

LANGUAGE RESOURCES AND TOOLS FOR LIVONIAN

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Abstract. This article describes linguistic collections of Livonian, development of digital resources, and their usage. The main motivation is to ensure the accessibility of Livonian intangible cultural heritage and linguistic materials for the Livonian and research communities as well as using digital technologies for the purpose of ensuring accessibility and making creation of resources more efficient. This paper also discusses digital technologies and tools needed by the Livonian community and researchers as well as challenges deriving from work with limited resources. A separate section discusses possibilities for adopting language technologies for low-resource languages based on the experiment of building a machine translation module for Livonian.

Keywords: language resources, digitalisation, corpus, digital resources, machine translation, Livonian

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1. Introduction

Currently, Livonian is considered a critically endangered language (Moseley 2010). However, compared to many other critically endangered languages, as a result of almost two centuries of collecting language data, Livonian is documented relatively well, especially taking into account its small number of speakers (at present, some 20–30 according to estimates; Druviete & Kļava 2018). This has created some preconditions for bringing Livonian into the digital space – both in terms of accessibility of the language data for better research and

ensuring overall sustainability of Livonian by improving access to language sources for the Livonian community.

Just as any other language, Livonian requires various tools to ensure its use, development, acquisition, and to allow for language research and access to the information found in language data. Digital technologies currently in development have already proven to be able to help overcome technical issues with language data accessibility, making it available globally for a wide spectrum of end-users. And Livonian has already started to take advantage of that, as a number of digital resources have been created and gradually offered to the general public.

Endangered languages, especially those with a critically low number of speakers like Livonian, face two crucial challenges on the path towards digital technologies: lack of sufficient data for acquiring or confirming all the necessary lexical, grammatical, and syntactic information (which is also needed for building digital language instruments), but above all, lack of people proficient enough in the language who could theoretically be involved in developing or evaluating digital resources and tools for that language. The latter challenge also sets limitations on who can benefit from language resources or tools and who can access the contents of the information resources they contain such as intangible cultural heritage or history (e.g., folklore, oral and written history, etc.).

These are fields where help from emerging digital solutions is being sought, not only in terms of technology, but also in terms of methods for data handling and extraction as well as prioritising resources and technologies needed by language communities and researchers.

The purpose of this article is to offer a brief overview of the Livonian language collections that could be and are already used for creating digital resources and tools, limitations set by the form and content of those collections to the development of digital instruments as well as priorities in developing digital resources and tools from the perspective of the language community. A separate section in this article is devoted to an experiment using natural language processing (NLP) technologies for overcoming the aforementioned challenges as well as analysing outcomes and ways to improve the acquired results in circumstances characterised by limited resources and data.

2. Collecting Livonian language data

Although Livonian is primarily a language spoken in Latvia, Livonian language data have mainly been collected by scholars outside Latvia. This is connected to the fact that unlike Latvian, which is one of the Indo-European languages, Livonian belongs to the Finno-Ugric language family. Thus, Livonian language and culture have in the past primarily been of interest to researchers of Finnic languages and intangible cultural heritage. In Latvia, up until recently, a key area of interest has been Livonian strata in Latvian and there has been only a very limited number of researchers proficient enough in Livonian to be capable of collecting Livonian language data. This section offers an overview of the most important and extensive collections of Livonian language data.

2.1. Scientific collections and publications

Major collection work of Livonian linguistic data began in the middle of the 19th century with the publication of the first major collection of Livonian – a Livonian-German and German-Livonian dictionary (Sjögren & Wiedemann 1861a) and a grammar with language examples (Sjögren & Wiedemann 1861b) by Finnish scholar Andreas Johan Sjögren and Estonian scholar Ferdinand Johann Wiedemann, who collected data during their expeditions in 1846, 1852, and 1858. At the end of the 19th century, Sjögren and Wiedemann's work was continued by Finnish linguist Eemil Nestor Setälä. His expeditions to the Courland Livonians took place in 1888 and 1912. Most of Setälä's Livonian materials, which include numerous songs, folklore stories, fairy tales, riddles, and proverbs were published in 1953 (Setälä 1953).

From the 1920s until the end of the 1930s, Finnish scholar Lauri Kettunen and his student Oskar Loorits had an important role in collecting Livonian data. They visited the Livonian-speaking area of the Livonian Coast almost every year. While Kettunen worked on collecting the linguistic data that resulted in a publication of Livonian texts (Kettunen 1925) and an extensive Livonian-German dictionary with a grammatical overview of Livonian (Kettunen 1938), Loorits devoted his work to collecting folklore. Results of his work include the largest and most diverse collection of written Livonian texts – the Livonian folklore archive (see Tuisk 2022), which includes folktales from all of

the Livonian settlements in the 1920s–1930s, folk songs (published in Loorits 1936), folk beliefs (Loorits 1926, 1928, 1998, 2000), etc. Additionally, his collections at the Estonian Literary Museum include numerous texts concerning the Livonian language, culture, and history along with letters from Livonian activists of the time (Blumberga 2014). In addition to this collection, there exists one other important source for Livonian lexicography – a catalogue (ca. 1500 entries) of Livonian ethnographic terms.

Livonian language data were also collected by Estonian linguist Julius Mägiste during visits to the Courland Livonian villages in 1943 (together with Estonian ethnologist Gustav Ränk; published in Mägiste 1964). After World War II, Mägiste emigrated to Sweden, where he continued to collect Livonian texts from the Livonians who had also emigrated to Sweden (this collection was published in Mägiste 2006). In Estonia during the 1980s, two editions of Livonian proverbs were compiled at the Institute of Language and Literature of the Academy of Sciences (Krikmann, Mälk & Viitso 1981). Although most of the proverbs are gathered from Sjögren and Wiedemann's grammar and dictionary (Sjögren & Wiedemann 1861a, 1861b), Setälä's text collection (Setälä 1953) and Loorits' folklore texts, a portion of the material was collected directly by Livonian linguist Pētõr Damberg. Some Livonian collections (e.g., place names) can also be found at the Institute of the Estonian Language.

One of the most important collections of Livonian lexical and morphological data as well as language examples is the Livonian-Estonian-Latvian dictionary (Viitso & Ernštreits 2012). Although it was published only in 2012, work on it began as a cooperation between Livonian linguist Pētõr Damberg and Estonian scholar Tiit-Rein Viitso in 1979 (Viitso & Ernštreits 2012: 9). As lemmas and example material were entirely supplemented with translations into Estonian and Latvian (currently English translations are also being added), it serves as the largest parallel corpus that includes Livonian.

Valuable materials have been collected and published also for the minor and currently extinct Livonian variety of Salaca (Winkler 1994, Winkler & Pajusalu 2016, 2018) as well as a Salaca Livonian dictionary (Winkler & Pajusalu 2009). The main source for these collections has been the expedition materials of the above-mentioned Finnish scholar A.J. Sjögren.

2.2. Collections of recordings

In addition to written documentation, Livonian has also been recorded in audio and video formats. The first audio recordings of Livonian were made already in the 1920s by O. Loorits as part of his documentation of Livonian folklore (these phonograph recordings can be found in the Estonian Literary Museum). The most important collections, however, were made during the post-war period and are found primarily in research institutions in Estonia.

The Archive of Estonian Dialects and Finno-Ugric Languages at the Institute of the Estonian Language incorporates the collections of the Mother Tongue Society and Institute of the Estonian Language (during 1947–1993, the Institute of Language and Literature of the Academy of Sciences) (Ermus, Kalvik & Laansalu 2019). Along with the world's largest collection of Estonian dialect examples, it also holds a remarkable 321 hours of Livonian recordings (<http://emsuka.eki.ee/>) – most of them made by University of Tartu professor Tiit-Rein Viitso.

About 147 hours of digital recordings from 39 Livonian speakers are found at the University of Tartu Archives of Estonian Dialects and Kindred Languages (Rätsep 2003, Lindström, Lippus & Tuisk 2019; accessible via <https://murdearhiiv.ut.ee>). These recordings have mainly been collected by University of Tartu researchers and students and are supplemented with manuscripts consisting of student coursework, report papers, fieldwork diaries, seminar papers, theses defended at the Institute of Estonian and General Linguistics, transcriptions, and written notes on Livonian.

Livonian has also been recorded by, e.g., Finnish linguist Seppo Suhonen (texts published in Suhonen 1975) and documented during the making of documentaries about the Livonians (the most important of these is *Liivi rannal* 'On the Livonian Coast' (Nõmberg & Mosolainen 1966) and *Viimeiset liiviläised?* 'The Last Livonians?' (Piela 1995).

2.3. Publications in literary Livonian

The tradition of compiling and publishing books in Livonian for the needs of the Livonian-speaking community has existed for nearly two centuries. The first such books – translations of the Gospel of St. Matthew – were published already in the 19th century (Mt 1863a,

Mt 1863b, Mt 1880). This tradition continued in the early 1920s with the publication of the first secular books in Livonian – five Livonian readers (*Esimene Liivi lugemik. Ežmi Līvād lugdābrōntāz* 1921, *Teine liivi lugemik. Toi līvād lugdābrōntāz* 1922, *Kolmas liivi lugemik. Kolmāz līvād lugdābrōntāz* 1923, *Neljas liivi lugemik. Nell'ōz līvōd lugdōbrōntōz* 1924, *Viies liivi lugemik. Vīdōz līvōd lugdōbrōntōz* 1926) compiled on the initiative of L. Kettunen and O. Loorits. Although these first books were a huge achievement for the Livonian-speaking community, content-wise they offer quite a limited number of Livonian texts as do many other minor publications in literary Livonian. Despite there being only some 40 books published and manuscripts prepared in Livonian, some of these, however, could be considered important collections of Livonian data (for a detailed survey of literary Livonian texts see Ernštreits 2011 and 2013).

From this point of view, four major groups of Livonian publications stand out. First, the monthly newspaper “Līvli”, which was published for almost a decade (1931–1939) offering a large variety of texts from numerous authors. Second, religious and secular texts compiled and/or translated by Livonian poet Kōrli Stalte, including a manuscript for a Livonian reader (published in Stalte 2011) and a full translation of the New Testament (*Ūž Testament* 1937, 1942). Third, publications and manuscripts compiled or initiated by Livonian scholar Pētōr Damberg. The latter group includes two Livonian readers (Damberg 1935 and an unpublished manuscript by Pētōr Damberg probably from 1967), a Livonian-Latvian-Esperanto dictionary (*Čače, Dambergs & Grīva* 1966), and a manuscript about phytotherapy (in Livonian and Esperanto; compiled by Pētōr Damberg and Ints Čače probably between 1959 and 1967).

The fourth group of texts consists of several poetry books published after the restoration of the independence of Latvia. Among these, the most significant are the Livonian poetry anthology *Ma akūb sīnda vizzō, tūrška!* (I’m craftier than you, cod!, Blumberga 1998), the poetry collections *Kui sūolōbōd līvlizt* (Livonian emergence, Blumberga & Ernštreits 2011), the Livonian-English *Trilium* (Ernštreit, Damberg & Ķempi Kārl 2018), and the Livonian-Estonian-Latvian *Trilium 2.0* (Ernštreit, Damberg & Ķempi Kārl 2020). The last two collections also include poems in Salaca Livonian by poet Ķempi Kārl, who has also published two separate books in Salaca Livonian – *Salats joug kolm āga* (The

Three Shores of the Salaca, Kēmpī Kārl 2013a) and *Toini sina* (Another You, Kēmpī Kārl 2013b).

In addition to these, a number of collections are likely found in private hands, i.e., owned by researchers involved in collecting Livonian data (e.g., Eduard Vääri, Seppo Suhonen, Tiit-Rein Viitso) or their families, but also by Livonian activists and culture workers. These collections could be of great importance as, for example, is evidenced by the collection of Livonian place names (ca. 1000 place names with their locative forms and comments in Livonian) compiled by Pētõr Damberg, which was recovered recently in two collections donated by private owners to the UL Livonian Institute (see Ernštreits 2020).

3. Livonian digital resources

It is important for every language to stay competitive – both in terms of research opportunities and possibilities for language use and accessing language data. In today’s world, this means not only getting the language into the digital domain by developing digital technologies to ensure the usability and sustainability of that language but also making research more efficient and precise. However, a precondition for development of such tools is the existence of digital language resources.

Presently, a number of Livonian linguistic resources already exist and some are in development. The first attempts to create digital resources for Livonian already took place in the 1990s when the Livonian-Latvian-Livonian dictionary (Ernštreits 1999) – based on L. Kettunen’s Livonian-German dictionary (Kettunen 1938) – was created using a digital database. However, more active work began with the publication of the Livonian-Estonian-Latvian Dictionary (Viitso & Ernštreits 2012) in 2012 and subsequent attempts to use data from this dictionary to create various linguistic datasets and databases (Ernštreits & Kļava 2021: 30).

Following the publication of the dictionary, it was transformed into a database (without convenient updating and/or correction options) and published online at livones.net (<http://www.livones.net/lingua/en/vardnica>). Following that, in 2015, the indexing tool *Liivike* was created at the University of Tartu, which used this database as a lemma reference source and enabled the creation of a corpus

of morphologically annotated Livonian texts in phonetic transcription within these archives. The aforementioned electronic dictionary and the tables of morphological patterns published in that dictionary were also used in the University of Helsinki project “Morphological Parsers for Minority Finno-Ugrian Languages” (2013–2014; Ernštreits 2019: 164; see also Rueter 2014) which worked to create a morphological analyser and spell-checking tools for Livonian.

In 2016, work began at the University of Tartu on developing an updateable Livonian lexical database based on the existing Livonian-Estonian-Latvian dictionary. During the following years, the lexical database was supplemented with a morphology database, which provided users with immediate access to morphological information. Later, also a Livonian text corpus was added. In 2018, work on these databases was taken over by the newly founded University of Latvia Livonian Institute and, currently, the cluster of Livonian resources consists of the three above-mentioned interconnected linguistic databases and three databases in development – a data source database, an informant database, and a geospatially linked place name database (Ernštreits & Kļava 2021: 30). These databases are currently accessible via the Livonian Institute’s Livonian resource page (*Livonian.tech*¹).

At present, the open-access and continuously updated lexical database contains ca. 12,500 lemmas with correspondences in Estonian and Latvian (English is currently being added). In the next years, pronunciation of headwords and examples is planned to be added. The morphology database, which was created due to Livonian having an extremely rich morphology, contains over 13,000 morphological forms (all forms and variations of declinable words) and the Livonian text corpus extends to ca. 500,000 indexed and unindexed words (Ernštreits & Kļava 2021: 31).

4. What digital technologies does Livonian need?

There are several potential users for the resources and technologies developed for Livonian. The two main groups are: (1) specialists interested in researching Livonian language, intangible cultural heritage,

1 Publicly available from April 2022.

and the Livonian community, (2) speakers and those who want to study Livonian language and culture. The needs of both of these groups are somewhat different; however, the two main types of technologies required by users can be identified.

Users need technologies that make further expansion and processing of language resources more efficient as well as support language use and acquisition by including technologies for accessing content by those not proficient in Livonian (a majority of users). When considering the development of certain language technologies, one, however, must bear in mind the efficiency of such technologies and the amount of data needed for creating and using them.

4.1. Technologies for the expansion and processing of language resources

The expansion of existing digital Livonian resources is closely connected with the existing sources of Livonian described earlier. Most Livonian language collections and publications date to before the digital age and use various transcriptions and orthographies. A majority of these sources also remain unpublished. This creates several challenges for transforming Livonian sources into a digital form.

The majority of Livonian sources are handwritten; however, there are also issues connected with the print quality of published sources. This varies considerably for materials in literary Livonian, ranging from printed books to poor copies of texts produced on a typewriter. Scientific publications, on the other hand, while being better in quality, generally use phonetic transcription to represent Livonian, which makes use of a vast array of diacritics and special symbols to represent Livonian pronunciation.

An obvious choice for transforming the already published and collected texts into digital text format would be OCR. Published Livonian sources to which OCR could be efficiently applied are already accessible in digital text formats. Training the OCR to recognise texts in phonetic transcription, handwritten, or poorly printed texts in different orthographies could be possible, but may require too much effort for too little gain and manual work inevitably seems to remain the primary method for digitising Livonian texts.

There are also few highly skilled scholars who are capable of ensuring the proper transformation of Livonian language collections into digital text – especially for handwritten collections, which quite often contain additions, strikethroughs, and corrections. In order to speed up the process of creating digital resources, personnel with less linguistic and language knowledge are already involved in transforming sources into digitally readable texts. Language technology could make this process more efficient by offering support for recognising possible words or forms used in the texts for those less proficient in Livonian as well as to help solve normalisation issues between orthographies and transcriptions. One important application would be a morphological analyser along with spell-checking tools, which could significantly support normalisation efforts.²

Taking into account the large number of Livonian recordings found in various archives and private collections, one technology that would definitely help expand current resources would be speech recognition. All the preconditions exist for building such a technology, as there have been a number of studies of Livonian phonetics (e.g., Tuisk & Teras 2009, Tuisk 2012). Also, the recently initiated addition of sound files to the existing lexicographical database and corpus will definitely serve as a good source for acquiring an audio corpus.

4.2. Technologies for language use, acquisition, and accessing content

In order to better understand the technologies needed for language use and acquisition – especially from the perspective of ensuring language sustainability – it is useful to look at a 2020 survey conducted as part of a postdoctoral study on Livonian-language acquisition (see more Kļava 2020).

Interviews with Livonian speakers and other Livonian community members were conducted as part of this survey. These showed a particular emphasis on the development of appropriate digital solutions for language use, as respondents felt that the digital arena had a particular potential to facilitate the use of Livonian in real life and to foster its

2 Experiments on building such technologies are underway (see Section 3) and are using the aforementioned existing Livonian morphological database for this purpose.

transmission to younger generations. As part of the concept labelled ‘language on the computer’, respondents mentioned different digital language resources. These included dictionaries and the possibility of checking for a correct word form as well as expanding the availability of language corpora, texts, information about and in Livonian, etc. (Kļava 2020).

If we translate the results of that survey into the technologies needed, four main areas for development of technologies can be identified: (1) developing tools necessary for writing in Livonian (e.g., keyboard drivers for various computer platforms and smart devices³), (2) increasing the functionality of the existing Livonian dictionary (e.g., by adding forms, pronunciations, and corpus data to the lexical units), (3) developing spell-checking tools in order to support communication efforts (e.g., in social media), (4) ensuring better access to the language corpora and especially to the diverse and authentic language sources collected for Livonian, which contain many important texts on Livonian history and intangible cultural heritage.

It should be noted that better access here means not only physical access to the language corpora, but also access to the contents of the corpora. As the majority of the Livonian community members involved in cultural activities have little to no proficiency in Livonian, in order to sufficiently use data from the corpora it is also important to grant them access to the content by providing translations into the main language used by the Livonian community – Latvian.

Access to the contents of the corpora has importance beyond Livonian speakers and the Livonian community. Taking into account all the information on recent Livonian history, intangible cultural heritage, and identity that Livonian language sources contain, it is important also to provide access to that information to the scholars conducting research in these areas who in most cases at best have only meagre knowledge of Livonian. As the primary language of science nowadays is English, it would be an obvious language to choose for translations of texts included in the corpora.

Development of various machine translation technologies has proven to be efficient in the case of languages with more speakers and greater

3 There are already attempts to create a Livonian keyboard, e.g., <https://rootroo.com/en/livonian-keyboard/> by the Finnish company RootRoo (Hämäläinen & Alnajjar 2021).

linguistic data. Development of machine translation technologies for translating Livonian texts into other languages would be very beneficial both for ensuring sustainability of the language as well as expanding possibilities of research into Livonian heritage.

As machine translation technologies are capable of working in both directions, there could also be a discussion of whether translation of texts from other languages into Livonian would also be beneficial for the same purposes. However, given the limited amount of Livonian language data available for machine translation technologies to build translation output for Livonian, there is a great chance that automatically generated Livonian texts might pollute the Livonian language environment with a large amount of low-quality content.

5. An example case: machine translation for Livonian

As the previous section shows, there are a number of language technologies and tools Livonian would need for better research and for language use and acquisition. Some of these technologies and tools, such as keyboard drivers, spell-checking software, and functionality updates of existing language resources, are already being created as the UL Livonian institute has launched a new project as part of the Latvian State Research Programme (see acknowledgments below). Other technologies, such as speech recognition or machine translation (MT), have yet to be developed.

In this section, we describe an experiment for creating an NLP-based machine translation technology for Livonian, offer our first conclusions about its results and feasibility, and suggest aspects necessary for improving the quality of the translation. This experiment was performed by the University of Tartu Institute of Computer Science Chair of Natural Language Processing.

5.1. The corpus used for building machine translation

For the purposes of the experiment, a specially selected Livonian parallel text corpus was compiled. It united all aligned corpora which were possible to find for Livonian, the largest of these being the parallel corpora from the Livonian-Estonian-Latvian dictionary (Viitso &

Ernštreits 2012). It should be noted that a significant part of the corpora is formed by newer texts (e.g., from social media or web pages), and that translation of, e.g., social media posts, does not always match between languages due to the different audiences for which these texts have been prepared and the contexts with which these audiences (e.g., English- and Livonian-speaking) are familiar. Thus, such texts tend not to be direct translations but rather separate interpretations of the same topic.

The sources of data included:

- the Constitution of the Republic of Latvia, translated into 9 languages, including Livonian, Estonian, and English (Latvijas Republikas Satversme 2012);
- a database of dictionary entries, phrases, and example sentences from the University of Latvia Livonian Institute’s website, with examples in Livonian, Estonian, and Latvian;
- the Livonian Institute’s Facebook page posts, partially parallel between Livonian, Latvian, Estonian, and English;
- books (Stalte 2011, Kurs et al. 2016, Ernštreit, Damberg & Ķempi Kārl 2020) with prefaces and content in Livonian-Estonian or Livonian-Latvian;
- abstracts from the Journal of Estonian and Finno-Ugric Linguistics special issues on Livonian Studies (Ernštreits & Pajusalu 2014, 2016, 2018) in Livonian, Estonian, and English.

This corpus has now been released as an open-access dataset – a part of the OPUS (Tiedemann 2012) corpus collection.⁴

5.2. Training of the translation model

To train modern machine translation models, large amounts of parallel data between the respective languages are required. Machine translation models learn to generate translations in a target language by iterating over vast amounts of example source language texts and their respective translations. Language pairs with fewer than several hundred thousand parallel sentences are usually considered to be low-resourced for this task. Therefore, Livonian also falls into this category,

⁴ <https://opus.nlpl.eu/liv4ever.php>

having only several ten thousand such sentences in total between all other languages, and mere hundreds for Livonian-English, which makes the task especially challenging.

In addition to parallel data between several languages, monolingual data from each of the languages can also be used to further improve the translation quality of already trained models. This can be done with the process of back-translation (BT, Sennrich, Haddow & Birch 2016), which requires an MT model to be trained in each translation direction (i.e., EN->LIV and LIV->EN, or a multi-direction model translating in all directions, as in our case) with which the monolingual data of each language are translated into the other direction. Then, the generated translations are used as the source and the original monolingual data as the target to create a set of synthetic parallel corpora, which are mixed together with the original clean data, and used to either train new models from the beginning or further fine-tune the initial models. This BT process can be repeated for multiple iterations until the quality of the models stops improving.

Aside from using BT and monolingual data, improvements for low-resource MT can also be achieved by transferring knowledge from related languages. A simple approach to transfer-learning is training a single model for translation between multiple languages instead of just one translation direction. This is useful when one of the languages in question has more resources paired with other languages, and especially when some of the other languages share linguistic features. In our example, we focus on maximising translation quality between LIV and EN, which is by far the lowest-resourced, by adding not only ET-LIV and LV-LIV, but also all translation directions between ET-EN-LV. The additional data help the model to better understand and generate English, while also providing a boost in understanding and generating Livonian from ET-LIV and LV-LIV.

We experimented with training a single model for translation in all directions between Livonian, English, Estonian, and Latvian. We further made full use of the available monolingual data by performing iterative back-translation for four iterations in each direction.

5.3. Results of the MT

The automatic evaluation results in Table 1 show that the MT for English into Livonian is still rather low, even though highly improved from the baseline, while the other translation directions have reached seemingly usable BLEU scores (Papineni et al. 2002). The BLEU metric was one of the first to report a high correlation with human judgement, and is the most widely used and most cited MT evaluation metric. It is calculated by counting overlapping n-grams between the automatic translations and human-created reference translations, and is usually reported as a number between 0 and 100 (higher is better). Modern state-of-the-art MT models achieve between 20 and 45 BLEU points, depending on the language pair, translation direction, and domain in question. The second part of Table 1 shows ChrF scores (Popović 2015), which are calculated similarly to BLEU, but instead of word n-grams focus on character n-grams; ChrF shows better correlation with human judgements in case of morphologically-rich languages.

To verify the automatic evaluation scores, we performed a manual evaluation of the translations and categorised the main critical errors. Evaluations were performed by Livonian language linguists on approximately 600 sentences per translation direction. About 70% of all sentences had at least one error, and about 20% had several errors in the same sentence. A detailed summary of the main errors can be found in Table 2.

Based on the manual evaluation, the general conclusion is that Livonian translations and mistakes are more connected with morphological aspects and incorrect forms. Sometimes the word in the translation is correct but in an incorrect morphological form (e.g., which covers 14 fishing villages > mis **kattõb** 14 kalāmīe **kilā** *pro* katāb 14 kalāmīe killõ, in Kuoštrõg > **Kuoštrõgõ** *pro* Kuoštrõgõl). Also, Latvian, Estonian, and English words occur in the Livonian translations (e.g., East and West Livonian > **Ida- ja Läänelivonian** *pro* idā- ja lāndlīvõd). In some cases, there are compound words put together from different languages (e.g., children’s playground > lapst **māngground** *pro* māngdõbkūož).

Table 1. BLEU and ChrF scores (higher is better) of baseline models (Base) and four iterations of back-translation (BT1 -BT4).

	BLEU				ChrF					
	Base	BT1	BT2	BT3	BT4	Base	BT1	BT2	BT3	BT4
LIV-EN	13.29	16.19	17.41	18.15	19.01	0.384	0.423	0.433	0.439	0.447
LIV-ET	15.08	20.05	21.61	21.78	23.05	0.424	0.495	0.512	0.517	0.528
LIV-LV	15.05	21.25	22.99	23.68	25.24	0.398	0.482	0.498	0.504	0.519
EN-LIV	4.19	9.96	10.49	10.88	11.03	0.151	0.332	0.347	0.355	0.361
ET-LIV	4.01	14.43	15.24	16.09	16.49	0.139	0.403	0.411	0.421	0.432
LV-LIV	4.84	15.18	16.25	16.77	17.65	0.137	0.396	0.412	0.420	0.433

Table 2. Most frequent errors in manual evaluation.

Error	Error description	EN-LIV	LIV-EN
Partially incorrect translation	The translation is generally understandable, but there are some unclear parts (incorrect vocabulary, morphology, 1–2 words are translated incorrectly).	115	218
Latvian word	The translation includes a Latvian word.	104	6
Estonian word	The translation includes an Estonian word.	97	6
Incorrect form	An incorrect morphological form (e.g., case ending, noun ending).	53	24
English word	The translation includes an English word.	47	–
Livonian word	The translation includes a Livonian word.	–	38
Incorrect translation	The translation is not understandable. Incorrect/completely different words/expressions are used in the translations; more than 2 words are incorrect.	44	140
Not translated	Missing the whole translation, i.e., the translation stays in the target language. The translation is in another language rather than the actual target language.	22	8
Style and semantics	Unclear structure or meaning. The literal translation of the word is correct, but semantically some other meaning/word should be used.	8	60
Total evaluated sentences		610	601
Sentences with errors		398	454
Unique errors		557	521

English translations and mistakes are evaluated to be more general and are mostly connected with semantics or style (e.g., *lapstā vōidō* > **save the baby** *pro* to *babysit*). Sometimes there were words from other languages, an incorrect form (a morphological error), and incorrect translation at the same time (e.g., *Adults may cross the second, sometimes also the third shoal when swimming* > **Pieaugušajiem vōib tūoizta rištō**, *mündakōrd ka kuolmōndiz spīdōb pro Sūrd rovst vōibōd gilgōs lādō iļ tuoiz, mündakōrd ka iļ kuolmōz oŗa*). The cases where the translations had more than one error category at once occurred in both directions. Also, mistakes with several error categories appear to be more common than those with only one category.

Although it seems that the resulting translation quality is a little far from being usable, some parts of the translations are good and no errors occurred. Some transfer of meaning can still be achieved with the currently available resources. For further work, additional materials should be included with the purpose of increasing the resulting translation quality.

6. Conclusions

Endangered languages need the same means for use, development, acquisition, and research as any other language in the world. Today this also means digital resources, technologies, and tools. However, as most endangered languages are low on resources, creation of these tools for these languages brings unique challenges.

As a highly endangered Finno-Ugric language, Livonian has already started down the path towards entering the digital space. A number of digital resources have been created and gradually provided to the public. Some technologies and tools like keyboard drivers and spell-checking software are already in the process of being created. However, some crucial technologies that are capable of significantly expanding Livonian language resources and improving possibilities for use or acquisition of Livonian, still need to be developed.

Analysing the needs of the researchers, resource builders, and the Livonian community, two technologies of particular interest can be identified – speech recognition and machine translation. While speech recognition would be capable of significantly expanding existing

Livonian corpora from various recordings, machine translation would help to make Livonian content accessible to a wide range of users – researchers of Livonian as well as Livonian speakers and the Livonian community.

Although speech recognition for Livonian remains a distant possibility, efforts of building machine translation are already in progress. The experiment of building MT for Livonian described in the current article showed that for simple sentences with frequently occurring words and phrases the automatic translations can actually be usable. Even when the MT produces errors, the overall meaning of the text is often transferred to the translation. There is, however, more work to be done in data collection, digitalisation, parallel data alignment, and quality control for the current models to become as competitive as they are in other translation directions.

The age of digital technology seems to be beneficial for safeguarding and developing endangered languages. However, in order to profit from the technology, investments in the research and development of new tools and approaches are necessary, paying special attention to languages that are low or critically low on resources. Successfully overcoming the low resource issue with the help of technology may help to ensure sustainable linguistic and cultural diversity for society at large.

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Kokkuvõte. Valts Ernštreits, Mark Fišel, Matīss Rikters, Marili Tomingas, Tuuli Tuisk: Keeleressursid ja -vahendid liivi keele jaoks. Käesolev artikkel annab ülevaate liivi keelekogudest, digitaalsete ressursside arendamisest liivi keele jaoks ja nende kasutamisest, et tagada liivi vaimse kultuuripärandi ja keeleliste materjalide kättesaadavus nii liivi kogukonnale kui ka laiemale teadlaskonnale. Samuti on digitehnoloogia kasutamise eesmärgiks tagada parem ligipääs allikatele ning muuta liivi keele jaoks vajalike ressursside loomine tõhusamaks. Artiklis käsitletakse liivlaste kogukonnale ja teadlastele vajalikke digitehnoloogiaid ja vahendeid ning piiratud ressurssidega tööst tulenevaid väljakutseid. Eraldi alapeatükis analüüsitakse vähese ressurssiga keelte keeletehnoloogia kasutuselevõttu, tuginedes liivi masintõlke katsetamisele.

Märksõnad: keelekogud, digiteerimine, korpus, digitaalsed allikad, masintõlge, liivi keel

Kubbõvõttõks. Valts Ernštreits, Mark Fišel, Matīss Rikters, Marili Tomingas, Tuuli Tuisk: Resursõd ja vaidõkst līvõ kīel pierāst. Kēra tāmikšõb iļvaņtlimiz iļ līvõ kīel kubūd, līvõ kīel pierāst lūodõd digitālizt resursõd, nānt kazāntimiz ja kōlbatimiz, višņtõs līvõd vaimlizt kultūr pierāndõkst ja tarmõs vōimiži pāzõ kīel materjalõd jūrõ līvliztõn eņšõdõn ja ka tuņšlijiztõn. Digitālizt tehnolōgijd kazāntimiz merk um ka parāntõ ovātõd kōlbatimiz vōimiži ja tīedõ līvõ kīel pierāst vajāglizt resursõd lūomiz jo kievāmõks. Kēra nīžõb iļ digitālizt tehnolōgijd ja vaidõkst, mis ātõ tārpalizt līvõd ja tuņšlijizt pierāst, ja iļ problēmõd, mis suggõbõd piškīzt resursõdõks jelāmizõst. Ižki kabāl um pivāstõd kīel tehnolōgijd kōlbatimizõn piškīzt resursõdõks kīeld pierāst – siesõ alizõks um kōlbatõd līvõ kīel mašintulkõm lūomiz nāgõtõb.