The csthm Package

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Contents

1 Introduction

The csthm package provides a set of customised theorem-like environments specifically designed for computer science documents. It offers pre-defined theorem styles and environments to streamline the creation of theorems, definitions, remarks, and other common structures in computer science papers and documents.

2 Package Options

The csthm package supports the following option:

`cleveref` Loads the cleveref package for enhanced cross-referencing capabilities. This option requires the hyperref package to be loaded before csthm.

3 Usage

To use the package with default settings:

```
\usepackage{csthm}
```

To use the package with cleveref support:

```
\usepackage{hyperref}
\usepackage[cleveref]{csthm}
```

4 Theorem Styles

The package defines four theorem styles:

thmstyle Used for theorems, lemmas, corollaries, etc.

defstyle Used for definitions, examples, problems, etc.

remarkstyle Used for remarks, notes, solutions, etc.

hltstyle Used for highlighted content like important points.

5 Predefined Environments

5.1 Theorem-like Environments

- `theorem`
- `fact`
- `assumption`
- `claim`
- `conjecture`

- `corollary`
- `lemma`
- `property`
- `proposition`

Usage:

```
\begin{theorem}[Optional Title]
    Theorem content...
\end{theorem}
```

5.2 Definition-like Environments

- `definition`
- `example`
- `exercise`
- `problem`
- `question`

Usage:

```
\begin{definition}[Optional Title]
    Definition content...
\end{definition}
```

5.3 Remark-like Environments

- `note`
- `remark`
- `solution`

Usage:

```
\begin{remark}[Optional Title]
    Remark content...
\end{remark}
```

5.4 Highlight Environments

- `important`
- `highlight`
- `keypoint`

Usage:

```
\begin{important}[Optional Title]
```

```
    Important content...
\end{important}
```

5.5 Special Environments

5.5.1 Case Environment

The `case` environment provides an enumerated list for describing different cases in a proof or analysis.

Usage:

```
\begin{case}[Optional arguments for enumerate]
    \item Case 1: ...
    \item Case 2: ...
\end{case}
```

5.5.2 Axiom Environment

The `axiom` environment provides an enumerated list for stating axioms.

Usage:

```
\begin{axiom}[Optional arguments for enumerate]
    \item Axiom 1: ...
    \item Axiom 2: ...
\end{axiom}
```

6 Customization

6.1 Accent Color

You can customise the accent colour used in the package by redefining the `\accentcolor` command:

```
\renewcommand{\accentcolor}{blue}
```

Or use the provided command:

```
\setaccentcolor{blue}
```

6.2 QED Symbol

The package redefines the QED symbol to a filled black square. You can customise this by redefining the `\qedsymbol` command:

```
\renewcommand\qedsymbol{$\square$}
```

7 Examples

Here are some examples demonstrating the usage of various environments:

THEOREM 7.1 (COMPLEXITY OF BUBBLE SORT). The time complexity of the Bubble Sort algorithm is $\mathcal{O}(n^2)$ in the worst and average cases, where n is the number of elements to be sorted. ⋆

Proof. Bubble Sort uses two nested loops to compare and swap adjacent elements. The outer loop runs $n-1$ times, and the inner loop runs $n-i-1$ times for each iteration i of the outer loop. This results in approximately $n^2/2$ comparisons, leading to a time complexity of $\mathcal{O}(n^2)$. ■

Definition 7.2 (Big O Notation). For functions $f(n)$ and $g(n)$, we say $f(n) = \mathcal{O}(g(n))$ if there exist positive constants c and n_0 such that $0 \leq f(n) \leq cg(n)$ for all $n \geq n_0$. ✠

Remark 7.3. While Bubble Sort has a worst-case time complexity of $\mathcal{O}(n^2)$, it can be useful for small datasets or nearly sorted arrays due to its simplicity and in-place sorting nature. ✠

IMPORTANT 7.1. Understanding time and space complexity is crucial for designing efficient algorithms and selecting appropriate data structures. ✠

Case 1: Best Case: The time complexity is $\mathcal{O}(n \log n)$ when the pivot always divides the array into two halves.

Case 2: Average Case: The expected time complexity is $\mathcal{O}(n \log n)$ with random pivot selection.

Case 3: Worst Case: The time complexity is $\mathcal{O}(n^2)$ when the pivot is always the smallest or largest element.

Axiom A: Axiom of Extensionality: Two sets are equal if and only if they have the same elements.

Axiom B: Axiom of Pairing: For any two sets a and b, there exists a set $\{a, b\}$ that contains exactly a and b as its elements.

8 Requirements

The csthm package requires the following packages:

- amsmath
- amssymb
- amsthm
- enumitem
- thmtools

If the `cleveref` option is used, the hyperref package must be loaded before csthm.

9 Version History

v1.0 (2024/08/31) Initial version

v1.1 (2024/08/31) Added `cleveref` support

v1.2 (2024/08/31) Improved documentation, code structure, and added to CTAN

10 License

11 Feedback and Contributions

For bug reports, feature requests, or general feedback, please contact the package maintainer, Agni Datta, at agnidatta.org@gmail.com.

Contributions to the package are welcome. Please submit pull requests or issues to the package's GitHub repository.

12 Package Source Code

The following listing shows the source code of the `csthm.sty` file:

```
%%
%% This is file 'csthm.sty',
%% generated with the docstrip utility.
%%
%% The original source files were:
%%
%% csthm.dtx (with options: 'package')
%%
%% This is a generated file.
%%
%% Copyright (C) 2024 by Agni Datta <agnidatta.org@gmail.com>
%%
%% This file may be distributed and/or modified under the conditions of
%% the LaTeX Project Public License, either version 1.3c of this license
%% or (at your option) any later version. The latest version of this
%% license is in:
%%
%% http://www.latex-project.org/lppl.txt
%%
%% and version 1.3c or later is part of all distributions of LaTeX
%% version 2008/05/04 or later.
%%
\NeedsTeXFormat{LaTeX2e}[1999/12/01]
\ProvidesPackage{csthm}
    [2024/08/31 v1.2 Theorem Environments for Computer Science]
```

```latex
\newif\if@csthm@loadcleveref
\DeclareOption{cleveref}{\@csthm@loadclevereftrue}
\ProcessOptions\relax

\RequirePackage{amsmath}
\RequirePackage{amssymb}
\RequirePackage{amsthm}
\RequirePackage{enumitem}
\RequirePackage{thmtools}

\if@csthm@loadcleveref
\AtBeginDocument{%
\@ifpackageloaded{hyperref}{%
\RequirePackage{cleveref}
}{%
\PackageWarning{csthm}{The 'cleveref' option was set, but 'hyperref' is not loaded. Skipping 'cleveref' loading.}
}%
}
\fi

\declaretheoremstyle[
spaceabove=\topsep,
spacebelow=\topsep,
headfont=\scshape,
notefont=\scshape,
bodyfont=\normalfont,
postheadspace=5pt,
numberwithin=section,
qed=$\scriptstyle\star$,
headpunct={.}
]{thmstyle}

\declaretheoremstyle[
spaceabove=\topsep,
spacebelow=\topsep,
headfont=\bfseries,
notefont=\bfseries,
bodyfont=\normalfont,
postheadspace=5pt,
numberwithin=section,
qed=$\scriptstyle\maltese$,
headpunct={.}
]{defstyle}

\declaretheoremstyle[
spaceabove=\topsep,
spacebelow=\topsep,
headfont=\itshape,
notefont=\itshape,
bodyfont=\normalfont,
postheadspace=5pt,
numberwithin=section,
qed=$\scriptstyle\maltese$,
headpunct={.}
]{remarkstyle}

\declaretheoremstyle[
spaceabove=\topsep,
spacebelow=\topsep,
headfont=\sffamily\scshape,
notefont=\sffamily\scshape,
bodyfont=\normalfont\sffamily,
postheadspace=5pt,
```

```
numberwithin=section,
qed=$\scriptstyle\maltese$,
headpunct={.}
]{hltstyle}

\declaretheorem[style=thmstyle,name=Theorem]{theorem}
\declaretheorem[style=defstyle,sibling=theorem]{fact}
\declaretheorem[style=thmstyle,sibling=theorem]{assumption}
\declaretheorem[style=thmstyle,sibling=theorem]{claim}
\declaretheorem[style=thmstyle,sibling=theorem]{conjecture}
\declaretheorem[style=thmstyle,sibling=theorem]{corollary}
\declaretheorem[style=thmstyle,sibling=theorem]{lemma}
\declaretheorem[style=thmstyle,sibling=theorem]{property}
\declaretheorem[style=thmstyle,sibling=theorem]{proposition}

\declaretheorem[style=defstyle,sibling=theorem]{definition}
\declaretheorem[style=defstyle,sibling=theorem]{example}
\declaretheorem[style=defstyle,sibling=theorem]{exercise}
\declaretheorem[style=defstyle,sibling=theorem]{problem}
\declaretheorem[style=defstyle,sibling=theorem]{question}

\declaretheorem[style=remarkstyle,sibling=theorem]{note}
\declaretheorem[style=remarkstyle,sibling=theorem]{remark}
\declaretheorem[style=remarkstyle,sibling=theorem]{solution}

\declaretheorem[style=hltstyle,name=Important]{important}
\declaretheorem[style=hltstyle]{highlight}
\declaretheorem[style=hltstyle]{keypoint}

\newlist{caseList}{enumerate}{1}
\setlist[caseList]{label=\textbf{Case~\arabic*:},leftmargin=*}

\NewDocumentEnvironment{case}{O{}}{%
\begin{caseList}[#1]%
}{%
\end{caseList}%
}

\newlist{axiomList}{enumerate}{1}
\setlist[axiomList]{label=\textbf{Axiom~\Alph*:}, leftmargin=*}

\NewDocumentEnvironment{axiom}{O{}}{%
\begin{axiomList}[#1]%
}{%
\end{axiomList}%
}

\renewcommand\qedsymbol{$\scriptstyle\blacksquare$}

\providecommand{\accentcolor}{black}

\providecommand{\csthmpkg}{\textsf{csthm}}
\providecommand{\email}[1]{\href{mailto:#1}{\texttt{#1}}}

\newcommand{\setaccentcolor}[1]{\renewcommand{\accentcolor}{#1}}
\endinput
%%
%% End of file ‘csthm.sty’.
```

A Real-Life Usage Examples

A.1 Theorem Environments

The csthm package provides several theorem-like environments commonly used in computer science literature:

THEOREM A.1 (GRAPH COLOURING). For any graph G, the chromatic number $\chi(G)$ is the minimum number of colours needed to colour the vertices of G such that no two adjacent vertices share the same colour. $\star$

LEMMA A.2 (SUM OF ODD NUMBERS). For every positive integer n, the sum of the first n odd numbers is equal to n^2. $\star$

Proof. We can prove this by induction on n:

Case 1: Base case: For $n = 1$, the first odd number is 1, and $1^2 = 1$. The statement holds.

Case 2: Inductive step: Assume the statement holds for some $k \geq 1$. We need to prove it for $k + 1$.

The $(k + 1)$-th odd number is $2k + 1$. So, we have:

$\sum_{i=1}^{k+1}(2i - 1) = \sum_{i=1}^{k}(2i - 1) + (2k + 1)$

$= k^2 + (2k + 1)$ (by induction hypothesis)

$= k^2 + 2k + 1$

$= (k + 1)^2$

Thus, the statement holds for $k + 1$, completing the proof.

■

COROLLARY A.3 (SUM OF INTEGERS). The sum of the first n positive integers is given by $\frac{n(n+1)}{2}$. $\star$

PROPOSITION A.4 (EVEN SUM PROPERTY). The sum of two even integers is always even. $\star$

CONJECTURE A.5 (GOLDBACH'S CONJECTURE). Every even integer greater than 2 can be expressed as the sum of two prime numbers. $\star$

A.2 Definition and Example Environments

To introduce key definitions and illustrative examples:

Definition A.6 (Tree). A *tree* is a connected, undirected graph with no cycles. ✠

Example A.7 (Binary Tree). Consider a binary tree with 7 nodes labelled from 1 to 7:

```
    1
  /   \
 2     3
```

```
  / \   / \
 4   5 6   7
```

This tree has 3 levels, and each parent node has at most 2 children. ✠

A.3 Remark Environments

To include remarks and notes that highlight important observations:

Remark A.8. While all trees are graphs, not all graphs are trees. A graph must be acyclic and connected to be classified as a tree. ✠

Note A.9. Many conjectures, like Goldbach's Conjecture, remain unproven for centuries despite numerous verified instances. This highlights the complexity of certain mathematical problems. ✠

A.4 Highlight Environments

To emphasise crucial points within the document:

IMPORTANT A.1. Algorithm efficiency is critical in computer science. Always consider time and space complexity when designing and analysing algorithms. ✠

KEYPOINT A.1. Understanding the P vs NP problem is fundamental in computational complexity theory and has significant implications for algorithm design and cryptography. ✠

A.5 Case Environment

Used to present distinct cases in an argument or proof:

THEOREM A.10 (FACTORIAL DEFINITION). The factorial of a non-negative integer n, denoted as $n!$, is defined as follows: ⋆

Case 1: When $n = 0$, $0! = 1$ (by definition).

Case 2: When $n > 0$, $n! = n \times (n-1) \times \cdots \times 2 \times 1$.

A.6 Axiom Environment

To enumerate foundational axioms in formal proofs:

Axiom A: For any sets A and B, $A \cup B = B \cup A$ (Commutative Law of Union).

Axiom B: For any sets A, B, and C, $A \cap (B \cup C) = (A \cap B) \cup (A \cap C)$ (Distributive Law).

Axiom C: For any set A, $A \cup \emptyset = A$ (Identity Law of Union).