

Proposal of team software project

Department of Software Engineering

Faculty of Mathematics and Physics, Charles University

Solvers: Bc. Ondřej Krsička

Study program: Computer Science - Software and Data Engineering

Project title: Using CRDTs to enable collaborative editing in Denicek

Project type: Research project

Supervisor: Mgr. Tomáš Petříček, Ph.D.

Expected start: 1.11.2025

Expected end: 1.7.2026

1 Introduction

Denicek [1] is a document-based end-user programming substrate and *Webnicek* is a web application built on top of *Denicek*. *Denicek* synchronization is done using Operational Transformation, which is error prone and complex and requires a central server for synchronization. This project will create *MyDenicek* backend built on top of CRDTs to make it simpler to implement and to follow principles of local-first software. *MyWebnicek* will be a new web-application on top of the new substrate.

2 Denicek end-user programming experiences

Denicek: Computational Substrate for Document-Oriented End-User Programming [1] provides the following end-user programming experiences:

- Collaborative editing
- Programming by demonstration (users can record actions and program a button to replay them on click)
- Incremental recomputation (formulas depending on changed values are invalidated and automatically recomputed)
- Schema change control (when a value is wrapped or unwrapped in an element, all references to it are updated)
- End-user debugging (values on which a formula depends can be highlighted for better understanding of the result)
- Concrete programming (copying and pasting formulas between contexts while preserving dependencies; when the original changes, the copied formula updates accordingly)

3 Denicek document structure

A *Denicek document* is a tree composed of named nodes of the following kinds:

- Ordered lists of nodes: all items are of the same type and addressable by index
- Records: children can be of different types and are addressable by their name
- References to other locations in the document
- Primitives: numeric or textual values

4 Denicek programs

A *Denicek program* is represented as a history of primitive actions. Histories can be replayed, merged, and compared, with conflict detection between them.

Primitive actions that do not affect references include:

- Add to record
- Append to list
- Reorder list
- Delete item from list
- Update tag of list or record
- Edit a primitive value (text or number)

Primitive actions that *do* affect references include:

- Rename a record
- Delete a record
- Wrap a node in a record
- Wrap a node in a list
- Copy node(s) from given selectors to specified target(s)

5 Denicek usage

Two end-user programming environments are currently built on top of the *Denicek* substrate:

- *Webnicek*: for creating interactive HTML documents
- *Datnicek*: for data science use cases similar to Jupyter Notebooks

The use cases of Denicek are illustrated by the following formative examples:

- **Counter app**: The user creates a document with value 1, wraps it in a formula (1+1), records the process, and replays it on button click: producing a simple counter.
- **Todo app**: Similar to the counter app, but the recorded actions add text from an input field as a new list item.
- **Conference list**: Alice refactors a list of speakers from comma-separated items (name, email) into a table with columns (name, email). Meanwhile, Bob adds a new list item. The merged result is a table containing all speakers, including Bob's addition.

- **Conference budget:** Building on the conference list, formulas depending on its values are automatically recomputed during refactoring.
- **Hello world:** The user makes the first line of a list of sentences lowercase, then capitalizes the first letter, copies the formula, and applies it to the whole list.
- **Traffic accidents:** Omitted from this research project, as it relates more closely to *Datnicek*.

6 Limitations of Denicek and goals of this research project

The current *Denicek* synchronization layer is implemented using Operational Transformation (OT). However, OT is complex, error-prone, and requires a central synchronization server, which does not satisfy the requirements of local-first software [6].

The goal of this research project is to create an alternative to *Webnicek* built on top of a CRDT-based local-first substrate. The new system should support the same end-user programming experiences demonstrated by the formative examples, possibly using a revised set of primitive operations. It should also maintain a clear separation between the user interface and the CRDT substrate to enable future development of a *Datnicek* alternative based on the same backend.

The resulting systems will be called *MyDenicek* and *MyWebnicek*, inspired by *MyWebstrates* [7]: a local-first, CRDT-based alternative to Webstrates [8]. Both parts will be implemented in TypeScript.

6.1 MyWebnicek functional requirements

MyWebnicek will have the following functionalities:

- Renderer of the final document
- Navigation through the document
- Commandline for user to perform primitive actions
- History view of user edit actions
- Sharing mechanism for collaborative editing via network
- Conflict resolution interface

7 Schedule

The project is expected to run for 8 months. The expected schedule is:

- Task 1 (Studying of materials, analysis and prototyping) - Month 1-3
- Task 2 (Production-ready *MyDenicek* and *MyWebnicek* implementation) - Month 4-7
- Task 3 (Textual and Video Documentation) - Month 8
- Task 4 (Testing and evaluation) - Month 8

8 Team structure

The work will be coordinated by the supervisor. The student will be responsible for the technical aspects of the project (developing the Grove encoding, prototype implementation) and evaluation. The design of the system will be developed in collaboration between the supervisor, the student and Jonathan Edwards (Denicek co-author).

9 Related work

This work directly builds on the Denicek system presented at *ACM UIST 2025* [1]. It extends ongoing research on Conflict-free Replicated Data Types (CRDTs), as summarized in Preguiça’s overview [2], and is informed by practical open-source CRDT frameworks (Yjs, Automerge). The project will first investigate the applicability of Grove’s typed, patch-based model [3] to Denicek’s document structures and editing workflows, while keeping the option to adopt or hybridize with other CRDTs if Grove proves unsuitable for some features.

References

- [1] T. Petříček, et al. *Denicek: Computational Substrate for Document-Oriented End-User Programming*. In Proceedings of the 38th Annual ACM Symposium on User Interface Software and Technology (UIST ’25). no. 32, pp. 1–19.
- [2] N. Preguiça. *Conflict-free Replicated Data Types: An Overview*. 2018. <https://arxiv.org/abs/1806.10254>.
- [3] M. D. Adams, et al. *Grove: A Bidirectionally Typed Collaborative Structure Editor Calculus*. ACM, 2024. DOI: <https://doi.org/10.1145/3704909>.
- [4] A. Cypher, et al. (eds.) *Watch what I do: programming by demonstration*. MIT Press, 1993.
- [5] J. Edwards, et al. *Schema Evolution in Interactive Programming Systems*. The Art, Science, and Engineering of Programming, 9(1), 2-1. 2024.
- [6] M. Kleppmann, et al. *Local-first software: you own your data, in spite of the cloud*. Proceedings of the 2019 ACM SIGPLAN International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Software. 2019.
- [7] Clemens Nylandsted Klokmose, James R. Eagan, and Peter van Hardenberg. 2024. *MyWebstrates: Webstrates as Local-first Software*. In Proceedings of the 37th Annual ACM Symposium on User Interface Software and Technology (UIST ’24). Association for Computing Machinery, New York, NY, USA, Article 42, 1–12. <https://doi.org/10.1145/3654777.3676445>
- [8] Clemens N. Klokmose, James R. Eagan, Siemen Baader, Wendy Mackay, and Michel Beaudouin-Lafon. 2015. *Webstrates: Shareable Dynamic Media*. In Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology (UIST ’15). Association for Computing Machinery, New York, NY, USA, 280–290. <https://doi.org/10.1145/2807442.2807446>