Progress report of a PhD Thesis – 2017-2018

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Subject of the PhD thesis: Efficient (re)naming in Conflict-free Replicated Data Types (CRDTs)

Short description of the subject

In order to serve an ever-growing number of users and provide an increasing volume of data, large scale systems such as data stores or collaborative editing tools have to adopt a distributed architecture. However, as stated by the CAP theorem, such systems cannot ensure both strong consistency and high availability in case of network partitions. As a result, literature and companies increasingly adopt the optimistic replication model known as eventual consistency to replicate data among nodes. This consistency model allows replicas to temporarily diverge to be able to ensure high availability, even in case of network partition. Each node owns a copy of the data and can edit it, before propagating updates to others. A conflict resolution mechanism is however required to handle updates generated in parallel on different replicas.

An approach, which gains in popularity since a few years, proposes to define Conflict-free Replicated Data Types (CRDTs). These data structures behave as traditional ones, like the *Set* or *Sequence* data structures, but are designed for a distributed usage. Their specification ensures that concurrent updates are resolved deterministically, without requiring any kind of agreement, and that replicas eventually converge immediately after observing some set of updates, thus achieving *Strong Eventual Consistency*.

To achieve convergence, CRDTs proposed in the literature mostly rely on unique identifiers to reference updated elements. To generate such element identifiers, nodes often use their own identifier as well as a logical clock. Thus, regarding to how node identifiers are generated, the size of element identifiers usually increases with the number of nodes. Furthermore, element identifiers have to comply to additional constraints according to the CRDT, for example forming a dense set in case of a sequence data structure. In this case, element identifiers' size also increases according to the number of elements contained in the data structure. Therefore, the size of element identifiers is usually not bounded.

Since the size of identifiers attached to each element is not bounded, the overhead of the replicated data structure increases over time. Since nodes have to store and broadcast the identifiers, the application's performances and efficiency decrease over time. This impedes the adoption of CRDTs.

This PhD aims to address this issue. A first approach is to study identifiers proposed in the literature to list existing constraints on identifiers and their consequences on identifiers generation in order to propose more efficient specifications of identifiers. A second approach is to study this issue as a particular case of the renaming problem and to propose mechanisms to rename identifiers in order to reduce their size, still without requiring any kind of agreement between nodes.

Main results

During this first year, I focused on designing a renaming mechanism for *Identifier-based Sequence CRDT*.

Identifier-based Sequence CRDTs

Identifier-based Sequence CRDTs are data structures used to represent replicable lists. Two operations are defined to update them : *insert* and *delete*.

The data structures attach an identifier to each inserted element. These identifiers allow us to achieve transaction-less and commutative updates by uniquely identifying each element and ordering them.

The downside of this approach is the increasing size of the identifiers. Since the identifiers are used to order the elements, they have to form a dense set so that users are always able to insert a new element between two others. However, two identifiers of the same size can be contiguous. When inserting a new element between two such identifiers, we have no other choice than to increases the size of the generated identifier to be able to generate one respecting the intended order.

Renaming mechanism

- Designed a renaming mechanism which does not require any kind of coordination
  - Performing a local renaming to reduce the overhead of the data structure is straightforward
  - Broadcasting the renaming to other nodes also
  - The issue is to deal with concurrent updates to a renaming (for example, deleting an element using its identifier)
  - The main idea is to transform concurrent updates to a renaming to preserve the intention of the user
- Introduced an optimization to reduce the bandwith comsuption of the renaming operation
- Implementing its prototype in *MUTE*, the collaborative editing tool from the team

Plan for next year

The plan for the next year is to complete the implementation of the proposed renaming mechanism and to proceed to its validation.

To validate the mechanism, the first approach is to run simulations to benchmark its performances. The goal is to measure the gain in memory usage provided by the mechanism as well as its cost on the performances of the application. These simulations could also be used to compare the efficiency of different strategies regarding the conditions triggering the renaming process.

The main issue regarding this approach is the authenticity of such simulations. Indeed, to run truthful simulations, the behaviour of the agents representing the collaborators should be credible. It is then required to study the literature on the behaviour of users in collaborations to reproduce their actions faithfully.

The second approach is to prove that transformation functions proposed are correct. Literature on Operational Transformation (OT) provides several constraints that such functions have to respect to ensure the correctness of the system.

Publications

No publications currently.

Project after the thesis

My current project is to pursue an academic career as a lecturer.

Scientific and professional modules validated

Scientific modules

- Réplication et cohérence des données

Professionnal modules

- Fi4 152 E Sauveteur Secouriste du Travail (SST)
- Fi4 162 C Formation à la communication orale et corporelle en milieu professionnel
- Fi4 282 Outils numériques pour la pédagogie (plateforme Arche, studio professeur)

Date and signature of the PhD student .....

Opinion of the supervisor

Name of the supervisor: .....

Opinion on this progress report: .....

Agreement for an additional year? Yes/No

Date of the defense: .....

Date and signature of the supervisor .....