Necromancing Diels: computerising the phonological analysis of early Slavonic texts using existing treebank data and a Late Common Slavonic computerised inflectional morphology

0. Introduction

Much progress has been made in the last twenty years in early Slavonic corpus linguistics as a result of the Old Church Slavonic part of the PROIEL project (Haug & Jøhndal 2008) and its subsequent expansion as the TOROT treebank (Eckhoff & Berdičevskis 2015), such that currently just over 240,000 words of canonical OCS have been manually lemmatised, part-of-speech and morphologically-tagged, and syntactically parsed. The focus of these projects, however, has been exclusively on the higher-level linguistic domains of syntax, semantics, and pragmatics: surface-morphology has been of only incidental concern, for example in investigations into differential-object marking (Eckhoff 2015, 2022). No inflection-class data is included in these corpora, and phonology has been totally ignored to the extent that some of the texts (esp. Kiev Folia, Codex Suprasliensis, and partially Codex Zographensis) contain quite severe typographical inconsistencies and errors that make them dangerous to use without reference to the manuscripts.

That being said, enough information is included in the lemmatisation and morphology-tagging that, with a few exceptions (e.g. comparatives), the morphological shape of the inflected text-forms can be predicted from just the tag-information, provided that inflection-class annotations are added to the lemmas. This means that the immediate Late Common Slavonic ancestors of surface-text forms can be generated by using a database of LCS inflectional-endings, reconstructing and inflection-class-marking the LCS lemmas, and then applying inflectional-endings to the stems according to the word's morphology-tag annotation[1]. Such LCS reconstructions are an extremely useful form of 'phonological annotation', since theoretically all the information required to give rise to an attested form must be present in any correct reconstructed proto-form, and the complete regularity of the idealised LCS forms makes texts predictably searchable regardless of orthographic variability, abbreviations, or other irregularities in the surface-texts. When applied to whole texts, they make the exhaustive investigation of almost any phonological or orthographic question trivially easy compared to manually reading and extracting relevant forms, or using TOROT's existing lemmatisation and morphology-tagging to try to gather morphological categories which might contain the sound-groups one is interested in.

In the next section I will describe my computerised LCS inflectional-morphology in more detail, show how it can be used to "autoreconstruct" different OCS texts, and explain how difficulties caused by things like morphological innovations, badly-integrated foreign loanwords, or insufficiently-precise tagging-data can be overcome.

Since morphology-tagging and lemmatisation are a prerequisite for my method of automatic reconstruction, Section 2 will survey recent work on automating these tasks for early Slavonic texts. Thanks to modern deep-learning techniques and the large and growing amount of manually-produced training-data in Eckhoff's corpus, accuracies of 90%+ can easily be reached (depending on the target-text), and I will see how far up this can be pushed by better neural-network design and more careful and informed pre-processing of training and target-data.

As a test-case of "wholly automatic" phonological annotation, Section 3 will apply such methods to the Codex Assemanianus, an OCS lectionary containing most of the gospels which has been digitised in an ASCII-encoded format by Jouko Lindstedt but is not included in Eckhoff's corpus. Accuracy will be evaluated by comparing both the automatic tagging and lemmatisation, and the resulting LCS reconstructions, to 10 randomly-selected manually-annotated shorter sections.

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1 Morphological innovations and variations are detected by inspecting the text-forms and then applying 'alternative' endings as specified in the inflectional-endings database; see Section 1.2.

Section 4 will then use the wholly-automatically-reconstructed Assemanianus as the basis for a short investigation into aspects of its phonological and orthographic system, which will be compared against existing treatments of this text in the literature, to see to what extent useful insights can be extracted even without any form of manual-annotation.

1. Auto-reconstructing texts using a computerised Late Common Slavic inflectional morphology

The premise of my chosen form of "phonological annotation" is that the earliest Slavic texts reflect languages which are **structurally** close enough to the broadly-agreed-upon system of Late Common Slavonic that the forms underlying the manuscript-spellings are more or less trivially derivable (by the application of sound-change rules) from their theoretical LCS ancestors.
By 'structurally' I am referring to structure at the phonological level; structural changes at higher levels of analysis (i.e. inflectional morphology, derivational morphology) are of no concern unless they are **made possible only by intervening phonological changes**.
My contention is that before about 1100 not enough of these structural changes are in evidence in any Slavic text, and thus texts can be relatively straightforwardly indexed using a well-chosen LCS system. Before giving examples of structural changes that are problematic for such an indexing-system, it's necessary to first lay out my LCS system in full:

1.1 Late Common Slavonic as a "phonological index"

In order to account for as much of the subsequently attested Slavic as possible, a point after the monophthongisation of diphthongs, but before the Second and Third Velar Palatalisations (PV2 and PV3) is chosen as the point of departure, because of the difference between the West Slavic /š/ and South/East /ś/ reflex of these two palatalisations of *x (Cz. loc. pl. *duších* vs Suprasliensis. ДОУСѢХЪ <*duxĕxъ; Polish *wszak* vs Supr. ВЬСАКЪ , Ru. *всяк[ий]* <*vьx-akъ), as well as the probable complete absence of PV2 in northern East Slavic[2] (Old Novgorodian, see Zaliznjak 2004: 42-45 for the evidence), and the blocking of PV2 by an intervening *v in West Slavic (Pol. *gwiazda*, Cz. *květ* <*gvězda, *květъ, etc.).
To be explicit, the native phonemes in my LCS system are given in the tables below:

2 The evidence regarding the possible absence of PV3 from Novgorodian is far less convincing: the Birchbark letters abound with examples of the PV3 reflex of *k (e.g. letter №439 from around 1200 has СВИНЕЦЕ <*svinьkь and ПОЛОТЕНЕЦА <*poltьnьka), and those of *g are not unknown: Zaliznjak (2004: 47) admits that palatalised forms of the Germanic loan КЪНАЗ- <*kъnęg- are the rule, but considers this to be a "supradialectal" word originating outside of the Novgorodian dialect-area; Галинская (2014: 10) is less convinced and adduces the form ОУСЬРАЗН (cf. Russian *серьга*, commonly assumed to be an Oghur, i.e. Bulgar, Turkic loan, cognate with e.g. Kazakh *сырга*) 'earrings' from letter №429 as a word of "вполне бытового характера" which thus supposedly shows a native Novgorodian reflex of PV3 of *g.
More importantly, as Галинская (op. cit.) points out, in all of the well-known Novgorodian forms of the pronoun *vьxъ 'all' which supposedly show a lack of PV3 by retaining both /x/ and back/hard desinences (e.g. fem. gen. sg. ВЪХОѢ <*vьxojĕ from letter №850), and which come from letters which otherwise correctly convey the jers (by writing <ь,є> for *ь and <о,ъ> for *ъ), the weak-jer is always written with <ъ,о>, unambiguously suggesting a /ъ/ pronunciation. These forms therefore more likely point to a LCS doublet-form *vъxъ which would never contain the conditioning environment for PV3 anyway, and thus you can't use them as evidence of a lack of PV3 in Novgorodian (on the plausibility of such a doublet see Галинская (2014: 14), though cf. Zaliznjak's (2004: 54) less convincing explanation of the /ъ/ in these words as an assimilation of original /ь/ to the back-vowels of the following syllable).

Table 2: LCS Vowels after the monophthongisation of diphthongs

	Front		Back
High	i		y u
	ŕ̥ ь ĺ̥	y	r̥ ъ l̥
Mid	e ę		ǫ o
	ě ę̌		
Low	Æ		
		a	

Table 1: LCS consonants before PV2/PV3 (adapted from Winslow 2022: 304)

Labial	Dental	Palatal	Velar
m	n	ń	
b p	t d	ħ ђ	k g
	s z	š ž	x
		č	
	l	ĺ	
	r	ŕ	
v		j	

Foreign sounds

In addition, the following symbols are used to represent phonemes of wholly foreign origin in order to represent badly-integrated foreign borrowings, whose level of integration into the native system we deliberately do not take a position on: /ḱ ǵ ś f ü/, e.g. in respectively ки҃тъ <*ḱitъ, ѥ҃емонъ <*iǵemonъ, χитонъ <*śitonъ, иосифъ <*ijosifъ[3], and мѵро <*müro. Almost none of the words containing these symbols would actually have existed in the language during Common Slavonic times, but they need to be included in the indexing-system because they often contain native Slavic elements (f.ex. inflectional endings). Normally they represent specific sounds in the source-language (usually Greek), so including them is useful for investigating the process of these sounds' integration into the native systems. For instance, the extent to which Greek /ü/ is integrated into either native /i/ or /u/ can be seen in variations in the OCS spellings of the word for 'Egypt' (*eǵüpьtъ): ѧ҃ѵ҃ѵ҃ѻ҃ѩ vs ѧ҃ѹ҃ѵ҃ѻ҃ѩ vs ѧ҃ѹ҃ѵ҃ѻ҃ѭ vs ѥ҃гѵѵптъ vs ѧ҃ѵ҃ѵ҃ѻ҃ѩ[4], etc.. One might also ask whether a separate <ѵ҃> letter for /ǵ/ (and the writing of <ѥ҃>/<ѧ҃> with the palatalisation-diacritic) could be linked to the inadmissibility in the native systems of soft [kʲ, gʲ] sounds, and whether their replacement with regular <ѯ,ѭ> or <г, к> was more likely in systems with some level of native [kʲ, gʲ] (for instance, in Rus' after the so-called Fourth Velar Palatalisation *ky,*gy,*xy > [kʲi, gʲi, xʲi], or in Novgorod due to the retention of native velars before front-vowels because of the non-action of PV2, etc.). In any case, such questions are far easier to investigate if all relevant forms can be reliably retrieved by giving them even a consciously artificial LCS representation.

Vowels

I have deliberately not included accentual information in my reconstruction of vowels, even though such information is in fact required to explain certain differing manuscript-reflexes, e.g. Russkaja Pravda fem. acc. sg. ѻрѣвѵ < *orb-ǫ vs Uspenskij Sbornik nt. acc. sg. ѻрѧло < *ordl-o, because for too large a proportion of the vocabulary this information is not sufficiently securely and

3 Of course the sequence /jo/ violates LCS phonotactics as well.

4 Forms are given as they appear in the manuscripts; modern fonts and Unicode symbols mean that the misleading and unhelpful practice of transcribing Glagolitic into Cyrillic is no longer defensible. Where specific forms from Eckhoff's corpus-texts are cited, they are hyperlinked to that place on the ocstexts.co.uk website, which is a work-in-progress web-interface for viewing and searching the annotated texts. Care should be taken with Eckhoff's digitisations, particularly in texts like Psal. where certain ruesome decisions from the editors Severjanov (1922) and Mareš (1997) have been compounded by further information-destroying simplifications (for instance, Severjanov transcribes <ѵ҃> with <ѵ̃>, but Eckhoff then replaces Severjanov's roundy diacritic with a titlo, leading to nonsense transcriptions like Psalm 8 <ѧнѵ̃лъ> for ms. <ѧнѵ҃ѵ҃ѧѭ>). Cleaned up digitisations, using the Glagolitic originals as the base-text, and a mechanism for displaying manuscript-images, are planned for the near future.

uncontroversially reconstructed to justify its inclusion, and anyway the (often post-LCS) derivational processes which are responsible for most of the actual words in the attested texts (and the inevitable accentual levelling processes likely to have occurred in the course of these derivations) complicate things even further.

The two extra nasal-vowels /ȳ/ and /ę̌/ are required to account for the split between North (East and West) and South Slavic forms of certain inflectional-endings:
*ȳ is used for the nom. sg. masc./nt. pres. act. participle of certain verb-classes whose present-stem ends on a hard-consonant, which in South Slavic remains high and backed, e.g. Supr. ꙁ҃ѹвꙑ <*zovȳ, Psalterium Sinaiticum ꙋстѣѧѭѥѫ <*stergȳ-jь, Codex Marianus ѧѩѣѫ <*jĀdȳ-jь (these forms lead Kortlandt (1979:260) to posit that some dialects of early OCS retained some kind of nasal character in this vowel and may even have developed the special "hooked" nasal letter <ѧ> for it), but which in most of North Slavic lowered to /a/: Old Polish (Kazania Świętokrzyskie) has both *recą* and *recǫ* (with the special Old Polish letter for the merged reflex of *ę and *ǫ) <*rekȳ, and in other texts also *biorǫ* <*berȳ; Russkaja Pravda ꙗєкѧ, Uspenskij Sbornik ѧонѧѧ <*dojьdȳ, Ru.Ch.Sl. (Vita Methodii) вьсємогѧи <*vьxemogȳ-jь. Kortlandt's positing of a CS *ȳ (which he writes as *aN) is far from universally accepted, and others consider these forms the result of various dialect-specific analogical process; see references and discussion in Olander (2015: 88-92). Whatever the truth of the matter, our *ȳ is a convenient placeholder which allows all the relevant evidence to be retrieved.
*ę̌ is responsible for the NSl. /ě/ vs SSl. /ę/ shapes of jo-stem masc. acc. pl. and the ja-stem nom./acc. pl. and gen. sg. endings, which are reflected in respectively the post- and pre-revolutionary spellings of the Russian nom./acc. pl. long-adjective endings -*ые* < *yjě < *yję̌ vs -*ыя* < *yja < *yję < *yję̌.[5]

The need for the retention of the /Ā/ archiphoneme, which represents merged Early Common Slavonic *ē *ā in the position after palatal consonants, up to this point of LCS, is explored in detail in Winslow (2022), but the same archiphoneme (along with its short counterpart /Æ/) was explicitly posited by Kortlandt as far back as 1979 (p.266) as part of his ECS system. In short, a combination of:

1.) the lack of any device in the Glagolitic alphabet to render /ja ńa ŕa Ĺa/ sequences (for which Glagolitic texts must use the jat' <ѧ> letter whose base-value is /ě/);

2.) overwhelming spellings of palatal-letter (<ꙗшѫѵ>) + jat' in the Kiev Folia (the oldest and therefore least distant ms. from the 'original' OCS, as first codified by Cyrill and Methodius and for which the Glagolitic alphabet was devised) for the reflexes of LCS *č/š/ž/ħ + *Ā (e.g. ѩѣѧѵѧѩѧ <*ob-vĕħĀlъ, ѩѫшѧѭѭ <*dušĀmi), as well as occasional traces of such spellings in later Glagolitic OCS (e.g. Psal. ꙗѧшѫє <*čĀšę); and

3.) the evidence of certain modern Bulgarian dialects, which have reflexes of LCS *ě in words like *ж'еба* <*žĀba 'toad' (Stojkov 1954: 74–78),

all together point very strongly towards there having occurred a split on the Southeastern periphery of Slavic between LCS dialects which have /ě/ < *Ā and the majority of the rest which got /a/, and that original OCS ('Urkirchenslavisch') was an *Ā > /ě/ dialect. I posit that *Ā remained until the opposition /a/:/ě/ after palatal consonants was reintroduced when PV2 and PV3 brought new soft-consonants /c ś dź/ into the system, which could be followed by both /a/ and /ě/: fem. nom. sg. /stьdźa/ < *stьga (PV3) vs fem. loc. sg. /nodźě/ <*nogě (PV2) (Winslow 2022: 304-305). Thus

5 Other troublesome pre-LCS morphological isoglosses reflected in the texts include the masc./nt. instr. sg. *o- and *jo-stem endings *-ъmь/*-ьmь (N.Sl., e.g. KF ѩѣьѥѩѭѭ, Uspensk. Sbor. кнѧзьмь) and *-omь/*-emь (S.Sl., e.g. Supr. ѻбраꙁомъ, кнѧꙁємь), which are most commonly (e.g. Olander 2015: 168) thought to be analogical replacements of the original instr. sg. ending ECS *-ā which is preserved in the adverb *vьčera 'yesterday'; and the *-tь (N.Sl.) vs *-tъ (S.Sl.) verbal endings of 3rd sg. and pl. present (plus its extension to 2nd and 3rd sg. aorists like OCS нѧчѧтъ, OR (Uspensk. Sbor.) бысть, нѧчѧть). Here I have no choice but to index them with dummy-symbols in the database: *-Omь/*-Emь for the instr. sg. ending and *-tQ for the verb-endings.

since my LCS system is based on a point just *before* PV2 and PV3, I must also retain the *Ǣ archiphoneme.[6]

The syllabic liquids /ŕ̥ Í̥ r̥ l̥/ are included as unitary vocalic phonemes, following Schenker (1995: 94), rather than as combinations of /ь ъ/ + /ŕ Í r l/, because these groups descend from PIE syllabic liquids and many descendant South Slavic dialects which retain syllabic liquids in this position (including most of those underlying canonical OCS) do not show any evidence of an intervening oral-vowel + liquid stage (such a view is shared by Bethin (1998: 71-72); cf. also Bulgarian dialectal evidence in Stojkov (1954: 130-131), where hard consonants precede reflexes of the LCS /Í̥ ŕ̥/ even in dialects with secondarily-palatalised consonants before fallen weak LCS /ь/). The need for both front and back *ŕ̥ *r̥ is unambiguously shown by the East Slavic reflexes /er/ and /or/ (Ru. *смерть*, *морковь*), but *Í̥ vs *l̥ is more complicated: PIE *pl̥nos, *wl̥kʷos > Lithuanian *pilnas* 'full', *wilkas* 'wolf' (LCS *pÍ̥nъ, *vÍ̥kъ) vs Lith. *stulpas* (LCS *stl̥pъ 'pillar') suggests that Balto-Slavic had differentiated front/back variants of the PIE syllabic *l̥ (Bethin 1998: 69), but the ancestor to East Slavic backed all vowels preceding tautosyllabic /l/ (Ru. молоко < Proto-ESl. *molko < LCS *melko > OCS млѣко), and thus only has /ol/ reflexes here: Ru. *волк*, *столб*, *полный*. It's true that Polish has *wilk* and *milczeć* (<*mÍ̥čÆti), but the Polish reflexes are complicated and likely have more to do with the surrounding consonants: *pÍ̥nъ by contrast gives *pełny* with hardened /l/ and the Polish non-palatalising-/e/ reflex of *ъ, and the differing reflexes in *wierzch* <*vŕ̥xъ, *śmierć* <*sъmŕ̥tь and *martwy* <*mŕ̥tvъjь rule out any explanation based on the nature of the LCS syllabic-liquid alone (for more discussion see Bethin op. cit.: 73-75).
While most OCS shows no sign at all of a front-back distinction in the syllabic-liquids and writes the reflexes of these groups overwhelmingly with <ꙋъ> and <лъ>, the Kiev Folia, which is the only OCS text that reflects a pre-Jer Shift stage and is very nearly flawless in its etymologically correct rendering of the jers, also spells *ŕ̥ *r̥ and *Í̥ as one would expect: ꙗꙑꙋь҃ꙗр- ѿꙋь҃ꙗѧ- ꙗь҃ꙗѧѧ- ꙗь҃ꙗѵ- ѧь҃ꙗѯ- <*ŕ̥, ꙗꙑь҃ꙗѣ̈ꙗрѡ <*r̥, and ꙗꙑѡ҃ꙗрꙗрѫ <*Í̥ (Winslow 2022: 313), and even Zographensis spells all 5 occurences of *vÍ̥k- 'wolf' with ꙋѧ҃ꙗ-/ꙋѧ҃ꙗѵ- and all 15 instances of its *-mÍ̥č- root with -ѿѧ҃ꙗꙗ- (e.g. ꙗѿѿѧ҃ꙗꙗꙗꙗшє). Therefore, taken as a whole the Slavic evidence pretty securely points to front and back variants of both syllabic liquids, and for searching purposes it's far preferable to denote them with separate symbols[7] rather than as the sequences /ьr ъr ьl ъl/[8].

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6 It's possible to argue that the short *Æ counterpart to *Ǣ persisted in East Slavic until after the Fall of the Jers, and that the ESl. so-called e > o shift before hard-consonants / back-vowelled syllables is actually just the resolution of this archiphoneme as /o/ (where palatalisation of the preceding consonant remained, in e.g. Ukr. *бджола* <*bьčÆla, or was newly phonemicised, in e.g. Ru. *вёсла* <*v'Æsla <*vesla), and that there was never a stage when these words had /e/ (based among other things on <o> spellings regardless of stress after palatal-letters in very early texts, and even after the letters for secondarily-soft LCS plain consonants in the Birchbark documents (Le Feuvre 1993, Nakonečnyj 1962), but there isn't space to elaborate on the issue here (see Winslow 2022: 304 fn.16). Unlike the situation with long *Ǣ, OCS shows no sign of anything but an /e/ reflex of short *Æ (and indeed the fact that the East Slavs inherited their writing system ultimately from the Urkirchenslavisch system designed for such a dialect, rather than one which had a clear way of writing /soft consonant/ + /o/, is likely the reason that /o/ reflexes are so rarely detectable in the early texts, since <e> had to be used for both /e/ and /'o/, cf. the spelling ê̅вшанъ of the Kipchak word /jovşan/ 'wormwood' in the Hypatian Codex, whose modern cognates (Turkmen *ýowşan* /jowşan/, Kazakh *жусан* /žuwsan/, Azeri *yovşan*) unambiguously point to a Kipchak /o/), and the history of the East Slavic /o/ reflexes remains the subject of much disagreement, so it's simpler for everyone if I continue the traditional practice of writing LCS *e after palatals, even if that strictly speaking is inconsistent with my use of *Ǣ.

7 In the database I will have to use the single Unicode characters <ṛ ṝ ḷ l̄>, rather than what's shown in my table, since the latter cannot actually be rendered without using the letters for /r ŕ l Í/ plus the 'combining ring below' U+0325 symbol, which means searches for the consonantal liquids on their own will also return results containing syllabic liquids. The same problem affects /ę̆ y̆/, which I will have to replace with <ę̆ ỹ>.

8 To my mind the only evidence in support of a genuine jer + liquid stage comes from the paradigms of verbs like OCS сътрьти < *sъtŕ̥ti, where the syllabic /ŕ̥/ in the stem alternates with /ьr/ depending on the vocality of the following morpheme: the e.g. 3sg. pres. *sъtьretъ (Zogr., Supr. сътьрєтъ) or (one possibility of the) 3rd sg. aorist *sъtьre (Supr. сътьрє) must have /ьre/, while the 3rd pl. aorist *sъtŕ̥šę (Supr. сътрѫшѧ) and the other possibility for the 3rd sg. aorist *sъtŕ̥ (Psal. Sin. ꙗѿмьѧ, or with a different prefix Mar. ѿмьѧ <*otŕ̥), being word-final or pre-consonantal, must be syllabic /ŕ̥/. The same alternation occurs in the zero-grade forms of verbs like *umerti, as is clear from the Polish reflexes *umarł* <*umŕ̥lъ vs *umrę* <*umьrǫ. The argument could be that at some stage, before

Consonants

Dejotation

Reflexes of the so-called jot-palatalisation are all written either as unitary palatal phonemes, or in the case of jot-palatalised labials as /vĺ mĺ bĺ pĺ/, rather than as sequences of consonant + /j/, hence /ń ĺ ŕ/ for *nj *lj *rj. The ‘dejotated’ reflexes of *tj (and *kt+front-vowel) and *dj are denoted using the modern Serbian Cyrillic letters /ћ/ and /ђ/ respectively, because the commonly used alternatives, i.e. /ť ď/ (as used in e.g. Olander 2015) or /ḱ ǵ/ (as used by me in Winslow 2022), or variations thereof, are visually too close to symbols used elsewhere in the system. /ḱ, ǵ/ are anyway already used in my system for foreign /k, g/ before front-vowels, and /ť ď/ look too similar to the common denotations of secondarily-palatalised post-Jer Shift /t' d'/, as used in discussions of systems like Russian or Eastern Bulgarian where they arise.

The compelling hypothesis, first proposed by Durnovo (1929: 55-58) but most recently elaborated by Vermeer (2014: 209-214), and accepted by Mathiesen (2014: 197 fn. 22) and Winslow (2022: 310 fn.25), according to which the Urkirchenslavisch reflexes of *ђ,ћ were close enough to foreign /g k/ before front-vowels that the original Glagolitic system used <ѧ ѫ> for both sets (i.e. alongside attested ѕѧѣѫѩ < ἡγεμών would have been **ѩѣєѧѩѕ <*osǫđeni, and alongside attested ѡѣѫѣ <*dъćerь would have been **ѫѕѩѣѣ < κῆνσος[9]), does not prevent us from keeping the foreign sounds separate for our LCS stage, since clearly they differed enough in all the dialects underlying actually attested OCS to be written separately.

Pre-dejotation *stj and *zdj are differentiated from the PV1 reflexes of *sk and *zg by writing the former as *šћ and *žђ and the latter as *ščć and *žǯ, even though their modern reflexes do not differ from each other anywhere and so must've fallen together in the CS period, because they often alternate with their respective un-palatalised counterparts morphologically and derivationally, e.g. očistiti:očišćenьje vs. jьskati:jьščǫ, jĀzditi:jĀžđǫ vs jьzgъnati:jьžǯenǫ.

There are convincing arguments for PV2/3 having preceded dejotation, at least in more central areas, most recently presented in e.g. Vermeer (2014: 197) and Wandl & Kavitskaya (2023: 244-247), and therefore it could be objected that my system, which contains the dejotation reflexes /ћђńĺŕ/ but not the PV2/3 reflexes /c ś dź/, is ahistorical. However it should be reemphasised that the primary goal of my LCS reconstructions is to act as an index which allows reflexes in texts to be found, not to be a historically realistic description of some actually-existing LCS dialect. The absence of PV2 in Novgorodian shows that it can’t have preceded dejotation everywhere in Slavic, and in any case the replacement of the sequences /tj dj nj lj rj/ by articulatorily distinct combined units, no longer associated by speakers with their /t/ and /j/ phonemes, is structurally completely irrelevant unless and until these new units merge with existing phonemes (or new sequences of dental + /j/ are introduced), as e.g. in the KF dialect where /tj/ merged with /c/ from PV2/3, or in ESl. where it merged with /č/ from PV1. A language which had distinct Czech-like palatal [c, ɟ] reflexes of *tj and *dj, and also no new sequences of [tj, dj], could not convicingly be argued to have undergone dejotation at the phonemic level, as these new units would just be phonetic realisations of /tj, dj/. Analysed like that, the symbols /ћђńĺŕ/ in my system strictly speaking would really just be cover-symbols for the pre-jotation sequences, but such notation is preferable since it

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the LCS tendency towards Open Syllables became dominant, the stems in these paradigms were surely unitary /tĭr/, /mĭr/, i.e. 3sg. aor. /sŭ.tĭ.re/ vs 3rd. pl. aor /sŭ.tĭr.šę/, and that the latter’s closed /tĭr/ syllable was only forced to open itself up by changing to /tŕ̥/ because of the Law of Open Syllables. Thus at least one source of the syllabic-liquids could be shown to have developed from a vowel + liquid stage, but that still doesn’t prove that they all did, or that the change of /ĭr/ to /ŕ̥/ in these verb-forms was not merely a move to an already-existing syllabic-liquid phoneme.

9 Interestingly, this aspect of the hypothesised Urksl. orthographic system has rearisen in the modern Macedonian standard due to Turkish loanwords: *ќемер* < Tk. *kemer* ‘belt’, *ќе* < *[хъ]ће[тъ]; *ѓон* < Tk. *gön* ‘leather’, *меѓу* <*među.

prevents searches for groups containing /j/ alone from returning results polluted by all the dejotation-groups. As I explored in my previous article (Winslow 2022), the status of /j/ as a phoneme in the earliest OCS texts is an intricate problem, so the ability to investigate the reflexes of *j in isolation from the dejotation-reflexes is important.

/j/

Word-initial *jĀ-/*a-

The tendency for ECS *ā- to have taken prothetic /j/ by LCS times (in accordance with the drive towards open syllables) can make it difficult to distinguish this group from *jĀ- in the absence of wider Indo-European evidence. Normally I've followed Derksen (2008), or the ESSJA (*Этимологический словарь славянских языков*, Trubačev 1974-), but for certain lexemes, e.g. *ama 'pit', which in OCS is spelt overwhelmingly with ѧꙗ- or ꙗм-, the single Greek cognate ἄμη adduced by ESSJa I p.70 in favour of jot-less *am- is not enough to categorically exclude the alternative *jĀma. In particular the 1sg. nom. pronoun *azъ/jĀzъ is especially problematic: I follow ESSJA I p.100 which ultimately plumps for *azъ, but Derksen doesn't discuss it at all. (A lengthy discussion of the evidence can be found in Teneva's (2012) article on the subject.)
Forms with insecure etymologies can't under any methodology be used as good evidence in phonological investigations, so in difficult cases like the above I simply mark the lemma in the database and provide some short discussion, so that eventually the web-interface can flag such forms in some way and inform users of the specific difficulties.

Like Derksen, I assume that roots going back to PIE jot-less long *ē or dipthongal *oi-, e.g. the root for 'to eat', PIE *h_1ēd-, all took prothetic *j and merged with *jĀ- from other sources, unlike Durnovo (1929: 54), who seems to think that such a development was limited to Bulgarian and Macedonian dialects, including those underlying OCS (where in the Cyrillic mss. we get regular ꙗсти etc.). Isolated nominal forms like Ru. *язва* (which Derksen (2008: 155) derives from a Balto-Slavic *oi- based on Lith. *aiža* and Old Prussian *eyswo*) suggest that *ě reflexes in the modern forms of verbs like Ru. *ехать*, Pol. *jeść* are later generalisations from prefixed forms like OR **ꙗѣсти**, where no jot-prothesis could take place (cf. Schenker 1995: 88, Winslow 2022: 302 fn.14).

Jers before *j

As explored more fully in Winslow (2022: 313-315), OCS spellings seem to suggest that free-variation between <ь,ъ> and <и,ы> was a feature of the pre-Jer Shift Urkirchenslavisch orthographic system for conveying the reflexes of the sound-groups *ьj and *ъj (so-called 'tense jers'), regardless of whether they were in strong or weak position. The examples given were: Zogr. ѳ҃ꙗ҃ѡ҃ѧ҃ѧ҃ѧ҃ѧ vs ѳ҃ꙗ҃ѡ҃ѧ҃ѹ҃ѧ <*znamenьjĀ, ѧꙁꙗ҃ь҃ѧ҃ѧ <*udaŕь-jь vs ѧ҃ѡ҃ѧ҃ѹ҃ѧ <*omočь-jь; Mar. ѧ҃ѧ҃ѥ҃ꙗ҃ѥ҃ѧ҃ ѧ vs ѧ҃ѧ҃ѥ҃ꙗ҃ѥ҃ѧ҃ ѹ <*osǫdętъ ‿jь; KF ѡ҃ѹ҃ꙗ҃ѧ҃ѧ҃ѥ҃ѥ vs ѡ҃ѹ҃ꙗ҃ѧ҃ѹ҃ѥ҃ѥ <*milostьjǫ, ѵ҃ѧ҃ѧ҃ѡ҃ѧ҃ѧ҃ѧ҃ѧ vs ѵ҃ѧ҃ѧ҃ѡ҃ѧ҃ѧ҃ѧ҃ѹ҃ѧ < *vьxomogy-jь). Of importance here is the fact that the same orthographic system characterises both pre- (i.e. KF) and post-Jer Shift texts; that even in strong position in a text like Zographensis, which shows pretty clear signs of having undergone the Jer Shift, spellings like ѧꙁꙗ҃ь҃ѧ҃ѧ, ѥ҃ѧ҃ѧ҃ѧ, ѵ҃ѥ҃ш҃ѧ҃ѧ for what in the live dialect underlying Zogr. must surely have been /udaŕij/, /boĺij/, /vęštij/, are not infrequent[10]. The fact that the same alternation occurs in the pre-Jer Shift KF (i-stem gen. plurals ѳ҃ꙗ҃ѡ҃ѧ҃ѵ҃ѧ҃ѧ <*zapovědьjь vs ѧ҃ꙗ҃ѧ҃ѹ҃ѧ <*ĺudьjь) suggests that it is a common inheritance from the Urkirchenslavisch spelling system, and thus that in pre-Jer Shift Slavic the difference between /ь ъ/ and /i y/ was neutralised before /j/, and we should perhaps posit archiphonemes (which I call /Î/ and /Ŷ/) in this position. These archiphonemes

10 Marianus and Psalterium Sinaiticum, on the other hand, frequently show a Russian-style /ej/ reflex of strong tense *ьj: Psal. ѵь҃ѥ҃ѧ <*vorbьjь, ꙗ҃ѧ҃ѥ҃ѧ <*plъtьjь, ѡ҃ѧ҃ѧ҃ѧ <*mьńjь; Mar. ѳ҃ꙗ҃ѡ҃ѧ҃ѧ҃ѹ҃ѹ <*zapověďьjь, ѧꙁꙗ҃ь҃ѧ҃ѹ <*udaŕь-jь, ѯ҃ѹ҃ѳ҃ѳ҃ѧ҃ѹ҃ѧ҃ѧ҃ѥ <*gvozďьjьny-ję̨. Psal. (Psalm 21) even has definite past. act. part. Nsg. masc. form ѯ҃ѣ҃ѧ҃ѧ҃ѧ <*jьstrgъ-jь that suggests an /oj/ reflex of *ъjь.

are, in slightly different terms, effectively posited by Trubetzkoy (1954: 70) in his analysis of the Urkirchenslavisch phoneme-system[11].
However, for simplicity and accessibility's sake it's better to avoid overburdening the indexing-system with unfamiliar and controversial archiphoneme-symbols, so I keep *ьj/*ъj as the denotations for these groups.

Difficulties arise though when deciding how to denote foreign sources of /ij/[12] which may or may not have been integrated into the native system as reflexes of /Îj/: words like марија < Μαρία, стадии < στάδιον, which are well-integrated into the morphological system as a fem. ja-stem and masc. jo-stem respectively, could either be reconstructed as consciously-foreign *marijĀ, *stadijь, or as nativised *marьjĀ, *stadьjь, but there are no occurrences of jer-spellings in these words in the OCS texts in TOROT. Other similarly-Greek words like диꙗволъ (< διάβολος), however, do show up in OCS with jer-spellings: Supr. дьꙗ́волꙗ, Zogr. Luke 8 and Psal. Psalm 108 ѩ҆ѯ҇дꙋѧѩѧ, which (alongside the modern Macedonian *ѓавол* with the reflex of *ђ produced by the Macedonian so-called 'new jotation' of /d/ after the fallen jer brought it into contact with /j/) clearly suggest an early adaption of this foreign /ij/-group to native /Îj/. Old Russian texts even show spellings of марија suggestive of full nativisation: Laurentian Primary Chronicle **м҃рьꙗ**, **м҃рьєю**, Zadonshchina **марꙗ**, **марьꙗ**, as well as First Novgorod Chronicle gen. sg. **васильꙗ** (jo-stem **василии** < Βασίλειος).
Since we can't ever be sure of the precise timing or route by which these late borrowings entered the various Slavic dialects, or of the extent of their adoption by Slavs beyond a tiny and often Greek-knowing scribal-class, the best solution is to set all such foreign /ij/ groups apart from the native vocabulary by using an *ij reconstruction, even where we can be pretty sure that early nativisation to reflexes of *ьj occurred: *dijĀvolъ, *vasilijь, *marijĀ etc.

Word-initial *jь-/*ji-/*i-
With native Slavic word-initial *ji-/*jь-, I follow Derksen's (2008: 16) practice of writing *jь-, even though Derksen himself (2003) has argued for a split between *ji- and *jь- conditioned partly by accentological factors (which, as stated above, I have chosen not to consider). Most of the modern languages reflect these groups as just /i-/, except for Czech and Ukrainian: forms like Cz. *jdou* and Ukr. (after vowels) *йдуть* appear to have dropped the weak-jer in *jьdǫtь just like any other and retained the /j/, and Ukr. *ськати* <*jьskati (with the restricted meaning 'look for nits/fleas in someone's hair' after the base-meaning 'seek' was taken over by the Polonism *шукати*) shows the expected Ukr. softening of the /s/ after fallen weak-jer in *ьsk groups (cf. *польський*).
I make an exception for certain forms of the personal-pronoun *jь, however, and write *jimь, *jima, *jixъ *jimъ and *jimi for the masc/nt. instr. sg. and dat./instr. dual/pl., because Czech here has *jim jich jimi*.
In badly-integrated clearly post-LCS foreign words, such as Biblical names like иꙗковъ (borrowed via Gk. *Ἰακώβ*), or ѥмонъ (< *ἡγεμών*), I keep a bare initial *i-, though this is rather an arbitrary choice and done partly as a way of marking such words as non-native[13] (cf. my treatment of foreign initial *e- below). An exception is made for исоусъ < Gk. *Ἰησοῦς*, which I have as *jisusъ, because of the greater likelihood that Slavs will have heard of Jesus even before the first biblical translations, and because spellings like Zogr. ѭ҇ѳ҇ ѹ҇ѳѳ suggest that it causes the same /Ŷ/

11 Though Trubetzkoy, like me, believes Urkirchenslavisch to have been based on a /j/-less dialect, so in that particular system the archiphonemes would be conditioned by the position before *vowels*, rather than before /j/.
12 The sequence /ij/ is not totally banned from native words, since it appears to be preserved across morpheme-boundaries, such as in prefixed-verbs like приꙗти <*prijęti or long-form adjectives like masc. nom. pl. дроугии <*drugi-ji, but within roots it does seem restricted to these post-LCS loanwords.
13 Spellings like Zogr. Mark 13:3 "ѩ҆ѡмьѩ. ѿ ѧ҆ꙗѯѩ. ѿ ѩ҆ѡ҆ѧѩ." "Peter and Jacob and John" would suggest that this initial *i- can get dropped after an /i/ of a preceding word, but whether this points to a dropping of the non-native *i-, simple deletion of a double /i i/ (haplology), or a native-like reflex of a weak-jer /*i *jьjĀkovъ/ > /i jakov/, is not really knowable, so indexing such words with a markedly foreign initial *ij- group is again the best way of allowing such difficult cases to be investigated.

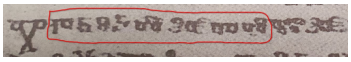
archiphoneme reflex of *ъ before *j as you get in e.g. native Mar. ѹѧѫ ѕѩᵐѕ҃ѯѥ < *vъ ‿ jьstinǫ (see above).
Prefixed forms like *do-jьti 'to come, arrive' for morphological reasons have to be distinguished from the class 4 verb *dojiti/dojiši/dojimъ etc. 'to breastfeed' (and its derived noun *dojidlika), a difference which is reflected in the modern Ukrainian *дійти* (<*dojьti with compensatorily-lengthened /o/ > /i/) vs *доїти*. Thus /i/ can follow /j/ when the former is part of a morpheme which just happens to be stuck onto a /j/-ending stem: I similarly allow words like *šujika (шюица) and *vojinъ 'warrior' (воинъ, as opposed to *vojьnъ, the gen. pl. of *vojьna), or the loc. sg/pl. desinences of any jo-stem noun whose stem ends on /j/, e.g. Psal. ѫьѧѣѧѫ <*žerbьji.

Word-initial *je-/*e-

No Glagolitic text makes any effort to distinguish /je/ (after vowels or word-initially) from post-consonantal /e/, writing both with <ѧ>, unlike the situation with the reflexes of *ję vs *ę, where in Zogr. and Mar. and partially in Assem. (Велчева 1981: p.168) the full front-nasal digraph <ѧє> is reserved for *ję, while just the second 'nasalising component' <є> is used for post-consontal *ę, e.g. Mar. 3rd pl. aorist ѧєѧ҃є <*jęsę, as opposed to KF ѣѫѧєᵐѯ <*prijęti vs ѹѧѹᵒѧєѧѫ <*vъzęli[14].
Glagolitic evidence alone therefore would suggest that foreign borrowings with word-initial /e-/ were simply adapted to whatever the reflex of native LCS *je was. Suprasliensis, though, which uses the jotated <ѥ> letter, does in fact make an extremely consistent spelling distinction between foreign borrowings and native Slavic words: of the 157 occurrences of the 13 foreign lemmas I have so far reconstructed with word-initial *e/*je- which appear in Supr. (*episkuръ, evanǵelьje, eǵürьtъ, elisavetь, elinъ, evanǵelistъ, eǵürьtьskъ, elinьskъ, episkuрьstvo, evrejьskъ, elisejь, emъmausъ, etijoрьskъ*), the only spellings with <ѥ> are ѥлисеи, Ѥ҃ппъ, Ѥ҃лини, and ѥ҃линѧ, i.e. 4/157 or 2.5%. By contrast, of the 3172 native Slavic words in Suprasliensis which I Autoreconstruct as starting with *je- (not all of whose *lemmas* start with *je-, e.g. forms of **byti*), just 88 are written with initial <є>, vs 3070 with <ѥ>[15]. Thus 97.2% of native word-initial *je- in Suprasliensis is spelt with <ѥ>, while 97.5% of the occurrences of the clearly post-LCS Greek-mediated foreign borrowings listed above instead use plain <є>, suggesting that *some* sort of difference was felt, at least by the scribes of Suprasliensis, and that we probably shouldn't index these with the same *je- as used for native forms. I therefore use non-jotated *e- for such foreign borrowings, and the extent to which they take prothetic *j- and fall together with the native vocabularly is left as something for investigators to determine based on the evidence of each manuscript.

Prefixes

The last particularity of my LCS indexing-system worth mentioning relates to the handling of consonant-clusters in prefixes: as exhaustively exemplified by Diels (1963: 121-125),
Common Slavic permitted only a restricted set of consonant-combinations in the syllable onset, generally either combinations of the continuants *s/*z plus obstruent or sonorant (except *r, see below), or of obstruents plus sonorant (with some curiosities such as the seeming dialectal diversity in the tolerance of *bn but not *pn: OCS гъıвнѫти <*gyb-nǫti > Ukr. *гинути*, vs OCS оусънѫти <*usъp-nǫti (cf. 3sg. aor. оусъпє), Ru. *тонуть* <*top-nǫti, though see Meillet (1965: 142)).
Geminate consonants were banned and either simplified (исѣшти <*jьs-sekti) or dissimilated (процвисти <*prokvit-ti).
The ban on *sr/*zr is dealt with by insertion of *t and *d respectively, but the commonly-cited examples of *str <*sr (сестра, строуıа, остръ) all concern root-internal *sr where insertion of *t is

14 Psalterium Sinaiticum contains at least five occurrences of non-digraph <є> for *ę: Eckhoff's digitisation suggests ѿьѧѯ҃є, ѹѧѹᵒѧѧıѧ҃є, ѕᵐѧѯ҃є, ᵐ҃є, ꙗ҃є, and ѣьѧıѧ҃єᵐѧ, but the last one ѣьѧıѧ҃єᵐѧ (which is from Psalm 151 in the part discovered in 1975) comes from a mistake in Mareš's (1997: 50) Cyrillicised edition: the manuscript-photograph in Tarnanidēs (1988: 260) clearly shows ѣьѧıѧ҃ѥᵐѧ: 

15 The leftover 14 are things like 1st. pres. dual. и҃мавѣ which Eckhoff's corpus wrongly lemmatises as имати instead of имѣти, and which thus get reconstructed as *jemĺevě instead of *jьmavě. At the time of writing only 3227/6862 Suprasliensis lemmas have been reconstructed, but those 3227 cover 89713/99194, or 90.4%, of the words.

common also to the Germanic and sometimes Baltic cognates. The examples given by Meillet (1965: 136) include: (for строуꙗ) Lith. dial. *srauja* next to Latvian *strauja*, then Germanic *straum- (> Eng. *stream*, Old Norse *straumr* etc.); (for остръ) Lith. *aštrus*, Gk. *ἄκροϛ* (here the *s is from PIE *ḱ). As Meillet says, "*ce n'est pas un developpement germano-balto-slave ; d'une part, le developpement d'un* -t- *dans le groupe* sr *est chose naturelle et se retrouve ailleurs (fr. pop.* castrole *de* casserole*) et, d'autre part, le developpement de* t *en ces conditions n'est pas general en baltique:* str *est regulier en lette, mais* sr *subsiste couramment en lituanien.*", so we can't really be sure when the Slavic change took place or whether it was still active during our LCS stage. The only indication of its activity in OCS is the single Psal. ѹ҆ѡрьѡѡѡѡ <*sorm-omь spelling cited by Diels (1963: 122); otherwise new /sr/ from metathesised *sErC groups is tolerated unchanged.

New occurences of *zr, on the other hand, are regularly generated in the language right up to OCS times, not only in the derivational-morphology because of the verb-prefixes *orz-, *vъz-, *jьz- (e.g. Supr. 3sg. aor. въздрꙋ 'roared', from *vъz-ruti), but also because of the clitic prepositions *jьz and *bez, which form one phonological word with whatever follows them and thus cause OCS spellings like Mar. Luke 1 ѹ҆рѧьѥѣ <*jь.z ‿rǫ.kъ. Meillet (p. 136) also cites the Old Polish adverb *zdręki* <*jьz ‿rǫ.ky, which proves that the phenomenon is not limited to SSl. or OCS. Curiously, though, despite this overwhelming evidence of a synchronic /zr/ > /zdr/ rule in OCS, /zr/ from the metathesised *zork- root is never spelt <здрак> and so seems to be tolerated, even though Diels cites prepositional forms like Supr. бєздрѧзꙋма <*bez ‿*orzuma, бєздрала <*bez ‿*ordla, which come from metathesised *orT- groups but *do* show inserted /d/. Such inconsistency is hard to explain unless the addition of /d/ has been partly morphologised as a variant of specifically the prepositions before /r/.

With such a sound-change that appears most often at morpheme or straight-up word-boundaries, there is a strong drive to restore the underlying shape of the constituent parts, hence the modern languages have mostly restored /zr/ groups in e.g. Russian *разрешить*, and there are traces of this even in Psalterium Sinaiticum: Psalm 48 ѹ҆рьѣѥѣѳ (Diels 1963: 122). In Old Russian, the Uspenskij Sbornik is pretty consistent in keeping prefixed verb-forms like **разрушнть** <*orzrušitь, but by the time of the Laurentian Codex we get forms like **бъзрадуєм** and **неизрєуєннoє**. Therefore even though *sr > *str and *zr > *zdr appear to be simply voiced and unvoiced variants of the same sound change, the practical effects are very different because the former is, from the LCS perspective, totally 'opaque', since it only occurs in roots and thus is not analysable by speakers into constituent morphemes without the inserted stop, in the way that /bez ‿drǫky/ can be identified with separate /bez/ and /rǫky/.

For this reason I don't include /zdr/ <*zr at prefix or preposition-boundaries in my LCS system, so that investigators can see for themselves the extent of each text's adherence to the expected phonological development vs restoration of /zr/ under morphological pressure.

Following the same logic I also retain illegal *ss and *sš groups in prefixed-verbs like Psal. ѹ҆зѥѧѥ <*jьs-sęče, Mar. ѿшѧьѧѣ <*jьs-šьdъ, Assemanianus ьѩшѿьѧѹєѹ <*ors-šiŕĀjǫtъ, because that same drive towards restoration of the underlying shapes of the prefixes *jьs-/*ors- etc. can be seen in modern Russian *исс*якнуть, *рас*ширять*, and Laurentian Codex **расшєдшє**.[16] This treatment is also more consistent with my handling of verbs like *jьs-kěliti (> OCS ищѣлити/исцѣлити) where simplification *must* have occurred posterior to our pre-PV2 LCS stage (since /sk/ is always totally

16 Conversely, sequences of *sk, *zg at prefix-boundaries which show PV1 reflexes, like Mar., Zogr. ьѩшѡѡѡѡ <*orš-čьtetъ (ECS *skĭt- > *ščĭt-), Psal. ьѩѯьѿѩѡѡ <*orž-ǯigajetъ (ECS *zgīg- > *žǯīg-) are kept as *ščˇ, *žǯˇ. Such forms may well not go all the way back to the time of PV1, and instead be just the result of a synchronic rule prohibiting /zž/ and /sč/ (> /žǯ/ and /šč/) that remained active until much more recently, especially given prepositional-phrase forms like Psal. ѿшѡьѧѹѩ <*jьs‿*červa, so this is arguably inconsistent with my treatment of *ss, *sš etc. My justification is firstly that *sk, *zg > *ščˇ, *žǯˇ are *conspicuously* PV1-changes, which we *know* originated well before our target LCS point, whereas the precise timing of de-gemination or simplification of *sš is less clear-cut; and secondly that even in languages like Russian which *orthographically* have restored <сч> and <зж> spellings in compounds like *исчезнуть* and *разжечь*, the pronunciations are still arguably direct reflexes of LCS *ščˇ and *žǯˇ, viz. [ɕː] and [ʐː] (or, in the conservative Moscow-dialect, the palatalised [ʑː] found also in дождь <*dъžďь).

permissible), and where manuscripts show great diversity, e.g. Zogr. and Assem. consistently have ѕ҃ѵ҇ѧѧ- while Mar. and Psal. keep ѕ҃ꙋ҇ѧѧ- (more discussion of the wider Slavic reflexes of this group, including the OCS <ст> spellings, can be found in Meillet 1965: 133).

Morphological innovations that scupper LCS reconstruction

The units of the phoneme-system sketched above serve as the building-blocks for all higher-level linguistic systems, most immediately the inflectional-morphology and derivational-morphology systems, whose features are thus constrained by said phoneme-system and the distributional-restrictions of its units (i.e. *phonotactics*). Changes which occur in the phoneme-system between the time of our theoretical LCS and the time of our texts can therefore trigger (or allow) restructuring of these morphological systems, which in turn can produce forms containing phoneme-sequences with no direct LCS ancestor-sequences.

An example of such morphological change contingent upon structural phonological change, leading to forms which preclude any direct LCS-stage reconstruction, is the replacement of i-stem endings with those of the corresponding jo- or jā-stems, in nouns whose stems end on labials or the subset of LCS dental consonants which lack palatal counterparts, viz. /d t s z/[17]. Evidence for such a change is furnished by the Old Russian masc gen./acc. form **тата** from the 1229 Treaty between Smolensk, Riga and Gotland (Version A). LCS *tatь is a masc. i-stem noun with genitive *tati, as it still appears in the Suprasliensis translation of John Chrysostom's Homily for Holy Thursday (…то кажетъ владъıкъı ѵловѣколюбьıѥ· ꙗко прѣданника ра҃збоиника тати…), but in the dialect underlying the 1229 Treaty the rise of phonemically palatalised /t'/ after the Jer Shift means that the stem (and the nom. sg. **тать** /tat'/) of this noun now ends on the same class of "soft" consonants as original jo-stem nouns like *końь > /kon'/, where the original LCS palatal *ń has fallen together with secondarily-palatalised /n'/ from plain LCS *n before LCS front-vowels, in e.g. the original i-stem *bornь > /boron'/. This system thus no longer distinguishes between descendants of the original LCS palatals and the newly secondarily-palatalised consonants like /t'/: both are now together in the set of 'soft' consonants, opposed to their 'plain' or 'hard' counterparts, and so tend towards taking the same set of inflectional endings (in this case those of the original jo-stems)[18]. Consequently, a word like **тать** has begun to take jo-stem endings, including the Old Russian /a/ reflex of LCS *Æ in the genitive/accusative singular.
LCS /Æ/, though, by definition can only occur after LCS palatal consonants (see above), so a reconstruction *tatÆ is just nonsensical. In the case of the dat. sg. /u/-desinence (which isn't attested in our Treaty but exists in modern Russian *матю*), we don't even have an LCS archiphoneme available to signal a preceding soft-consonant; there's simply no way of getting from LCS *tatu to Russian /tat'u/, because such a form was only made possible by the rise of phonemic /t'/, so our ability to index it with our LCS system is gone.

Were the same shift from i-stem to jo-stem to occur in a word like *zvěrь, then the structural change would not be so catastrophic, because our LCS system *does* contain a palatal *ŕ which any allophonically-softened LCS hard *r could easily be subsumed into. Indeed, interestingly Suprasliensis does in fact contain 3X gen. sg. звѣрѣ, with what looks like a jo-stem reflex of *ŕÆ (spelt with jat' as an overhang of the Glagolitic tradition, cf. 2X морѣ vs 1X морꙗ spellings),

17 In some dialects (notably East Slavic) the PV3 reflexes *ś and *ʒ became patalised counterparts to plain /s z/, i.e. /s' z'/, and merged with the /s' z'/ that developed from LCS *s,z before front-vowels, but in most OCS they seem to have just hardened to /s, z/: searching my database for the sequence *ьxǫ, for example, turns up exclusively <ѯѧ> spellings in Marianus, just one <ѯѧє> in Zogr., and exclusively <сѫ> in Suprasliensis, with only Assem. and Psal. containing a significant minority of <ѯѧє> spellings.

18 Russian feminine i-stems like *весь* (<*vьsь, 'village') do not fall together with ja-stems in the way the masculines like *zvěrь fall together with jo-stems, but they do all still take the /am, ax, ami/ endings in the dat., loc. and instr. pl., e.g. *ве́сям*, which contain the same LCS ja-stem *-Æ- vocalism which can only occur after LCS palatals, meaning they too end up totally unreconstructable due to an illegal **sÆ sequence.

suggesting that Russian-style secondary palatalisation of *r > /r’/ may have occured in the Bulgarian dialect underlying it[19]. You don’t, though, get anything like ⰤⰐⰤⰐ[20], so the system-wide development of secondary-palatalisation does not seem to have advanced enough to have caused the sort of fundamental structural reorganising which shifted *tatь into the jo-stems in Old Russian.

Forms like ⰤⰐⰤⰐ, then, though they frustrate our goal of reconstructing entire texts, do provide us some objective measure of ‘linguistic distance’ between stages of a language, because their existence presupposes at least one intervening stage where the structure of the phonological system has changed enough from our LCS stage to have caused/allowed restructuring of the morphological system.

1.2 LCS Morphology and the Autoreconstructor

The ten-place morphology-tags included as part of the word-level annotations in Eckhoff’s TOROT corpus constitute a veritable goldmine of linguistic data, because, based as they are on the *form* of a word rather than the *function*, they bridge the gap between the higher (syntax, semantics etc.) and lower (phonology, orthography, morphology) levels of linguistics analysis. An example TOROT annotation for the word ѵѡѳѹѵѧшѡѥ is given below:

```
<token id="3589172" form="възвѣштѫ" citation-part="70.17"
lemma="възвѣстити" part-of-speech="V-" morphology="1spia----i"
relation="pred" presentation-after=" "/>
```

Figure 1: TOROT annotation for Psal. Sin. Psalm 70 ѵѡѳѹѵѧшѡѥ in XML format

TOROT token XML-tags include various attributes, but for the Autoreconstructor all that’s needed are *form*, *lemma*, *part-of-speech*, and *morphology.* The *form* attribute is used to check for morphological variations/innovations, to ensure that what gets produced is the direct phonological ancestor of the actually-occurring word (see below for more about this deviance-detection). The *lemma* and *part-of-speech* attributes, when concatenated, serve as a unique key linking each word to its lemma[21] and thus to its LCS reconstruction and inflexion-class information[22]. Finally the *morphology* attribute consists of a 10-character string to hold values for the 10 morphological-features used by TOROT (and the wider PROIEL corpora). Not all features are relevant for all words, in which case a dash ‘-’ is used as a placeholder.
A detailed explanation of each feature can be found in Section 6 of Eckhoff et al. (2018: 41), but here it suffices to say that in this example the tag “1spia----i” is telling us that ѵѡѳѹѵѧшѡѥ is **1**st person, **s**ingular, **p**resent-tense, **i**ndicative-mood, **a**ctive-voice, has no gender, case, degree, or strength features, and is **i**nflectable rather than non-inflecting.

Of importance here is the *present* tense tagging, even though вѫзвѣстити (even in OCS) can be taken as a perfective verb, opposed to its imperfective counterpart вѫзвѣщати, and thus has future-

19 Numerous spellings in Supr. like воура <*buŕĀ, оукаралѣтъ <*ukaŕĀjetь, мороу <*moŕu etc., however, point to a hardening of LCS palatal *ŕ to plain /r/, so it’s difficult to know whether звѣрѣ spellings stem from a genuine /zvěŕa/ form in the history of the language, or if they instead represent synchronic /zvěra/, i.e. with a hard o-stem ending, but with confusion by the scribe between <ра> and <рꙗ>/<рѣ> spellings for what in his/her dialect would’ve all been /ra/.

20 Except the numerous gen. sg. господа and dat. sg. господоу for the i-stem *gospodь, but this word seems to be an isolated special case, because it bafflingly turns up even in early Glagolitic OCS with endings like ѻ҃ѵѵ (ju-stem dat. sg. *-evi, cf. Supr. господеви), ѻ҃ѵ (jo-stem dat. sg. *-u), and ѻ҃ѧ (jo-stem gen. sg. *-Ā). See Van Wijk (1929).

21 Identical lemmas with the *same* part-of-speech tag, such as вести ‘to lead’ <*ved-ti and вести ‘to drive’ <*vez-ti, both of which have ‘V-’ for verb, are differentiated by appending #2 etc. to the extra homomorphs, i.e. вести vs. вести#2.

22 The spreadsheet containing my reconstructions and inflection-class annotations for the TOROT OCS lemmas can be downloaded from https://github.com/12401453/torot_2023/blob/main/lemma_lists/chu_lemmas_master.xlsx

tense meaning in its non-past indicative forms (and the Greek Septuagint here has ***ἀναγγελῶ*** *τὰ θαυμάσιά σου*, with a morphologically future-formed *ἀναγγελῶ* ‘I will proclaim’ from *ἀναγγέλλω*). The tagging thus follows the *inflectional*-morphology of ѹѩѹѧшѥ, rather than the future-meaning which is carried by the *derivational*-morphology. This is important because the Autoreconstructor works by *inflecting* LCS lemmas according to those morphology-tags; the annotation gives no information about its derivational-morphology or derivational relationship to its imperfective (and thus 1sg. *present* tense) counterpart ѹѩѹѧшѥ, since that is annotated with a separate lemma.
An even clearer example where this *form* over *function* annotation helps us is with the accusatives of animate nouns: it’s well known that a type of so-called differential-object-marking is beginning to take hold in Early Slavic, whereby syntactic accusatives use genitive endings to varying extents as a way of encoding the semantic ensouledness (and possibly definiteness) of the noun (the details aren’t important; for a recent thorough diachronic treatment of the topic see e.g. Eckhoff 2022), e.g. Supr. ꙗзбоѝника въ пороѧѫ вьѣведе ‘he brought the robber into paradise’. If these were all tagged as accusatives, the Autoreconstructor would produce the wrong ancestor to the text-form, i.e. *orzbojьnik-ъ, because the semantic information needed to decide whether this differential-object-marking is needed is not available. Happily though all such animate-accusatives are marked as genitive in TOROT: the morphology-tag for ꙗзбоѝника above is “-s---m**g**--i”, so the Autoreconstructor produces *orzbojьnik-a.

The Autoreconstructor reads the morphology-tag character-by-character and numerifies each field, and from that it computes a number which corresponds to the row of the inflection-table where the endings for that particular word’s inflection-class are stored. For verbs this will be a number between 1 and 44 (9 person/number combinations for each of present, aorist, imperfect, and imperative, plus 8 non-finite forms, 9*4+8), and for nominals between 1 and 63 (7 cases * 3 numbers * 3 genders). A version of the function which actually implements this tag-reading process can be seen in the OcsServer::numerifyMorphTag() function here: https://github.com/12401453/ocs_server/blob/main/OcsServer.cpp#L2714.[23]

Currently each inflection-class has up to three tables associated with it, the first of which is full (i.e. contains 44 or 63 entries) and holds the ‘basic’ or ‘correct’ (from the LCS perspective) endings. The second and third tables are ‘sparse’, in that they only contain entries for those parts of the paradigm where we expect to encounter alternative forms, with those I consider ‘deviant’ or ‘innovated’ held in table 2, and ‘alternative’ but still ‘correct’ endings (i.e. LCS allomorphs) in table 3. An example of some of the endings in the three tables for basic class 1 verbs like *rěći is given below:

23 Extra handling is required for forms of *byti, since that has a separate future-paradigm (and future-participle) which TOROT does actually specify separately with an ‘f’ value for the *tense* feature, as well as two variant imperfect sets (3sg. *bě vs. *běaše, which aren’t tagged, but which I detect), and a ‘conditional’ *bimь, *bi, *bǫ etc. Participles require an extra step to read their nominal-features and add their adjective-like endings.

```
inner_map v_11_c0 = {
{1, "ǫ"},
{2, "eši"},
{3, "etǫ"},
{4, "evě"},
{5, "eta"},
{6, "ete"},
{7, "emь"},
{8, "ete"},
{9, "ǫtǫ"},
{10, "ь"},
{11, "e"},
{12, "e"},
{13, "ově"},
{14, "eta"},
{15, "ete"},
{16, "omь"},
{17, "ete"},
{18, "ǫ"},
```

```
inner_map v_11_c1 = {
{6, "eta"},
{10, "oxь"},
{13, "oxově"},
{14, "osta"},
{15, "oste"},
{16, "oxomь"},
{17, "oste"},
{18, "ošę"},
{24, "ěašeta"},
{37, "ǫtj"},
};
```

```
inner_map v_11_c2 = {
{10, "sь"},
{13, "sově"},
{14, "sta"},
{15, "ste"},
{16, "somь"},
{17, "ste"},
{18, "sę"},
};
```

*Figure 2: Inflection-endings for class 1 verbs like *reħi, *greti stored using C++ std::unordered_map<int, std::string>*

Here the ‘deviant’ endings consist mostly of the ‘extended S-’, or *-ox- aorists (e.g. Assem. ҂ѧѣѣѣшє), while the third ‘alternative’ table contains the primary S-aorist endings (e.g. Assem. ҂ѳѯѣѧѧє <*pogrěb-sę). Clearly those primary S-aorist endings just being stuck onto a stem like *greb- would not produce the correct LCS form, so for certain inflection-classes there are post-processing functions which do things like replace all “ebsę” with “ěsę”, or (for stems which end on RUKI-consonants like *rek-) all “eks” with “ěx”. The full routines for verbs can be found in https://github.com/12401453/ocs_server/blob/main/autoreconstructor/verb_cleaning.h; to a large extent this is just enforcing the Slavic consonant-cluster restrictions discussed in Section 1.1.

The inflection-tables themselves are indexed by integer-keys associated with each inflection-class, such that the ‘correct’ table’s key always ends on ‘1’, meaning that shifting to the alternative tables is a matter of simply incrementing the key by either 1 or 2, and I can keep track of whether or not a form has required a deviant or alternative ending by inspecting the final value of this key[24]:

```
std::unordered_map<int, inner_map> verb_ = {

  {111, v_11_c0},
  {112, v_11_c1},
  {113, v_11_c2},
```

Figure 3: Integer-keys of the three inflection-tables in Figure 2

Multiple inflection-classes can share the same tables, for instance the *masc_o*, *nt_o*, and *fem_a* noun-classes all take endings from the *adj_hard* table, since the same set of 63 endings (21 for each gender) is used in all four paradigms[25].

24 This is bad design and prevents me from easily handling more than one type of morphological innovation per class: for the *masc_jo* class nom. pl. I have the i-stem *-ьje ending in the ‘deviances’ table (as found in e.g. Supr. стѫжиѥ <*storž-ьje ‘guards’), which leaves no room for forms like Supr. знѡєвє <*znoj-eve, Psal. ѕмѣѣѣѣѣѣ <*zmьj-eve, which have the *-eve ending from the ju-stems.

25 The long-form adjectives (and participles) are then formed by just sticking the inflected-form of the pronoun *jь onto the end, since this is the origin of such long-forms (Vaillant 1942). I agree with Townsend and Janda (1996: 178) that some simplification of these concatenated endings must have occurred by LCS, especially where the short-form endings contain *m or *x (e.g. the dat. and loc. pl. for all genders), because it’s unreasonable that e.g. Mar. Matt. 24 masc. loc. pl. ҂ѣѣѣѣѣѣѣѣѣѣѣ could've developed directly from *nebesьskěxъjixъ (here not least because of the lack of PV2-reflex). I am however relucant to adopt the (undiscussed) simplified LCS forms they present in the tables on p. 182-3 before I've done a more thorough investigation of early manuscript-forms, so for

Full paradigms for the 4,500-ish OCS lemmas I have so far reconstructed can be dynamically generated here https://ocstexts.co.uk/words; these are constructed from LCS lemmas in the same way the Autoreconstructor reconstructs individual forms, except it produces every form in the paradigm, rather than just the one specified by a text-word's morphology-tag. The LCS forms are then converted into 'normalised' OCS by the browser using the convertToOCS() function here: https://github.com/12401453/ocs_server/blob/main/HTML_DOCS/LCS_to_OCS.js#L197.

Figure 4: Dynamically-generated paradigm for the OCS verb **сътрьти**, *based on the Autoreconstructor's computerised LCS inflectional-morphology*

The accuracy of the generated-forms can then be gauged by comparing them to tables populated only by forms which actually occur in Eckhoff's corpus-texts, using the 'Corpus-forms' switch:

now I've left all such adjectives wholly uncontracted (though the Autoreconstructor does actually mark long-adjectivals that contain such problematic concatenations and this information could be used to exclude them from searches).

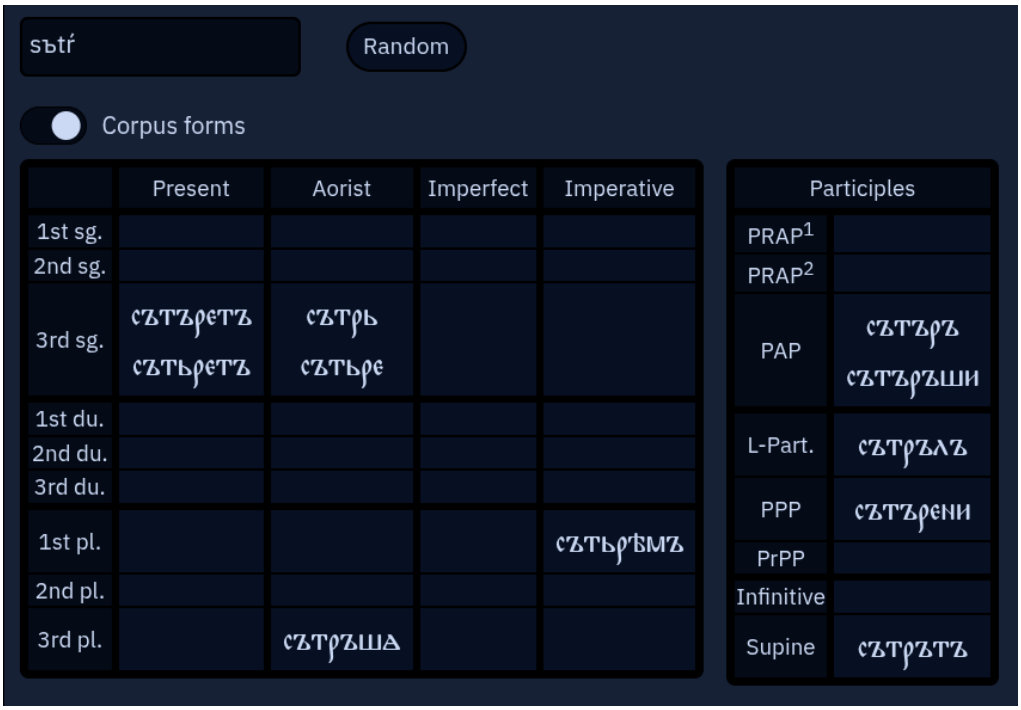


Figure 5: Forms of the same сътрьти *verb as they actually occur in Eckhoff's (Cyrillicised) TOROT corpus of Church Slavic texts*

Deviance detection

217066	приведоша	3paia----i	privedošę	privedǫ
217101	въздъхнѫвъ	-supamn-si	vъzdъxnǫvъ	vъzdъxъ
217112	разврьзосте	3daia----i	orzvŕ̥zoste	orzvŕ̥zete
217261	бгвивъ	-supamn-si	bolgoslovivъ	bolgoslovĺь
217266	ѣша	3paia----i	jÆšę	jÆsę
217272	вьзаша	3paia----i	vъzęšę	vъzęsę
217302	начаша	3paia----i	načęšę	načęsę
217316	въздъхнѫвъ	-supamn-si	vъzdъxnǫvъ	vъzdъxъ
217455	приведоша	3paia----i	privedošę	privedǫ
217600	начать	3saia----i	načętь	načę
217605	сн̄оу	-s---md--i	synu	synovi
217635	начать	3saia----i	načętь	načę
217787	поѭть	3saia----i	pojętь	poję
217832	мосѣомь	-s---mi--i	mosijomь	mosijemь
217856	мосѣови	-s---md--i	mosijovi	mosiju
217869	быс	3saia----i	bystь	by
217960	сн̄ѣ	-s---ml--i	synĕ	synu
218067	невѣрьнъ	-s---mvpsi	nevĕrьnъ	nevĕrьne
218108	быс	3saia----i	bystь	by
218173	нѣмы	-s---mvpwi	nĕmъjь	nĕmejь
218175	глоухы	-s---mvpwi	gluxъjь	glušejь
218198	бысть	3saia----i	bystь	by
218206	оумрѣтъ	3saia----i	umertь	umer
218388	ѥмени	-s---nl--i	jьmeni	jьmene
218419	ѥмени	-s---nl--i	jьmeni	jьmene
218561	окомь	-s---ni--i	okomь	očesьmь
218648	мѫжю	-s---md--i	mǫžu	mǫževi
218688	мѫжа	-s---mg--i	mǫžĀ	mǫžu
218755	прѣлю̄бы	-s---fa--i	perĺuby	perĺubъvь
218762	поустивъши	-supafn-si	pustivъši	pušťьši

Figure 6: Auto-detected and -reconstructed morphological deviances from a small part of the Book of Mark in Codex Zographensis

The screenshot above shows some raw data from my autoreconstructed SQLite database of the TOROT OCS texts; in this case it's forms from Zographensis (around Mark 7 to Mark 10) where the Autoreconstructor has detected morphological innovations. The fourth column shows what the Autoreconstructor thinks is the direct phonological ancestor to the text-form, but the ancestor of the 'original', 'correct', or 'default' morphological form is also generated and stored in the fifth column, so that such cases of innovation can be easily searched-for and counted (since non-innovated forms have NULL values in this column).

Types of innovation detected here include:

- extended S-aorists of class 1 verbs: 3rd pl. приведоша vs. приведѫ, 3rd dual разврьзосте vs *разврьзете[26]
- unetymological extension of the RUKI-rule-produced *š in 3rd pl. primary sigmatic aorists: ѣша vs. ѣса <*jÆd-s-ę, вьзаша vs. възаса <*vъzьm-s-ę, начаша vs. начаса <*načьn-s-ę (neither *d, *m, nor *n have ever been RUKI sounds)
- extension of the *-nǫ- suffix to the past. act. part. of class 2 verbs like въздъхнѫти: въздъхнѫвъ (cf. Mar. ꙗꙋꙗꙗшѥ from оусъхнѫти)

26 Koch (1990: 293) lists only sigmatic aorists as possibilities for the *-verz-/*-vŕ̥z- stem verbs, and it seems that outside of the 3rd sg. (e.g. Psal. ьѩꙋꙋьꙗꙋѩ, Zogr. ѧмꙋꙋьꙗꙋѩ) no root-aorists are attested in any Slavic text, so maybe I am wrong to set up asigmatic root-aorists like 3rd dual *-vŕ̥zete as a possibility alongisde primary sigmatic *-verste (e.g. Mar. Mark 7 ьѩꙋꙋьꙗꙋѩ). My justification is that the *-verg-/*-vŕg- stem verbs *do* attest such root-aorists, e.g. 3rd pl. ѧмꙋꙋьꙗꙋѩ in Psal. Psalm 77, and I don't see what, apart from the nature of the final stem-consonant (obstruent vs. continuant), could be grounds for classifying these two verbs differently.

- addition of the *-tQ suffix from the 3rd sg. pres. (see fn. 5 above) to 3rd sg. aorist forms: ꙗꙋѧтъ, поѩтъ, оумрѣтъ
- original u/ju-stem nouns taking o/jo-stem endings: dat. sg. с҃ноу, мѫжю; loc. sg. с҃нѣ, gen. sg. мѫжа
- past act. part. of class 4 verbs using the suffix *-ivъ rather than *-jь: б҃гвивъ, поустивъши (cf. Mar. Mark 10 ꙋѯшедшꙋ <*pust-jьši)

Deciding upon the "correct" morphological endings for an unattested language inevitably entails some uncertainty and controversy: for instance, *-ox- aorists occur in both OCS and Old Russian, so why do I consider them LCS deviances? Basically because they **never**[27] occur in Marianus, which would be quite improbable if they were a discarded archaism (especially given their ubiquity in the closely related Zographensis).
In other cases we are dealing with hodge-podge paradigms which are only ever attested with endings from multiple older classes, and sometimes dialectal or orthographic features of the manuscripts can make it difficult to distinguish potential LCS ancestors of certain endings. For instance, I have a *masc_tel* class used for agent-nouns like OCS дѣлателъ (i.e. Diels 1963: 166), which in the sg. and dual. behave exactly like masc jo-stems, but which in the gen. and instr. plural are attested also with basically consonant-stem endings on a hard *-tel- stem, e.g. Zogr. ѡтєѫѧмѣѧ <*tęžĀtelъ, Supr. свѧтителꙑ <*svętitely. The nom. pl. appears also to take a consonant-stem *-e ending, but as Diels (op. cit.) points out, the spellings in Zogr. and Supr. (where use of the palatalisation-diacritic <ˆ> to denote LCS *Í is consistent enough to suggest a real phonemic /Í/ in the underlying dialects) like мѫчитєлѣ[28] mean we can't follow Meillet (1965: 426) in setting up *-tele as the 'correct' ending, because spellings like ѫєѡмѣѧѣ in Mar. could just as easily descend from *žęteĺe as from *žętele. Absent a manuscript which both consistently marks *Í *and* doesn't use such a mark in this nom. pl. desinence, there's no hard evidence of this *-tele ending ever actually existing. I thus use *-teĺe in the 'correct' table, and the jo-stem *-teĺi in the 'deviances' table[29].

Overcoming poor lemmatisation practice

Sometimes Eckhoff's lemmatisation is too coarse-grained, in that forms which clearly descend from distinct doublets are subsumed under one lemma. To demonstrate just one example of how the Autoreconstructor deals with this sort of problem, take the numeral ѥдинъ <*jedinъ, which in the earliest OCS has straightforward hard pronominal endings and which therefore goes in my *pron_hard* class alongside demonstratives like *onъ. There is, however, what must be viewed as an LCS doublet *jedьnъ[30], which gives e.g. Serbian *jedan* and the modern Russian fem. nt. and oblique-case forms *одна, одного* etc., and which is used for the majority of non masc. nom./acc. sg. forms of the pronoun in Suprasliensis[31], e.g. ѥд҆номоу. Notwithstanding Eckhoff's habit of

27 Having Autoreconstructed all of Marianus I can verify this (admittedly already well-established) fact far more quickly and easily than was possible just with Eckhoff's morphology and part-of-speech annotation-information: using TOROT the smallest net you could cast would be one that caught all aorist-tense verbs, whereas I can just search for reflexes of *oxъ, *oxov, *oxom, *ošę, *osta$, and *oste$ (the latter two using 'regular-expression' mode and $ to specify end-of-word), which for Mar. turns up nothing except the three occurrences of ѧѯмѣ.

28 Searching my database for *teĺe$ returns only a single власте́ле in Supr. without the diacritic; everything in Zogr. has it.

29 Diels mentions only Psal. Psalm 26 ѯѣѵѧѩѧмѣѧѣѵ, but the Autoreconstructor is intended for use with other early texts beyond canonical OCS which might also contain this type of assimilation to the jo-stems.

30 This despite Meillet's (1965: 144) incoherent speculation about the /i/ in *jedinъ resulting from a phonetic development of strong *ь, analogous to what happens in the vicinity of *j, because "or il s'agit d'un composé dont le second élément est *jĭnŭ*". While this interpretation of *jedinъ's derivation could be true (and according to Derksen's (2008: 212) etymology of the*jьnъ pronoun, its *j is prothetic, meaning it wouldn't develop if already attached to a stem ending in *d), the idea that a synchronic *-dьnъ by any purely phonological means could become /-din/, let alone early enough to completely displace by analogy the oblique forms in the earliest OCS where ѧѣѹр-spellings are overwhelming, is ludicrous and contradicted by all the philological evidence.

31 According to my database there are 145 reflexes of *jedьn- in this category vs 46 from *jedin-, though all 107 reflexes of the masc. nom./acc. sg. are from *jedinъ. Interestingly the Uspenskij Sbornik, in contrast to later

lemmatising these with ѥдинъ instead of ѥдьнъ, it's trivial for the Autoreconstructor to check the form (which has in a previous step already been aggressively normalised to get rid of morphologically-irrelevant variation) for a <дін> sequence, which would never occur in the inflexional-ending and so always point to a *jedin-descended stem, and then replace our autoreconstruction with *jedьn- if such isn't found:

```
 // check for *jedьn-
if (lemma_ref.lemma_id == compileTimeHashString("Рхѥдинъ") || lemma_ref.lemma_id == compileTimeHashString("Маѥдинъ"))
{
  if (Sniff(cyr_id, "дін", 20) == false)
  {
    stem = "jedьn";
  }
}
```

*Figure 7: Part of the Autoreconstructor's code which checks for reflexes of *jedьn- that TOROT has mistakenly lemmatised under* ѥдинъ

In the long-term TOROT itself should fix such lemmatisation problems, but in the meantime checks like the above are computationally extremely cheap and prevent great swathes of the texts from being wrongly autoreconstructed.

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