Proceedings of the 10th Workshop on the Representation and Processing of Sign Languages (sign-lang@LREC 2022), pages 132–138
Language Resources and Evaluation Conference (LREC 2022), Marseille, 20-25 June 2022

Two New AZee Production Rules Refining Multiplicity in French Sign Language

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Abstract

This paper is a contribution to sign language (SL) modeling. We focus on the hitherto imprecise notion of "Multiplicity", assumed to express plurality in French Sign Language (LSF), using AZee approach. AZee is a linguistic and formal approach to modeling LSF. It takes into account the linguistic properties and specificities of LSF while respecting constraints linked to a modeling process. We present the methodology to extract AZee production rules. Based on the analysis of strong form–meaning associations in SL data (elicited image descriptions and short news), we identified two production rules structuring the expression of multiplicity in LSF. We explain how these newly extracted production rules are different from existing ones. Our goal is to refine the AZee approach to allow the coverage of a growing part of LSF. This work could lead to an improvement in SL synthesis and SL automatic translation.
Keywords: AZee, Sign language, Formal representation, Multiplicity, Plural

1. Introduction

The framework of this study is sign language (SL) formal description with the AZee model (Filhol et al., 2014). One of the outcomes of SL formal description is the potential use for SL generation with an avatar.

Current approaches are often elaborated based on spoken languages, which are linear systems (see (Hadjadj et al., 2018) for a review of existing systems). This may pose some fundamental problems since SLs are multi-linear visual-gestural languages. In contrast, AZee aims at integrating all the forms and phenomena observable in SL. It is a corpus-based approach that defines systematic links between observed forms and interpreted meanings.

This article deals with a specific problem related to one of these form–meaning associations: the case previously marked as "Multiplicity", which covered a vague notions of plurality. We propose a systematic study of this phenomenon in French Sign Language (LSF).

After briefly presenting the basics of the AZee approach, its production rules system, and a methodology to identify them (section 2), we will introduce the notion of `multiplicity` and explain why it needs refinement (section 3). Then, we will present the LSF data we analyzed (section 4) and detail the application of the methodology (section 5). We expose the obtained results, i.e. two new production rules (section 6). We will discuss this contribution (section 7) and finish with some propositions for future studies (section 8).

2. The AZee Approach

AZee is a formal approach for representing SL utterances and discourse. This is done by constructing recursive expressions that combine *production rules* applied to arguments.

Production rules are systematic links between observable forms (a set of articulators and the way they are synchronized or arranged in time) and semantic functions (an interpretation of such observable forms, i.e. their meaning). The forms can be parameterised with arguments, which can be mandatory or optional (Hadjadj et al., 2018). For example, rule `vêtement` associates the meaning "clothing" with the form given in figure 1, and has no arguments. Rule `all-of`, with list argument *items*, creates the meaning of a set containing all the *items*, focusing on the set as a whole (McDonald and Filhol, 2021).[1] The associated form is the concatenation of each item in *items*, recursively produced in an accelerated manner.

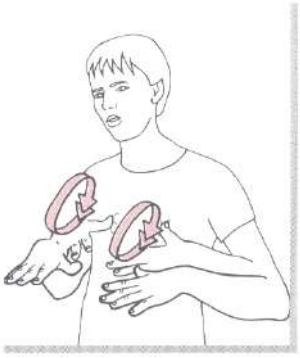

Figure 1: Form of production rule `vêtement` (IVT, 1997)

The set of all identified production rules is called the production set. It is then possible to combine them and build tree-structured expressions that represent complex utterances in SL, called *discourse expressions*. The AZeefication process consists in elaborating an AZee expression to represent a given SL utterance. This has recently been done on the corpus of real-life short news items *40 brèves v2* (Challant and Filhol, 2022), totalling 120 AZee discourse expressions covering 1 hour of signed discourse.

AZee provides a corpus-based methodology to identify production rules through the analysis of SL data. It consists in alternating search criteria of form and meaning until regular form–meaning associations are determined. In general,

[1] For information, the language of the name of the production rules (French and English here) is arbitrary, as any gloss can potentially be.

form observations are done on videos with the naked eye, which is the case in the work reported here, although additional software measurements would be possible for more accurate data, in particular for better analysis of dynamics. Meaning interpretation, though, is assumed to be performed by a human in the process. We explain the steps of the process below (Hadjadj et al., 2018), as we will be applying it later in section 5:

1. start with a form or meaning criterion X to explore;
2. locate and list all occurrences of X in a selected SL corpus, and let N_{occ} be the number of occurrences;
3. for each occurrence of X listed, add description elements:
   - elements of interpretation if X is a form criterion;
   - elements of form if X is a semantic criterion;
4. identify groups of at least two occurrences with similar description elements, and let:
   - N_{gp} be the number of identified groups;
   - N_{out} be the number of occurrences not included in any group;
5. if all of the following conditions are satisfied:
   - X is a meaning criterion;
   - $N_{gp} = 1$;
   - N_{out} is less than a threshold, e.g. 15% of N_{occ};

   then the form elements defining the unique group $X.1$ can be considered invariant, and we define a new production rule associating X with the invariant form, and this iteration stops;
6. if this iteration has not stopped, for each group $X.k, k \in 1..N_{gp}$:
   - if X is a meaning that can already be expressed using known production rules justifying the form $X.k$ or, conversely, $X.k$ is a meaning that can already be expressed using known production rules justifying the form X, then no new rule is to be found, nor any new search to be fired;
   - otherwise, recursively apply this methodology with a new iteration starting with the criterion defining group $X.k$.

3. The `Multiplicity` Issue

The AZeefication of the *40 brèves v2* corpus (LIMSI and LISN, 2022a) mentioned above resulted in some phenomena that AZee could not represent. In the AZee expressions, the authors have filled the parts covering those instances with an "ellipsis", using a dummy rule application and marking it with `%E`. Many of these ellipses were tentatively marked as `multiplicity` when concerning the expression of plurality.

For instance, Figure 2 shows two examples of motion repetition labeled `multiplicity`. Arrows show the trajectory of movement repetitions, and crosses stand for each of these repetitions. On the left side, the signer represents a series of three aligned poles. His left hand stands for a roof while his right hand shows the set of successive aligned poles. On the right side, the virtual signer repeats three times the sign for "*town*" in LSF, with the meaning "towns everywhere".

Figure 2: Two examples of motion repetition with different forms and meaning. Left side: from *Mocap1*: i06l1, 00:09:32 ; Right side: from *Rosetta-LSF*: RST_X0047.demonstrateur1.mp4 00:03:60

Previous work in SL linguistics also mentions movement repetition as a strategy for expressing plurality in some SLs (Pfau and Steinbach, 2006; Kuhn, 2015). Although differences between SLs have been observed (Perniss et al., 2007; Steinbach, 2012; van Boven, 2021), it appears to be a possible strategy in LSF as well (Sallandre et al., 2021). However, these studies often use as examples a few isolated signs but there is no systematic analysis based on a corpus of SL data.

The problem with the `multiplicity` instances is that while the meanings might be captured with a common notion of quantity (count, duration, repetition...), no stable invariant form can be associated with it. Looking at figure 2, we can observe that in the left case, the trajectory is straight whereas in the right case, the trajectory is in contrast a circular one. In terms of meaning, finer distinctions seem also to be possible: the example on the left means for the geometric alignment to be interpreted, as opposed to that on the right. It would be wrong to interpret the towns as aligned on a circle.

Our objective was to clarify what rules should account for these repetitions and better define the "multiplicity" phenomenon with true form–meaning pairs extracted from SL data. To do this, we chose to apply the methodology for the extraction of production rules, starting from the most salient element that seems common to all cases in question, i.e. the repeated movement criterion (R), which we define as follows:

R Succession of deliberate motion strokes similar in path, by a same or symmetric body part, with no other significant motion in between. By *similar*, we mean to allow for geometric translation, symmetry and scaling.

We will apply the methodology to two different LSF video sets, which we present below.

Figure 3: Screenshot of a video from *Mocap1* corpus

4. Data

Available LSF corpora are scarce. The corpora we selected, *Mocap1* (LIMSI and CIAMS, 2020) and *Rosetta-LSF* (LIMSI and LISN, 2022b) are downloadable from Ortolang. They offer the advantage of containing two different discourse genres.

4.1. *Mocap1*

Mocap1 is a corpus of LSF recorded with a motion capture system and an HD camera. It was designed with the goal of carrying out multidisciplinary studies in Movement Sciences, Linguistics, and Computer Science.
This corpus is composed of 5 different tasks. The task on which we focused is a description task of 25 images, performed by eight deaf signers facing the camera, as shown in Figure 3. 94 videos out of 187 video files corresponding to this task were analyzed.
The nature of these data is challenging for the formal representation of LSF since they are descriptions of spatialized elements, where the signers use less lexical signs but instead rely on the iconic representation potentialities of their language.

4.2. *Rosetta-LSF*

Rosetta-LSF is an LSF corpus captured by a motion capture system (Vicon) with retroreflective markers recording at 100 Hz and a head-mounted oculometer (MocapLab MLab 50-W) recording at 50 Hz and rendered as a 3D avatar animation (Figure 4). This 3D rendering in good quality allows us to see the necessary details (movement, facial expression, gaze, etc.) to do the analysis. It was designed in the framework of a French public/private project that studied accessibility solutions for audiovisual content (Bertin-Lemée et al., 2022).
In contrast with *Mocap1*, the news titles translation task was chosen among the four of the ROSETTA project. This constitutes a list of nearly 194 news titles from a French public information channel. News content exhibits clean language, deals with any topic, which makes it a more conventional nature of the data.

Figure 4: Screenshot of a video from *Rosetta-LSF*

5. Applying the Methodology

This section follows the methodology presented in section 2, starting with the form criterion R.

Iteration R

The first step is to identify and list all occurrences of criterion R (form criterion defined above, of a repeated movement) in the selected corpus. We found 756 occurrences (640 in *Mocap1* and 116 in *Rosetta-LSF*). For each occurrence of R, we then indicate elements of interpretation since R was a form criterion. For instance: a set of countable and counted elements.
After the description of the occurrences, 25 groups of at least two entries could be constituted on the basis of similar features, covering a significant portion of the list but leaving out 52 entries. We summarise this below:

- $N_{occ} = 756$
- $N_{gp} = 25$
- $N_{out} = 52$

Of the 25 groups formed, we give the first ten in size below, with the common semantic feature defining them and examples.

R.1 Set of countable but uncounted elements (448 entries)
Examples: “many flowers on the ground”, “rows of trees”, “companies”

R.2 Set of countable and counted elements (157 entries)
Example: “four chairs set around a table”, “three people”

R.3 Set of uncounted countable and numerous elements (57 entries)
Example: “laying of tiles”, “carpet mesh”

R.4 Permanence of a capacity/function for an object (25 entries)
Example: “curtain opening”, “mechanical arm motion”

R.5 Wood (9 entries)

R.6 Clothing (8 entries)

R.7 Salt (6 entries)

R.8 Construction (5 entries)

R.9 Wine (5 entries)

R.10 House (3 entries)

...

Following the methodology requires that we now take each of these groups separately and either recognise a meaning–form association already accounted for by other rules of the known production set, or explore further by going through the steps again, starting with the criteria defining the group. All groups numbered R.5 and up happen to be trivial cases of known signs (dictionary entries) for which we already have a production rule justifying the observed form. For example R.6, whose form is that of figure 1, is easily explained with an application of rule `vêtement`. These groups need therefore not be explored any further.
In contrast, the other groups R.1 to R.4 must be explored recursively because no trivial way can be found to justify form R with a combination of known rules that would match the meaning defining the group. We do this below for R.1 and R.2, the last two R.3 and R.4 being marked as future research and not covered in this paper. For every cascading iteration, we report on the values for N_{occ}, N_{gp} and N_{out}, followed by a definition of each formed group in the iteration.

Iteration R.1

This iteration starts with a search for all occurrences meaning "set of countable, but uncounted, elements." The result of this search follows:

- $N_{occ} = 427$
- $N_{gp} = 2$
- $N_{out} = 21$

Most of the occurrences include either or both of the following conditions on a repeated motion:

(a) attenuation of precision or amplitude over the repetitions

(r) relocation of the successive repetitions

The two groups formed in this iteration are given below.

R.1.1 Repetition of a movement with (a) and (r)
Example: "shelves", the repeated movement being that for each flat shelf under the previous (see Fig. 5)

R.1.2 Repetition of a movement without (a) or without (r)
Example: "traffic jam", repetition of the shape of a car with forward relocation

This is not a stopping case, and none of those groups can be entirely accounted for with known rules. Two new iterations, one for each group, are necessary. They are presented below.

Iteration R.1.1

Search for form: repeated movement with attenuation and relocation.

- $N_{occ} = 406$
- $N_{gp} = 2$
- $N_{out} = 96$

We found two groups defined by meaning in this iteration.

R.1.1.1 Set of countable but uncounted elements without any order
Examples: "towns" (Fig. 2) (right), "roofs"

R.1.1.2 Set of countable but organized uncounted elements
Example: "poles", "shelves"

This is still not a stopping case. Two new iterations are necessary, one for each of those groups.

Iteration R.1.1.1

Search for meaning: set of uncounted, unordered countables.

- $N_{occ} = 49$
- $N_{gp} = 1$
- $N_{out} = 1$

A unique group formed:

R.1.1.1.1 Repetition of a movement along a circular path, with attenuation
Example: "towns" in Fig. 2 (right)

Because a unique group formed in an iteration started with a meaning criterion, and only one out of 49 occurrences falls out of the group (below 15% threshold), this is a stopping case. As explained in step 5 of the methodology, a new production rule, named `mult-around`, can now be defined. It associates meaning R.1.1.1 with form R.1.1.1.1, depending on a signed *item* and an optional location *loc* (default is neutral space in front of signer). A stand-alone specification is given in the result section recap.

Iteration R.1.1.2

Search for meaning: set of organized uncounted countables.

- $N_{occ} = 223$
- $N_{gp} = 1$
- $N_{out} = 4$

A unique group formed:

R.1.1.2.1 Repetition of a movement along a straight path, with attenuation
Example: "shelves" (Fig. 5)

Again this is a stopping case of the methodology. A new production rule is defined: `mult-in-a-row`, depending on a signed *item* and a *path* along which the items are placed. See the result section for a full specification.

This terminates iteration R.1.1.

Iteration R.1.2

Search for form: repeated movement without attenuation or without relocation.

- $N_{occ} = 37$
- $N_{gp} = 1$
- $N_{out} = 11$

A unique group formed:

R.1.2.1 Set of items, with exact count known
Example: "four chairs positioned at [...]"

The meaning defining R.1.2.1 can be constructed using the known `all-of` rule applied to the item list, which creates an expression meaning the set of items, focusing on the set as a whole. Such expression generates a form compatible with R.1.2.1, which means that R.1.2.1 needs no further exploration.

This being the only group in the iteration, no further exploration is needed for R.1.2. This indeed terminates R.1 all together.

Iteration R.2

Search for meaning: set of countable and counted elements.

- $N_{occ} = 156$
- $N_{gp} = 3$
- $N_{out} = 1$

Three groups formed:

R.2.1 repeated and relocated movement without attenuation
Example: "four plates"

R.2.2 repetition of a movement where each hand realizes an item
Example: "both sides of a river"

R.2.3 repetition of a movement with a hold and a blink between each repetition
Example: "two lamps"

We notice that all groups are defined by forms that we can already generate with combinations of existing rules such as `all-of`, `simultaneous`, `each-of` or `place-object` (McDonald and Filhol, 2021), which match the meaning of the current criterion R.2.
No groups are left to explore under iteration R.2. And as we said above, R.3 and R.4 are left for future research, which makes this the end of exploration R.

6. Results

Figure 6 provides a summary of the study. It allowed the identification of two new regular form–meaning associations. This constitutes two new production rules, as detailed below (section 61). We will test these new production rules by applying them to other data (section 62).

Figure 5: Example of R.1.1: movement repeated with attenuation and relocation, from *Mocap1*: i08l2, 00:34:17

6.1. Two New Production Rules

`mult-around` discovered in iteration R.1.1.1

- arguments: signed *item*, point location *loc* (default is in front of signer)
- meaning: multiple instances of *item* scattered or spread out on a surface around *loc*, with the exact count unknown
- form: *item* repeated along an arc trajectory sweeping around *loc*, with attenuation of the movement

`mult-in-a-row` discovered in iteration R.1.1.2

- arguments: signed *item*, *path*
- meaning: multiple instances of *item* aligned along *path*, with the exact count unknown
- form: *item* repeated along *path*, with attenuation of the movement

6.2. Evaluation of the New Production Rules

To evaluate our newly extracted production rules, we applied them to another LSF corpus, the *40 brèves v2*. Indeed, (Challant and Filhol, 2022) initially found 207 occurrences of cases labeled `multiplicity` in this data. We have reviewed them to identify the occurrences now covered by our two production rules. In total, 63.5% of these cases are now covered by our new production rules. More precisely, 36.5% are `mult-around` occurrences, and 27% are `mult-in-a-row` occurrences: their form and meaning correspond to these rules.
Figure 7 shows examples of each of the two production rules in this data (`mult-around`, and `mult-in-a-row`). As in Figure 2, arrows stand for the trajectory of movement repetitions. On the left, the signer repeats the item for "dead," and, on the center, the signer repeats the item for "inhabitant,".
Another outcome of this study is that it allows increasing the portion of LSF phenomena AZee can cover. In total, including the two new production rules, 96.1% of the

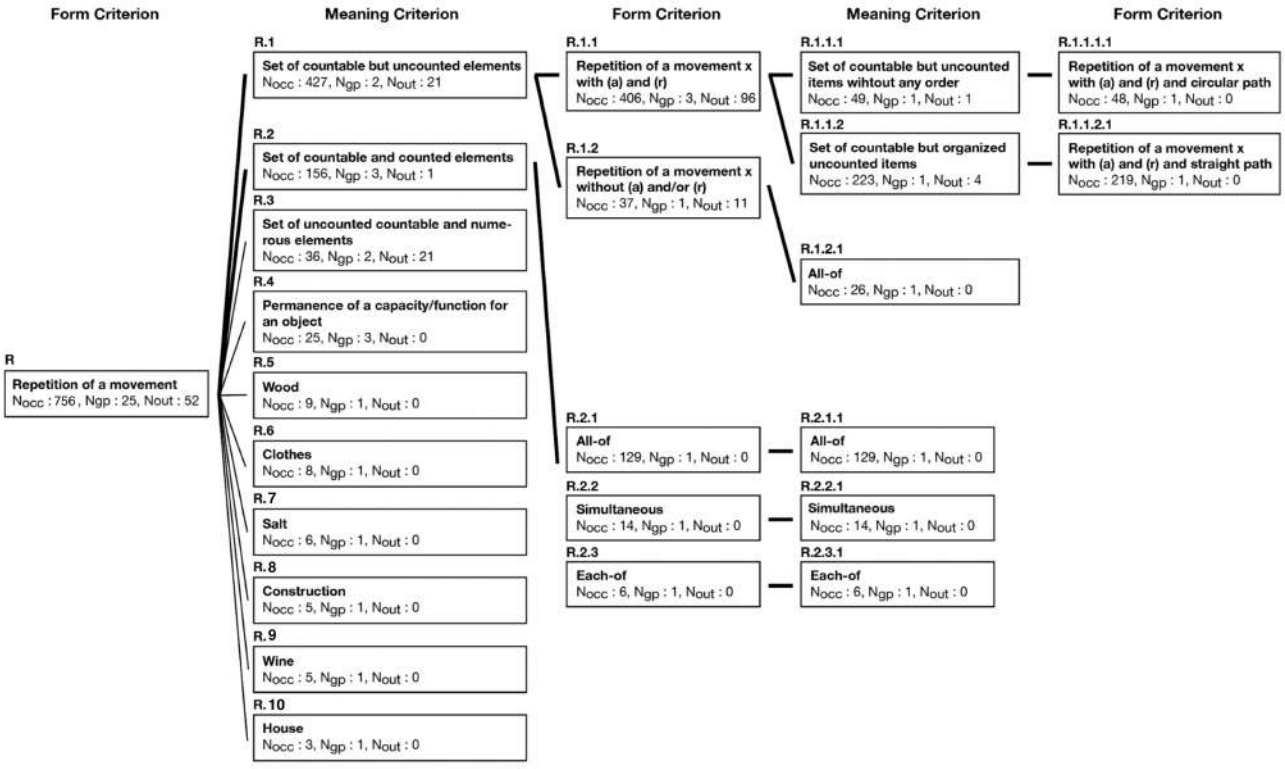

Figure 6: Overview of AZee production rules extraction process from R

LSF discourse from the *40 brèves v2* can be formally represented with AZee.

7. Discussion

In addition to enriching the existing production set, this study to us also exhibits the precision of the existing rules, which we explain in this section.

In our work, 70.27% of R.1.2 occurrences are occurrences of an existing rule we already mentioned, `all-of`.

This observation means that `all-of` is both formally and semantically close to the two rules that were finally highlighted. As a reminder, Rule `all-of`, its arguments, and its meaning are given hereinafter (McDonald and Filhol, 2021):

- All-of (*items*): Set of *items*, with focus on the set as a whole

In other words, this rule presents the association between the form of a list of items produced in an accelerated manner, and a meaning corresponding to "Set of items, with focus on the set as a whole".

From the meaning point of view, the two new production rules (i.e., `mult-around` and `mult-in-a-row`), on one side, and `all-of` on the other, are disjoint subsets of the previously labeled `multiplicity`. Our application of methodology highlighted that this assumption was not supported by the data. `all-of` creates the meaning of a set containing *items*, focusing on the set as a whole. But in the case of `mult-around` and `mult-in-a-row`, it is the same item that is repeated, and this item is necessarily countable and not counted, and either without any order or aligned.

From the form point of view, some cues are decisive in differentiating `all-of` from our two new production rules: the attenuation of the amplitude (or precision) of the repeated movement and the presence of a relocation of movement repetitions.

This observation overall underlines the semantic finesse of the different production rules, in line with semantic nuances observed in LSF.[2]

8. Conclusion and Prospects

The present study provided a better understanding of regular form–meaning associations regarding movement repetition in LSF. This contributes to enriching and refining the AZee LSF production set by adding two new production rules. This contributes to increase the ever growing proportion of the language that AZee can describe. Other studies could be conducted on the basis of this one.

Firstly, groups left unexplored (R.3 and R.4) might lead to other new production rules.

Secondly, among the initial 207 occurrences in *40 brèves v2*, we noticed that 36.7% are similar to what we observed in N_{out} from R.1.1 in our data. These occurrences displayed a specific type of relocation resulting from an alternation of movement of both hands. Moreover, this form seems to often refer to the same element. Indeed,

[2]In this regard, we notice that `mult-in-a-row` captures the possibility in LSF to project time into the signing space. Indeed, items repeated along *path* can represent items aligned in space, or repeated in time.

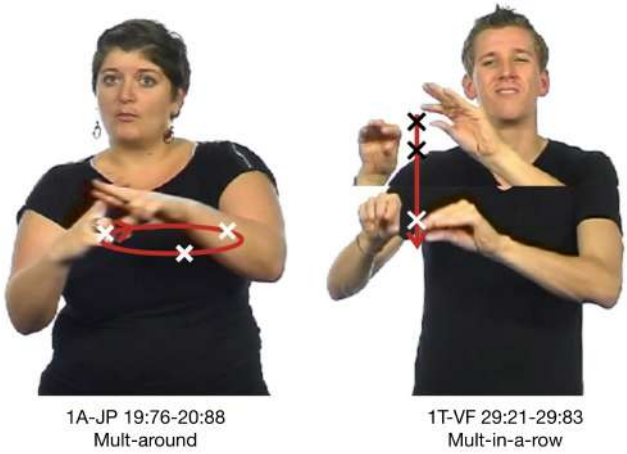

Figure 7: Examples of new production rules in *40 brèves v2*

in our data, 53.6% of these cases of specific relocation concerned the item "*people*" in LSF. In *40 brèves v2*, it represents 36.25%. Thus, these occurrences seem to share a similar form criterion. This subset could also be submitted to another iteration to reveal a possible specific form–meaning association.

Thirdly, we intend to test our two new production rules using a small-scale experimental study. Image stimuli containing only various multiplicities of entities (disordered or aligned) will be presented to a deaf signer equipped with a motion capture system. Their task will be to describe this plurality of entities. This will allow us to verify that the form cues included in the two rules (attenuation of movement and specific trajectories) are systematically verified in production.

Finally, AZeefication of more data in LSF could also be a good evaluation of these two new rules and the AZee system in general.

9. Acknowledgement

This work has been funded by the Bpifrance investment "Structuring Projects for Competitiveness" (PSPC), as part of the Serveur Gestuel project (IVès and 4Dviews Companies, LISN — University Paris-Saclay, and Gipsa-Lab — Grenoble Alpes University).

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