

Manages interactive tutorials by highlighting UI elements and guiding the user.

This class implements a step-by-step overlay system that visually highlights widgets and shows textual instructions to guide the user through the interface. It supports multiple tutorials (e.g., for LL(1) and SLR(1) modes), with custom steps and signals for tutorial completion.

10.20.2 Constructor & Destructor Documentation

10.20.2.1 TutorialManager()

```
TutorialManager::TutorialManager (
    QWidget * rootWindow)
Constructs a TutorialManager for a given window.
```

Parameters

<i>rootWindow</i>	The main application window used for relative positioning.
-------------------	--

10.20.3 Member Function Documentation

10.20.3.1 addStep()

```
void TutorialManager::addStep (
    QWidget * target,
    const QString & htmlText)
```

Adds a new step to the tutorial sequence.

Parameters

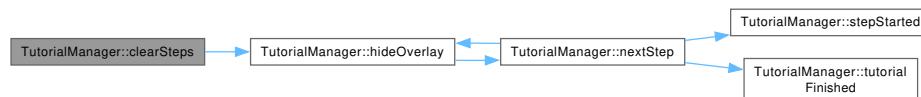
<i>target</i>	The widget to highlight during the step.
<i>htmlText</i>	The instructional HTML message for the step.

10.20.3.2 clearSteps()

```
void TutorialManager::clearSteps ()
```

Clears all steps in the tutorial.

Here is the call graph for this function:



10.20.3.3 eventFilter()

```
bool TutorialManager::eventFilter (
    QObject * obj,
    QEvent * ev) [override], [protected]
```

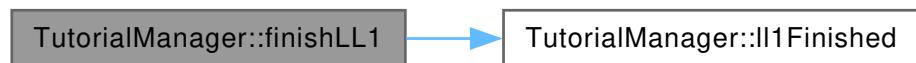
Intercepts UI events to handle overlay behavior.

10.20.3.4 finishLL1()

```
void TutorialManager::finishLL1 ()
```

Ends the LL(1) tutorial sequence and emits its corresponding signal.

Here is the call graph for this function:



10.20.3.5 finishSLR1()

```
void TutorialManager::finishSLR1 ()
```

Ends the SLR(1) tutorial sequence and emits its corresponding signal.

Here is the call graph for this function:



10.20.3.6 hideOverlay()

```
void TutorialManager::hideOverlay ()
```

Hides the tutorial overlay immediately.

Here is the call graph for this function:



Here is the caller graph for this function:



10.20.3.7 ll1Finished

```
void TutorialManager::ll1Finished () [signal]
```

Emitted when the LL(1) tutorial ends.

Here is the caller graph for this function:

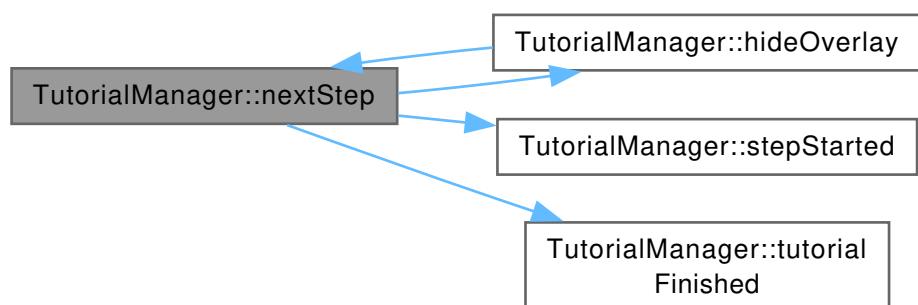


10.20.3.8 nextStep

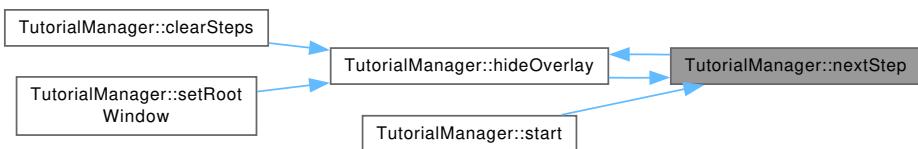
```
void TutorialManager::nextStep () [slot]
```

Advances to the next tutorial step.

Here is the call graph for this function:



Here is the caller graph for this function:



10.20.3.9 setRootWindow()

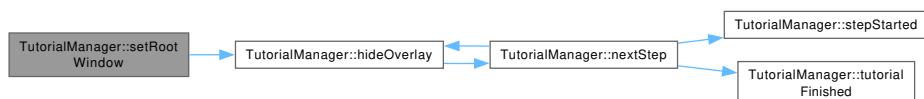
```
void TutorialManager::setRootWindow (
    QWidget * newRoot)
```

Sets the root window (used for repositioning the overlay).

Parameters

<i>newRoot</i>	The new main window to reference.
----------------	-----------------------------------

Here is the call graph for this function:



10.20.3.10 slr1Finished

```
void TutorialManager::slr1Finished () [signal]
```

Emitted when the SLR(1) tutorial ends.

Here is the caller graph for this function:



10.20.3.11 start()

```
void TutorialManager::start ()
```

Starts the tutorial from the beginning.

Here is the call graph for this function:



10.20.3.12 stepStarted

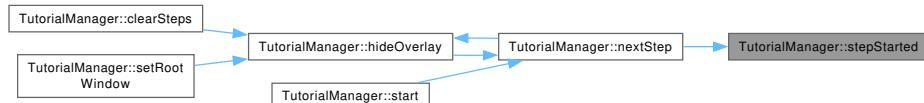
```
void TutorialManager::stepStarted (
    int index) [signal]
```

Emitted when a new tutorial step starts.

Parameters

<i>index</i>	Index of the current step.
--------------	----------------------------

Here is the caller graph for this function:

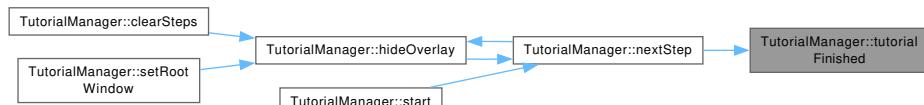


10.20.3.13 tutorialFinished

```
void TutorialManager::tutorialFinished () [signal]
```

Emitted when the full tutorial is finished.

Here is the caller graph for this function:



The documentation for this class was generated from the following files:

- `tutorialmanager.h`
- `tutorialmanager.cpp`

10.21 TutorialStep Struct Reference

Represents a single step in the tutorial sequence.

```
#include <tutorialmanager.h>
```

Public Attributes

- `QWidget * target`
Widget to highlight during the tutorial step.
- `QString htmlText`
HTML text to show as instruction or explanation.

10.21.1 Detailed Description

Represents a single step in the tutorial sequence.

Each step highlights a target widget and displays an associated HTML-formatted message.

10.21.2 Member Data Documentation

10.21.2.1 htmlText

```
QString TutorialStep::htmlText
```

HTML text to show as instruction or explanation.

10.21.2.2 target

`QWidget* TutorialStep::target`

Widget to highlight during the tutorial step.

The documentation for this struct was generated from the following file:

- [tutorialmanager.h](#)

10.22 UniqueQueue< T > Class Template Reference

A queue that ensures each element is inserted only once.

```
#include <UniqueQueue.h>
```

Public Member Functions

- void `push` (const T &value)
Pushes an element to the queue if it hasn't been inserted before.
- void `pop` ()
Removes the front element from the queue.
- const T & `front` () const
Accesses the front element of the queue.
- bool `empty` () const
Checks whether the queue is empty.
- void `clear` ()
Clears the queue and the set of seen elements.

10.22.1 Detailed Description

```
template<typename T>
class UniqueQueue< T >
```

A queue that ensures each element is inserted only once.

This data structure behaves like a standard FIFO queue but prevents duplicate insertions.

Internally, it uses a `std::queue` for ordering and a `std::unordered_set` to track seen elements.

Template Parameters

<code>T</code>	The type of elements stored in the queue. Must be hashable and comparable.
----------------	--

10.22.2 Member Function Documentation

10.22.2.1 clear()

```
template<typename T>
void UniqueQueue< T >::clear () [inline]
Clears the queue and the set of seen elements.
```

10.22.2.2 empty()

```
template<typename T>
bool UniqueQueue< T >::empty () const [inline]
Checks whether the queue is empty.
```

Returns

true if the queue is empty; false otherwise.

10.22.2.3 front()

```
template<typename T>
const T & UniqueQueue< T >::front () const [inline]
Accesses the front element of the queue.
```

Returns

A reference to the front element.

10.22.2.4 pop()

```
template<typename T>
void UniqueQueue< T >::pop () [inline]
Removes the front element from the queue.
```

10.22.2.5 push()

```
template<typename T>
void UniqueQueue< T >::push (
    const T & value) [inline]
```

Pushes an element to the queue if it hasn't been inserted before.

Parameters

<i>value</i>	The element to insert.
--------------	------------------------

The documentation for this class was generated from the following file:

- [UniqueQueue.h](#)

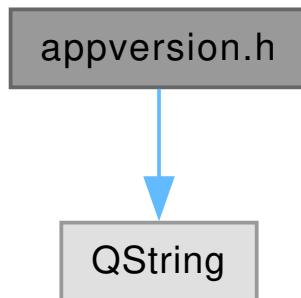
Chapter 11

File Documentation

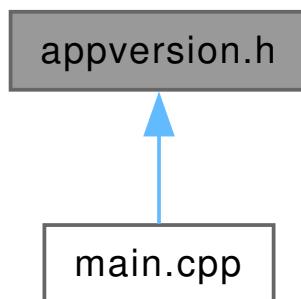
11.1 appversion.h File Reference

```
#include <QString>
```

Include dependency graph for appversion.h:



This graph shows which files directly or indirectly include this file:



Namespaces

- namespace [SyntaxTutor](#)
- namespace [SyntaxTutor::Version](#)

Functions

- `QString SyntaxTutor::Version::current ()`
- `const char * SyntaxTutor::Version::raw ()`

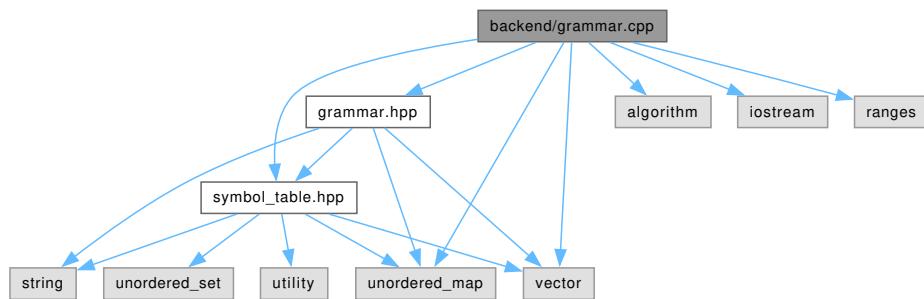
11.2 appversion.h

[Go to the documentation of this file.](#)

```
00001 #ifndef APPVERSION_H
00002 #define APPVERSION_H
00003
00004 #include <QString>
00005
00006 namespace SyntaxTutor::Version {
00007     inline QString current() {
00008         return QStringLiteral("1.0.4");
00009     }
00010
00011     inline const char* raw() {
00012         return "1.0.4";
00013     }
00014 } // namespace SyntaxTutor::Version
00015 #endif // APPVERSION_H
```

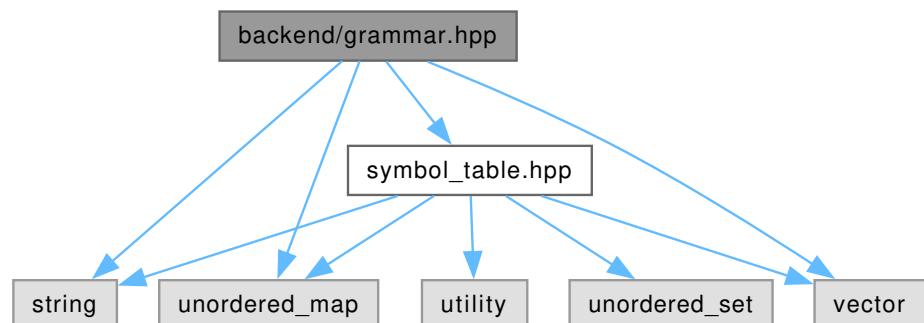
11.3 backend/grammar.cpp File Reference

```
#include "grammar.hpp"
#include "symbol_table.hpp"
#include <algorithm>
#include <iostream>
#include <ranges>
#include <unordered_map>
#include <vector>
Include dependency graph for grammar.cpp:
```

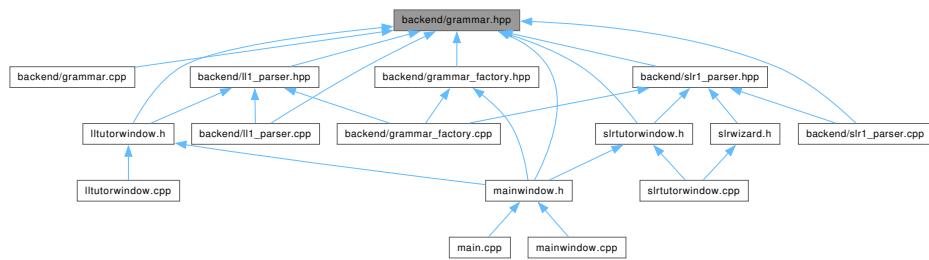


11.4 backend/grammar.hpp File Reference

```
#include "symbol_table.hpp"
#include <string>
#include <unordered_map>
#include <vector>
Include dependency graph for grammar.hpp:
```



This graph shows which files directly or indirectly include this file:



Classes

- struct `Grammar`

Represents a context-free grammar, including its rules, symbol table, and starting symbol.

TypeDefs

- using `production` = `std::vector<std::string>`
Represents the right-hand side of a grammar rule.

11.4.1 Typedef Documentation

11.4.1.1 `production`

using `production` = `std::vector<std::string>`

Represents the right-hand side of a grammar rule.

A production is a sequence of grammar symbols (terminals or non-terminals) that can be derived from a non-terminal symbol in the grammar.

For example, in the rule $A \rightarrow a B c$, the production would be: {"a", "B", "c"}

11.5 grammar.hpp

Go to the documentation of this file.

```

00001 /*
00002  * SyntaxTutor - Interactive Tutorial About Syntax Analyzers
00003  * Copyright (C) 2025 Jose R. (jose-rzm)
00004  *
00005  * This program is free software: you can redistribute it and/or modify it
00006  * under the terms of the GNU General Public License as published by
00007  * the Free Software Foundation, either version 3 of the License, or
00008  * (at your option) any later version.
00009  *
00010  * This program is distributed in the hope that it will be useful,
00011  * but WITHOUT ANY WARRANTY; without even the implied warranty of
00012  * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
00013  * GNU General Public License for more details.
00014  *
00015  * You should have received a copy of the GNU General Public License
00016  * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018 #pragma once
00019 #include "symbol_table.hpp"
00020 #include <string>
00021 #include <unordered_map>
00022 #include <vector>
00023
00034 using production = std::vector<std::string>;
00035
00046 struct Grammar {
00047
00048     Grammar();
00049     explicit Grammar(
00050         const std::unordered_map<std::string, std::vector<production>&>
00051         grammar);
00052
00061     void SetAxiom(const std::string& axiom);

```

```

00062
00073     bool HasEmptyProduction(const std::string& antecedent) const;
00074
00086     std::vector<std::pair<const std::string, production>>
00087     FilterRulesByConsequent(const std::string& arg) const;
00088
00095     void Debug() const; // NOSONAR
00096
00109     void AddProduction(const std::string& antecedent,
00110                         const std::vector<std::string>& consequent);
00111
00123     std::vector<std::string> Split(const std::string& s);
00124
00129     std::unordered_map<std::string, std::vector<production>> g_;
00130
00134     std::string axiom_;
00135
00139     SymbolTable st_;
00140 };

```

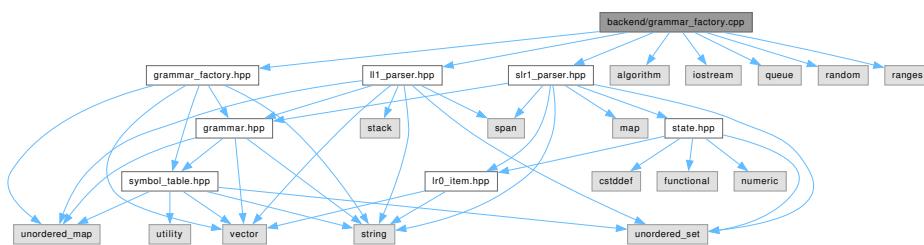
11.6 backend/grammar_factory.cpp File Reference

```

#include "grammar_factory.hpp"
#include "l11_parser.hpp"
#include "slrl1_parser.hpp"
#include <algorithm>
#include <iostream>
#include <queue>
#include <random>
#include <ranges>

```

Include dependency graph for grammar_factory.cpp:



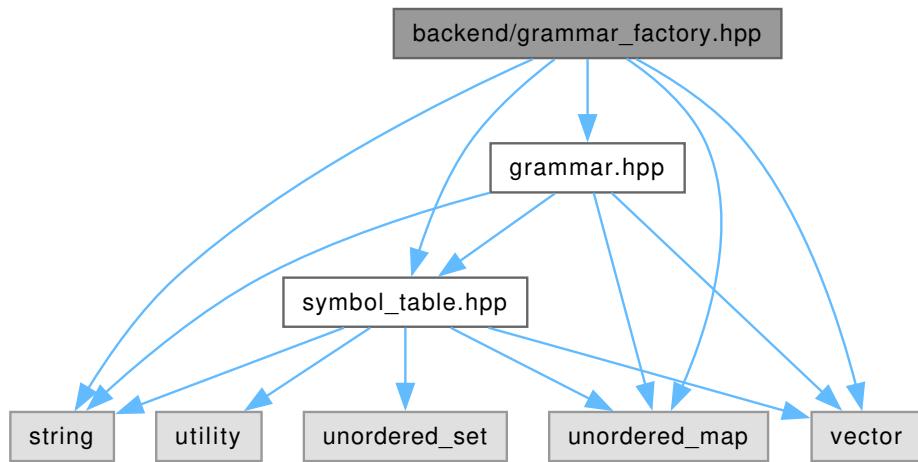
11.7 backend/grammar.hpp File Reference

```

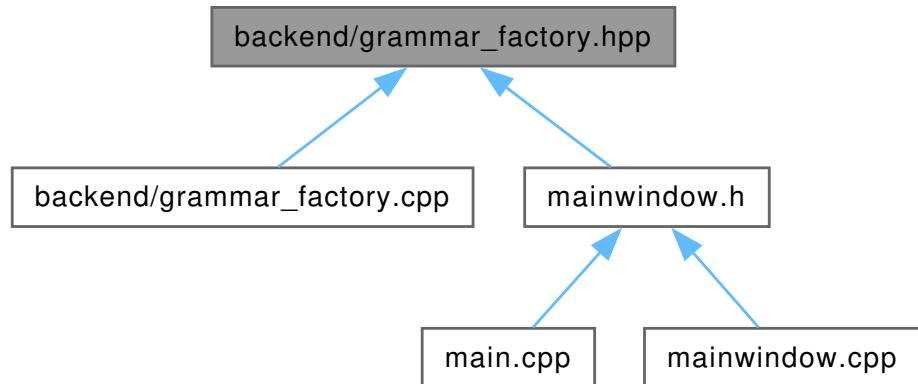
#include "grammar.hpp"
#include "symbol_table.hpp"
#include <string>
#include <unordered_map>
#include <vector>

```

Include dependency graph for grammar_factory.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- struct [GrammarFactory](#)
Responsible for creating and managing grammar items and performing checks on grammars.
- struct [GrammarFactory::FactoryItem](#)
Represents an individual grammar item with its associated symbol table.

11.8 grammar_factory.hpp

[Go to the documentation of this file.](#)

```

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00017 */
  
```

```

00018
00019 #pragma once
00020 #include "grammar.hpp"
00021 #include "symbol_table.hpp"
00022 #include <string>
00023 #include <unordered_map>
00024 #include <vector>
00025
00026 struct GrammarFactory {
00027
00028     struct FactoryItem {
00029         std::unordered_map<std::string, std::vector<production>> g_;
00030
00031         SymbolTable st_;
00032
00033         explicit FactoryItem(
00034             const std::unordered_map<std::string, std::vector<production>&>
00035             grammar);
00036     };
00037
00038     void Init();
00039
00040     Grammar PickOne(int level);
00041
00042     Grammar GenL1Grammar(int level);
00043     Grammar GenSLR1Grammar(int level);
00044
00045     Grammar Lvl();
00046
00047     Grammar Lv2();
00048
00049     Grammar Lv3();
00050
00051     Grammar Lv4();
00052
00053     Grammar Lv5();
00054
00055     Grammar Lv6();
00056
00057     Grammar Lv7();
00058
00059     FactoryItem CreateLv2Item();
00060
00061     bool HasUnreachableSymbols(Grammar& grammar) const;
00062
00063     bool IsInfinite(Grammar& grammar) const;
00064
00065     bool HasDirectLeftRecursion(const Grammar& grammar) const;
00066
00067     bool HasIndirectLeftRecursion(const Grammar& grammar) const;
00068
00069     bool HasCycle(
00070         const std::unordered_map<std::string, std::unordered_set<std::string>&
00071         graph) const;
00072
00073     std::unordered_set<std::string>
00074     NullableSymbols(const Grammar& grammar) const;
00075
00076
00077     void RemoveLeftRecursion(Grammar& grammar);
00078
00079
00080     void LeftFactorize(Grammar& grammar);
00081
00082     std::vector<std::string>
00083     LongestCommonPrefix(const std::vector<production>& productions);
00084
00085     bool StartsWith(const production& prod,
00086                      const std::vector<std::string>& prefix);
00087
00088     std::string GenerateNewNonTerminal(Grammar& grammar,
00089                                         const std::string& base);
00090
00091     void NormalizeNonTerminals(FactoryItem& item, const std::string& nt) const;
00092
00093     void AdjustTerminals(FactoryItem& base, const FactoryItem& cmb,
00094                           const std::string& target_nt) const;
00095
00096     std::unordered_map<std::string, std::vector<production>>
00097     Merge(const FactoryItem& base, const FactoryItem& cmb) const;
00098
00099     std::vector<FactoryItem> items;
00100
00101     std::vector<std::string> terminal_alphabet_{ "a", "b", "c", "d", "e", "f",
00102                                         "g", "h", "i", "j", "k", "l" };
00103
00104     std::vector<std::string> non_terminal_alphabet_{ "A", "B", "C", "D",
00105                                         "E", "F", "G", "H", "I", "J", "K", "L" };

```

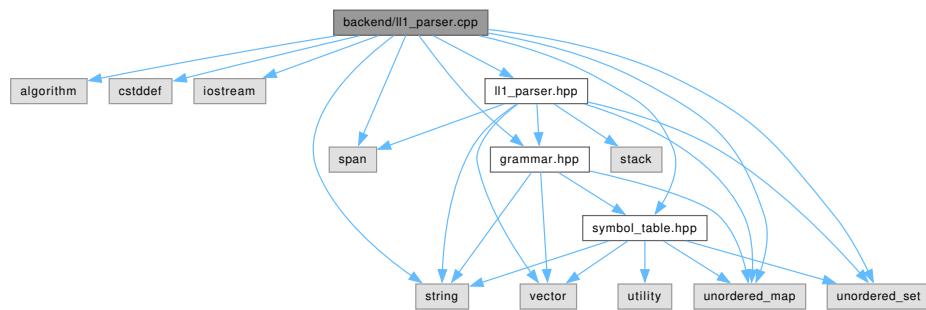
```
00375
00376 };
```

"E", "F", "G"};

11.9 backend/ll1_parser.cpp File Reference

```
#include <algorithm>
#include <cstddef>
#include <iostream>
#include <span>
#include <string>
#include <unordered_map>
#include <unordered_set>
#include "grammar.hpp"
#include "ll1_parser.hpp"
#include "symbol_table.hpp"
```

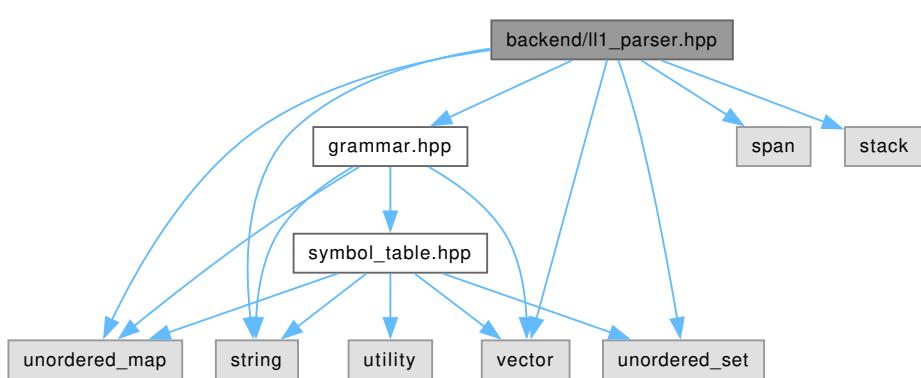
Include dependency graph for ll1_parser.cpp:



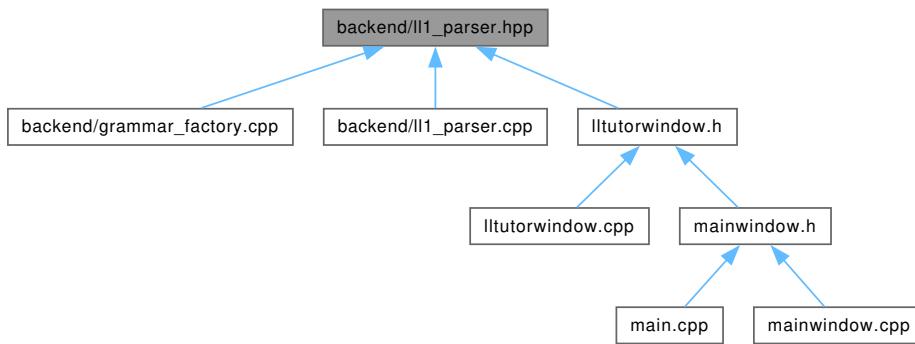
11.10 backend/ll1_parser.hpp File Reference

```
#include "grammar.hpp"
#include <span>
#include <stack>
#include <string>
#include <unordered_map>
#include <unordered_set>
#include <vector>
```

Include dependency graph for ll1_parser.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class [LL1Parser](#)

11.11 ll1_parser.hpp

[Go to the documentation of this file.](#)

```

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00017 */
00018
00019 #pragma once
00020 #include "grammar.hpp"
00021 #include <span>
00022 #include <stack>
00023 #include <string>
00024 #include <unordered_map>
00025 #include <unordered_set>
00026 #include <vector>
00027
00028 class LL1Parser {
00029
00045     using ll1_table = std::unordered_map<
00046         std::string, std::unordered_map<std::string, std::vector<production>>>;
00047
00048 public:
00049     LL1Parser() = default;
00050     explicit LL1Parser(Grammar gr);
00056
00078     bool CreateLL1Table();
00079
00106     void First(std::span<const std::string> rule,
00107                 std::unordered_set<std::string>& result);
00108
00119     void ComputeFirstSets();
00120
00146     void ComputeFollowSets();
00147
00162     std::unordered_set<std::string> Follow(const std::string& arg);
00163
00185     std::unordered_set<std::string>
00186     PredictionSymbols(const std::string& antecedent,
00187                       const std::vector<std::string>& consequent);
00188
00191     ll1_table ll1_t_;
00192
  
```

```

00194     Grammar gr_;
00195
00197     std::unordered_map<std::string, std::unordered_set<std::string>>
00198         first_sets_;
00199
00201     std::unordered_map<std::string, std::unordered_set<std::string>>
00202         follow_sets_;
00203 };

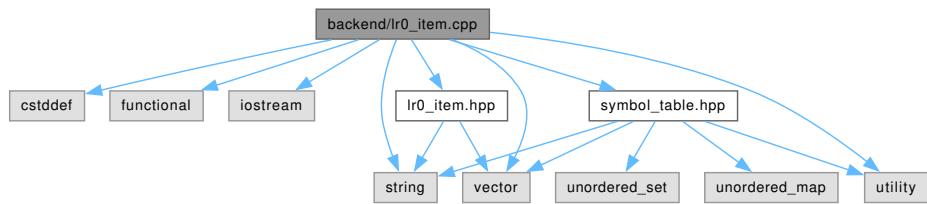
```

11.12 backend/Ir0_item.cpp File Reference

```

#include <cstddef>
#include <functional>
#include <iostream>
#include <string>
#include <utility>
#include <vector>
#include "lr0_item.hpp"
#include "symbol_table.hpp"
Include dependency graph for lr0_item.cpp:

```

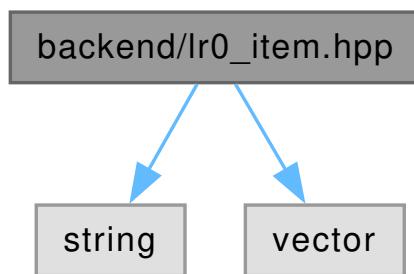


11.13 backend/Ir0_item.hpp File Reference

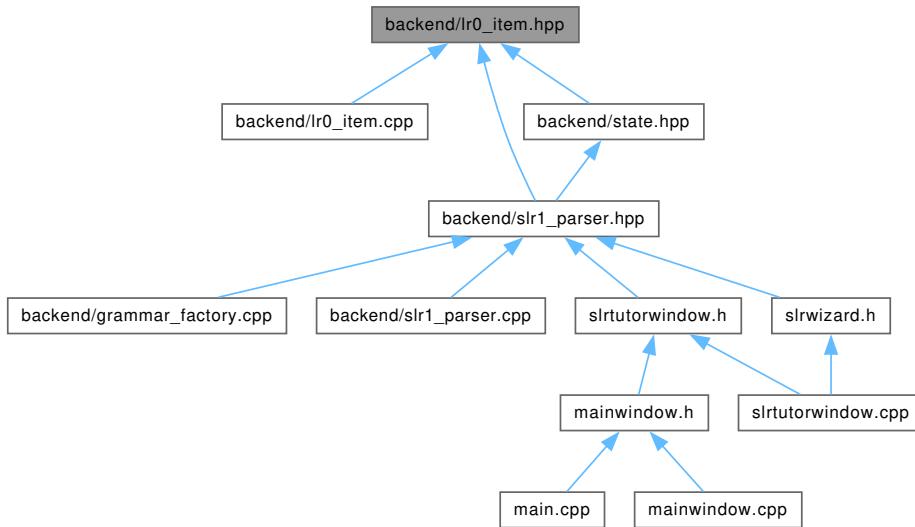
```

#include <string>
#include <vector>
Include dependency graph for lr0_item.hpp:

```



This graph shows which files directly or indirectly include this file:



Classes

- struct [Lr0Item](#)

Represents an LR(0) item used in LR automata construction.

11.14 lr0_item.hpp

[Go to the documentation of this file.](#)

```

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00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #pragma once
00020 #include <string>
00021 #include <vector>
00022
00034
00035 struct Lr0Item {
00039     std::string antecedent_;
00040
00044     std::vector<std::string> consequent_;
00045
00049     std::string epsilon_;
00050
00054     std::string eol_;
00055
00059     unsigned int dot_ = 0;
00060
00068     Lr0Item(std::string antecedent, std::vector<std::string> consequent,
00069             std::string epsilon, std::string eol);
00070
00079     Lr0Item(std::string antecedent, std::vector<std::string> consequent,
00080             unsigned int dot, std::string epsilon, std::string eol);
00081
00087     std::string NextToDot() const;
00088
00093     void PrintItem() const;
  
```

```

00094
00100     std::string ToString() const;
00101
00105     void AdvanceDot();
00106
00111     bool IsComplete() const;
00112
00118     bool operator==(const Lr0Item& other) const;
00119 };
00120
00121 namespace std {
00122 template <> struct hash<Lr0Item> {
00123     size_t operator()(const Lr0Item& item) const;
00124 };
00125 } // namespace std

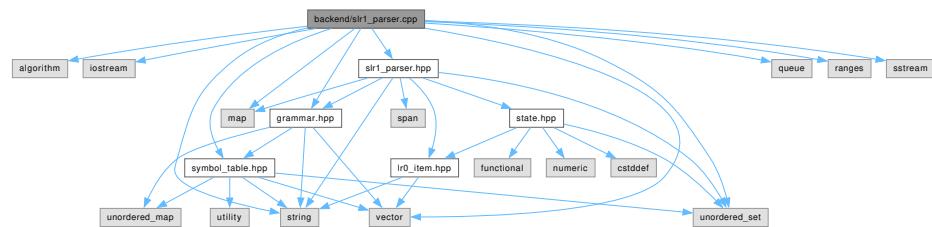
```

11.15 backend/slr1_parser.cpp File Reference

```

#include <algorithm>
#include <iostream>
#include <map>
#include <queue>
#include <ranges>
#include <sstream>
#include <string>
#include <unordered_set>
#include <vector>
#include "grammar.hpp"
#include "slr1_parser.hpp"
#include "symbol_table.hpp"
Include dependency graph for slr1_parser.cpp:

```

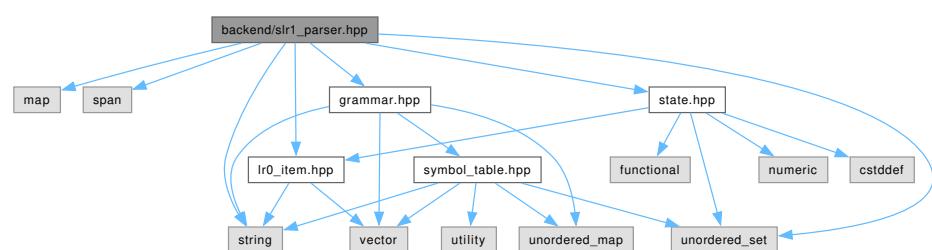


11.16 backend/slr1_parser.hpp File Reference

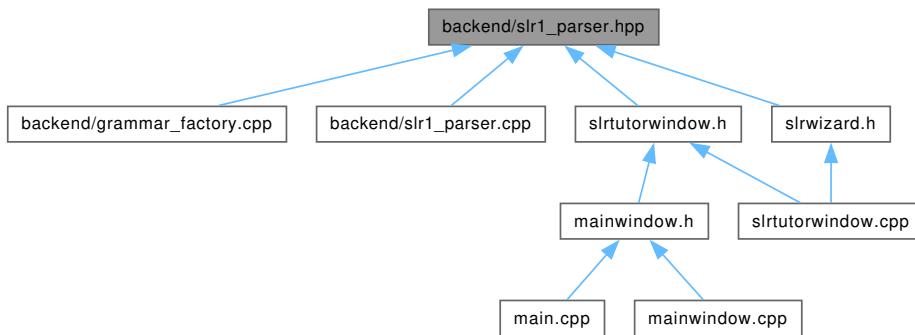
```

#include <map>
#include <span>
#include <string>
#include <unordered_set>
#include "grammar.hpp"
#include "lro_item.hpp"
#include "state.hpp"
Include dependency graph for slr1_parser.hpp:

```



This graph shows which files directly or indirectly include this file:



Classes

- class [SLR1Parser](#)
Implements an SLR(1) parser for context-free grammars.
- struct [SLR1Parser::s_action](#)

11.17 slrl_parser.hpp

[Go to the documentation of this file.](#)

```

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00017 */
00018
00019 #pragma once
00020 #include <map>
00021 #include <span>
00022 #include <string>
00023 #include <unordered_set>
00024
00025 #include "grammar.hpp"
00026 #include "lr0_item.hpp"
00027 #include "state.hpp"
00028
00029 class SLR1Parser {
00030 public:
00031     enum class Action { Shift, Reduce, Accept, Empty };
00032
00033     struct s_action {
00034         const Lr0Item* item;
00035         Action action;
00036     };
00037
00038     using action_table =
00039         std::map<unsigned int, std::map<std::string, SLR1Parser::s_action>>;
00040
00041     using transition_table =
00042         std::map<unsigned int, std::map<std::string, unsigned int>>;
00043
00044     SLR1Parser() = default;
00045     explicit SLR1Parser(Grammar gr);
00046
00047     std::unordered_set<Lr0Item> AllItems() const;
00048
00049     void Closure(std::unordered_set<Lr0Item>& items);
00050
00051
00052
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```

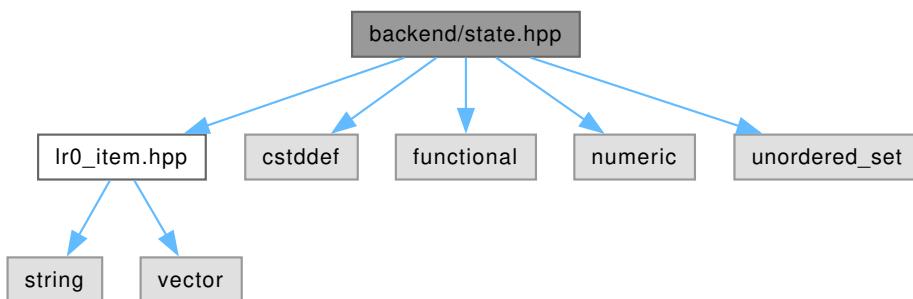
```

00137     void ClosureUtil(std::unordered_set<Lr0Item>& items, unsigned int size,
00138                         std::unordered_set<std::string>& visited);
00139
00150     std::unordered_set<Lr0Item> Delta(const std::unordered_set<Lr0Item>& items,
00151                                         const std::string& str);
00152
00165     bool SolveLRConflicts(const state& st);
00166
00193     void First(span<const std::string> rule,
00194                 std::unordered_set<std::string>& result);
00195
00206     void ComputeFirstSets();
00207
00233     void ComputeFollowSets();
00234
00249     std::unordered_set<std::string> Follow(const std::string& arg);
00250
00263     void MakeInitialState();
00264
00282     bool MakeParser();
00283
00293     std::string PrintItems(const std::unordered_set<Lr0Item>& items) const;
00294
00296     Grammar gr_;
00297
00299     std::unordered_map<std::string, std::unordered_set<std::string>>
00300         first_sets_;
00301
00303     std::unordered_map<std::string, std::unordered_set<std::string>>
00304         follow_sets_;
00305
00308     action_table actions_;
00309
00312     transition_table transitions_;
00313
00315     std::unordered_set<state> states_;
00316 };

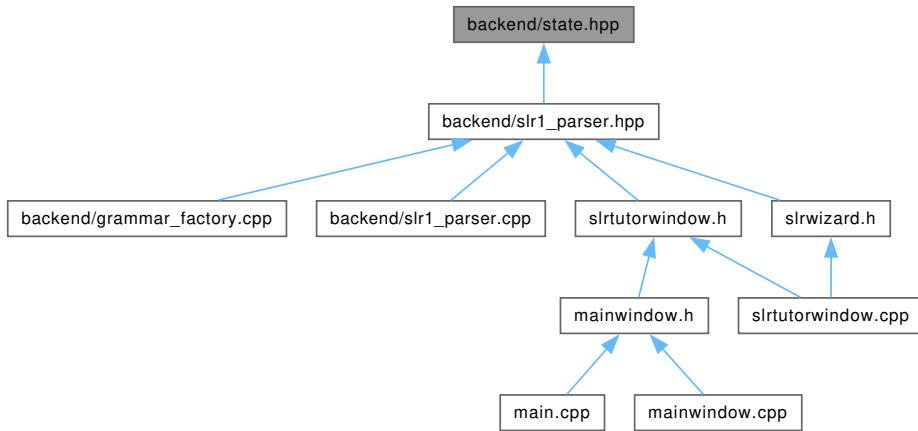
```

11.18 backend/state.hpp File Reference

```
#include "lr0_item.hpp"
#include <cstddef>
#include <functional>
#include <numeric>
#include <unordered_set>
Include dependency graph for state.hpp:
```



This graph shows which files directly or indirectly include this file:



Classes

- struct **state**

Represents a state in the LR(0) automaton.

11.19 state.hpp

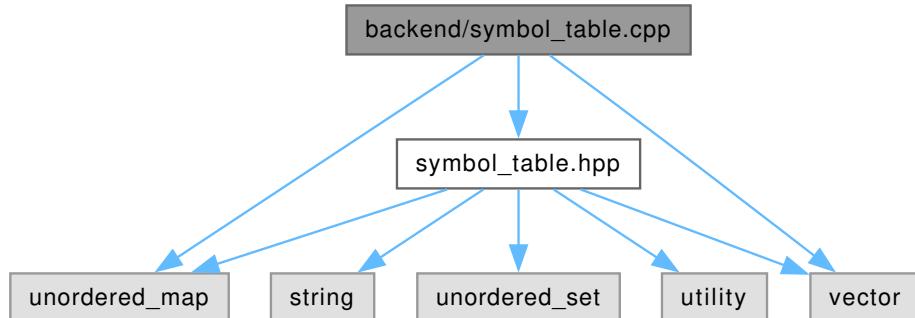
[Go to the documentation of this file.](#)

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00017 */
00018
00019 #pragma once
00020 #include "lro_item.hpp"
00021 #include <cstddef>
00022 #include <functional>
00023 #include <numeric>
00024 #include <unordered_set>
00025
00033 struct state {
00037     std::unordered_set<Lr0Item> items_;
00038
00042     unsigned int id_;
00043
00049     bool operator==(const state& other) const { return other.items_ == items_; }
00050 };
00051
00052 namespace std {
00053 template <> struct hash<state> {
00054     size_t operator()(const state& st) const {
00055         size_t seed =
00056             std::accumulate(st.items_.begin(), st.items_.end(), 0,
00057                           [] (size_t acc, const Lr0Item& item) {
00058                             return acc ^ (std::hash<Lr0Item>() (item));
00059                         });
00060         return seed;
00061     }
00062 };
00063 } // namespace std
  
```

11.20 backend/symbol_table.cpp File Reference

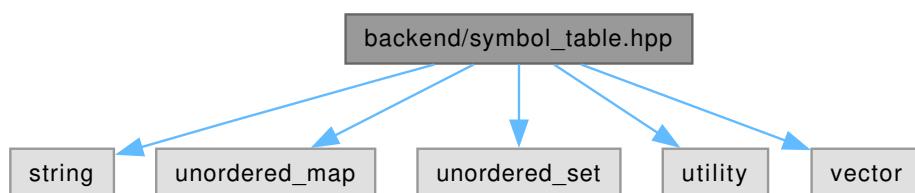
```
#include "symbol_table.hpp"
#include <unordered_map>
#include <vector>
Include dependency graph for symbol_table.cpp:
```



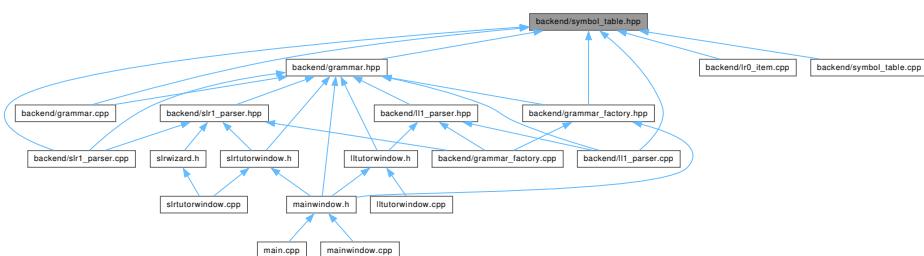
11.21 backend/symbol_table.hpp File Reference

```
#include <string>
#include <unordered_map>
#include <unordered_set>
#include <utility>
#include <vector>
```

Include dependency graph for symbol_table.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- struct [SymbolTable](#)

Stores and manages grammar symbols, including their classification and special markers.

Enumerations

- enum class [symbol_type](#) { `NO_TERMINAL` , `TERMINAL` }

Represents the type of a grammar symbol.

11.21.1 Enumeration Type Documentation

11.21.1.1 symbol_type

```
enum class symbol_type [strong]
```

Represents the type of a grammar symbol.

This enum distinguishes between terminal and non-terminal symbols within the grammar and the symbol table.

Enumerator

NO_TERMINAL	
TERMINAL	

11.22 symbol_table.hpp

[Go to the documentation of this file.](#)

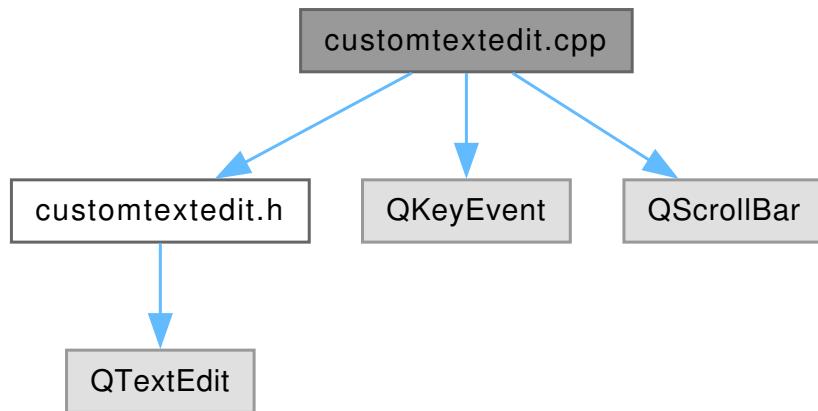
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00017 */
00018
00019 #pragma once
00020 #include <string>
00021 #include <unordered_map>
00022 #include <unordered_set>
00023 #include <utility>
00024 #include <vector>
00025
00033 enum class symbol_type { NO_TERMINAL, TERMINAL };
00034
00045 struct SymbolTable {
00047     std::string EOL_{"$"};
00048
00051     std::string EPSILON_{"EPSILON"};
00052
00055     std::unordered_map<std::string, symbol_type> st_{
00056         {EOL_, symbol_type::TERMINAL}, {EPSILON_, symbol_type::TERMINAL}};
00057
00061     std::unordered_set<std::string> terminals_{EOL_};
00062
00066     std::unordered_set<std::string> terminals_wtho_eol_{};
00067
00071     std::unordered_set<std::string> non_terminals_;
00072
00079     void PutSymbol(const std::string& identifier, bool isTerminal);
00080
00087     bool In(const std::string& s) const;
00088
00095     bool IsTerminal(const std::string& s) const;
00096
00103     bool IsTerminalWthoEol(const std::string& s) const;
00104 },
```

11.23 CHANGELOG.md File Reference

11.24 customtextedit.cpp File Reference

```
#include "customtextedit.h"
#include <QKeyEvent>
#include <QScrollBar>
```

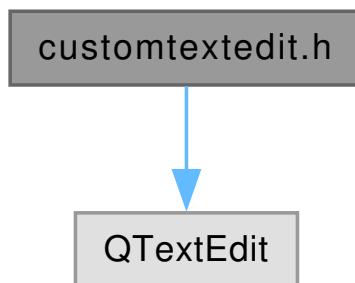
Include dependency graph for customtextedit.cpp:



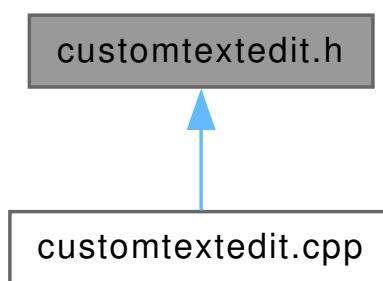
11.25 customtextedit.h File Reference

```
#include <QTextEdit>
```

Include dependency graph for customtextedit.h:



This graph shows which files directly or indirectly include this file:



Classes

- class [CustomTextEdit](#)

11.26 customtextedit.h

[Go to the documentation of this file.](#)

```
00001 /*
00002  * SyntaxTutor - Interactive Tutorial About Syntax Analyzers
00003  * Copyright (C) 2025 Jose R. (jose-rzm)
00004 *
```

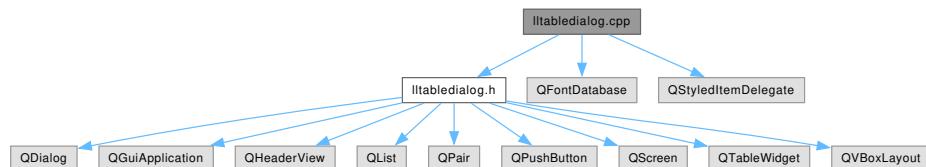
```

00005 * This program is free software: you can redistribute it and/or modify it
00006 * under the terms of the GNU General Public License as published by
00007 * the Free Software Foundation, either version 3 of the License, or
00008 * (at your option) any later version.
00009 *
00010 * This program is distributed in the hope that it will be useful,
00011 * but WITHOUT ANY WARRANTY; without even the implied warranty of
00012 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
00013 * GNU General Public License for more details.
00014 *
00015 * You should have received a copy of the GNU General Public License
00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef CUSTOMTEXTEDIT_H
00020 #define CUSTOMTEXTEDIT_H
00021
00022 #include <QTextEdit>
00023
00024 class CustomTextEdit : public QTextEdit {
00025     Q_OBJECT
00026 public:
00027     explicit CustomTextEdit(QWidget* parent = nullptr);
00028
00029 signals:
00030     void sendRequested();
00031
00032 protected:
00033     void keyPressEvent(QKeyEvent* event) override;
00034 };
00035
00036 #endif // CUSTOMTEXTEDIT_H

```

11.27 lltabledialog.cpp File Reference

```
#include "lltabledialog.h"
#include <QFontDatabase>
#include <QStyledItemDelegate>
Include dependency graph for lltabledialog.cpp:
```



Classes

- class [CenterAlignDelegate](#)

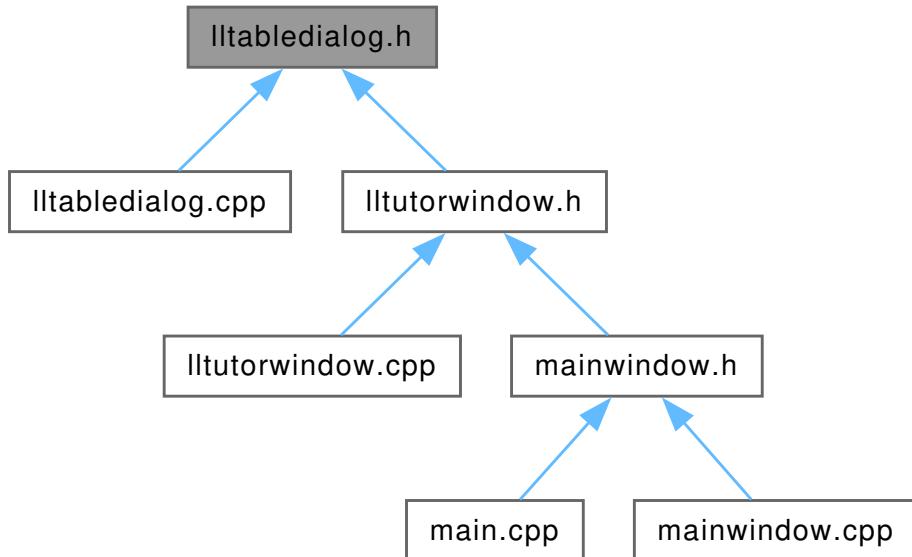
11.28 lltabledialog.h File Reference

```
#include <QDialog>
#include <QGuiApplication>
#include <QHeaderView>
#include <QList>
#include <QPair>
#include <QPushButton>
#include <QScreen>
#include <QTableWidget>
#include <QVBoxLayout>
```

Include dependency graph for `Iltabledialog.h`:



This graph shows which files directly or indirectly include this file:



Classes

- class [LLTableDialog](#)
Dialog for filling and submitting an LL(1) parsing table.

11.29 Iltabledialog.h

[Go to the documentation of this file.](#)

```

00001 /*
00002  * SyntaxTutor - Interactive Tutorial About Syntax Analyzers
00003  * Copyright (C) 2025 Jose R. (jose-rzm)
00004  *
00005  * This program is free software: you can redistribute it and/or modify it
00006  * under the terms of the GNU General Public License as published by
00007  * the Free Software Foundation, either version 3 of the License, or
00008  * (at your option) any later version.
00009  *
00010  * This program is distributed in the hope that it will be useful,
00011  * but WITHOUT ANY WARRANTY; without even the implied warranty of
00012  * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
00013  * GNU General Public License for more details.
00014  *
00015  * You should have received a copy of the GNU General Public License
00016  * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef LLTABLEDIALOG_H
00020 #define LLTABLEDIALOG_H
00021
00022 #include <QDialog>
00023 #include <QCoreApplication>
00024 #include <QHeaderView>
00025 #include <QList>
00026 #include <QPair>
00027 #include <QPushButton>
00028 #include <QScreen>
00029 #include <QTableWidget>
00030 #include <QVBoxLayout>
  
```

```

00031
00041 class LLTableDialog : public QDialog {
00042     Q_OBJECT
00043 public:
00052     LLTableDialog(const QStringList& rowHeaders, const QStringList& colHeaders,
00053                 QWidget* parent,
00054                 QVector<QVector<QString>>* initialData = nullptr);
00055
00060     QVector<QVector<QString>> getTableData() const;
00061
00070     void setInitialData(const QVector<QVector<QString>>& data);
00071
00076     void highlightIncorrectCells(const QList<QPair<int, int>>& coords);
00077
00078 signals:
00083     void submitted(const QVector<QVector<QString>>& data);
00084
00085 private:
00086     QTableWidget* table;
00087     QPushButton* submitButton;
00088 };
00089
00090 #endif // LLTABLEDIALOG_H

```

11.30 lltutorwindow.cpp File Reference

```

#include "lltutorwindow.h"
#include "tutorialmanager.h"
#include "ui_lltutorwindow.h"
#include <QAbstractButton>
#include <QFontDatabase>
#include <QRandomGenerator>
#include <QRegularExpression>
#include <QWheelEvent>

```

Include dependency graph for lltutorwindow.cpp:



11.31 lltutorwindow.h File Reference

```

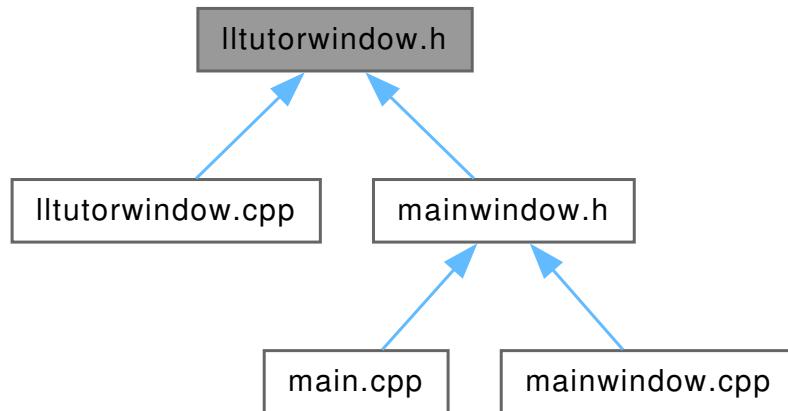
#include <QAbstractItemView>
#include <QDialog>
#include <QFileDialog>
#include <QGraphicsColorizeEffect>
#include <QGraphicsScene>
#include <QGraphicsTextItem>
#include <QGraphicsView>
#include <QListWidgetItem>
#include <QMainWindow>
#include <QMessageBox>
#include <QPainter>
#include <QPropertyAnimation>
#include <QPushButton>
#include <QScrollBar>
#include <QShortcut>
#include <QTableWidget>
#include <QTextDocument>
#include <QTextEdit>
#include <QTime>
#include <QTimer>
#include <QTreeWidgetItem>

```

```
#include <QVBoxLayout>
#include <QtPrintSupport/QPrinter>
#include "backend/grammar.hpp"
#include "backend/ll1_parser.hpp"
#include "lltabeledialog.h"
Include dependency graph for Iltutorwindow.h:
```



This graph shows which files directly or indirectly include this file:



Classes

- class [LLTutorWindow](#)
Main window for the LL(1) interactive tutoring mode in [SyntaxTutor](#).
- struct [LLTutorWindow::TreeNode](#)
TreeNode structure used to build derivation trees.

Enumerations

- enum class [State](#) {
 [A](#) , [A1](#) , [A2](#) , [A_prime](#) ,
 [B](#) , [B1](#) , [B2](#) , [B_prime](#) ,
 [C](#) , [C_prime](#) , [fin](#) }

11.31.1 Enumeration Type Documentation

11.31.1.1 State

```
enum class State [strong]
```

Enumerator

A	
A1	
A2	
A_prime	

B	
B1	
B2	
B_prime	
C	
C_prime	
fin	

11.32 `lltutorwindow.h`

[Go to the documentation of this file.](#)

```

00001 /*
00002 * SyntaxTutor - Interactive Tutorial About Syntax Analyzers
00003 * Copyright (C) 2025 Jose R. (jose-rzm)
00004 *
00005 * This program is free software: you can redistribute it and/or modify it
00006 * under the terms of the GNU General Public License as published by
00007 * the Free Software Foundation, either version 3 of the License, or
00008 * (at your option) any later version.
00009 *
00010 * This program is distributed in the hope that it will be useful,
00011 * but WITHOUT ANY WARRANTY; without even the implied warranty of
00012 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
00013 * GNU General Public License for more details.
00014 *
00015 * You should have received a copy of the GNU General Public License
00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef LLTUTORWINDOW_H
00020 #define LLTUTORWINDOW_H
00021
00022 #include <QAbstractItemView>
00023 #include <QDialog>
00024 #include <QFileDialog>
00025 #include <QGraphicsColorizeEffect>
00026 #include <QGraphicsScene>
00027 #include <QGraphicsTextItem>
00028 #include <QGraphicsView>
00029 #include <QListWidgetItem>
00030 #include <QMainWindow>
00031 #include <QMessageBox>
00032 #include <QPainter>
00033 #include <QPropertyAnimation>
00034 #include <QPushButton>
00035 #include <QScrollBar>
00036 #include <QShortcut>
00037 #include <QTableWidget>
00038 #include <QTextDocument>
00039 #include <QTextEdit>
00040 #include <QTime>
00041 #include <QTimer>
00042 #include <QTreeWidgetItem>
00043 #include <QVBoxLayout>
00044 #include <QtPrintSupport/QPrinter>
00045
00046 #include "backend/grammar.hpp"
00047 #include "backend/lll_parser.hpp"
00048 #include "lltalledialog.h"
00049
00050 class TutorialManager;
00051
00052 namespace Ui {
00053 class LLTutorWindow;
00054 }
00055
00056 // ===== LL(1) Tutor States =====
00057 enum class State { A, A1, A2, A_prime, B, B1, B2, B_prime, C, C_prime, fin };
00058
00059 // ===== LL(1) Tutor Main Class =====
00079 class LLTutorWindow : public QMainWindow {
00080     Q_OBJECT
00081
00082 public:
00083     // ===== Derivation Tree (used in TeachFirst) =====
00087     struct TreeNode {
00088         QString label;

```

```

00089     std::vector<std::unique_ptr<TreeNode>> children;
00090 }
00091
00092 // ====== Constructor / Destructor ======
00093 explicit LLTutorWindow(const Grammar& grammar,
00094                         TutorialManager* tm      = nullptr,
00095                         QWidget*       parent = nullptr);
00096 ~LLTutorWindow();
00097
00098 // ====== State Machine & Question Logic ======
00099 QString generateQuestion();
00100
00101 void updateState(bool isCorrect);
00102
00103 QString FormatGrammar(const Grammar& grammar);
00104
00105 // ====== UI Interaction ======
00106 void addMessage(const QString& text,
00107                  bool        isUser);
00108 void addWidgetMessage(QWidget* widget);
00109 void
00110 exportConversationToPdf(const QString& filePath);
00111 void showTable();
00112 void showTableForCPrime();
00113 void updateProgressPanel(); // Update progress panel
00114
00115 // ====== Visual Feedback / Animations ======
00116 void animateLabelPop(QLabel* label);
00117 void animateLabelColor(QLabel* label, const QColor& flashColor);
00118 void wrongAnimation();
00119 void
00120 wrongUserResponseAnimation();
00121 void markLastUserIncorrect();
00122
00123 // ====== Tree Generation (TeachFirst mode) ======
00124 void TeachFirstTree(const std::vector<std::string>& symbols,
00125                      std::unordered_set<std::string>& first_set, int depth,
00126                      std::unordered_set<std::string>& processing,
00127                      QTreeWidgetItem* parent);
00128
00129 std::unique_ptr<TreeNode>
00130 buildTreeNode(const std::vector<std::string>& symbols,
00131                 std::unordered_set<std::string>& first_set, int depth,
00132                 std::vector<std::pair<std::string, std::vector<std::string>>&
00133                 active_derivations);
00134
00135 int computeSubtreeWidth(const std::unique_ptr<TreeNode>& node,
00136                          int           hSpacing);
00137 void drawTree(const std::unique_ptr<TreeNode>& root, QGraphicsScene* scene,
00138                QPointF pos, int hSpacing, int vSpacing);
00139
00140 void showTreeGraphics(
00141     std::unique_ptr<TreeNode> root); // Display derivation tree visually
00142
00143 // ====== User Response Verification ======
00144 bool verifyResponse(const QString& userResponse); // Delegates to current
00145 // state's verification
00146 bool verifyResponseForA(const QString& userResponse);
00147 bool verifyResponseForA1(const QString& userResponse);
00148 bool verifyResponseForA2(const QString& userResponse);
00149 bool verifyResponseForB(const QString& userResponse);
00150 bool verifyResponseForB1(const QString& userResponse);
00151 bool verifyResponseForB2(const QString& userResponse);
00152 bool verifyResponseForC(); // C is non-textual (checks internal table)
00153
00154 // ====== Expected Solutions (Auto-generated) ======
00155 QString solution(const std::string& state);
00156 QStringList solutionForA();
00157 QString    solutionForA1();
00158 QString    solutionForA2();
00159 QSet<QString> solutionForB();
00160 QSet<QString> solutionForB1();
00161 QSet<QString> solutionForB2();
00162
00163 // ====== Feedback (Corrective Explanations) ======
00164 QString feedback(); // Delegates by state
00165 QString feedbackForA();
00166 QString feedbackForA1();
00167 QString feedbackForA2();
00168 QString feedbackForABprime();
00169 QString feedbackForB();
00170 QString feedbackForB1();
00171 QString feedbackForB2();
00172 QString feedbackForBprime();
00173 QString feedbackForC();
00174 QString feedbackForCPrime();
00175 void    feedbackForB1TreeWidgetItem(); // TreeWidget of Teach (LL1 TeachFirst)

```

```

00195     void feedbackForB1TreeGraphics(); // Show derivation tree
00196     QString TeachFollow(const QString& nt);
00197     QString TeachPredictionSymbols(const QString& ant,
00198                                     const production& conseq);
00199     QString TeachLL1Table();
00200
00201     void handleTableSubmission(const QVector<QVector<QString>>& raw,
00202                                const QStringList& colHeaders);
00203
00204 private slots:
00205     void on_confirmButton_clicked();
00206     void on_userResponseTextChanged();
00207
00208 signals:
00209     void sessionFinished(int cntRight, int cntWrong);
00210
00211 protected:
00212     void closeEvent(QCloseEvent* event) override {
00213         emit sessionFinished(cntRightAnswers, cntWrongAnswers);
00214         QWidget::closeEvent(event);
00215     }
00216
00217     bool eventFilter(QObject* obj, QEvent* event) override;
00218
00219 private:
00220     // ===== Core Objects =====
00221     Ui::LLTutorWindow* ui;
00222     Grammar grammar;
00223     LL1Parser l1l;
00224
00225     // ===== State & Grammar Tracking =====
00226     State currentState;
00227     size_t currentRule = 0;
00228     const unsigned kMaxHighlightTries = 3;
00229     const unsigned kMaxTotalTries = 5;
00230     unsigned lltries = 0;
00231     unsigned cntRightAnswers = 0, cntWrongAnswers = 0;
00232
00233     using Cell = std::pair<QString, QString>;
00234     std::vector<Cell> lastWrongCells;
00235     LLTableDialog* currentDlg = nullptr;
00236
00237     QVector<QString> sortedNonTerminals;
00238     QVector<QPair<QString, QVector<QString>>> sortedGrammar;
00239     QString formattedGrammar;
00240
00241     QMap<QString, QMap<QString, QVector<QString>>> lltable;
00242     QVector<QVector<QString>> rawTable;
00243     QSet<QString> solutionSet;
00244
00245     // ===== Conversation Logging =====
00246     struct MessageLog {
00247         QString message;
00248         bool isUser;
00249         bool isCorrect = true;
00250         MessageLog(const QString& message, bool isUser)
00251             : message(message), isUser(isUser) {}
00252         void toggleIsCorrect() { isCorrect = false; }
00253     };
00254
00255     QVector<MessageLog> conversationLog;
00256     QWidget* lastUserMessage = nullptr;
00257     qsizetype lastUserMessageLogIdx = -1;
00258
00259     QMap<QString, QString> userCAB;
00260     QMap<QString, QString> userSIG;
00261     QMap<QString, QString> userSD;
00262
00263     // ===== Helper Conversions =====
00264     std::vector<std::string> qvectorToStdVector(const QVector<QString>& qvec);
00265     QVector<QString> stdVectorToQVector(const std::vector<std::string>& vec);
00266     QSet<QString>
00267     stdUnorderedSetToQSet(const std::unordered_set<std::string>& uset);
00268     std::unordered_set<std::string>
00269     qsetToStdUnorderedSet(const QSet<QString>& qset);
00270
00271     void setupTutorial();
00272
00273     void
00274     fillSortedGrammar(); // Populate sortedGrammar from internal representation
00275
00276     QPropertyAnimation* m_shakeAnimation =
00277         nullptr; // For interrupting userResponse animation if they spam enter
00278         // key
00279
00280     TutorialManager* tm = nullptr;
00281
00282     const QRegularExpression kRe{"^\\s+|\\s+$"};

```

```
00282     const QRegularExpression kWhitespace{ "\s+" };
00283 };
00284
00285 #endif // LLTUTORWINDOW_H
```

11.33 main.cpp File Reference

```
#include "appversion.h"
#include "mainwindow.h"
#include <QApplication>
#include <QFont>
#include <QFontDatabase>
#include <QImageReader>
#include <QSettings>
#include <QTranslator>
Include dependency graph for main.cpp:
```



Functions

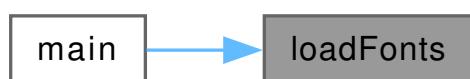
- void `loadFonts()`
- int `main(int argc, char *argv[])`

11.33.1 Function Documentation

11.33.1.1 `loadFonts()`

```
void loadFonts ()
```

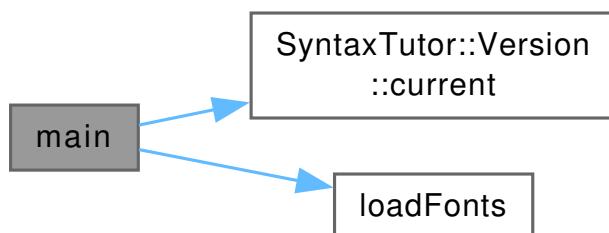
Here is the caller graph for this function:



11.33.1.2 `main()`

```
int main (
    int argc,
    char * argv[])
```

Here is the call graph for this function:



11.34 mainwindow.cpp File Reference

```
#include "mainwindow.h"
#include "tutorialmanager.h"
#include "ui_mainwindow.h"
#include <QMessageBox>
#include <QPixmap>
#include <QProcess>
```

Include dependency graph for mainwindow.cpp:



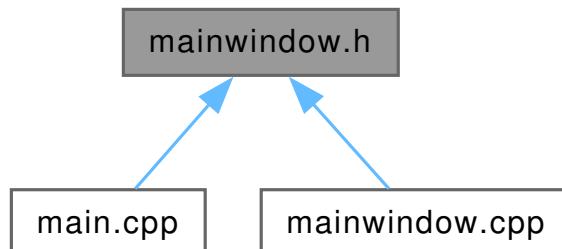
11.35 mainwindow.h File Reference

```
#include "backend/grammar.hpp"
#include "backend/grammar_factory.hpp"
#include "lltutorwindow.h"
#include "slrtutorwindow.h"
#include "tutorialmanager.h"
#include <QMainWindow>
#include <QSettings>
```

Include dependency graph for mainwindow.h:



This graph shows which files directly or indirectly include this file:



Classes

- class [MainWindow](#)
*Main application window of *SyntaxTutor*, managing levels, exercises, and UI state.*

11.36 mainwindow.h

[Go to the documentation of this file.](#)

```
00001 /*
00002  * SyntaxTutor - Interactive Tutorial About Syntax Analyzers
00003  * Copyright (C) 2025 Jose R. (jose-rzm)
00004  *
00005  * This program is free software: you can redistribute it and/or modify it
00006  * under the terms of the GNU General Public License as published by
00007  * the Free Software Foundation, either version 3 of the License, or
00008  * (at your option) any later version.
00009  *
```

```
00010 * This program is distributed in the hope that it will be useful,
00011 * but WITHOUT ANY WARRANTY; without even the implied warranty of
00012 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
00013 * GNU General Public License for more details.
00014 *
00015 * You should have received a copy of the GNU General Public License
00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef MAINWINDOW_H
00020 #define MAINWINDOW_H
00021
00022 #include "backend/grammar.hpp"
00023 #include "backend/grammar_factory.hpp"
00024 #include "lltutorwindow.h"
00025 #include "slrtutorwindow.h"
00026 #include "tutorialmanager.h"
00027 #include <QMainWindow>
00028 #include <QSettings>
00029
00030 static const QVector<QString> levelColors = {
00031     "#2C3E50", // 1: Navy oscuro
00032     "#2980B9", // 2: Azul brillante
00033     "#16A085", // 3: Teal
00034     "#27AE60", // 4: Verde esmeralda
00035     "#8E44AD", // 5: Púrpura medio
00036     "#9B59B6", // 6: Púrpura claro
00037     "#E67E22", // 7: Naranja
00038     "#D35400", // 8: Naranja oscuro
00039     "#CD7F32", // 9: Bronce
00040     "#FFD700" // 10: Oro puro
00041 };
00042
00043 QT_BEGIN_NAMESPACE
00044 namespace Ui {
00045 class MainWindow;
00046 }
00047 QT_END_NAMESPACE
00048
00049 class MainWindow : public QMainWindow {
00050     Q_OBJECT
00051     Q_PROPERTY(unsigned userLevel READ userLevel WRITE setUserLevel NOTIFY
00052                 userLevelChanged)
00053
00054 public:
00055     MainWindow(QWidget* parent = nullptr);
00056     ~MainWindow();
00057
00058     unsigned thresholdFor(unsigned level) { return BASE_THRESHOLD * level; }
00059
00060     unsigned userLevel() const { return m_userLevel; }
00061
00062     void setUserLevel(unsigned lvl) {
00063         unsigned clamped = qMin(lvl, MAX_LEVEL);
00064         if (m_userLevel == clamped)
00065             return;
00066         m_userLevel = clamped;
00067         emit userLevelChanged(clamped);
00068     }
00069
00070 private slots:
00071     void on_lv1Button_clicked(bool checked);
00072     void on_lv2Button_clicked(bool checked);
00073     void on_lv3Button_clicked(bool checked);
00074
00075     void on_pushButton_clicked();
00076
00077     void on_pushButton_2_clicked();
00078
00079     void on_tutorial_clicked();
00080
00081     void on_actionSobre_la_aplicaci_n_triggered();
00082
00083     void on_actionReferencia_LL_1_triggered();
00084
00085     void on_idiom_clicked();
00086
00087 signals:
00088     void userLevelChanged(unsigned lvl);
00089     void userLevelUp(unsigned newLevel);
00090
00091 private:
00092     void setupTutorial();
```

```

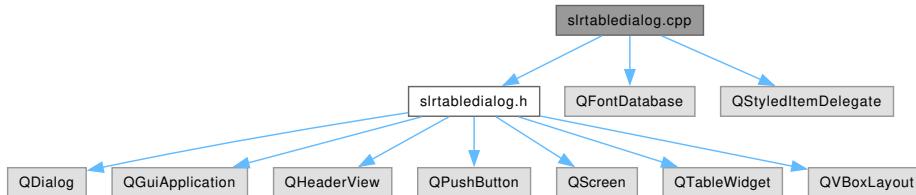
00159
00163     void restartTutorial();
00164
00170     void handleTutorFinished(int cntRight, int cntWrong);
00171
00175     void saveSettings();
00176
00180     void loadSettings();
00181
00182     Ui::MainWindow* ui;
00183     GrammarFactory factory;
00184     int level = 1;
00185     TutorialManager* tm = nullptr;
00186
00187     static constexpr unsigned MAX_LEVEL = 10;
00188     static constexpr unsigned MAX_SCORE = 999;
00189
00190     unsigned m_userLevel = 1;
00191     unsigned userScore = 0;
00192     QSettings settings;
00193
00194     const unsigned BASE_THRESHOLD = 10;
00195 }
00196 #endif // MAINWINDOW_H

```

11.37 README.md File Reference

11.38 slrtabledialog.cpp File Reference

```
#include "slrtabledialog.h"
#include <QFontDatabase>
#include <QStyledItemDelegate>
Include dependency graph for slrtabledialog.cpp:
```

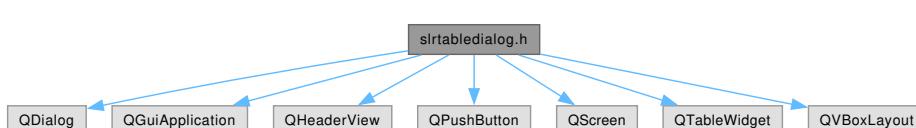


Classes

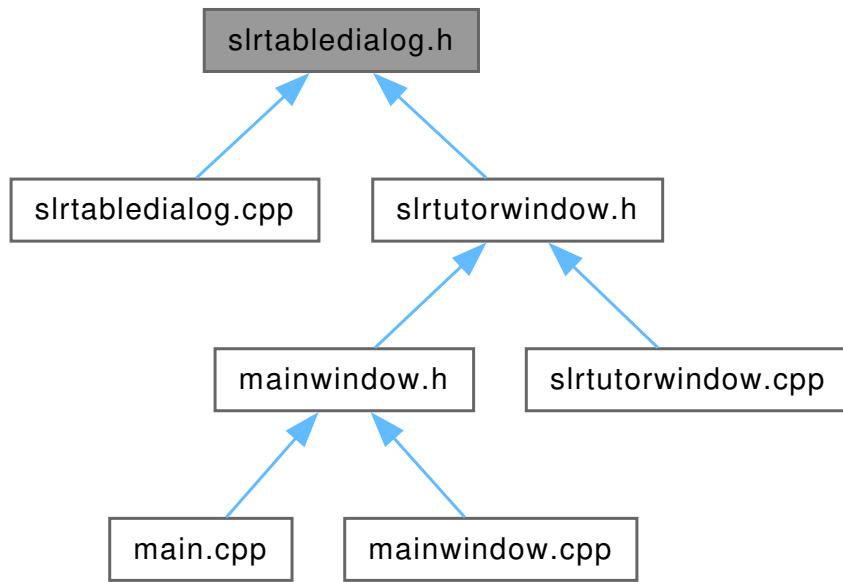
- class [CenterAlignDelegate](#)

11.39 slrtabledialog.h File Reference

```
#include <QDialog>
#include <QGuiApplication>
#include <QHeaderView>
#include <QPushButton>
#include <QScreen>
#include <QTableWidget>
#include <QVBoxLayout>
Include dependency graph for slrtabledialog.h:
```



This graph shows which files directly or indirectly include this file:



Classes

- class [SLRTableDialog](#)

Dialog window for completing and submitting an SLR(1) parsing table.

11.40 slrtabledialog.h

[Go to the documentation of this file.](#)

```

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00014 *
00015 * You should have received a copy of the GNU General Public License
00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef SLRTABLEDIALOG_H
00020 #define SLRTABLEDIALOG_H
00021
00022 #include <QDialog>
00023 #include <QGuiApplication>
00024 #include <QHeaderView>
00025 #include <QPushButton>
00026 #include <QScreen>
00027 #include <QTableWidget>
00028 #include <QVBoxLayout>
00029
00030
00031
00032
00033 class SLRTableDialog : public QDialog {
00034     Q_OBJECT
00035 public:
00036     SLRTableDialog(int rowCount, int colCount, const QStringList& colHeaders,
00037                     QWidget* parent = nullptr,
00038                     QVector<QVector<QString>>* initialData = nullptr);
00039
00040     QVector<QVector<QString>> getTableData() const;
00041
00042     void setInitialData(const QVector<QVector<QString>& data);
00043
00044
00045
00046
00047
00048
00049
00050
00051
00052
00053
00054
00055
00056
00057
00058
00059
00060
00061
00062
00063
00064
00065
00066
00067
00068
00069
00070
  
```

```

00071     private:
00072         QTableWidget* table;
00073         QPushButton* submitButton;
00074     };
00075
00076 #endif // SLRTABLEDIALOG_H

```

11.41 slrtutorwindow.cpp File Reference

```

#include "slrtutorwindow.h"
#include "tutorialmanager.h"
#include "ui_slrtutorwindow.h"
#include <QEasingCurve>
#include <QFontDatabase>
#include <sstream>
#include "slrwizard.h"
Include dependency graph for slrtutorwindow.cpp:

```



11.42 slrtutorwindow.h File Reference

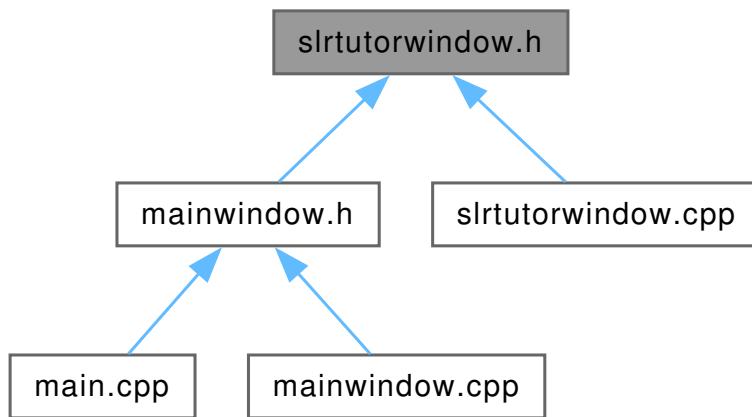
```

#include "UniqueQueue.h"
#include "backend/grammar.hpp"
#include "backend/slrl_parser.hpp"
#include "slrtabledialog.h"
#include <QAbstractItemView>
#include <QDialog>
#include <QFileDialog>
#include <QGraphicsColorizeEffect>
#include <QListWidgetItem>
#include <QMainWindow>
#include <QMessageBox>
#include <QPropertyAnimation>
#include <QPushButton>
#include <QRegularExpression>
#include <QScrollBar>
#include <QShortcut>
#include <QTableWidget>
#include <QTextDocument>
#include <QTextEdit>
#include <QTime>
#include <QTimer>
#include <QVBoxLayout>
#include <QtPrintSupport/QPrinter>
Include dependency graph for slrtutorwindow.h:

```



This graph shows which files directly or indirectly include this file:



Classes

- class [SLRTutorWindow](#)

Main window for the SLR(1) interactive tutoring mode in [SyntaxTutor](#).

Enumerations

- enum class [StateSlr](#) {

A , A1 , A2 , A3 ,

A4 , A_prime , B , C ,

CA , CB , D , D1 ,

D2 , D_prime , E , E1 ,

E2 , F , FA , G ,

H , H_prime , fin }

11.42.1 Enumeration Type Documentation

11.42.1.1 StateSlr

```
enum class StateSlr [strong]
```

Enumerator

A	
A1	
A2	
A3	
A4	
A_prime	
B	
C	
CA	
CB	
D	
D1	

D2	
D_prime	
E	
E1	
E2	
F	
FA	
G	
H	
H_prime	
fin	

11.43 slrtutorwindow.h

[Go to the documentation of this file.](#)

```

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00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef SLRTUTORWINDOW_H
00020 #define SLRTUTORWINDOW_H
00021
00022 #include "UniqueQueue.h"
00023 #include "backend/grammar.hpp"
00024 #include "backend/srl_parser.hpp"
00025 #include "slrtabledialog.h"
00026 #include <QAbstractItemView>
00027 #include <QDialog>
00028 #include <QFileDialog>
00029 #include <QGraphicsColorizeEffect>
00030 #include <QListWidgetItem>
00031 #include <QMainWindow>
00032 #include <QMessageBox>
00033 #include <QPropertyAnimation>
00034 #include <QPushButton>
00035 #include <QRegularExpression>
00036 #include <QScrollBar>
00037 #include <QShortcut>
00038 #include <QTableWidget>
00039 #include <QTextDocument>
00040 #include <QTextEdit>
00041 #include <QTime>
00042 #include <QTimer>
00043 #include <QVBoxLayout>
00044 #include <QtPrintSupport/QPrinter>
00045
00046 namespace Ui {
00047 class SLRTutorWindow;
00048 }
00049
00050 // ===== SLR(1) Tutor States =====
00051 enum class StateSlr {
00052     A,
00053     A1,
00054     A2,
00055     A3,
00056     A4,
00057     A_prime,
00058     B,

```

```

00059     C,
00060     CA,
00061     CB,
00062     D,
00063     D1,
00064     D2,
00065     D_prime,
00066     E,
00067     E1,
00068     E2,
00069     F,
00070     FA,
00071     G,
00072     H,
00073     H_prime,
00074     fin
00075 };
00076
00077 class TutorialManager;
00078
00079 // ===== Main Tutor Class for SLR(1) =====
00094 class SLRTutorWindow : public QMainWindow {
00095     Q_OBJECT
00096
00097 public:
00098     // ===== Constructor / Destructor =====
00105     explicit SLRTutorWindow(const Grammar& g, TutorialManager* tm = nullptr,
00106                             QWidget* parent = nullptr);
00107     ~SLRTutorWindow();
00108
00109     // ===== Core Flow Control =====
00114     QString generateQuestion();
00115
00120     void updateState(bool isCorrect);
00121     QString
00122     FormatGrammar(const Grammar& grammar);
00123     void fillSortedGrammar();
00124
00125     // ===== UI Interaction =====
00126     void addMessage(const QString& text, bool isUser);
00127     void exportConversationToPdf(
00128         const QString& filePath);
00129     void showTable();
00130     void launchSLRWizard();
00131     void updateProgressPanel();
00132     void addUserState(unsigned id);
00133     void addUserTransition(unsigned fromId, const std::string& symbol,
00134                           unsigned toId); // Register a user-created transition
00135
00136     // ===== Visual Feedback & Animations =====
00137     void animateLabelPop(QLabel* label);
00138     void animateLabelColor(QLabel* label, const QColor& flashColor);
00139     void wrongAnimation(); // Label animation for incorrect answer
00140     void wrongUserResponseAnimation(); // Message widget animation for incorrect
00141                                         // answer
00142     void markLastUserIncorrect();
00143
00144     // ===== Response Verification =====
00145     bool verifyResponse(const QString& userResponse);
00146     bool verifyResponseForA(const QString& userResponse);
00147     bool verifyResponseForA1(const QString& userResponse);
00148     bool verifyResponseForA2(const QString& userResponse);
00149     bool verifyResponseForA3(const QString& userResponse);
00150     bool verifyResponseForA4(const QString& userResponse);
00151     bool verifyResponseForB(const QString& userResponse);
00152     bool verifyResponseForC(const QString& userResponse);
00153     bool verifyResponseForCA(const QString& userResponse);
00154     bool verifyResponseForCB(const QString& userResponse);
00155     bool verifyResponseForD(const QString& userResponse);
00156     bool verifyResponseForD1(const QString& userResponse);
00157     bool verifyResponseForD2(const QString& userResponse);
00158     bool verifyResponseForE(const QString& userResponse);
00159     bool verifyResponseForE1(const QString& userResponse);
00160     bool verifyResponseForE2(const QString& userResponse);
00161     bool verifyResponseForF(const QString& userResponse);
00162     bool verifyResponseForFA(const QString& userResponse);
00163     bool verifyResponseForG(const QString& userResponse);
00164     bool verifyResponseForH();
00165
00166     // ===== Correct Solutions (Auto-generated) =====
00167     QString solution(const std::string& state);
00168     std::unordered_set<Lr0Item> solutionForA();
00169     QString solutionForA1();
00170     QString solutionForA2();
00171     std::vector<std::pair<std::string, std::vector<std::string>>>
00172                     solutionForA3();
00173     std::unordered_set<Lr0Item> solutionForA4();

```

```

00174     unsigned          solutionForB();
00175     unsigned          solutionForC();
00176     QStringList      solutionForCA();
00177     std::unordered_set<Lr0Item> solutionForCB();
00178     QStringList      solutionForD();
00179     QString           solutionForD1();
00180     QString           solutionForD2();
00181     std::ptrdiff_t    solutionForE();
00182     QSet<unsigned>    solutionForE1();
00183     QMap<unsigned, unsigned> solutionForE2();
00184     QSet<unsigned>    solutionForF();
00185     QSet<QString>    solutionForFA();
00186     QSet<QString>    solutionForG();
00187
00188 // ===== Pedagogical Feedback =====
00189 QString feedback(); // Delegates to appropriate feedback based on state
00190 QString feedbackForA();
00191 QString feedbackForA1();
00192 QString feedbackForA2();
00193 QString feedbackForA3();
00194 QString feedbackForA4();
00195 QString feedbackForAPrime();
00196 QString feedbackForB();
00197 QString feedbackForB1();
00198 QString feedbackForB2();
00199 QString feedbackForBPrime();
00200 QString feedbackForC();
00201 QString feedbackForCA();
00202 QString feedbackForCB();
00203 QString feedbackForD();
00204 QString feedbackForD1();
00205 QString feedbackForD2();
00206 QString feedbackForDPrime();
00207 QString feedbackForE();
00208 QString feedbackForE1();
00209 QString feedbackForE2();
00210 QString feedbackForF();
00211 QString feedbackForFA();
00212 QString feedbackForG();
00213 QString TeachDeltaFunction(const std::unordered_set<Lr0Item>& items,
00214                           const QString&                         symbol);
00215 void TeachClosureStep(std::unordered_set<Lr0Item>& items, unsigned int size,
00216                        std::unordered_set<std::string>& visited, int depth,
00217                        QString& output);
00218 QString TeachClosure(const std::unordered_set<Lr0Item>& initialItems);
00219 private slots:
00220     void on_confirmButton_clicked();
00221     void on_userResponseTextChanged();
00222
00223 signals:
00224     void sessionFinished(int cntRight, int cntWrong);
00225
00226 protected:
00227     void closeEvent(QCloseEvent* event) override {
00228         emit sessionFinished(cntRightAnswers, cntWrongAnswers);
00229         QWidget::closeEvent(event);
00230     }
00231
00232 private:
00233 // ===== Helper Functions =====
00234     std::vector<std::string> qvectorToStdVector(const QVector<QString>& qvec);
00235     QVector<QString> stdVectorToQVector(const std::vector<std::string>& vec);
00236     QSet<QString>
00237     stdUnorderedSetToQSet(const std::unordered_set<std::string>& uset);
00238     std::unordered_set<std::string>
00239     qsetToStdUnorderedSet(const QSet<QString>& qset);
00240     std::unordered_set<Lr0Item> ingestUserItems(const QString& userResponse);
00241     std::vector<std::pair<std::string, std::vector<std::string>>
00242     ingestUserRules(const QString& userResponse);
00243     void setupTutorial();
00244 // ===== Core Components =====
00245     Ui::SLRTutorWindow* ui;
00246     Grammar          grammar;
00247     SLR1Parser       slrl;
00248
00249 // ===== State and Grammar Tracking =====
00250     StateSlr          currentState;
00251     QVector<QString> sortedNonTerminals;
00252     QVector<QPair<QString, QVector<QString>>> sortedGrammar;
00253     QString           formattedGrammar;
00254
00255     unsigned cntRightAnswers = 0;
00256     unsigned cntWrongAnswers = 0;
00257
00258 // ===== State Machine Runtime Variables =====
00259     std::unordered_set<state> userMadeStates; // All states the user has created
00260     std::unordered_map<unsigned, std::unordered_map<std::string, unsigned>

```

```

00261     userMadeTransitions; // Transitions made by the user
00262     UniqueQueue<unsigned>
00263         statesIdQueue; // States to be processed in B-C-CA-CB loop
00264     unsigned currentStateId = 0;
00265     state    currentSlrState;
00266
00267     QStringList followSymbols; // Used in CA-CB loop
00268     qsizetype    currentFollowSymbolsIdx = 0;
00269     unsigned int nextStateId           = 0;
00270
00271     QVector<const state*> statesWithLr0Conflict; // Populated in F
00272     std::queue<unsigned> conflictStatesIdQueue;
00273     unsigned        currentConflictStateId = 0;
00274     state          currentConflictState;
00275
00276     std::queue<unsigned>
00277         reduceStatesIdQueue; // States without conflicts but with reduce
00278     unsigned currentReduceStateId = 0;
00279     state    currentReduceState;
00280
00281     struct ActionEntry {
00282         enum Type { Shift, Reduce, Accept, Goto } type;
00283         int      target;
00284         static ActionEntry makeShift(int s) { return {Shift, s}; }
00285         static ActionEntry makeReduce(int r) { return {Reduce, r}; }
00286         static ActionEntry makeAccept() { return {Accept, 0}; }
00287         static ActionEntry makeGoto(int g) { return {Goto, g}; }
00288     };
00289
00290     QMap<int, QMap<QString, ActionEntry>> slrtable;
00291     QVector<QVector<QString>> rawTable;
00292
00293 // ===== Conversation Log =====
00294     struct MessageLog {
00295         QString message;
00296         bool   isUser;
00297         bool   isCorrect = true;
00298
00299         MessageLog(const QString& message, bool isUser)
00300             : message(message), isUser(isUser) {}
00301
00302         void toggleIsCorrect() { isCorrect = false; }
00303     };
00304
00305     QVector<MessageLog> conversationLog;
00306     QWidget*           lastUserMessage       = nullptr;
00307     qsizetype          lastUserMessageLogIdx = -1;
00308
00309     QPropertyAnimation* m_shakeAnimation =
00310         nullptr; // For interrupting userResponse animation if they spam enter
00311         // key
00312
00313     TutorialManager* tm;
00314
00315     QRegularExpression re{"^\\s+|\\s+$"};
00316     const QRegularExpression kWhitespace{"\\s+"};
00317 };
00318
00319 #endif // SLRTUTORWINDOW_H

```

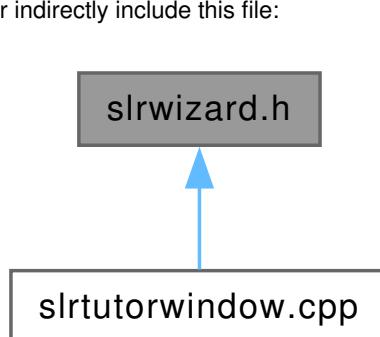
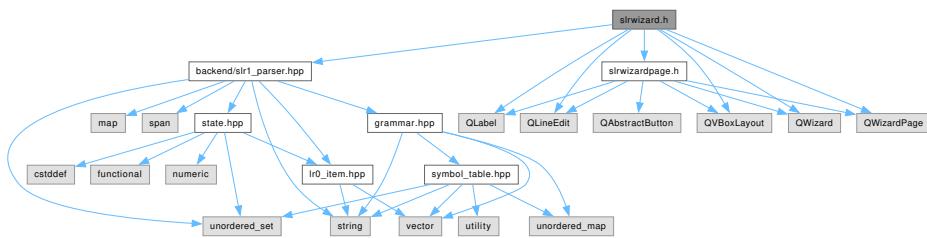
11.44 slrwizard.h File Reference

```

#include "backend/slrl1_parser.hpp"
#include "slrwizardpage.h"
#include <QLabel>
#include <QLineEdit>
#include <QVBoxLayout>
#include <QWizard>
#include <QWizardPage>

```

Include dependency graph for slrwizard.h:



Classes

- class **SLRWizard**

Interactive assistant that guides the student step-by-step through the SLR(1) parsing table.

11.45 slrwizard.h

Go to the documentation of this file.

```

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00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef SLRWIZARD_H
00020 #define SLRWIZARD_H
00021
00022 #include "backend/slr1_parser.hpp"
00023 #include "slrwizardpage.h"
00024 #include <QLabel>
00025 #include <QLineEdit>
00026 #include <QVBoxLayout>
00027 #include <QWizard>
00028 #include <QWizardPage>
00029
00045 class SLRWizard : public QWizard {
00046     Q_OBJECT
00047 public:
00059     SLRWizard(SLR1Parser& parser, const QVector<QVector<QString>>& rawTable,
00060                const QStringList& colHeaders,
00061                const QVector<QPair<QString, QVector<QString>>>& sortedGrammar,
00062                QWidget* parent = nullptr)
00063     : QWizard(parent) {

```

```

00064     setWindowTitle(tr("Ayuda interactiva: Tabla SLR(1)"));
00065
00066     const int nTerm =
00067         parser.gr_.st_.terminals_.contains(parser.gr_.st_.EPSILON_)
00068         ? parser.gr_.st_.terminals_.size() - 1
00069         : parser.gr_.st_.terminals_.size();
00070     SLRWizardPage* last = nullptr;
00071     // Generar explicación y páginas
00072     int rows = rawTable.size();
00073     int cols = colHeaders.size();
00074     for (int i = 0; i < rows; ++i) {
00075         for (int j = 0; j < cols; ++j) {
00076             QString sym = colHeaders[j];
00077             QString expected;
00078             QString explanation;
00079             if (j < nTerm) {
00080                 auto itAct = parser.actions_.at(i).find(sym.toStdString());
00081                 SLR1Parser::s_action act =
00082                     (itAct != parser.actions_.at(i).end()
00083                      ? itAct->second
00084                      : SLR1Parser::s_action{nullptr,
00085                                         SLR1Parser::Action::Empty});
00086                 switch (act.action) {
00087                     case SLR1Parser::Action::Shift: {
00088                         unsigned to =
00089                             parser.transitions_.at(i).at(sym.toStdString());
00090                         expected = QString("$%1").arg(to);
00091                         explanation = tr("Estado %1: existe transición (%1, "
00092                                           "'%2'). ¿A qué "
00093                                           "estado harías shift?")
00094                                         .arg(i)
00095                                         .arg(sym);
00096                         break;
00097                     }
00098                     case SLR1Parser::Action::Reduce: {
00099                         int idx = -1;
00100                         for (int k = 0; k < sortedGrammar.size(); ++k) {
00101                             auto& rule = sortedGrammar[k];
00102                             if (rule.first.toStdString() ==
00103                                 act.item->antecedent_ &&
00104                                 stdVectorToQVector(act.item->consequent_) ==
00105                                 rule.second) {
00106                             idx = k;
00107                             break;
00108                         }
00109                         expected = QString("r%1").arg(idx);
00110                         // explicación con FOLLOW
00111                         std::unordered_set<std::string> F;
00112                         F = parser.Follow(act.item->antecedent_);
00113                         QStringList followList;
00114                         for (auto& t : F)
00115                             followList << QString::fromStdString(t);
00116                         explanation = tr("Estado %1: contiene el ítem [%2 → "
00117                                           "...] y '%3' "
00118                                           "SIG(%2). ¿Qué regla usas para "
00119                                           "reducir (0, 1, ...)?")
00120                                         .arg(i)
00121                                         .arg(QString::fromStdString(
00122                                               act.item->antecedent_))
00123                                         .arg(colHeaders[j]);
00124                         break;
00125                     }
00126                     case SLR1Parser::Action::Accept:
00127                         expected = "acc";
00128                         explanation = tr("Estado %1: contiene [S → A · $.] . "
00129                                           "¿Qué palabra clave "
00130                                           "usas para aceptar?")
00131                                         .arg(i);
00132                         break;
00133                     case SLR1Parser::Action::Empty:
00134                         default:
00135                             continue;
00136                         }
00137                     } else {
00138                         // GOTO sobre no terminal
00139                         auto nonT = sym.toStdString();
00140                         if (!parser.transitions_.contains(i)) {
00141                             continue;
00142                         }
00143                         auto itGo = parser.transitions_.at(i).find(nonT);
00144                         if (itGo != parser.transitions_.at(i).end()) {
00145                             expected = QString::number(itGo->second);
00146                             explanation = tr("Estado %1: (%1, '%2') existe. ¿A "
00147                                           "qué estado va "
00148                                           "la transición? (pon solo el número)")
00149                                         .arg(i)
00150                     }

```

```

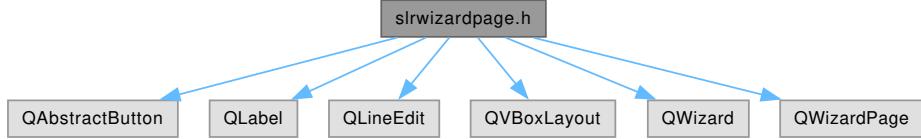
00151                               .arg(sym);
00152                         } else {
00153                           continue;
00154                         }
00155                     }
00156
00157                     SLRWizardPage* page =
00158                       new SLRWizardPage(i, sym, explanation, expected, this);
00159                     last = page;
00160                     addPage(page);
00161                 }
00162             }
00163             if (last) {
00164               last->setFinalPage(true);
00165             }
00166         }
00167     }
00168     QVector<QString> stdVectorToQVector(const std::vector<std::string>& vec) {
00169       QVector<QString> result;
00170       result.reserve(vec.size());
00171       for (const auto& str : vec) {
00172         result.push_back(QString::fromStdString(str));
00173       }
00174     }
00175   }
00176   return result;
00177 }
00178 };
00179
00180 #endif // SLRWIZARD_H

```

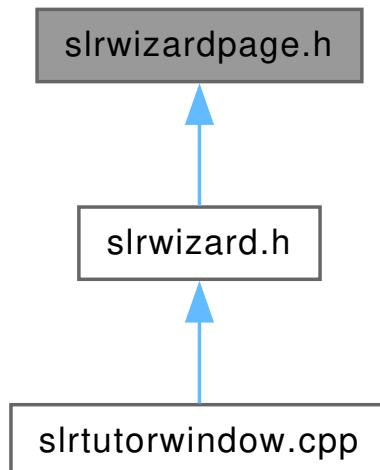
11.46 slrwizardpage.h File Reference

```
#include <QAbstractButton>
#include <QLabel>
#include <QLineEdit>
#include <QVBoxLayout>
#include <QWizard>
#include <QWizardPage>
```

Include dependency graph for slrwizardpage.h:



This graph shows which files directly or indirectly include this file:



Classes

- class **SLRWizardPage**

A single step in the SLR(1) guided assistant for table construction.

11.47 slrwizardpage.h

[Go to the documentation of this file.](#)

```

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00014 *
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00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef SLRWIZARDPAGE_H
00020 #define SLRWIZARDPAGE_H
00021
00022 #include <QAbstractButton>
00023 #include <QLabel>
00024 #include <QLineEdit>
00025 #include <QVBoxLayout>
00026 #include <QWizard>
00027 #include <QWizardPage>
00028
00029 class SLRWizardPage : public QWizardPage {
00030     Q_OBJECT
00031 public:
00032     SLRWizardPage(int state, const QString& symbol, const QString& explanation,
00033                 const QString& expected, QWidget* parent = nullptr)
00034         : QWizardPage(parent), m_state(state), m_symbol(symbol),
00035           m_expected(expected) {
00036         setTitle(tr("Estado %1, símbolo '%2'").arg(state).arg(symbol));
00037
00038         QLabel* lbl = new QLabel(explanation, this);
00039         lbl->setWordWrap(true);
00040
00041         m_edit = new QLineEdit(this);
00042         m_edit->setPlaceholderText(
00043             tr("Escribe tu respuesta (p.ej. s3, r2, acc, 5)"));
00044
00045         QVBoxLayout* layout = new QVBoxLayout(this);
00046         layout->addWidget(lbl);
00047         layout->addWidget(m_edit);
00048         setLayout(layout);
00049
00050         connect(m_edit, &QLineEdit::textChanged, this,
00051                 &SLRWizardPage::onTextChanged);
00052     }
00053 private slots:
00054     void onTextChanged(const QString& text) {
00055         bool correct = (text.trimmed() == m_expected);
00056         setComplete(correct);
00057         if (correct) {
00058             setSubTitle(
00059                 tr(" Respuesta correcta, pasa a la siguiente pregunta"));
00060         } else {
00061             setSubTitle(tr(" Incorrecto, revisa el enunciado. Consulta los "
00062                           "estados que has construido."));
00063         }
00064         wizard()->button(QWizard::NextButton)->setEnabled(correct);
00065     }
00066
00067     private:
00068         void setComplete(bool complete) {
00069             m_isComplete = complete;
00070             emit completeChanged();
00071         }
00072
00073     bool isComplete() const override { return m_isComplete; }
00074

```

```

00111     int      m_state;
00112     QString  m_symbol;
00113     QString  m_expected;
00114     QLineEdit* m_edit;
00115     bool    m_isComplete =
00116         false;
00117 };
00118
00119 #endif // SLRWIZARDPAGE_H

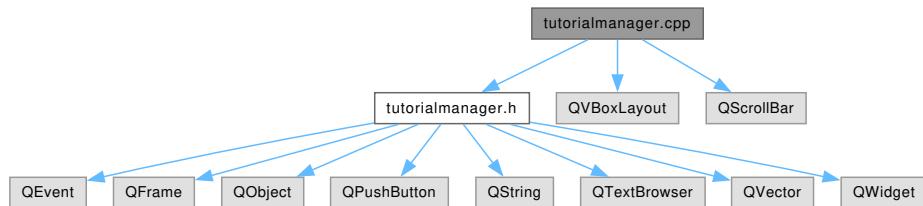
```

11.48 tutorialmanager.cpp File Reference

```

#include "tutorialmanager.h"
#include <QVBoxLayout>
#include <QScrollBar>
Include dependency graph for tutorialmanager.cpp:

```

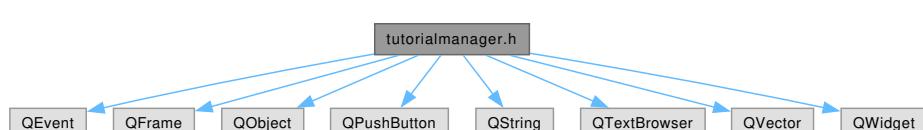


11.49 tutorialmanager.h File Reference

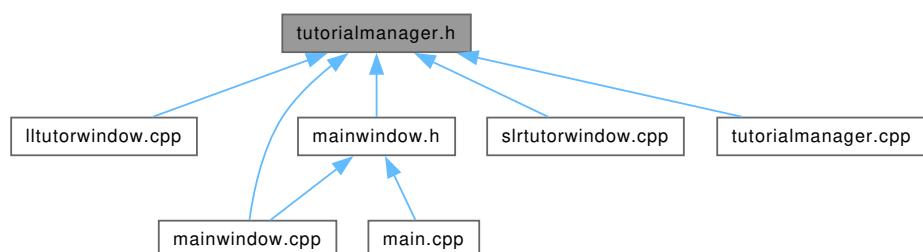
```

#include <QEvent>
#include <QFrame>
#include <QObject>
#include <QPushButton>
#include <QString>
#include <QTextBrowser>
#include <QVector>
#include <QWidget>
Include dependency graph for tutorialmanager.h:

```



This graph shows which files directly or indirectly include this file:



Classes

- struct `TutorialStep`

Represents a single step in the tutorial sequence.

- class **TutorialManager**

Manages interactive tutorials by highlighting UI elements and guiding the user.

11.50 tutorialmanager.h

[Go to the documentation of this file.](#)

```
00001 /*
00002 * SyntaxTutor - Interactive Tutorial About Syntax Analyzers
00003 * Copyright (C) 2025 Jose R. (jose-rzm)
00004 *
00005 * This program is free software: you can redistribute it and/or modify it
00006 * under the terms of the GNU General Public License as published by
00007 * the Free Software Foundation, either version 3 of the License, or
00008 * (at your option) any later version.
00009 *
00010 * This program is distributed in the hope that it will be useful,
00011 * but WITHOUT ANY WARRANTY; without even the implied warranty of
00012 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
00013 * GNU General Public License for more details.
00014 *
00015 * You should have received a copy of the GNU General Public License
00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef TUTORIALMANAGER_H
00020 #define TUTORIALMANAGER_H
00021
00022 #include <QEvent>
00023 #include <QFrame>
00024 #include <QObject>
00025 #include <QPushButton>
00026 #include <QString>
00027 #include <QTextBrowser>
00028 #include <QVector>
00029 #include <QWidget>
00030
00031 struct TutorialStep {
00032     QWidget* target;
00033     QString htmlText;
00034 };
00035
00036 class TutorialManager : public QObject {
00037     Q_OBJECT
00038 public:
00039     TutorialManager(QWidget* rootWindow);
00040
00041     void addStep(QWidget* target, const QString& htmlText);
00042
00043     void start();
00044
00045     void setRootWindow(QWidget* newRoot);
00046
00047     void clearSteps();
00048
00049     void hideOverlay();
00050
00051     void finishLL1();
00052
00053     void finishSLR1();
00054
00055 protected:
00056     bool eventFilter(QObject* obj, QEvent* ev) override;
00057
00058 signals:
00059     void stepStarted(int index);
00060
00061     void tutorialFinished();
00062
00063     void ll1Finished();
00064
00065     void slr1Finished();
00066
00067 public slots:
00068     void nextStep();
00069
00070 private:
00071     void showOverlay();
00072
00073     void repositionOverlay();
00074
00075     QWidget* m_root;
00076     QVector<TutorialStep> m_steps;
00077     int m_index = -1;
```

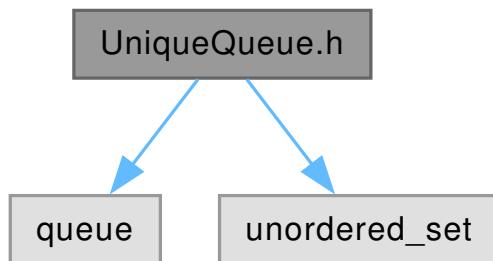
```

00151     QWidget* m_overlay = nullptr;
00152     QFrame* m_highlight =
00153         nullptr;
00154     QTextBrowser* m_textBox = nullptr;
00155     QPushButton* m_nextBtn = nullptr;
00156 }
00157 */
00158
00159 #endif // TUTORIALMANAGER_H

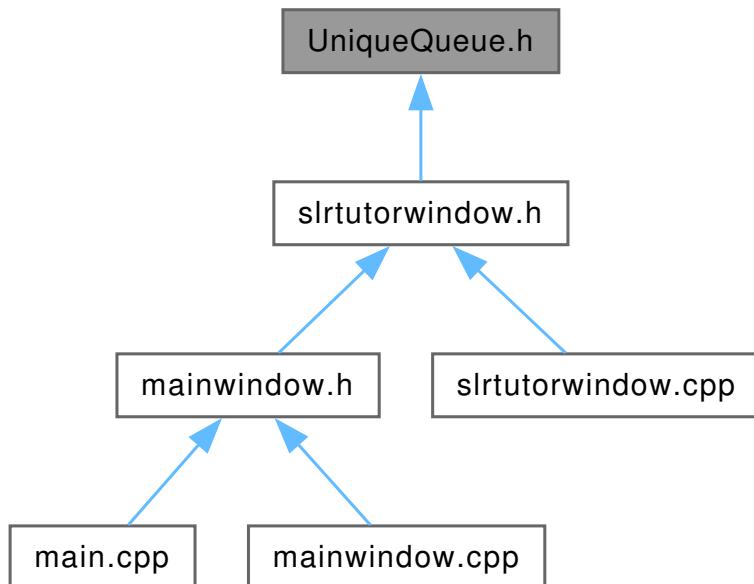
```

11.51 UniqueQueue.h File Reference

```
#include <queue>
#include <unordered_set>
Include dependency graph for UniqueQueue.h:
```



This graph shows which files directly or indirectly include this file:



Classes

- class [UniqueQueue< T >](#)
A queue that ensures each element is inserted only once.

11.52 UniqueQueue.h

[Go to the documentation of this file.](#)

```

00001 /*
00002  * SyntaxTutor - Interactive Tutorial About Syntax Analyzers

```

```
00003 * Copyright (C) 2025 Jose R. (jose-rzm)
00004 *
00005 * This program is free software: you can redistribute it and/or modify it
00006 * under the terms of the GNU General Public License as published by
00007 * the Free Software Foundation, either version 3 of the License, or
00008 * (at your option) any later version.
00009 *
00010 * This program is distributed in the hope that it will be useful,
00011 * but WITHOUT ANY WARRANTY; without even the implied warranty of
00012 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
00013 * GNU General Public License for more details.
00014 *
00015 * You should have received a copy of the GNU General Public License
00016 * along with this program. If not, see <https://www.gnu.org/licenses/>.
00017 */
00018
00019 #ifndef UNIQUEQUEUE_H
00020 #define UNIQUEQUEUE_H
00021 #include <queue>
00022 #include <unordered_set>
00023
00037 template <typename T> class UniqueQueue {
00038 public:
00043     void push(const T& value) {
00044         if (seen_.insert(value).second) {
00045             queue_.push(value);
00046         }
00047     }
00048
00052     void pop() {
00053         if (!queue_.empty()) {
00054             queue_.pop();
00055         }
00056     }
00057
00062     const T& front() const { return queue_.front(); }
00063
00068     bool empty() const { return queue_.empty(); }
00069
00073     void clear() {
00074         while (!queue_.empty())
00075             queue_.pop();
00076         seen_.clear();
00077     }
00078
00079 private:
00080     std::queue<T> queue_;
00081     std::unordered_set<T> seen_;
00082 };
00083 #endif // UNIQUEQUEUE_H
```


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