# Neural Predicate Invention from Visual Scenes*

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**Abstract**

A clear and well-documented LaTeX document is presented as an article formatted for publication by CEUR-WS in a conference proceedings. Based on the "ceurart" document class, this article presents and explains many of the common variations, as well as many of the formatting elements an author may use in the preparation of the documentation of their work.

**Keywords**

LaTeX class, paper template, paper formatting, CEUR-WS

## 1. Introduction

## 2. Related Work

## 3. Target Map

The goal of our work is to find a predicate invention pipeline so that some high level concepts are not necessarily given from reasoning language directly. But they can be invented as needed during training. The invention is important since it is a way to acquire new knowledge and shows the ability of intelligence. On the other hand, it improves the generalization of AI models for adapting unseen tasks. The invention model improves the system to describe the problem more accurate.

However, the invention is still based on given background knowledge. It has to be simple, combinable, and mutually compatible, so that the new concepts are various and accurate.

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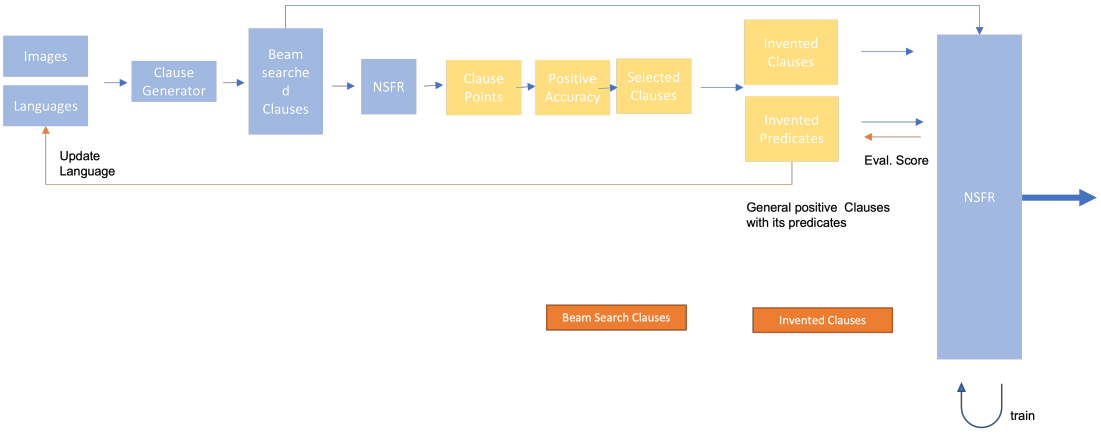



**Figure 1:** Predicate invention workflow.

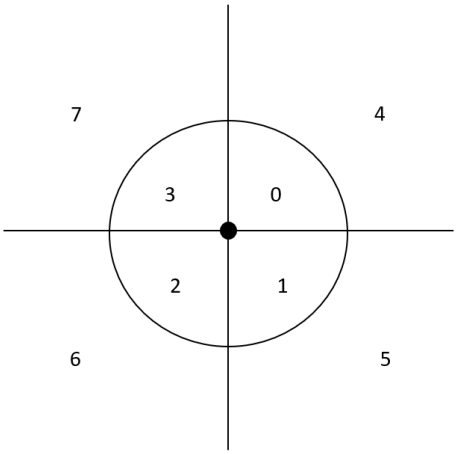



**Figure 2:** 8-divide spatial area map with a clockwise naming.

In order to using a single language to cover two objects spatial relations as many as possible, we designed an area division map called *target map*. As shown in figure 2, the surrounding area according to the reference object has been divided into 8 sub-areas. The areas in the target map are considered as background knowledge. The concepts like left, right, nearby supposed to be invented as new predicates during the training if any of them are needed to represent the target pattern in the positive images. This map both considers the distance and directions of the latent relation objects. Using the target map, multiple real-world related spatial concepts can be represented by combining some of atom areas, such as *left* (combining area 2,3,6,7), *right*(combining area 0,1,4,5), *nearby*(combining area 0,1,2,3) and so on.

# 4. Predicate Invention

The target of inductive logic programming is to find a target clause $P$ for the positive patterns $Q$ , such that the clause $P$ describes some logical relations that exist and only exist in the positive patterns. Thus the target clause $P$ is sufficient and necessary for the positive patterns $Q$.

$$P \Leftrightarrow Q$$

## 4.1. Clause generation loop.

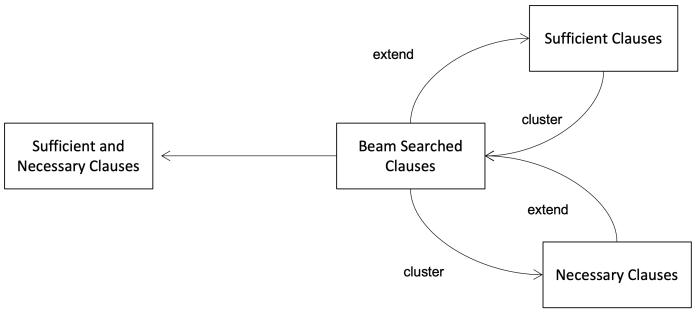



**Figure 3:** Clause Invention Chart.

Base on the scoring areas of the predicates, we can classify them into several groups, where $N$ is the number of PN pairs.

- **Sufficient and Necessary Clause**: scores on $(0, 1)$ only, i.e. $s_{01} = N$ They are sufficient and necessary for the target pattern.
- **Necessary Clause**: scores on $(0, 1)$ and $(1, 1)$, i.e. $s_{01} + s_{11} = N$. They are necessary for the target pattern. They always true in the positive images, but also can be true in negative images.
- **Sufficient Clause**: scores on $(0, 0)$ and $(0, 1)$, i.e. $s_{00} + s_{01} = N$. They represents the concepts that might appear in the positive image, but never in a negative image.
- **Useless Clause**: Sometimes the clauses getting from cluster or extending can be useless.

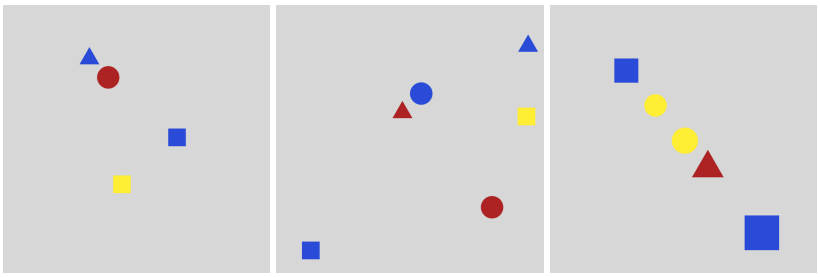
As shown in figure 3, we apply cluster and extend operations on the clauses to get a sufficient and necessary clause.

**Sufficient Condition**: In order to find a sufficient clause, we can **extend** the beam search clauses with adding more predicates in the body, until it is sufficient.

**Necessary Condition**: In order to invent a necessary predicate, we can **cluster** independent beam search clauses. Independent means the clauses do not share same predicates. This kind of predicates invent high level concepts. For example, cluster low level concept *south*, *east*, *north*, *west*, which are independent with each other, we can have a high level concept *directions*.

This invention approach may take several rounds. After each round, we check if any sufficient and necessary clauses have been generated, if there exist such, it is the target clause we want to find. If no such clauses, we take another round for clause searching.

## 4.2. Solving Kandinsky Patterns with PI



(a) Nearby (b) 5 Online with a pair (c) Red triangle

**Figure 4:** Kandinsky Patterns. (a) blah (b) blah (c) blah (d) blah

### 4.2.1. Nearby

To solve the nearby pattern, we invent the concept $inv\_pred\_1O\_1, O\_2$ by cluster clauses, which actually represent the concept *nearby*. It is necessary for the target patterns since it is true in all the positive images. It is also directly a sufficient predicate since no negative image has this pattern. The target clauses can be described as follows:

$$\begin{aligned} target(X) &: -in(O_1, X), in(O_2, X), inv\_pred\_1(O_1, O_2). \\ inv\_pred\_1(O_1, O_2) &: -in(O_1, X), in(O_2, X), a\_0(O_1, O_2). \\ inv\_pred\_1(O_1, O_2) &: -in(O_1, X), in(O_2, X), a\_1(O_1, O_2). \end{aligned}$$

### 4.2.2. Red Triangle

To solve the red triangle pattern, we require the concept *nearby* first by cluster clauses. It is necessary for the target patterns but not yet sufficient. Then we use beam search to extend this necessary clause with adding predicates, a sufficient and necessary clause is generated in several steps.

$$\begin{aligned} target(X) : -&in(O_1, X), in(O_2, X), inv\_pred\_1(O_1, O_2), \\ &shape(O_1, triangle), color(O_1, red), \\ &diff\_shape\_pair(O_{1,O}\,2), diff\_color\_pair(O_1, O_2) \end{aligned}$$

$$\begin{aligned} inv\_pred\_1(O_1, O_2) &: -in(O_1, X), in(O_2, X), a\_0(O_1, O_2). \\ inv\_pred\_1(O_1, O_2) &: -in(O_1, X), in(O_2, X), a\_1(O_1, O_2). \\ inv\_pred\_1(O_1, O_2) &: -in(O_1, X), in(O_2, X), a\_2(O_1, O_2). \\ inv\_pred\_1(O_1, O_2) &: -in(O_1, X), in(O_2, X), a\_3(O_1, O_2). \end{aligned}$$

#### 4.2.3. Online-Pair

For online-pair patterns, five objects are align on a line, whereas two of them have the same color and same pair. In this pattern, no necessary clauses can be found by clustering predicates. Thus we have to extend the clauses using beam search, until it is sufficient. Then for the sufficient clauses that we have found, we perform clustering for necessity.

A possible target clauses searching by predicate invention system is shown as follows

$$\begin{aligned} target(X) : -& in(O_1, X), in(O_2, X), in(O_3, X), in(O_4, X), in(O_5, X) \\ & inv\_pred\_1(O_1, O_2, O_3, O_4, O_5) \end{aligned}$$

$$\begin{aligned} inv\_pred\_1(O_1, O_2, O_3, O_4, O_5) : -& in(O_1, X), in(O_2, X), in(O_3, X), in(O_4, X), in(O_5, X) \\ & a\_0(O_4, O_1), a\_2(O_2, O_1), same\_shape\_pair(O_2, O_4) \\ inv\_pred\_1(O_1, O_2, O_3, O_4, O_5) : -& in(O_1, X), in(O_2, X), in(O_3, X), in(O_4, X), in(O_5, X) \\ & a\_2(O_2, O_5), a\_2(O_5, O_3), color(O_3, blue) \\ inv\_pred\_1(O_1, O_2, O_3, O_4, O_5) : -& in(O_1, X), in(O_2, X), in(O_3, X), in(O_4, X), in(O_5, X) \\ & a\_3(O_2, O_1), a\_3(O_4, O_2), a\_3(O_5, O_4) \end{aligned}$$

$$\begin{aligned} inv\_pred\_2(O_1, O_2, O_3, O_4, O_5) : -& in(O_1, X), in(O_2, X), in(O_3, X), in(O_4, X), in(O_5, X) \\ & a\_0(O_4, O_1), a\_2(O_2, O_1), same\_shape\_pair(O_2, O_4) \\ inv\_pred\_2(O_1, O_2, O_3, O_4, O_5) : -& in(O_1, X), in(O_2, X), in(O_3, X), in(O_4, X), in(O_5, X) \\ & a\_1(O_3, O_1), a\_3(O_2, O_4), same\_color\_pair(O_2, O_4) \\ inv\_pred\_2(O_1, O_2, O_3, O_4, O_5) : -& in(O_1, X), in(O_2, X), in(O_3, X), in(O_4, X), in(O_5, X) \\ & a\_2(O_2, O_5), a\_2(O_5, O_3), color(O\_3, blue) \\ inv\_pred\_2(O_1, O_2, O_3, O_4, O_5) : -& in(O_1, X), in(O_2, X), in(O_3, X), in(O_4, X), in(O_5, X) \\ & a\_3(O_2, O_1), a\_3(O_4, O_2), a\_3(O_5, O_4) \end{aligned}$$

Note that the predicate $inv\_pred\_1(O_1, O_2, O_3, O_4, O_5)$ share the same bodies $same\_shape\_pair(O_1, O_2), same\_color\_pair(O_1, O_2)$, which corresponds the concept $five\_object\_on\_the\_same\_line\_with\_one\_pair\_of\_same\_color\_and\_shape\_objects$. We can remove shared bodies in the clause definition. Then the predicate corresponds a simpler concept $five\_object\_on\_the\_same\_line$, which is a necessary predicate. It becomes sufficient after adding the deleted predicate back to. Removing shared bodies is not necessary but it can simplify the corresponding concepts of invented predicates.

### 4.3. Evaluation by Sufficiency

The invented predicates can be sufficient for positive patterns, which equivalent to the target predicate as well. Once we have found a sufficient predicate for the positive patterns, we are done. Thus it is desirable for the task. However, for searching complicate target patterns, the

sufficient predicates usually cannot be invented in one step. Instead, they need other invented predicates as prerequisites. In this case, these prerequisite predicates are necessary for sufficient predicates. Thus they are supposed to be invented beforehand and used for sufficient predicate invention.

### 4.4. Evaluation by Necessity

Necessary evaluation keeps predicates those are true in all positive patterns. They can be insufficient, thus they can also be true in negative patterns. Necessary predicates are invented as prerequisite for sufficient predicate invention. The necessity guarantees the searching for invented predicates is controlled in a proper scale, since only limited necessary conditions exist in the positive patterns. If we loose the necessity assumption, the searching domain for invented predicates can be huge since the conditions that doesn't exist in the positive patterns are irregular and countless. However, searching for some that necessary for the majority of positive patterns is reasonable. In this paper, we apply the necessity condition only for all the positive patterns.

### 4.5. Invented Clause Evaluation

Invented predicates are trivial if they are necessary for both positive and negative patterns.

A partial strict positive predicate During evaluation, only predicates which evaluate all the PN pairs as general positive and the number of strict positive PN pairs is more than half are kept. The They don't reduce the searching domain for the target predicate invention. Instead of evaluate on images one by one. We can take a pair of positive and negative image

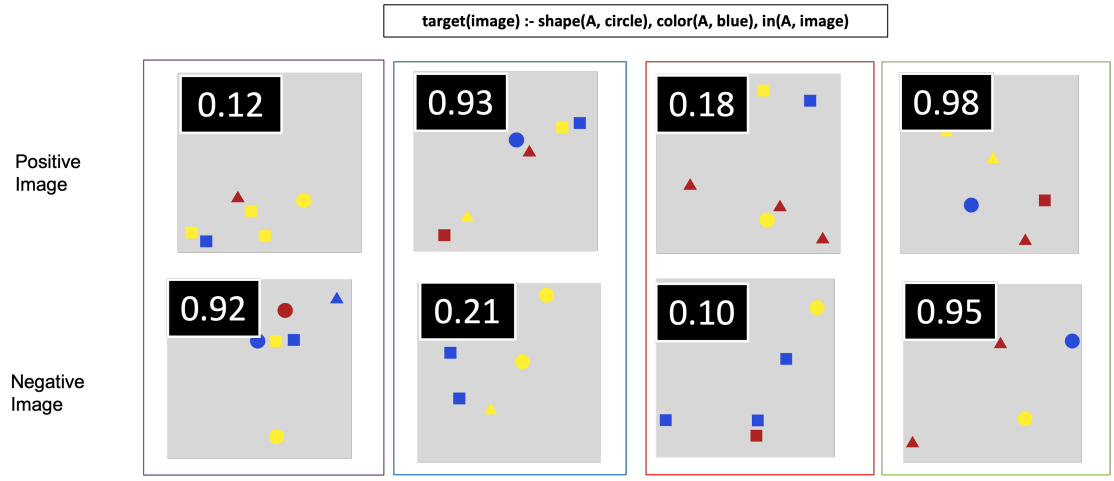



**Figure 5:** PN pair.

Each PN-pair consists of one positive image and one negative image. For a pair of image, its

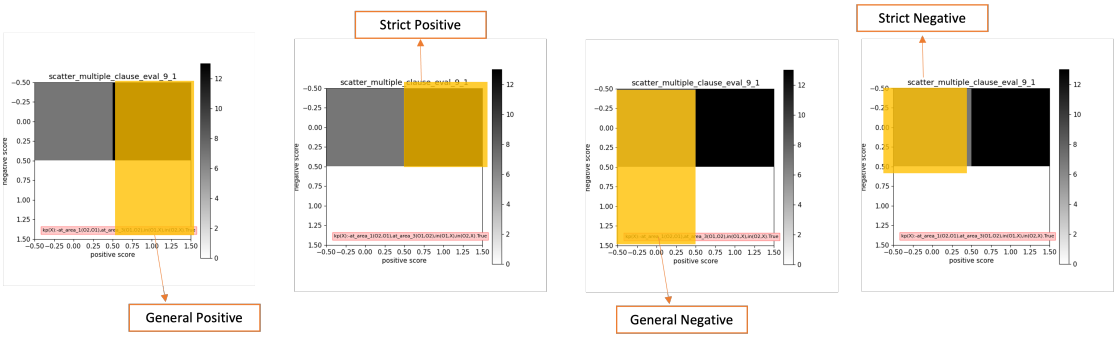



**Figure 6:** PN pair.

## 5. Inference Result

Think about "How" to cluster the existing clauses. Simply cluster all the clauses as one single concept cannot handle complicate rules.

If NSFR gives following clauses, then which of those clauses should be clustered as the new concept?

If there is a pattern with multiple rules, a iteration-based approach should be proposed. First several iteration, it should be able to learn some new predicates, then use new predicates to describe the new scenarios.

New predicate has to be able to 100% describe the positive images. Otherwise, reconsider it.

$$
\begin{aligned}
target(X,Y) &\leftarrow atArea0(X,Y), atArea2(Y,X)\\
target(X,Y) &\leftarrow atArea1(X,Y), atArea3(Y,X)\\
target(X,Y) &\leftarrow atArea1(X,Y)\\
target(X,Y) &\leftarrow atArea2(X,Y)\\
target(X,Y) &\leftarrow atArea4(X,Y), atArea6(Y,X)\\
target(X,Y) &\leftarrow atArea5(X,Y), atArea7(Y,X)\\
target(X,Y) &\leftarrow atArea5(X,Y)\\
target(X,Y) &\leftarrow atArea6(X,Y)\\
target(X,Y) &\leftarrow pred1(X,Y)
\end{aligned}
$$

### 5.1. Chaining

[1] supports predicate invention.

## 6. Experiments

Using the baseline $\alpha$ILP, the nearby concept test accuracy is upto xxx, after xxx iterations.

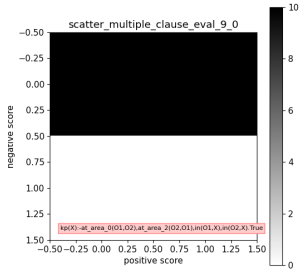



**Figure 7:** Caption

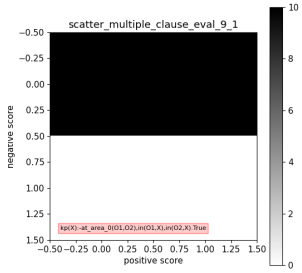



**Figure 8:** Caption

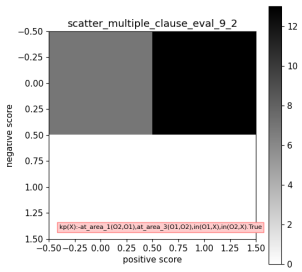



**Figure 9:** Caption

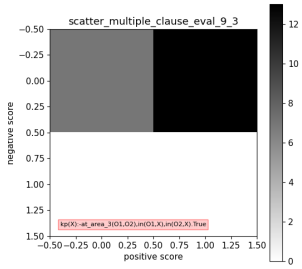



**Figure 10:** Caption

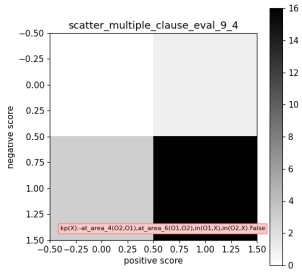



**Figure 11:** Caption

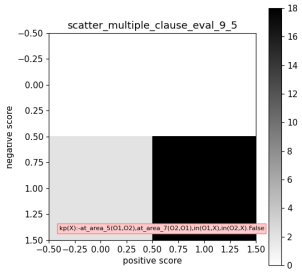



**Figure 12:** Caption

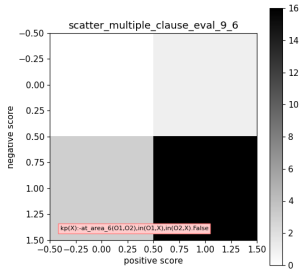



**Figure 13:** Caption

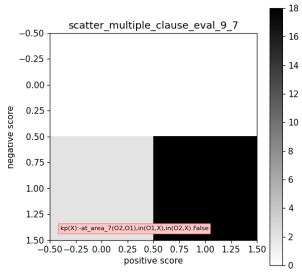



**Figure 14:** Caption

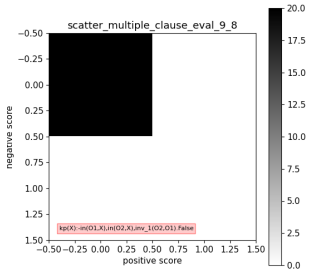



**Figure 15:** Caption

**Figure 16:** Pipeline of NSFR with PI module.

# 7. Modifications

Modifying the template — including but not limited to: adjusting margins, typeface sizes, line spacing, paragraph and list definitions, and the use of the `\vspace` command to manually adjust the vertical spacing between elements of your work — is not allowed.

**Table 1**
PI Evaluation Result

| Module | Red-Triangle | Nearby | Online | Two Pairs |
|---|---|---|---|---|
| $\alpha$ILP | 0.90 | 1.0 | | 0.95 |
| $\alpha$ILP + PI | 0.96 | 1.0 | | |

# 8. Template parameters

There are a number of template parameters which modify some part of the `ceurart` document class. This parameters are enclosed in square brackets and are a part of the `\documentclass` command:

```
\documentclass[parameter]{ceurart}
```

Frequently-used parameters, or combinations of parameters, include:

- `twocolumn` : Two column layout.
- `hf` : Enable header and footer[1].

# 9. Front matter

## 9.1. Title Information

The titles of papers should be either all use the emphasizing capitalized style or they should all use the regular English (or native language) style. It does not make a good impression if you or your authors mix the styles.

Use the `\title` command to define the title of your work. Do not insert line breaks in your title.

## 9.2. Title variants

`\title` command have the below options:

- `title`: Document title. This is default option.

  ```
  \title[mode=title]{This is a title}
  ```

  You can just omit it, like as follows:

  ```
  \title{This is a title}
  ```

- `alt`: Alternate title.

  ```
  \title[mode=alt]{This is a alternate title}
  ```

- `sub`: Sub title.

[1]You can enable the display of page numbers in the final version of the entire collection. In this case, you should adhere to the end-to-end pagination of individual papers.

```
\title[mode=sub]{This is a sub title}
```

You can just use `\subtitle` command, as follows:

```
\subtitle{This is a sub title}
```

- `trans`: Translated title.

  ```
  \title[mode=trans]{This is a translated title}
  ```

- `transsub`: Translated sub title.

  ```
  \title[mode=transsub]{This is a translated sub title}
  ```

### 9.3. Authors and Affiliations

Each author must be defined separately for accurate metadata identification. Multiple authors may share one affiliation. Authors' names should not be abbreviated; use full first names wherever possible. Include authors' e-mail addresses whenever possible.

`\author` command have the below options:

- `style` : Style of author name (chinese)
- `prefix` : Prefix
- `suffix` : Suffix
- `degree` : Degree
- `role` : Role
- `orcid` : ORCID
- `email` : E-mail
- `url` : URL

Author names can have some kinds of marks and notes:

- affiliation mark: `\author[<num>]`.

The author names and affiliations could be formatted in two ways:

1. Group the authors per affiliation.
2. Use an explicit mark to indicate the affiliations.

Author block example:

```
\author[1,2]{Author Name}[%
    prefix=Prof.,
    degree=D.Sc.,
    role=Researcher,
    orcid=0000-0000-000-0000,
    email=name@example.com,
    url=https://name.example.com
]

\address[1]{Affiliation #1}
\address[2]{Affiliation #2}
```

## 9.4. Abstract and Keywords

Abstract shall be entered in an environment that starts with `\begin{abstract}` and ends with `\end{abstract}`.

```
\begin{abstract}
  This is an abstract.
\end{abstract}
```

The key words are enclosed in a `keywords` environment. Use `\sep` to separate keywords.

```
\begin{keywords}
  First keyword \sep
  Second keyword \sep
  Third keyword \sep
  Fourth keyword
\end{keywords}
```

At the end of front matter add `\maketitle` command.

## 9.5. Various Marks in the Front Matter

The front matter becomes complicated due to various kinds of notes and marks to the title and author names. Marks in the title will be denoted by a star ($\star$) mark; footnotes are denoted by super scripted Arabic numerals, corresponding author by an Conformal asterisk (*) mark.

### 9.5.1. Title marks

Title mark can be entered by the command, `\tnotemark[<num>]` and the corresponding text can be entered with the command `\tnotetext[<num>]{<text>}`. An example will be:

```
\title{A better way to format your document for CEUR-WS}

\tnotemark[1]
\tnotetext[1]{You can use this document as the template for
   preparing your
  publication. We recommend using the latest version of the
     ceurart style.}
```

`\tnotemark` and `\tnotetext` can be anywhere in the front matter, but should be before `\maketitle` command.

### 9.5.2. Author marks

Author names can have some kinds of marks and notes:

- footnote mark : `\fnmark[<num>]`
- footnote text : `\fntext[<num>]{<text>}`
- corresponding author mark : `\cormark[<num>]`
- corresponding author text : `\cortext[<num>]{<text>}`

**Table 2**
Frequency of Special Characters

| Non-English or Math | Frequency | Comments |
|---|---|---|
| Ø | 1 in 1,000 | For Swedish names |
| $\pi$ | 1 in 5 | Common in math |
| $ | 4 in 5 | Used in business |
| $\Psi_1^2$ | 1 in 40,000 | Unexplained usage |

### 9.5.3. Other marks

At times, authors want footnotes which leave no marks in the author names. The note text shall be listed as part of the front matter notes. Class files provides `\nonumnote` for this purpose. The usage

```
\nonumnote{<text>}
```

and should be entered anywhere before the `\maketitle` command for this to take effect.

## 10. Sectioning Commands

Your work should use standard LaTeX sectioning commands: `\section`, `\subsection`, `\subsubsection`, and `\paragraph`. They should be numbered; do not remove the numbering from the commands.

Simulating a sectioning command by setting the first word or words of a paragraph in boldface or italicized text is not allowed.

## 11. Tables

The "`ceurart`" document class includes the "`booktabs`" package — https://ctan.org/pkg/booktabs — for preparing high-quality tables.

Table captions are placed *above* the table.

Because tables cannot be split across pages, the best placement for them is typically the top of the page nearest their initial cite. To ensure this proper "floating" placement of tables, use the environment `table` to enclose the table's contents and the table caption. The contents of the table itself must go in the `tabular` environment, to be aligned properly in rows and columns, with the desired horizontal and vertical rules.

Immediately following this sentence is the point at which Table 2 is included in the input file; compare the placement of the table here with the table in the printed output of this document.

To set a wider table, which takes up the whole width of the page's live area, use the environment `table*` to enclose the table's contents and the table caption. As with a single-column table, this wide table will "float" to a location deemed more desirable. Immediately following this sentence is the point at which Table 3 is included in the input file; again, it is instructive to compare the placement of the table here with the table in the printed output of this document.

**Table 3**
Some Typical Commands

| Command | A Number | Comments |
|---|---|---|
| `\author` | 100 | Author |
| `\table` | 300 | For tables |
| `\table*` | 400 | For wider tables |

## 12. Math Equations

You may want to display math equations in three distinct styles: inline, numbered or non-numbered display. Each of the three are discussed in the next sections.

### 12.1. Inline (In-text) Equations

A formula that appears in the running text is called an inline or in-text formula. It is produced by the `math` environment, which can be invoked with the usual `\begin` ... `\end` construction or with the short form `$` ... `$`. You can use any of the symbols and structures, from $\alpha$ to $\omega$, available in LaTeX [2]; this section will simply show a few examples of in-text equations in context. Notice how this equation: $\lim_{n\to\infty} \frac{1}{n} = 0$, set here in in-line math style, looks slightly different when set in display style. (See next section).

### 12.2. Display Equations

A numbered display equation—one set off by vertical space from the text and centered horizontally—is produced by the `equation` environment. An unnumbered display equation is produced by the `displaymath` environment.

Again, in either environment, you can use any of the symbols and structures available in LaTeX; this section will just give a couple of examples of display equations in context. First, consider the equation, shown as an inline equation above:

$$\lim_{n\to\infty} \frac{1}{n} = 0. \tag{1}$$

Notice how it is formatted somewhat differently in the `displaymath` environment. Now, we'll enter an unnumbered equation:

$$S_n = \sum_{i=1}^{n} x_i,$$

and follow it with another numbered equation:

$$\lim_{x\to 0}(1+x)^{1/x} = e \tag{2}$$

just to demonstrate LaTeX's able handling of numbering.

**Figure 17:** 1907 Franklin Model D roadster. Photograph by Harris & Ewing, Inc. [Public domain], via Wikimedia Commons. (https://goo.gl/VLCRBB).

## 13. Figures

The "`figure`" environment should be used for figures. One or more images can be placed within a figure. If your figure contains third-party material, you must clearly identify it as such, as shown in the example below.

Your figures should contain a caption which describes the figure to the reader. Figure captions go below the figure. Your figures should also include a description suitable for screen readers, to assist the visually-challenged to better understand your work.

Figure captions are placed below the figure.

## 14. Introduction

CEUR-WS's article template provides a consistent LaTeX style for use across CEUR-WS publications, and incorporates accessibility and metadata-extraction functionality. This document will explain the major features of the document class.

If you are new to publishing with CEUR-WS, this document is a valuable guide to the process of preparing your work for publication.

The "`ceurart`" document class can be used to prepare articles for any CEUR-WS publication, and for any stage of publication, from review to final "camera-ready" copy with *very* few changes to the source.

This class depends on the following packages for its proper functioning:

- `natbib.sty` for citation processing;
- `geometry.sty` for margin settings;
- `graphicx.sty` for graphics inclusion;
- `hyperref.sty` optional package if hyperlinking is required in the document;
- `fontawesome5.sty` optional package for bells and whistles.

All the above packages are part of any standard LaTeX installation. Therefore, the users need not be bothered about downloading any extra packages.

## 15. Citations and Bibliographies

The use of BibTeX for the preparation and formatting of one's references is strongly recommended. Authors' names should be complete — use full first names ("Donald E. Knuth") not initials ("D. E. Knuth") — and the salient identifying features of a reference should be included: title, year, volume, number, pages, article DOI, etc.

The bibliography is included in your source document with these two commands, placed just before the `\end{document}` command:

```
\bibliography{bibfile}
```

where "`bibfile`" is the name, without the "`.bib`" suffix, of the BibTeX file.

### 15.1. Some examples

A paginated journal article [3], an enumerated journal article [4], a reference to an entire issue [5], a monograph (whole book) [6], a monograph/whole book in a series (see 2a in spec. document) [7], a divisible-book such as an anthology or compilation [8] followed by the same example, however we only output the series if the volume number is given [9] (so series should not be present since it has no vol. no.), a chapter in a divisible book [10], a chapter in a divisible book in a series [11], a multi-volume work as book [12], an article in a proceedings (of a conference, symposium, workshop for example) (paginated proceedings article) [13], a proceedings article with all possible elements [14], an example of an enumerated proceedings article [15], an informally published work [16], a doctoral dissertation [17], a master's thesis: [18], an online document / world wide web resource [19, 20, 21], a video game (Case 1) [22] and (Case 2) [23] and [24] and (Case 3) a patent [25], work accepted for publication [26], prolific author [27] and [28]. Other cites might contain 'duplicate' DOI and URLs (some SIAM articles) [29]. Multi-volume works as books [30] and [31]. A couple of citations with DOIs: [32, 29]. Online citations: [33, 19, 34, 35].

## 16. Acknowledgments

Identification of funding sources and other support, and thanks to individuals and groups that assisted in the research and the preparation of the work should be included in an acknowledgment section, which is placed just before the reference section in your document.

This section has a special environment:

```
\begin{acknowledgments}
  These are different acknowledgments.
\end{acknowledgments}
```

so that the information contained therein can be more easily collected during the article metadata extraction phase, and to ensure consistency in the spelling of the section heading.

Authors should not prepare this section as a numbered or unnumbered `\section`; please use the "`acknowledgments`" environment.

## 17. Appendices

If your work needs an appendix, add it before the "`\end{document}`" command at the conclusion of your source document.

Start the appendix with the "`\appendix`" command:

```
\appendix
```

and note that in the appendix, sections are lettered, not numbered.

## Acknowledgments

Thanks to the developers of ACM consolidated LaTeX styles https://github.com/borisveytsman/acmart and to the developers of Elsevier updated LaTeX templates https://www.ctan.org/tex-archive/macros/latex/contrib/els-cas-templates.

## References

[1] R. Evans, E. Grefenstette, Learning explanatory rules from noisy data (extended abstract), in: Proceedings of the Twenty-Seventh International Joint Conference on Artificial Intelligence, IJCAI-18, International Joint Conferences on Artificial Intelligence Organization, 2018, pp. 5598–5602. URL: https://doi.org/10.24963/ijcai.2018/792. doi:10.24963/ijcai.2018/792.

[2] L. Lamport, LaTeX: A Document Preparation System, Addison-Wesley, Reading, MA., 1986.

[3] P. S. Abril, R. Plant, The patent holder's dilemma: Buy, sell, or troll?, Communications of the ACM 50 (2007) 36–44. doi:10.1145/1188913.1188915.

[4] S. Cohen, W. Nutt, Y. Sagic, Deciding equivalances among conjunctive aggregate queries, J. ACM 54 (2007). doi:10.1145/1219092.1219093.

[5] J. Cohen (Ed.), Special issue: Digital Libraries, volume 39, 1996.

[6] D. Kosiur, Understanding Policy-Based Networking, 2nd. ed., Wiley, New York, NY, 2001.
[7] D. Harel, First-Order Dynamic Logic, volume 68 of *Lecture Notes in Computer Science*, Springer-Verlag, New York, NY, 1979. doi:10.1007/3-540-09237-4.
[8] I. Editor (Ed.), The title of book one, volume 9 of *The name of the series one*, 1st. ed., University of Chicago Press, Chicago, 2007. doi:10.1007/3-540-09237-4.
[9] I. Editor (Ed.), The title of book two, The name of the series two, 2nd. ed., University of Chicago Press, Chicago, 2008. doi:10.1007/3-540-09237-4.
[10] A. Z. Spector, Achieving application requirements, in: S. Mullender (Ed.), Distributed Systems, 2nd. ed., ACM Press, New York, NY, 1990, pp. 19–33. doi:10.1145/90417.90738.
[11] B. P. Douglass, D. Harel, M. B. Trakhtenbrot, Statecarts in use: structured analysis and object-orientation, in: G. Rozenberg, F. W. Vaandrager (Eds.), Lectures on Embedded Systems, volume 1494 of *Lecture Notes in Computer Science*, Springer-Verlag, London, 1998, pp. 368–394. doi:10.1007/3-540-65193-4_29.
[12] D. E. Knuth, The Art of Computer Programming, Vol. 1: Fundamental Algorithms (3rd. ed.), Addison Wesley Longman Publishing Co., Inc., 1997.
[13] S. Andler, Predicate path expressions, in: Proceedings of the 6th. ACM SIGACT-SIGPLAN symposium on Principles of Programming Languages, POPL '79, ACM Press, New York, NY, 1979, pp. 226–236. doi:10.1145/567752.567774.
[14] S. W. Smith, An experiment in bibliographic mark-up: Parsing metadata for xml export, in: R. N. Smythe, A. Noble (Eds.), Proceedings of the 3rd. annual workshop on Librarians and Computers, volume 3 of *LAC '10*, Paparazzi Press, Milan Italy, 2010, pp. 422–431. doi:99.9999/woot07-S422.
[15] M. V. Gundy, D. Balzarotti, G. Vigna, Catch me, if you can: Evading network signatures with web-based polymorphic worms, in: Proceedings of the first USENIX workshop on Offensive Technologies, WOOT '07, USENIX Association, Berkley, CA, 2007.
[16] D. Harel, LOGICS of Programs: AXIOMATICS and DESCRIPTIVE POWER, MIT Research Lab Technical Report TR-200, Massachusetts Institute of Technology, Cambridge, MA, 1978.
[17] K. L. Clarkson, Algorithms for Closest-Point Problems (Computational Geometry), Ph.D. thesis, Stanford University, Palo Alto, CA, 1985. UMI Order Number: AAT 8506171.
[18] D. A. Anisi, Optimal Motion Control of a Ground Vehicle, Master's thesis, Royal Institute of Technology (KTH), Stockholm, Sweden, 2003.
[19] H. Thornburg, Introduction to bayesian statistics, 2001. URL: http://ccrma.stanford.edu/~jos/bayes/bayes.html.
[20] R. Ablamowicz, B. Fauser, Clifford: a maple 11 package for clifford algebra computations, version 11, 2007. URL: http://math.tntech.edu/rafal/cliff11/index.html.
[21] Poker-Edge.Com, Stats and analysis, 2006. URL: http://www.poker-edge.com/stats.php.
[22] B. Obama, A more perfect union, Video, 2008. URL: http://video.google.com/videoplay?docid=6528042696351994555.
[23] D. Novak, Solder man, in: ACM SIGGRAPH 2003 Video Review on Animation theater Program: Part I - Vol. 145 (July 27–27, 2003), ACM Press, New York, NY, 2003, p. 4. URL: http://video.google.com/videoplay?docid=6528042696351994555. doi:99.9999/woot07-S422.
[24] N. Lee, Interview with bill kinder: January 13, 2005, Comput. Entertain. 3 (2005). doi:10.

1145/1057270.1057278.
[25] J. Scientist, The fountain of youth, 2009. Patent No. 12345, Filed July 1st., 2008, Issued Aug. 9th., 2009.
[26] B. Rous, The enabling of digital libraries, Digital Libraries 12 (2008). To appear.
[27] M. Saeedi, M. S. Zamani, M. Sedighi, A library-based synthesis methodology for reversible logic, Microelectron. J. 41 (2010) 185–194.
[28] M. Saeedi, M. S. Zamani, M. Sedighi, Z. Sasanian, Synthesis of reversible circuit using cycle-based approach, J. Emerg. Technol. Comput. Syst. 6 (2010).
[29] M. Kirschmer, J. Voight, Algorithmic enumeration of ideal classes for quaternion orders, SIAM J. Comput. 39 (2010) 1714–1747. URL: http://dx.doi.org/10.1137/080734467. doi:10.1137/080734467.
[30] L. Hörmander, The analysis of linear partial differential operators. IV, volume 275 of *Grundlehren der Mathematischen Wissenschaften [Fundamental Principles of Mathematical Sciences]*, Springer-Verlag, Berlin, Germany, 1985. Fourier integral operators.
[31] L. Hörmander, The analysis of linear partial differential operators. III, volume 275 of *Grundlehren der Mathematischen Wissenschaften [Fundamental Principles of Mathematical Sciences]*, Springer-Verlag, Berlin, Germany, 1985. Pseudodifferential operators.
[32] IEEE, Ieee tcsc executive committee, in: Proceedings of the IEEE International Conference on Web Services, ICWS '04, IEEE Computer Society, Washington, DC, USA, 2004, pp. 21–22. doi:10.1109/ICWS.2004.64.
[33] TUG, Institutional members of the TEX users group, 2017. URL: http://www.tug.org/instmem.html.
[34] R Core Team, R: A language and environment for statistical computing, 2019. URL: https://www.R-project.org/.
[35] S. Anzaroot, A. McCallum, UMass citation field extraction dataset, 2013. URL: http://www.iesl.cs.umass.edu/data/data-umasscitationfield.

## A. Online Resources

The sources for the ceur-art style are available via

- GitHub,
- Overleaf template.