FM26 artifact

Table of content

Artifact structure

The `generalizer` folder contains the following subfolders:

```
generalizer
    LICENSE.txt
    README.pdf
    README.md
    Dockerfile
    Executable
    Benchmark
    smoke_tests
    Interactions_examples
    generalizer_sources.zip
    readme
    Benchmark_with_results.zip
    smoke_tests_with_results.zip
    Interaction_examples_with_results.zip
```

The Docker image includes a pre-built executable located in `generalizer/Executable`.

Additional resources are organized as follows:

- **Smoke tests**: `generalizer/smoke_tests`
- **Benchmark scripts and files**: `generalizer/Benchmark`
- **Interaction examples** (including composition scripts): `generalizer/Interactions_examples`

The provided archives contain :

- `generalizer_sources.zip` — Source code of the program
- `Benchmark_with_results.zip` — Benchmark results
- `smoke_tests_with_results.zip` — Smoke test results
- `Interaction_examples_with_results.zip` — Interaction examples composition results

Docker instructions

The artefact is wrapped in a docker image available on Zenodo(todo: link). After downloading the image, it is loaded with the following command:

```
$ docker load -i generalizer.tar.gz
```

Alternatively, the image can be built from the root of the repository generalizer with the following command:

```
$ docker build -t generalizer .
```

After loading or building the image, running the container is done with the following command:

```
$ docker run -it --rm --name custom_container generalizer:latest
```

To avoid conflics, use a different container name for each run (in this example `custom_container`).

Our experiments generate image that cannot be easily visualized inside the docker image directly. We recommend copying output images to the host machine.

While the container is running (its name is `custom_container` in the example above), you can copy a file from the container to the host machine with the following command:

```
$ docker cp custom_container:/home/fm/generalizer/README.pdf
target_folder_on_host
```

where `target_folder_on_host` is the folder where you want to copy the file in the host machine. The above command will copy the file `generalizer/README.pdf` from the container to the folder `target_folder_on_host`.

Smoke tests

By running the container, `Docker` will open as shell inside a directory named `generalizer`. The smoke tests are located in the `generalizer/smoke_tests` directory. There are two smoke tests: a composition smoke test and a reduced benchmark smoke test.

Composition smoke test

To check whether the composition of two interactions works, we check that with the example in the introduction of the paper. It is located in `generalizer/smoke_tests/composition_smoke_test`. The folder contains:

- `signature.hsf`: the signature file of the interactions containing the declaration of lifelines and messages.
- `i.hif`: the first interaction.
- `j.hif`: the second interaction.
- `composition_smoke_test.sh`: the script to run the composition of the interaction models `i` and `j`.

The `.hsf` and `.hif` can be visualized with the `cat` command.

```
$ cat signature.hsf
$ cat i.hif
$ cat j.hif
```

```
$ cd smoke_tests/composition_smoke_test
$ ./composition_smoke_test.sh
```

The *Figure 1* illustrates the composition of the two interactions.

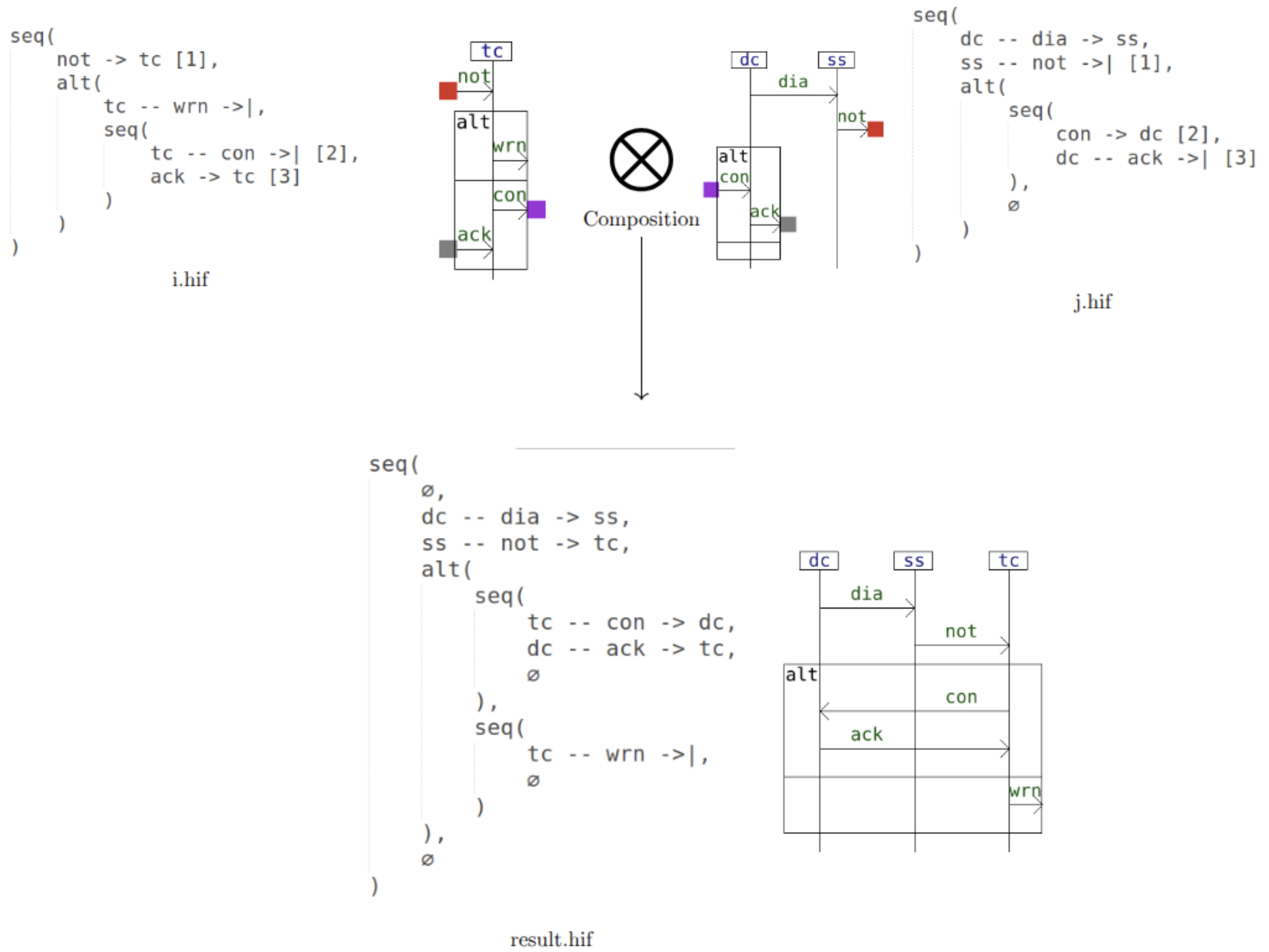


Figure 1: Illustration of the composition smoke test.

If successful, the success message will be printed in the terminal as shown in *Figure 2*.

```
---------------------------------------
Composition smoke test with a simple example
This script uses the executable at the location:  generalizer/target/release/generalizer
Starting composition: ven. 13 févr. 2026 12:05:35 CET
Results will be written to: ./Composition_Output
---------------------------------------

GENERALIZER

Using Anti-unification modulo ACU

Composition successful
Duration: 0.000993334 s
---------------------------------------
Execution time: 0 seconds
Composition smoke test: ven. 13 févr. 2026 12:05:35 CET
Check results inside: ./Composition_Output
```

Figure 2: Success message printed in the terminal for the composition smoke test.

The command runs in less than `1` seconds. The result will be put in the folder `Composition_Output` which contains a folder `result` containing the files `result.hif`(interaction file) and `result.png`(visual representation of the result). The folder `input` also contains pictures `i.png` and `j.png` of the interactions. All the images can be visualized by copying them to the host machine according to the instruction in Docker instructions. The file `result.hif` can be visualized with the `cat` command to obtain the model represented in *Figure 1*.

```
$ cat Composition_Output/result/result.hif
```

Reduced benchmark smoke test

To quickly check wheher the benchmark runs successfully, we provide a reduced version of the benchmark. It is located in `generalizer/smoke_tests/reduced_benchmark_smoke_test`. The folder contains the script `reduced_benchmark_smoke_test.sh` to run the small benchmark.

```
$ cd smoke_tests/reduced_benchmark_smoke_test
$ ./reduced_benchmark_smoke_test.sh
```

If successful, a success message will be printed in the terminal as shown in *Figure 3*.

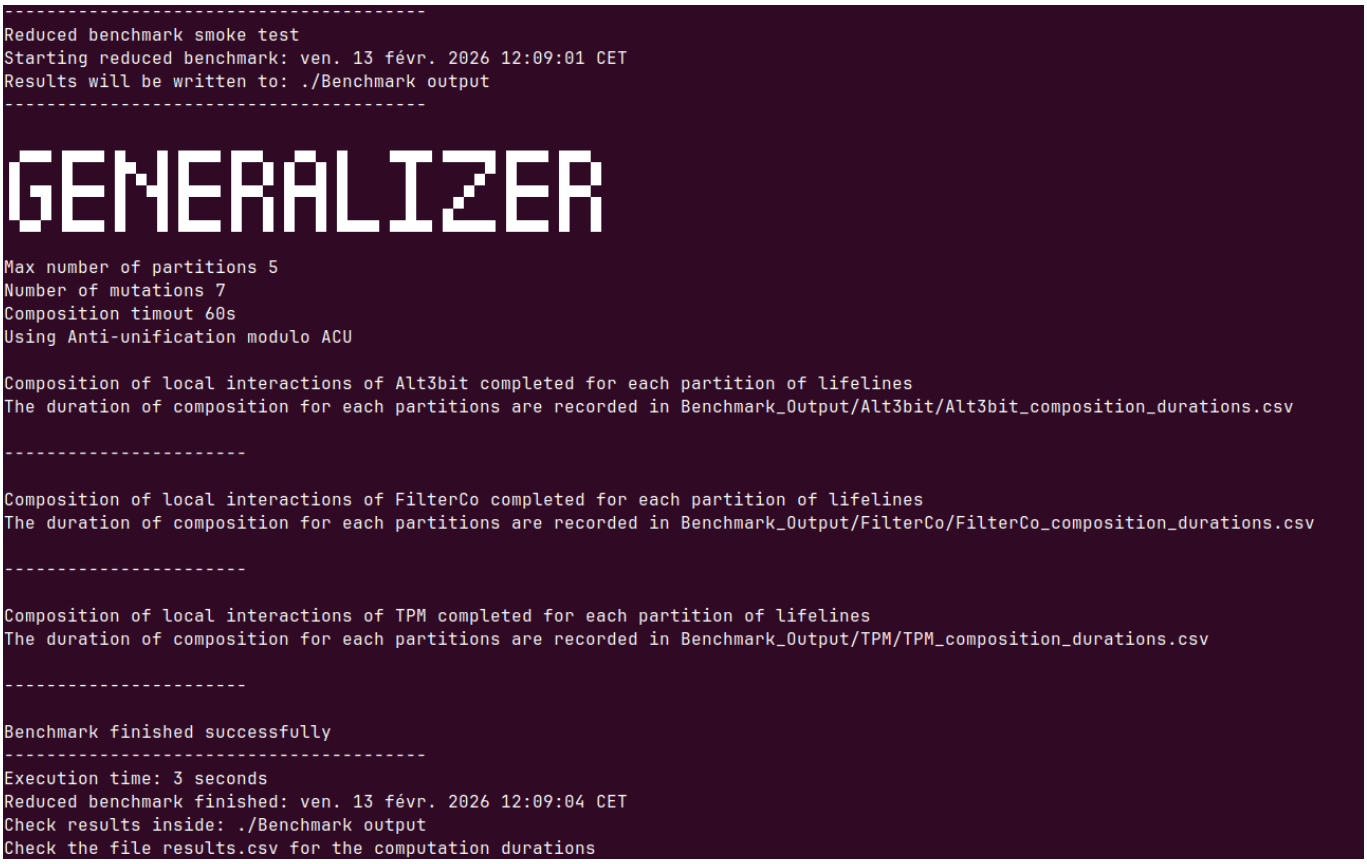


Figure 3: Success message printed in the terminal for the reduced benchmark smoke test.

The execution takes approximatively `3` seconds. The result will be put in the folder `Benchmark_Output`. It containts a csv file `result_one_pass.csv` containing a table akin the exprerimental section of the paper.

To visualize the results inside the docker container, the following command can be used:

```
$ csvlook -d '&' Benchmark_Output/results_one_pass.csv | less -S
```

To shrink the size of columns, the following command can be used:

```
$ csvlook -d '&' --max-column-width 10
Benchmark_Output/results_one_pass.csv | less -S
```

The table of *Figure 4* should be printed (up to some small differences in numbers, which are durations):

Global ...	Size of...	Gates r...	(Normal...	(Normal...	(Mutate...	(Mutate...
Alt3bit	12	6	4.143(Ok)	20.925(Ok)	5.833(Ok)	30.848(Ok)
FilterCo	11	5	1.54(Ok)	1.728(Ok)	2.165(Ok)	2.433(Ok)
TPM	17	7	2.818(Ok)	4.733(Ok)	4.288(Ok)	7.083(Ok)

Figure 4: Table of results for the reduced benchmark smoke test

This smoke test executes in one pass the three steps of the benchmark described in details the Section Benchmark below.

Introduction

This README file describes the artifact related to the paper ["Specializing anti-unification for interaction models composition via gate connections"] accepted to the `FM26` conference.

The paper proposes an approach to the composition of interaction models using anti-unification. The program, named `generalizer` is developped in Rust.

Interaction language

Representation of interactions

Our implementation of Interactions models is based on the work of Mahe et al. and the tool HIBOU.

We follow the notation of HIBOU for signature files (.hsf) and interaction files (.hif).

Let us consider the signature (sig.hsf):

```
@message{
    bwin;cwin;close;blose;busy;msg;sig;free
}

@lifeline{
    l0;l1;l2;l3
}
```

and the interaction (i.hif):

```
loopS(
    seq(
        par(
            alt(
```

```
                l0 -- cwin ->|,
                l0 -- bwin ->|
            ),
            busy -> l3
        ),
        msg -> l0,
        sig -> l0,
        l0 -- free -> l3
    )
)
```

For instance `l0 -- cwin ->|` is an emission of the message `cwin` from lifeline `l0` to environment; and `busy -> l3` is reception of the message `busy` from environment to lifeline `l3`. The term `l0 -- free -> l3` represents the transmission of the message `free` from lifeline `l0` to lifeline `l3`, and is called a `value passing` in the paper.

The above interaction can be visualized as depicted in *Figure 5*.

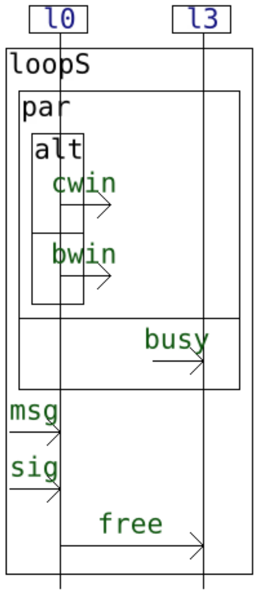


Figure 5: Sequence diagram of a local interaction

Gates

We introduce *gates* in our implementation to mark complementary communications for the composition as described in the paper.

Gates are assigned by adding number under brackets next to the relevant action.

For example, the previous interaction decorated with gates is:

```
loopS(
    seq(
        par(
            alt(
                l0 -- cwin ->| [3],
```

```
                l0 -- bwin ->| [1]
            ),
            busy -> l3 [5]
        ),
        msg -> l0 [6],
        sig -> l0 [7],
        l0 -- free -> l3
    )
)
```

which can be visually represented as depicted in *Figure 6*.

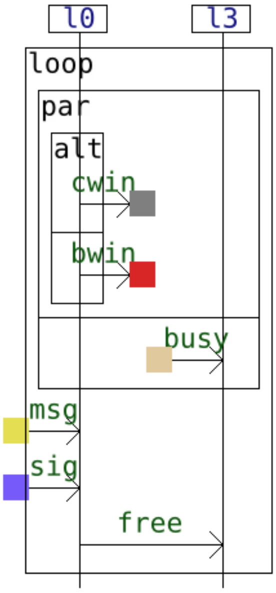


Figure 6: Sequence diagram of a local interaction with gates

Composition Examples

The folder `Interactions_examples` contains several examples of interactions composition described in the appendix of the paper, and the example of the introduction. Each folder contains a signature file `signature.hsf`, and interaction files `i.hif` and `j.hif`. In addition there is a script `example_run.sh` to run the composition of the two interactions, in exactly the same way as in the smoke test of the composition.

Benchmark

To execute the benchmark, move into the `Benchmark` folder from the root of `generalizer` folder. The produced images may be visualized by copying them to the host machine according to the instruction in [Docker instructions](#).

```
$ cd Benchmark
```

The paper's experiments were run on an Intel Core i7-13850HX (20-core, 2.1 GHz) with 32 GB RAM. The benchmark is divided into three steps each performed by the scripts described in the following table,

Script	Description	est. time
benchmark_step_1_projection.sh	Projection,mutation,normalization	~21 seconds
benchmark_step_2_composition.sh	Composition of local interactions	~33 minutes
benchmark_step_3_nf_checking.sh	Normal form Checking	~1 seconds
benchmark_one_pass.sh	Run all three steps at once	~ 33 minutes

Step 1: projection, normalization and mutation

We use the interactions in the folder Benchmark as our starting global models. For each global interaction `k`, we extract at most `N_p` partitions of its set of lifelines `L` into a pair of subsets each of size at least `L/2`.

For each partition `(L1,L2)` of a set of lifelines of a global interaction `k`:

- we project `k` onto `L1` and `L2` to obtain local interactions `i1` and `i2`;
- we normalize `i1` and `i2` using HIBOU to obtain `i1_norm` and `i2_norm` respectively.
- we apply mutation operations to `i1` and `i2`, with consists of successively applying `N_m` times one of the following rewrite operation selected uniformly at random: `alt(x,y) -> alt(y,x)` and `par(x,y) -> par(y,x)`. We obtain the interactions `i1_mut` and `i2_mut` from `i1` and `i2` respectively. The mutations are done with Maude. Those mutation operations are achieved by the scripts under the folder `maude_mutation`.

To start the first step, we execute the following command:

```
$ ./benchmark_step_1_projection.sh
```

The program will create a folder `Benchmark_Output` containing a folder for each starting global interaction.

In the case of the interaction `Game`, we have the following structure:

```
Game
    input_global_interaction
         Game.png
         Game.hif
         Game_tree.png
    Partition0
        original_locals
            i1.hif
            i1.png
            i1_tree.png
            i2.hif
            i2.png
            i2_tree.png
        with_mutated_locals
            mutated_local_interactions
                i1.hif
```

```
                    i1.png
                    i1_tree.png
                    i2.hif
                    i2.png
                    i2_tree.png
                results_with_rule_fail
                results_without_rule_fail
            with_normalized_locals
              ...
        Partition1
            ...
        Partition2
            ...
        Partition3
            ...
        Partition4
            ...
```

The folder `original_locals` contains the local interactions `i1` and `i2` obtained after the projection of the global interaction.

The partition folders have the same structure. Each of them contains the folders `with_normalized_locals` and `with_mutated_locals` have the same structure They contain the models `i1_norm`, `i2_norm` and `i1_mut`, `i2_mut` respectively (`.hif` files and `.png` pictures).

The folders `results_with_rule_fail` and `results_without_rule_fail` are empty at this stage, are are meant to contain the results of the composition with and without the rule **Fail**, in the next step.

Step 2: composition

This step consists of the composition of the pairs `(i1_norm, i2_norm)` and `(i1_mut, i2_mut)`.

In the case of the interaction `Game`, this step will compose the interaction `i1.hif` and `i2.hif` in the folders of each of the folders `partition{i}/with_normalized_locals/normalized_local_interactions` and `partition{i}/with_mutated_locals/mutated_local_interactions`, for each of the partitions `i`.

This step is performed by the script `benchmark_step_2_composition.sh`.

```
$ ./benchmark_step_2_composition.sh
```

```
    Game
        Game_composition_durations.csv
        input_global_interaction
             Game.png
             Game.hif
             Game_tree.png
        Partition0
            original_locals
```

```
                i1.hif
                i1.png
                i1_tree.png
                i2.hif
                i2.png
                i2_tree.png
            with_mutated_locals
                mutated_local_interactions
                    i1.hif
                    i1.png
                    i1_tree.png
                    i2.hif
                    i2.png
                    i2_tree.png
                results_with_rule_fail
                    result.hif
                    result.png
                    result_tree.png
                    time.txt
                results_without_rule_fail
                    result.hif
                    result.png
                    result_tree.png
                    time.txt
            with_normalized_locals
                 ...
        Partition1
            ...
        Partition2
            ...
        Partition3
            ...
        Partition4
            ...
```

The folders `results_with_rule_fail` and `results_without_rule_fail` contain the results of the composition with and without the rule **Fail**. The duration of the compositions are in the file `time.txt` in each folder.

This step produces a csv file `results_step_2.csv` in the folder `Benchmark_Output`.

You can visualize it with the following command:

```
$ csvlook -d '&' Benchmark_Output/results_step_2.csv | less -S
```

Or with column shrinked down:

```
$ csvlook -d '&' --max-column-width 10 Benchmark_Output/results_step_2.csv
| less -S
```

We obtain the table of *Figure 7* (with shrinked down columns).

Global ...	Size of...	Gates r...	(Normal...	(Normal...	(Mutate...	(Mutate...
ATM	33	[7, 17]	13,872	timeout	25,621	timeout
Alt3bit	12	6	3,654	19.916	5,700	29.604
DistVoting	23	8	7,192	timeout	10,144	timeout
FilterCo	11	5	1,288	1.392	1,876	2.108
Game	16	[5, 6]	2,146	3.099	2,856	4.2
HealthSys	22	[5, 9]	4,493	18.363	6,057	47.957
Logistic	26	[6, 11]	11,358	timeout	15,577	timeout
ProfOnline	68	[23, 25]	57,644	timeout	75,822	timeout
Sanitary	30	[6, 13]	8,527	28.438	11,487	41.636
TPM	17	7	2,695	4.528	4,069	6.785
Travel	26	[6, 11]	6,892	timeout	9,119	timeout
TwoBuyers	22	[5, 11]	3,052	5.665	4,198	7.564

Figure 7: Table of results for the step 2 of the benchmark benchmark.

Each interaction corresponds to a row in the table. The second column reports the size of the interaction, while the third column indicates the range of gate counts in the local interactions obtained after projection onto the lifeline partitions. The last four columns present the average composition time across partitions, both with and without the optimization rule **Fail**. This rule is designed to compute compositions more efficiently. Specifically, the fourth and fifth columns show the average duration for composing normalized local interactions, whereas the last two columns report the average duration for mutated local interactions.

A truncated version of the table is shown in *Figure 8*.

Global interaction	Size of the global interaction	Gates range	(Normalized locals) Av.Composition duration with Fail(ms)	(Normalized locals) Av.Composition duration without Fail(ms)
ATM	33	[7, 17]	13,872	timeout
Alt3bit	12	6	3,654	19.916
DistVoting	23	8	7,192	timeout
FilterCo	11	5	1,288	1.392
Game	16	[5, 6]	2,146	3.099
HealthSys	22	[5, 9]	4,493	18.363
Logistic	26	[6, 11]	11,358	timeout
ProfOnline	68	[23, 25]	57,644	timeout
Sanitary	30	[6, 13]	8,527	28.438
TPM	17	7	2,695	4.528
Travel	26	[6, 11]	6,892	timeout
TwoBuyers	22	[5, 11]	3,052	5.665

Figure 8: Truncated table of results for the step 2 of the benchmark benchmark.

Consider the interaction `ATM`, highlighted in yellow. Its size is `33`. After projection, the number of gates in its local interactions ranges from `7` to `17`. With the optimization rule **Fail**, the average composition time across partitions for normalized local interactions is `13.872 ms`. Without the **Fail** rule, the composition process times out (after 60 seconds) for at least one partition.

Now consider the interaction `Game`, highlighted in red. Its size is `16`, and the projected local interactions contain either `5` or `6` gates. With the **Fail** optimization, the average composition time across partitions is `2.146 ms`. Without this optimization, the average duration across partitions increases to `3.099 ms`. These results illustrate that the **Fail** rule not only reduces the average composition time but can also prevent timeouts (set to 60 seconds).

In addition, in each folder corresponding to a global interaction, there is a `.csv` file showing the composition duration for each partitions non-averaged. For example, for the interaction `Game`, such a file is `Benchmark_Output/Game/Game_composition_durations.csv`. It contains a table similar to the one in *Figure 9*.

Partition	(Normal...	(Normal...	(Mutate...	(Mutate...
Partiti...	2,355	3,503	3,174	5,237
Partiti...	1,977	3,377	3,328	5,154
Partiti...	2,070	3,412	4,291	4,458
Partiti...	2,180	2,104	2,844	4,404

Figure 9: Composition durations for each partitions for the interaction Game

Step 3: Normal Form Checking

In this step, we check whether the normal form of the results of compositions in the previous step is the same as the normal form of the original interactions.

It is accomplished by applying the normal form checking algorithm of HIBOU to the interactions obtained in the previous step.

We execute the following command:

```
$ ./benchmark_step_3_nf_checking.sh
```

It produces a csv file `results_step_3.csv` in the folder `Benchmark_Output`. The new csv file is basically `results_step_2.csv` with a verdict (Ok) besides durations to confirm that the normal form of the result of each composition across partitions matches with the normal form of the original interaction before projections.

The final table should be similar to the one in the experiment section of the paper (up to some small differences in numbers, due to the randomness of the mutation operations and different execution environments).

An execution gives the table of *Figure 10*.

Global ...	Size of...	Gates r...	(Normal...	(Normal...	(Mutate...	(Mutate...
ATM	33	[7, 17]	13.872(Ok)	timeout	25.621(Ok)	timeout
Alt3bit	12	6	3.654(Ok)	19.916(Ok)	5.7(Ok)	29.604(Ok)
DistVoting	23	8	7.192(Ok)	timeout	10.144(Ok)	timeout
FilterCo	11	5	1.288(Ok)	1.392(Ok)	1.876(Ok)	2.108(Ok)
Game	16	[5, 6]	2.146(Ok)	3.099(Ok)	2.856(Ok)	4.2(Ok)
HealthSys	22	[5, 9]	4.493(Ok)	18.363(Ok)	6.057(Ok)	47.957(Ok)
Logistic	26	[6, 11]	11.358(Ok)	timeout	15.577(Ok)	timeout
ProfOnline	68	[23, 25]	57.644(Ok)	timeout	75.822(Ok)	timeout
Sanitary	30	[6, 13]	8.527(Ok)	28.438(Ok)	11.487(Ok)	41.636(Ok)
TPM	17	7	2.695(Ok)	4.528(Ok)	4.069(Ok)	6.785(Ok)
Travel	26	[6, 11]	6.892(Ok)	timeout	9.119(Ok)	timeout
TwoBuyers	22	[5, 11]	3.052(Ok)	5.665(Ok)	4.198(Ok)	7.564(Ok)

Figure 10: Table of results for the step 3 of the benchmark benchmark.

The table of results from the paper is shown in *Figure 11*.

Interaction k	**size**(k)	**Nb. Gates**	**Avg. composition Time (ms)**			
			$(i_{\text{norm}}, j_{\text{norm}})$		$(i_{\text{mut}}, j_{\text{mut}})$	
			with F	without F	with F	without F
ATM	33	[7, 17]	15.016(✓)	timeout	17.757(✓)	timeout
Alt3bit	12	6	4.132(✓)	21.804(✓)	6.01(✓)	32.932(✓)
DistVoting	23	8	8.243(✓)	timeout	10.955(✓)	timeout
FilterCo	11	5	1.396(✓)	1.565(✓)	2.069(✓)	2.339(✓)
Game	16	[5, 6]	2.525(✓)	3.179(✓)	3.163(✓)	4.283(✓)
HealthSys	22	[4, 8]	5.978(✓)	18.496(✓)	7.495(✓)	22.786(✓)
Logistic	26	[6, 11]	9.22(✓)	timeout	12.457(✓)	timeout
ProfOnline	68	[14, 27]	59.567(✓)	timeout	75.474(✓)	timeout
Sanitary	30	[6, 13]	11.491(✓)	40.242(✓)	14.795(✓)	51.265(✓)
TPM	17	7	3.204(✓)	4.911(✓)	4.915(✓)	7.437(✓)
Travel	26	[6, 11]	6.411(✓)	timeout	8.203(✓)	timeout
TwoBuyers	22	[5, 11]	3.78(✓)	5.558(✓)	4.852(✓)	7.162(✓)

Figure 11:Table of results from the paper.

The `Ok` in the csv files are represented by green checkmarks in the table of the paper.

Summary of the workflow for the interaction Game

The *Figure 12* illustrates the protocol of the benchmark with the Game global interaction, with only the mutation scenario.

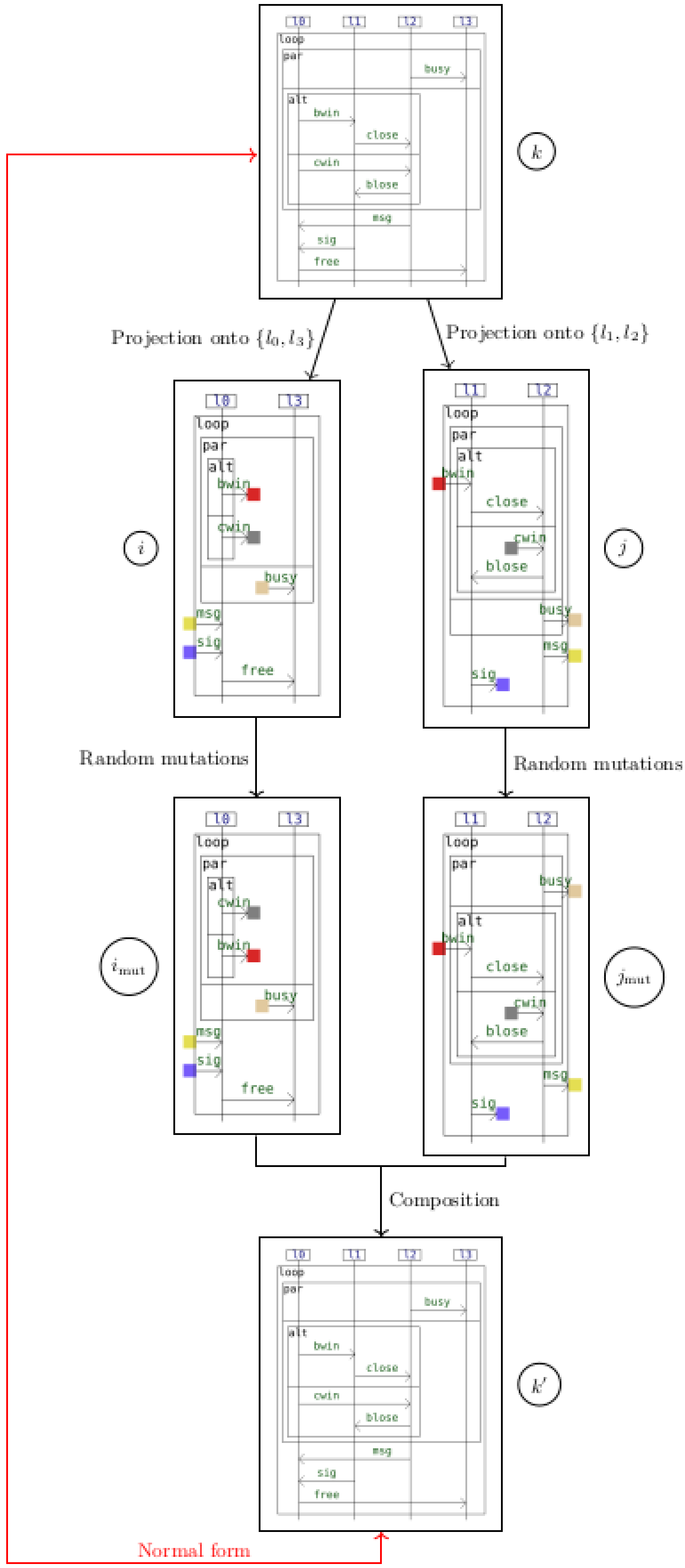


Figure 12: Protocol of the benchmark for the interaction Game.

To Execute all three steps in one pass

To execute all three steps in one pass, we can use the script `benchmark_one_pass.sh`.

```
$ ./benchmark_one_pass.sh
```

It directly produces a csv file `result_one_pass.csv` in the folder `Benchmark_Output` which is the same as the one produced at the end of step 3.

To take a closer look at the command running the benchmark in one pass, The subcommand to run the benchmark is `benchmark`. It takes as arguments:

- the name of the subfolder containing the interactions. In the downloadable folder, it is Benchmark.
- the number of mutation per partition
- the maximal number of random partitions extracted by global interaction.
- Timout in seconds

We can add flags, `-m` to have the duration in milliseconds, `-d` to draw the models for visualization.

The command to execute to have the result in the table above is:

```
$ generaliser benchmark Benchmark 7 5 60 -m
```

It means:

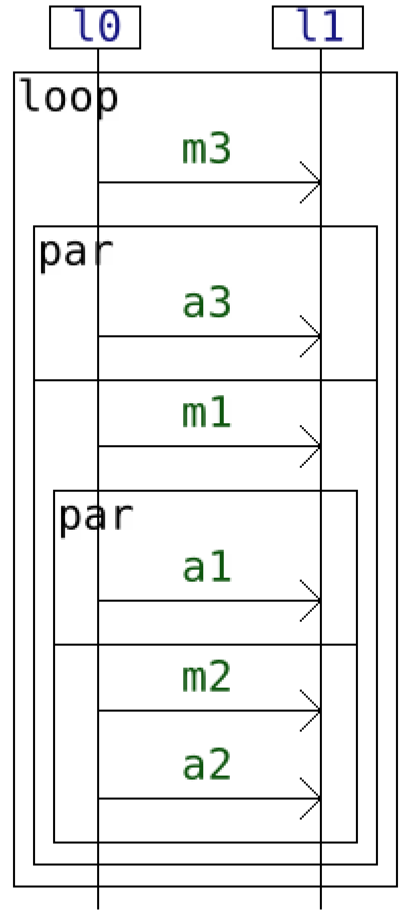
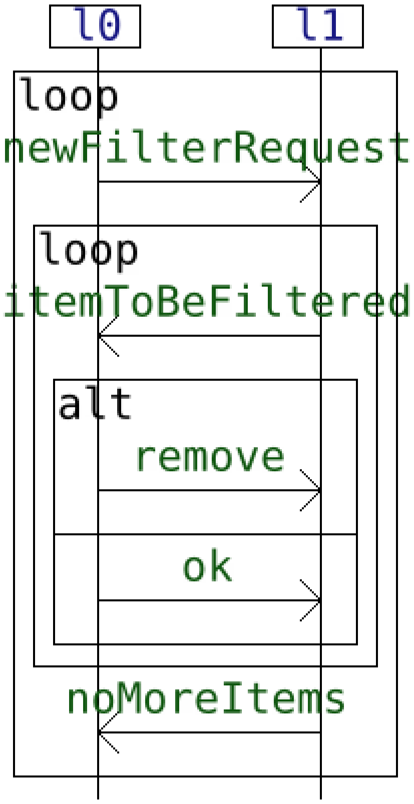
For each global interaction, at most 5 partitions of its lifelines will be extracted; after projection onto the partitions, 7 random mutations are operated in the local interactions. The timout threshold is of 60s. the flag -m means that in the output csv file, the duration will be given in milliseconds. The theory for the composition is ACU (all the rules are used).

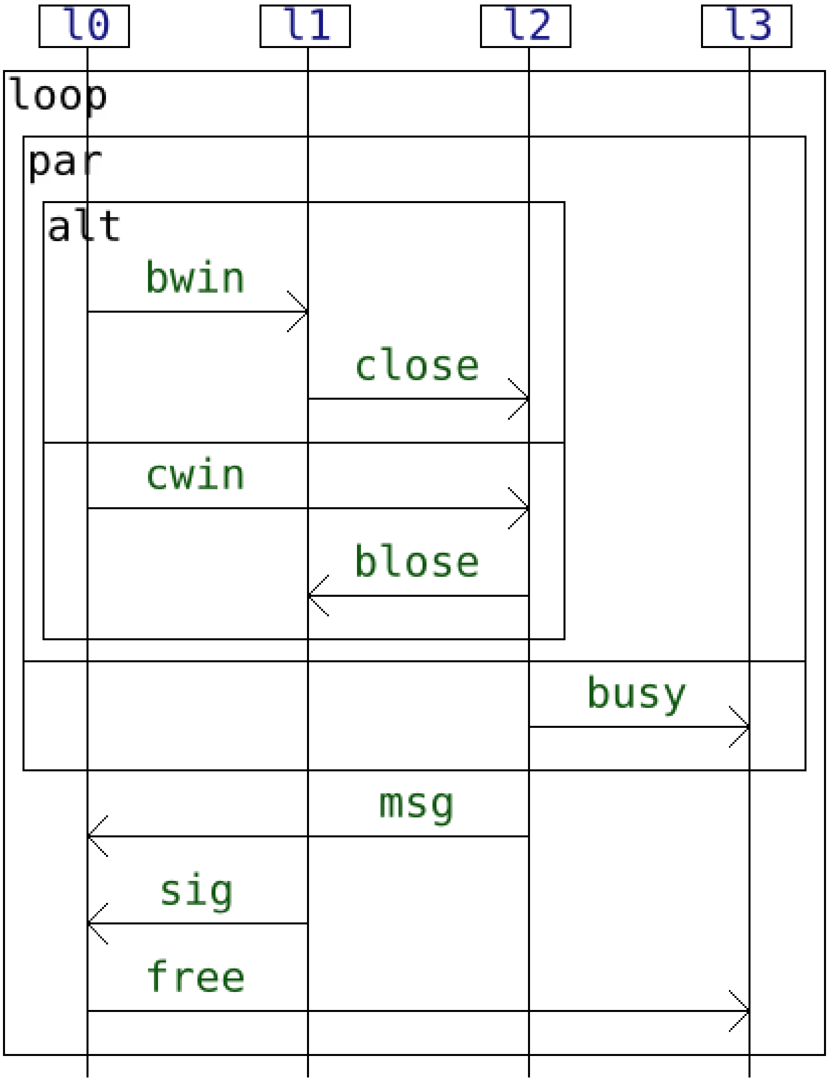
To draw the interactions involved in the process, we can use the flag `-d`.

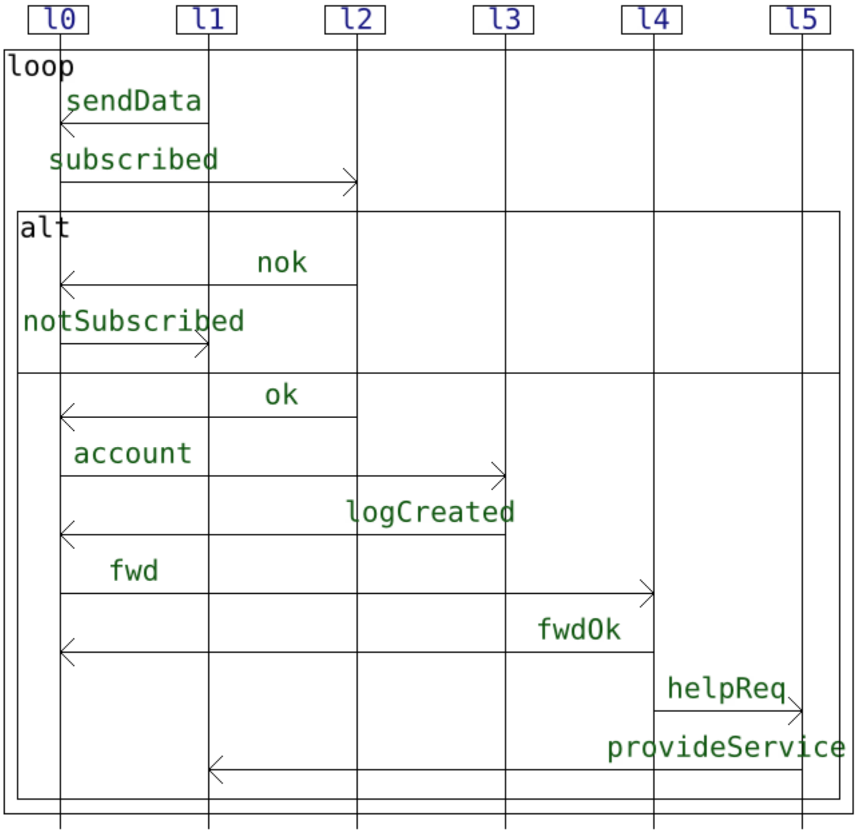
Interactions of the benchmark

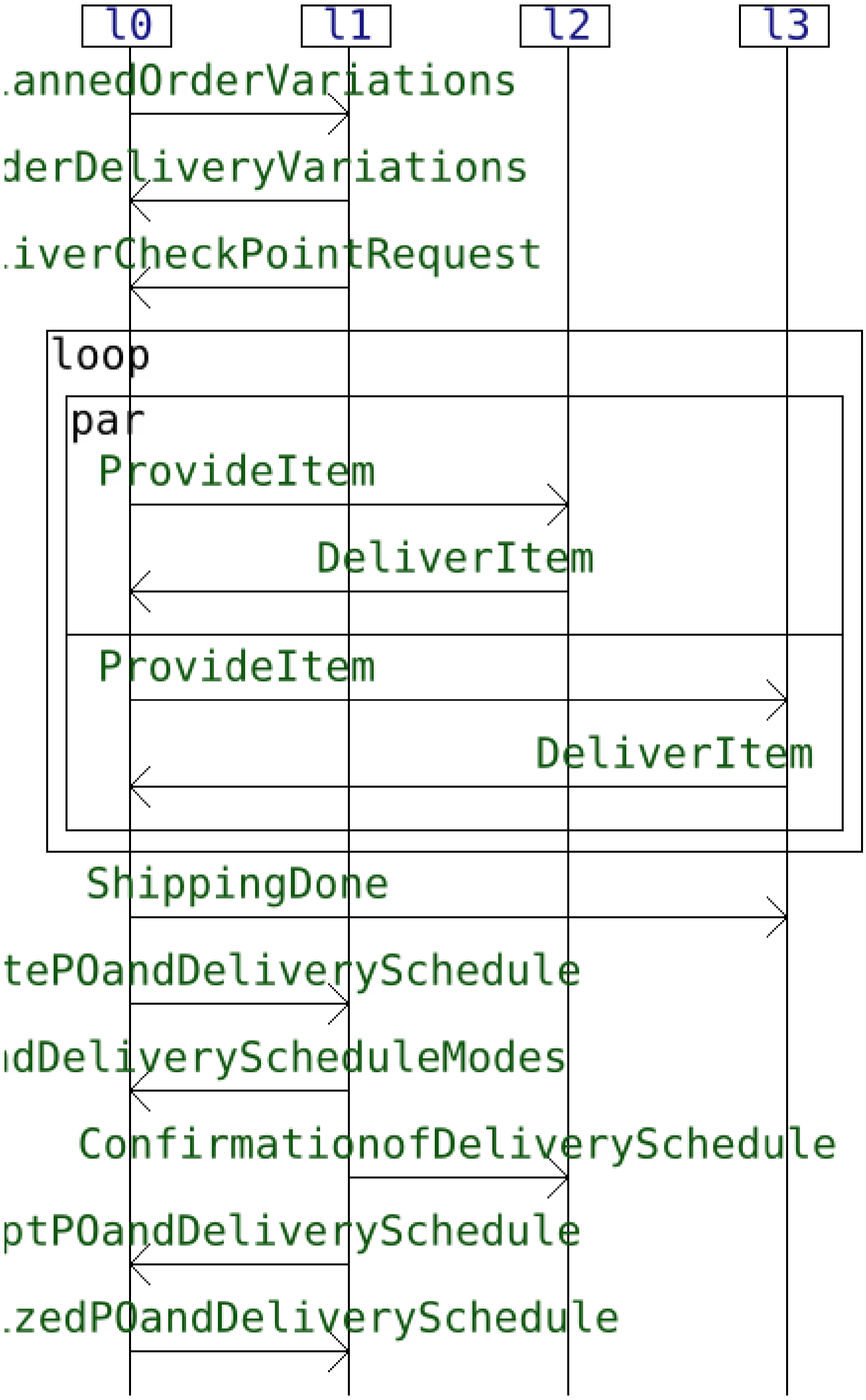
We present in the following table sequence diagram representation of the interactions of the benchmark, which files are in the folder Benchmark. Those interaction were adapted from examples and experiments from the literature.

Name	Interaction graphical representation	Reference

Name	Interaction graphical representation	Reference
Alternating3Bit Protocol		Lange et al.
Filter collaboration		Lange et al.

Name	Interaction graphical representation	Reference
Game		Lange et al.

Name	Interaction graphical representation	Reference
Health System		Lange et al.
Logistic		Lange et al.

Name	Interaction graphical representation	Reference
		

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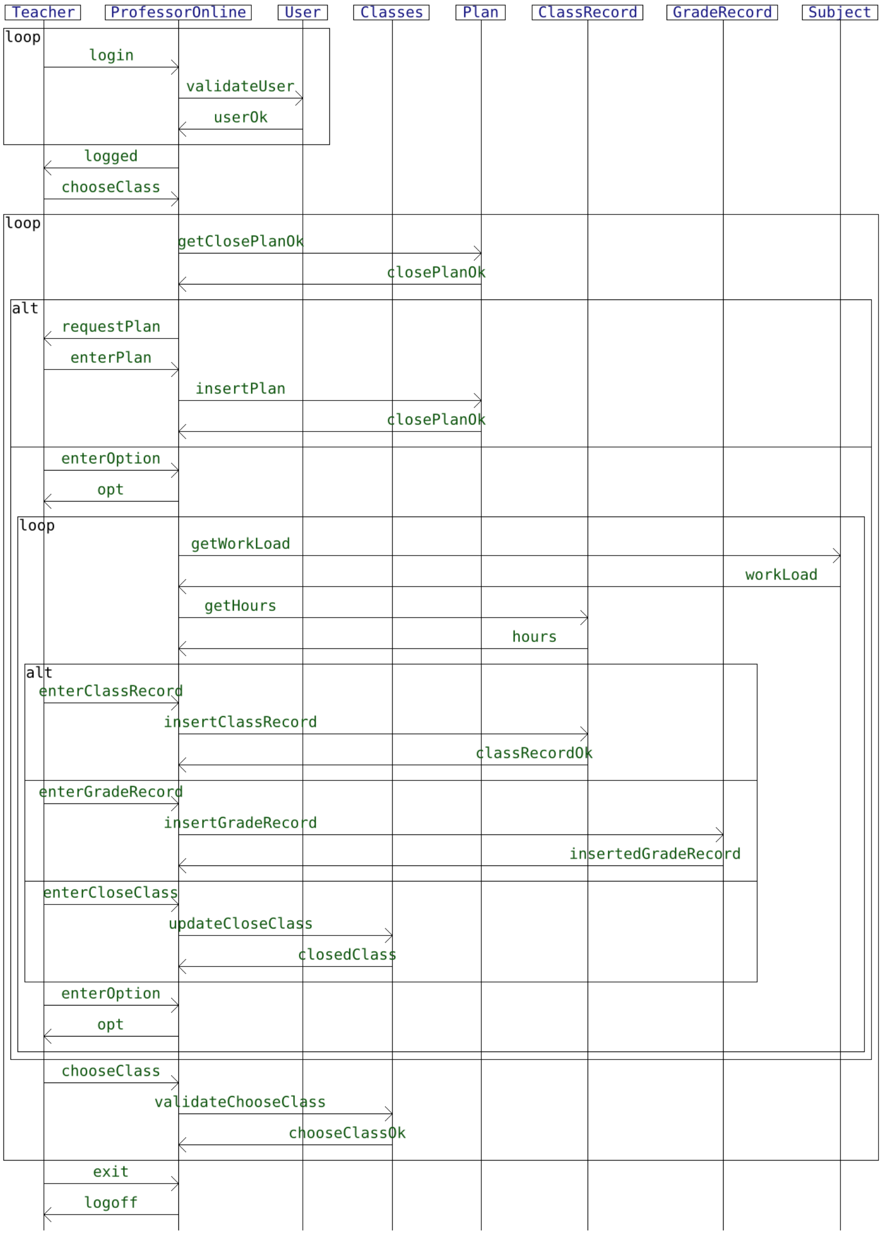

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<tr><td>Sanitary Agency</td><td></td><td>Lange et al.</td></tr>
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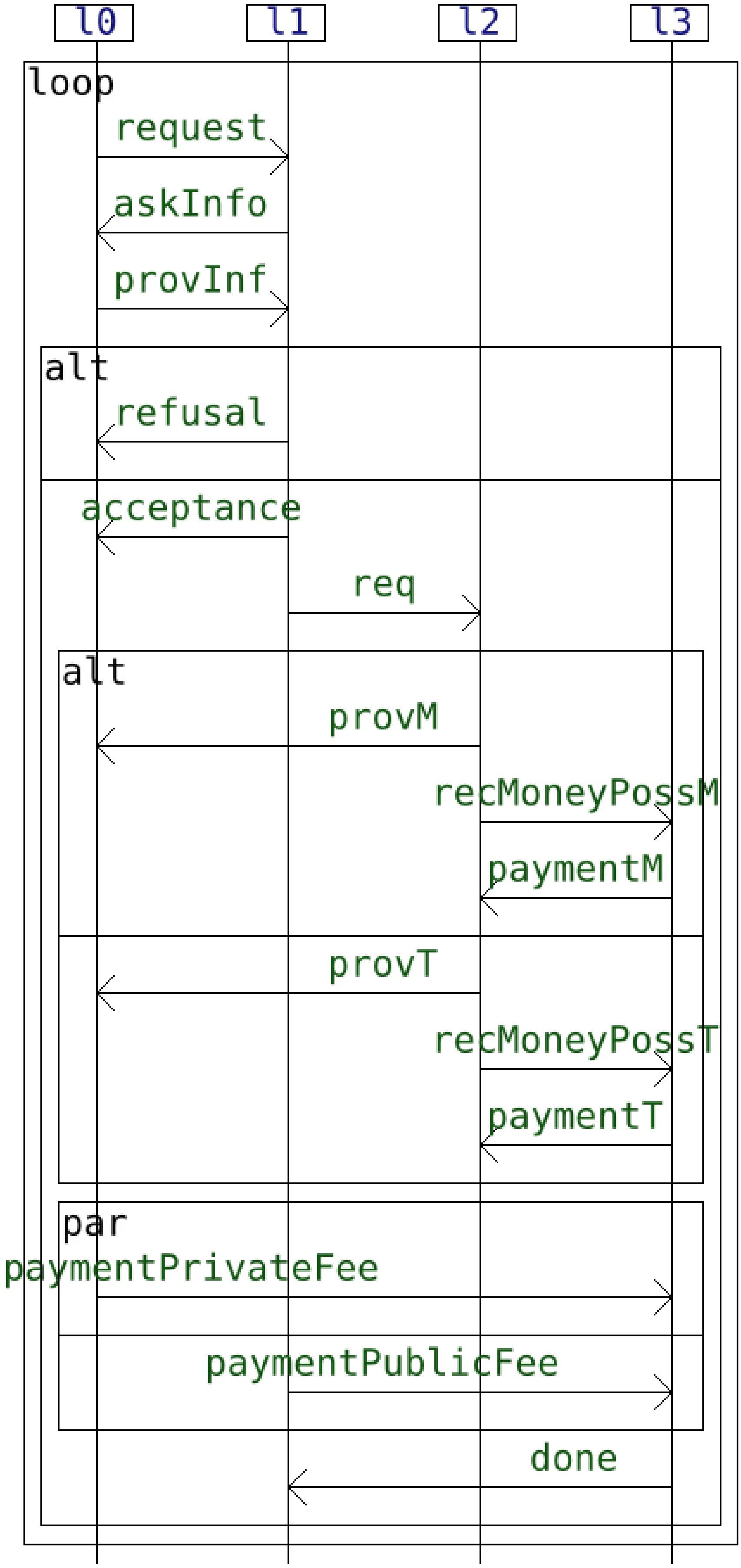
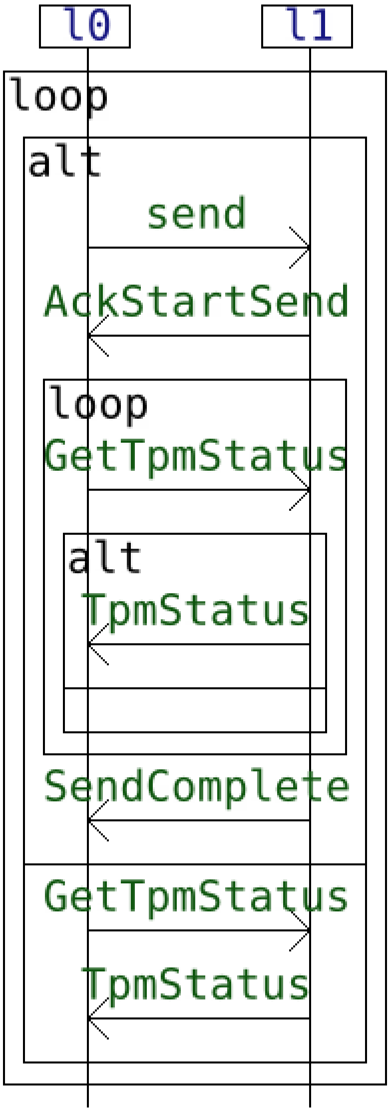
Name	Interaction graphical representation	Reference
		

Name	Interaction graphical representation	Reference
TPM Contract v2		Lange et al.
Travel		Bouma et al.

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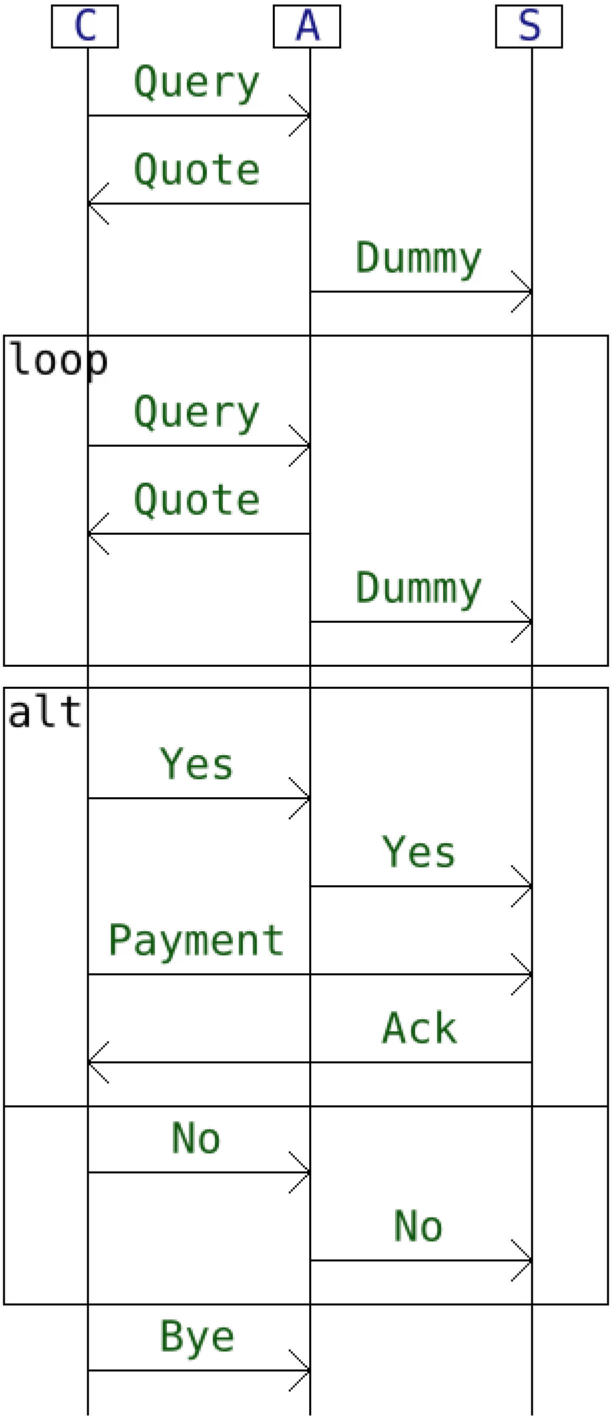
<tr><td></td><td>
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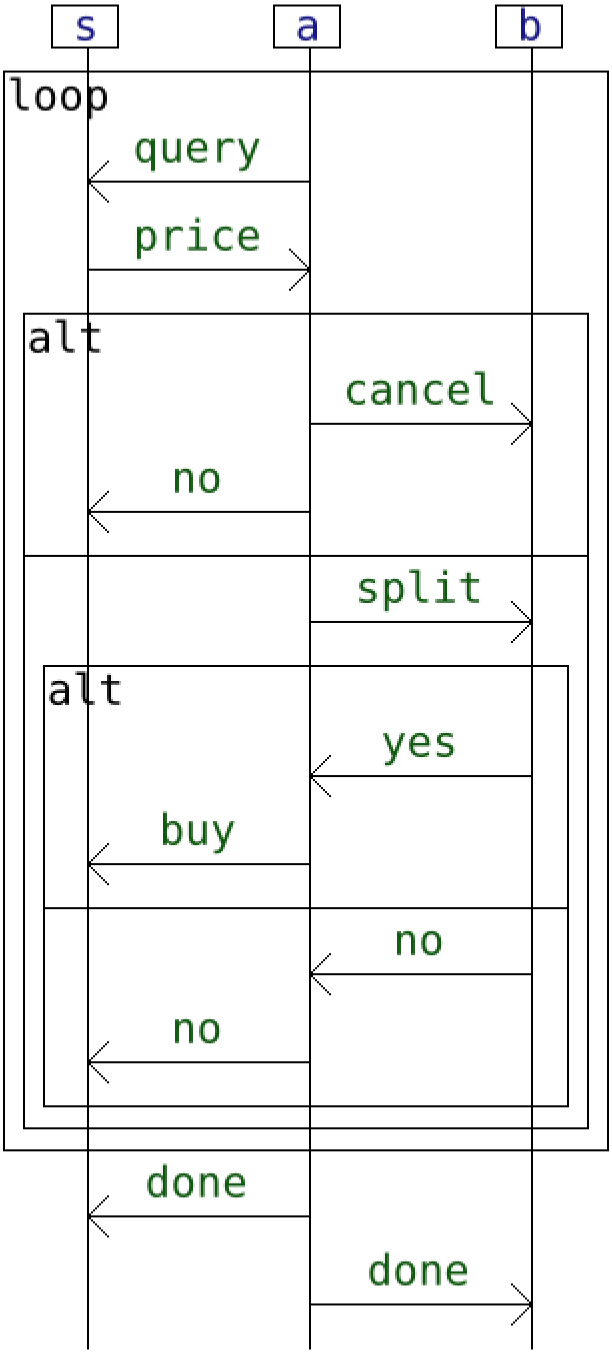
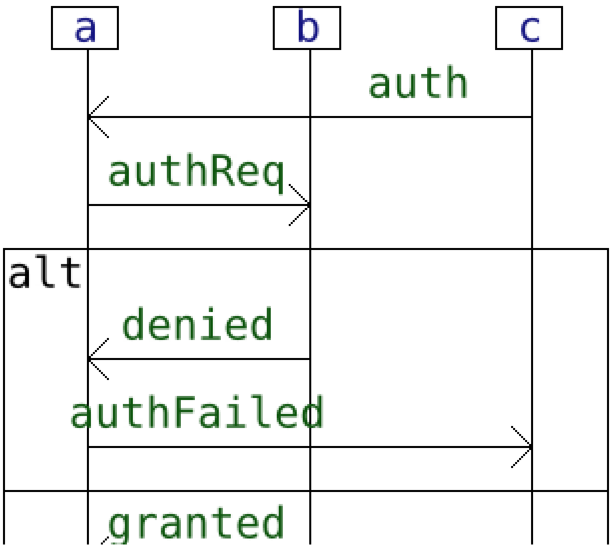
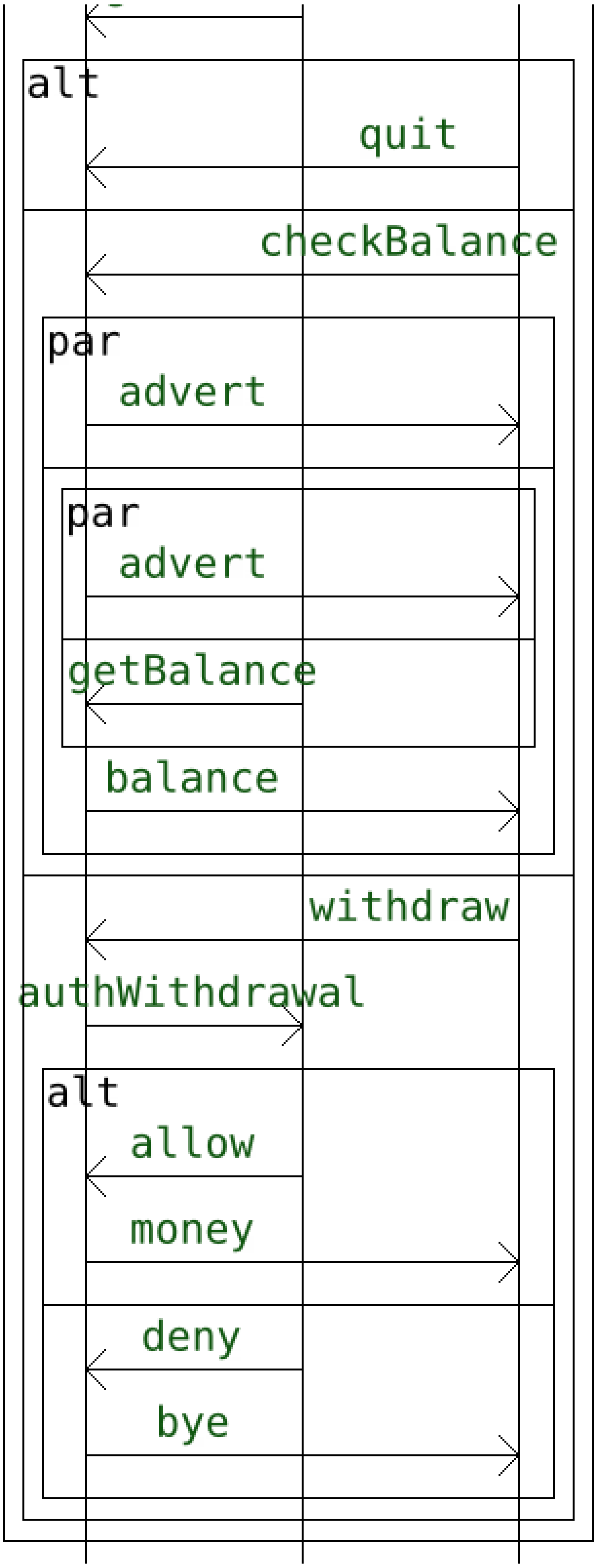
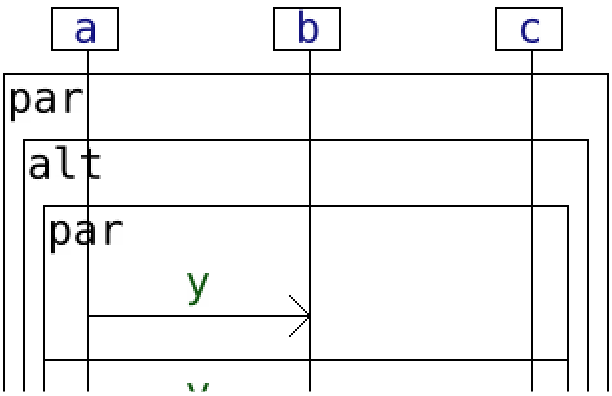
Name	Interaction graphical representation	Reference
Two Buyers protocol		Honda et al.
ATM		Edixhoven et al.

Name		Reference
		
Distributed Voting		Edixhoven et al.

Name		Reference