# Archaic cuneiform numbers

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# 1 Summary

This document proposes encoding some numerals used in the Uruk and Early Dynastic periods in conjunction with the Sumero-Akkadian cuneiform script<sup>1</sup> and the proto-cuneiform script<sup>2</sup>. The proposed characters are listed in section 2.

The non-numeric signs of proto-cuneiform will be the subject of a separate proposal; we need only note here that the divergence between the approaches to character identity in modern scholarship requires that proto-cuneiform be disunified from cuneiform: proto-cuneiform is effectively treated as an undeciphered script. In contrast, the cuneiform encoding model is semantic, requiring an understanding of the text to correctly encode it.

However, the *numerals* used in proto-cuneiform should be unified with ones used in the Early Dynastic period, for the reasons set forth in section 4. The proposed "curved", or "curviform", numerals<sup>3</sup> should however *not* be unified with the already-encoded cuneiform numerals<sup>4</sup>. Since the encoding proposals for the cuneiform script twenty years ago provisionally considered the curviform numerals to be glyph variants of the cuneiform numerals, a detailed rationale is provided in section 3, including compatibility considerations in section 3.7.

The overall picture of unifications and disunifications over time is illustrated in table 1. The Script\_Extensions property assignments in section 2.2 reflect the overlap.

[TODO(egg): Mention the other sections here too.]

	Uruk III & earlier	ED – Ur III	OB & later
Numerals	This proposal		
Numerals		Fyictin	a Yeny
Non-numeric signs	Future Pcun	Existing Xsux	

Table 1: Usage of existing, proposed, and future characters across functions and time periods.

 $<sup>^1</sup>$ lSO 15924: Xsux, Script property value long name: Cuneiform; encoded since Unicode Version 5.0.  $^2$ lSO 15924: Pcun, not yet encoded.

 $<sup>^3 \</sup>bowtie -1111 - 9(aš^c = N_1), \cdot - # 1 - 5(u^c = N_{14}), \triangleright - \frac{11111}{1000} 1 - 9(neš_2^c = N_{34}), \bowtie - \frac{111111}{1000} 1 - 5(neš_1^c = N_{48}), \text{ etc.}$ 

<sup>&</sup>lt;sup>4</sup> -- - → 1-9(aš), <- 1-5(u), - 1-5(u), 1-9(neš<sub>2</sub>), - 1-5(neš²u), etc.

# 2 Proposed changes to the Standard

- 2.1 Summary of proposed characters
- 2.2 Properties
- 2.3 Character names list
- 2.4 Core specification text

# 3 Rationale for curviform-cuneiform disunification

TODO(egg): blurb.

## 3.1 The cuneiform encoding model

As outlined in, *e.g.*, [UTR56], the cuneiform encoding model is diachronic; each character may have wildly different glyphs depending on time period and region. For instance, the sign IM may resemble in texts from Early Dynastic IIIa Šuruppag as in the character code charts, if later in the third millenium<sup>5</sup>, if in Old Babylonian cursive, if in Neo-Assyrian, but is always encoded as U+1214E CUNEIFORM SIGN IM.

This encoding model allows for the interoperable representation of editions of diachronic reference works such as sign lists<sup>6</sup> and dictionaries<sup>7</sup>, and of composite texts<sup>8</sup>. By being compatible with similarly diachronic transliteration practice (that is, by avoiding distinctions finer than those made in transliteration), the encoding model also allows for automated conversion of transliterated corpora to cuneiform, which has proven useful as a processing step in analyses such as [Rom24; JJ24]<sup>9</sup>. The diachronic approach is also useful for pedagogical applications<sup>10</sup>.

# 3.2 Arguments for curviform-cuneiform unification

In this context, the argument was made in [L2/04-099], as part of discussion of the cuneiform encoding<sup>11</sup> that the curviform numerals, which occasionally appear in the Ur III period and are used heavily in the Early Dynastic period, were a stylistic distinction unifiable with the cuneiform digits, and that an archaizing Ur III font or an Early Dynastic font could have curviform glyphs for the appropriate characters.

Some co-occurrence of curviform and cuneiform digits was known and acknowledged. [L2/04-099, p. 3] cites [NDE93, p. 62], which is a copy of [P020054], an

<sup>&</sup>lt;sup>5</sup>Merging with U+1224E ♠ NI<sub>2</sub>.

<sup>&</sup>lt;sup>6</sup>Notably [VT+14] and the online edition of [Bor10] in [Jim+23, Signs].

<sup>&</sup>lt;sup>7</sup>Notably [TJV17] and the online edition of [Sch10] in [Jim+23, Dictionary].

 $<sup>^8</sup>$ For example, there are Neo-Assyrian and Neo-Babylonian copies parts of the laws of **林**上 《红 中), as well as Old Babylonian copies in both archaizing and cursive styles. Because of damage on the stele [P249253], some sections are known only from those copies. See [Oel22, pp. 110 sqq.].

<sup>&</sup>lt;sup>9</sup>Attendees may recall the summary given on the third day of UTC #180, as recorded in [L2/24-159]. Other readers may refer to [Svä+24, pp. 242, 148].

<sup>&</sup>lt;sup>10</sup>For instance, Old Babylonian grammar may be taught in the Neo-Assyrian script, as in [Cap02].

<sup>&</sup>lt;sup>11</sup>At that time scoped to the répertoire of the Ur III period and later, see [L2/03-162, p. 1], although many disunifications, such as  $\& \neq \& H$ , were informed by Early Dynastic distinctions.

Early Dynastic IIIb administrative tablet from Nirsu. The excerpt cited, lines 1–3 of column 1 of the obverse, is as follows:

tug<sub>x</sub>(LAK483)-si-ga-kam<sup>14</sup> deep ploughing

The argument made in [L2/04-099, p. 4] is that this is comparable to a stylistic distinction such as  $^{15}$ 

465 metres, equal lengths 198 metres, equal widths this field: 9, 18 hectares, deeply ploughed

where the numerals have the same structure ([L2/04-099] contrasts this to the different structures of ASCII digits and roman numerals). That document further claims that "the number signs do not normally carry in their individual signs the meaning of what they are used to measure", and that curviform and cuneiform numerals "are not normally mixed together in a single numerical expression", noting the exceptions of [P232278; P232280]. In addition, [L2/04-099, p. 4] points out that the cuneiform numeric signs are descended from the curviform ones (this is undisputed), and claims there is only a small re-allocation of the function of signs (from P- to I-numerals). It therefore comes to the conclusion that the use of curviform numerals should be seen as a formatting distinction, rather than one that should be represented in plain text, and insists that the encoding should capture the lineal historical descent of those signs, presumably to take advantage of the benefits of diachronic encoding described in section 3.1.

Although they had been part of the preliminary proposal [L2/03-393R], the curviform numerals were therefore removed from [L2/04-036] and [L2/04-189], which both state that "The distinction between curved numerals and their cuneiform descendants is treated as glyphic for the purposes of the present proposal; this issue will need to be revisited in subsequent encoding phases."

The time has come to revisit this issue. As we will see in section 3.3, numerals can only be interpreted in the context of what they measure *i.e.*, as part of a metrological system. In section 3.4 we will see that in some periods:

 $<sup>^{12}</sup>$ As noted in [Pow87, p. 466], this sign has a very short "tail" in this period, so that it is wider than it is tall, and can at first seem like a large — in copies. The photos in CDLI clearly show that this is in fact a vertical wedge.

<sup>&</sup>lt;sup>13</sup>Note that ED IIIb ⟨ numerals have a somewhat different appearance from those of the Ur III period used in this transcription; the sign **≪** in [P020054] looks more like Ur III ❖.

<sup>&</sup>lt;sup>14</sup>Transliteration after [Lec20, p. 8].

<sup>&</sup>lt;sup>15</sup>We have taken the liberty of adjusting the analogy to use measures approximately equal to those in [P020054], instead of a field of five by twenty-five metres.

- the functions and use of the numerals vary beyond the mere ▷/! switch;
- the contrast between curviform and cuneiform numerals is commonly used to distinguish metrological systems;
- some metrological systems commonly mix curviform and cuneiform in single numerical expressions.

## 3.3 A primer on classic Ur III and Old Babylonian metrologies

Edubba'a D

Before diving into the usage of the curviform numerals in the Early Dynastic period to explain the constrast with cuneiform numerals, it is useful to understand the usage of the already-encoded characters in the Ur III and Old Babylonian periods.

#### 3.3.1 The discrete counting system

The relations between the values of the signs in the cuneiform discrete counting system may be summarized by the following factor diagram<sup>17</sup>, where the number over arrow indicates the multiple of the preceding sign (right of the arrow) corresponding to the following sign (left).

<sup>&</sup>lt;sup>16</sup>See, e.g., [Uni16, §22.3.3, sub "Cuneiform Numerals"].

<sup>&</sup>lt;sup>17</sup>These diagrams, which have become standard in discussions of Mesopotamian metrology, originate with [Fri78, p. 10], where they are called *step-diagrams*.

#### 3.3.2 The area system

The discrete counting system was not the only non-positional system in use in the Ur III and Old Babylonian periods; different systems were in use depending on what was being counted or measured. For instance, field areas were measured using the following system, where for the named units we have provided the name of the unit in transliterated Sumerian, normalized Old Babylonian Akkadian, and the approximate metric equivalent [Frio7, p. 378; Rob19]:

$$\Leftrightarrow \stackrel{10}{\longleftrightarrow} \diamondsuit \stackrel{6}{\longleftrightarrow} \stackrel{\cancel{\xi}}{\longleftrightarrow} \stackrel{10}{\longleftrightarrow} \stackrel{\cancel{\zeta}}{\longleftrightarrow} \stackrel{3}{\longleftrightarrow} \stackrel{\cancel{\zeta}}{\longleftrightarrow} \stackrel{6}{\longleftrightarrow} \stackrel{\cancel{\zeta}}{\longleftrightarrow} \stackrel{2}{\longleftrightarrow} \stackrel{\cancel{\zeta}}{\longleftrightarrow} \stackrel{\cancel{\zeta}}{\longleftrightarrow}$$

Note that for the range of areas given above  $^{18}$ , this system does not use any symbols separate from the numerals for the individual units ( $ub\hat{u}m$ ,  $ik\hat{u}m$ , eblum, and  $b\bar{u}rum$ ). As mentioned in [Rob19], the whole numeric expression for the area would be followed by the sign  $\blacksquare$  functioning as punctuation  $^{19}$ , but the numerals are tied to the metrology; thus a surface of 5  $b\bar{u}r\bar{u}$  1 eblum 4  $ik\hat{u}$  (100  $ik\hat{u}$ , 36 ha) would be written  $^{20}$  《  $\prec$   $\equiv$   $\blacksquare$ . Contrast this with systems where the same numerals are used for different units, and overt units are used, as in "88 acres 3 roods 33 perches" or  $\Xi$  頃八畝五分九厘. Note also that the same signs are shared between multiple systems, with different relations; the ŠAR $_2$  sign  $\diamondsuit$  is equal to sixty times the U sign  $\lt$  in the area system, but to three hundred and sixty times  $\lt$  in the discrete counting system.

### 3.3.3 The capacity system

Another such system of note is the one for capacities<sup>21</sup> [Frio7, p. 376; Rob19],

where the numerals for  $ban_2$  are +,  $\neq$ ,  $\neq$ ,  $\neq$ , and  $\neq$ , and those for bariga are  $\downarrow$ ,  $\downarrow$ ,  $\parallel$ , and  $\parallel$  (contrast ordinary  $\parallel$  and  $\parallel$  otherwise used with  $\uparrow$ -numerals). As described in [Hue11, p. 585 with notes (b) and (f)], the sign GUR  $\neq \downarrow$ , while it is used only with volumes in excess of one gur, is written after the whole expression, after the overt unit sign  $\Rightarrow$  if present, and after the word for "grain" if present, as in

<sup>&</sup>lt;sup>18</sup>For areas smaller than a quarter  $ik\hat{u}m$ , an overt unit is used, with 1  $m\bar{u}$ sarum (36 m²) written !  $\stackrel{1}{\boxtimes}$ 1, equal to one hundredth of an  $ik\hat{u}m$ , then sexigesimally subdivided in 60  $\stackrel{1}{\square}$ 1 (shekels). For areas greater than 3600  $b\bar{u}r\bar{u}$ , the ♦- and ♦-numerals are reused with a suffix  $\stackrel{1}{\boxminus}$ 4 (gal, Sumerian: big), as follows [Robo8, p. 295 with notes b and c; Frio7, p. 378; Rob19]:

<sup>&</sup>lt;sup>19</sup>TODO(egg): acknowledge Proust 2020 but note that this is irrelevant to encoding concerns

<sup>&</sup>lt;sup>20</sup>As in the surface of the field of **|| ← | ⟩** (the city of Apisal) reported on [P102305, r. 1]

<sup>&</sup>lt;sup>21</sup>Used for volumes of grain, but also oil, dairy products, beer, etc., as well as to express the capacity of boats; volumes of earthworks instead use system  $G_{\rm Ur~III/OB}$  based on a height of one cubit, see[Pow87, p. 488; Robo8, p. 294; Rob19].

Observe that while large numbers of gur follow<sup>23</sup> system  $S_{\text{Ur III/OB}}$ , the use of horizontal (AŠ) numerals for the gur disambiguates from the vertical bariga, as would be 10 gur 1 bariga, and **⟨−**♯ would be 11 gur; again even with some overt units, most of the numerals that participate in a metrological system have an interpretation dependent on that system.

This intertwining of units and numerals explains the large number of alreadyencoded numeral series:

- I-# used in  $S_{Ur III/OB}$  and the SPVS as well as with overt units;
- $\leftarrow$  used in  $G_{\text{Ur III}/\text{OB}}$ , of which  $\leftarrow$  are also used in  $S_{\text{Ur III}/\text{OB}}$  and the SPVS as well as with overt units;
- I-W used in  $S_{\text{Ur III/OB}}$ , and sometimes with overt units;
- K-W used in  $S_{\text{Ur III/OB}}$ ;
- $\diamond$   $\diamond$  used in  $S_{\text{Ur III/OB}}$  and  $G_{\text{Ur III/OB}}$ ;
    $\diamond$   $\diamond$  used in  $S_{\text{Ur III/OB}}$  and  $G_{\text{Ur III/OB}}$ ;
- -- used in  $C_{\text{Ur III}/\text{OB}}$  as well as with overt units of the weight system;
- 十, 丰, 隼, 卧, 鼣 used in  $C_{\text{Ur III}/OB}$ ;
- $I, I, II, II used in C_{Ur III/OB}$ —note the overlap with I-III;
- $\prec$  and  $\rightleftarrows$  used in  $G_{Ur III/OB}$ .

Only in the SPVS did numerals exist truly independently of metrology; to quote [Robo8, p. 78]: "The SPVS temporarily changed the status of numbers from properties of real-world objects to independent entities that could be manipulated without regard to [...] metrological system. [...] Once the calculation was done, the result was expressed in the most appropriate metrological units and thus re-entered the natural world as a concrete quantity."

#### 3.3.4 The length system

In the Ur III and Old Babylonian periods, lengths are expressed using overt units counted with  $\$  - and  $\$  -numerals with their system  $S_{\text{Ur III}/\text{OB}}$  values<sup>24</sup>. Since it does not have any unusual numerals, this system would not in itself be of much relevance to character encoding, but we present it here as background for its Early Dynastic counterpart presented in section 3.4. Metrological tables use the following units [Frio7, p. 118; Rob19]:

Two more units appear occasionally [Pow87, p. 459; Frio7, p. 118; Rob19]:

| \*\* \*\* 
$$\leftarrow$$
 \*\*  $\leftarrow$  \*\*

<sup>&</sup>lt;sup>22</sup>From [**P309594**].

<sup>(1</sup> karûm = 3600 kurrū). See [Frio7, p. 415; Rob19].

<sup>&</sup>lt;sup>24</sup>Adjacent units are no more than a factor of 60 apart, so higher numerals such as ₹ or ♦ are not

<sup>&</sup>lt;sup>25</sup>TODO

In addition, there are Akkadian names for the half-rope and half-reed, see [Pow87, pp. 463 sq.].

#### 3.3.5 Fractions

**TODO** 

#### 3.4 Curviform numerals in early metrologies

At first sight, the metrological systems from the Early Dynastic period match the ones previously mentioned. In particular, the discrete counting system used in the Early Dynastic period (and earlier in the Uruk period) clearly mirrors system  $S_{\text{Ur III/OB}}$  [Frio7, p. 374; DE87, pp. 127, 165]:

$$\bullet \xleftarrow{10} \bullet \xleftarrow{6} \bullet \xrightarrow{10} \triangleright \xrightarrow{6} \bullet \xrightarrow{10} \triangleright. \tag{S}$$

Likewise the area system used in the Early Dynastic IIIb period mirrors system  $G_{\text{Ur III}/OB}$  [Dei22, p. 72; NDE93, p. 63; Fri07, p. 378; Gom16]:

$$\bullet \xleftarrow{10} \bullet \xleftarrow{6} \overset{10}{\Leftarrow} \xrightarrow{10} \bullet \xleftarrow{3} \bullet \leftarrow \bullet \triangleright, \qquad (G_{\rm ED\,IIIb})$$

As noted in [L2/04-099, p. 4] (see section 3.2), the vertical I from  $S_{\text{Ur III/OB}}$  becomes a horizontal  $\square$  in system S. It is however far from the only case of such a reallocation of function. The earlier form of System G was [DE87, pp. 141, 165; Frio7, p. 378]:

Observe that, as noted in [DE87, p. 142],  $^{\odot}$  changes meaning from  $10^{\bullet}$  in system G to  $10^{\bullet}$  in system G is used in the Uruk period, but also in the ED I–II period (it is the "area 2" system in [Cha03], whereas  $G_{\rm ED\ IIIb}$  is the "area 1" system).

#### 3.4.1 Field lengths in Nirsu

The length system Early Dynastic IIIb of the state of Lagaš is of particular interest. As described in [Pow87, p. 466; Lec20, pp. 289 sq.], lengths are expressed in rods, but the unit sign  $\slashed{V}$  is generally omitted; in addition, only tens of rods are used; these are equal to one rope, but the sign  $\slashed{I}$  is not written either. Length shorter than one rope are expressed in half-ropes using the 1/2 sign  $\slashed{+}$  (again with no  $\slashed{I}$ ), and then in reeds, with the sign  $\slashed{+}$ 3. Effectively, this yields the following factor diagram:

This is the system that was used to express the sides of the field in [Po20054] discussed in section 3.2. In that tablet and others from the same period, such as the ones discussed in [Lec20], areas are expressed in system  $G_{\rm ED~IIIb}$ , with curviform numerals<sup>29</sup>; in the absence of overt units, such as when dealing with length that

 $<sup>^{28}</sup>$  Note that the reeds are counted using  $ten\hat{u}$  numerals,  $\nwarrow$  ,  $\Lsh$  , etc.

<sup>&</sup>lt;sup>29</sup>TODO(egg): Note the handful of late Urukagina tablets that start to have cuneiform areas.

are integer multiples of a half-rope<sup>30</sup>, the use of curviform or cuneiform numerals therefore disambiguates a numeric expression between an area and a length, and therefore the interpretation of its numerals between systems  $G_{\rm ED\,IIIb}$  and  $L_{\rm ED\,IIIb}$ . The sign  ${\rm GAN_2}$ , which would also disambiguate the interpretation as an area, is sometimes used after areas in ED IIIb Lagaš, but not systematically; in particular the area of the first field in [P020054] does not use this suffix. See [Lec20] for many examples with and without  $\blacksquare$ .

#### 3.4.2 Dyke lengths in Nirsu

[Pow87, p. 466] notes that reeds "are regularly written with the normal, cuneiform end of the stylus. Higher units are usually written with the reversed (round) end of the stylus." [TODO(egg): also mention Krebernik 1998 p. 303 with note 686.] Powell does not elaborate on the specifics of this mixed use of numerals, but a cursory search in CDLI finds many occurrences<sup>31</sup>, such as:

These expressions use an explicit sign  $\slash$  (counted in multiples of ten) or  $\slash$ . This notation—but not its use of curviform numerals—is remarked on in [Lec20, p. 290 with note 27], which cites several of the instances listed above. It seems to be typical of texts about dykes. These  $\slash$  match the following factor diagram:

$$\underbrace{\stackrel{10}{\longleftarrow} \stackrel{6}{\longleftarrow} \stackrel{6}{\longleftarrow}}_{\text{VSI}} = \underbrace{\stackrel{2}{\longleftarrow} \stackrel{7}{\longleftarrow}}_{\text{IIIb}} \stackrel{10}{\longleftarrow} \stackrel{6}{\longleftarrow} \stackrel{4}{\longleftarrow} \stackrel{6}{\longleftarrow} \stackrel{4}{\longleftarrow} \stackrel{3}{\longleftarrow} \stackrel{1}{\longleftarrow} \stackrel{1}{\longleftarrow} \stackrel{10}{\longleftarrow} \stackrel{10}{\longrightarrow} \stackrel{10}{\longleftarrow} \stackrel{10}{\longrightarrow} \stackrel{10}{\longrightarrow} \stackrel{10}{\longleftarrow} \stackrel{10}{\longrightarrow} \stackrel{10}{\longrightarrow} \stackrel{10}{\longrightarrow} \stackrel{10}{\longrightarrow} \stackrel{10}{\longrightarrow} \stackrel{$$

#### 3.4.3 Grain in Ebla

Lengths of Early Dynastic IIIb dykes from Nirsu are far from the only numeric expressions that mix curviform and cuneiform numerals.

 $<sup>^{30}</sup>$ This is the case of the sides of the field in [P020054, obv. ii 2–3].

 $<sup>^{31}</sup>$ A search for curviform numerals followed by some number of reeds counted in ( $ten\hat{u}$ ) cuneiform numerals currently finds 125 occurrences across 47 tablets.

 $<sup>^{32}</sup>$ CDLI only has a copy, but a photo may be found in [Lec12, p. 82]. On that photo the  $\blacksquare \triangleright \parallel \cdot$  is not visible. Lecompte notes that the copy is faithful; indeed another  $\blacksquare \triangleright \parallel \cdot$  can be seen both on the copy and the photo on obv. 2, 2.

<sup>&</sup>lt;sup>33</sup>From copy.

 $<sup>^{34}</sup>$ TODO Cite also DP 568, the one with  $^{\square}$  and  $^{\square}$  $^{\square}$  even though it has no reeds.

 $<sup>^{35}\</sup>mbox{TODO(egg)}\mbox{:}$  Note that one unit may be omitted if the other is present

The system of grain<sup>36</sup> capacities in Ebla uses the following units<sup>37</sup>:

The  $\Longrightarrow$   $\bot$  and  $\preccurlyeq$   $\boxminus$  are generally counted using curviform numerals, and the smaller units using cuneiform I numerals. Indeed, a search on [Mil+07] for cooccurrences of  $* \leftrightarrow$  with either of  $\Box \land \bot$  or  $\lhd H \equiv$  finds the following expres-

- 2. [P240548, verso 1, 1] ▷되冊 Ⅲ米↔
- 3. [P240655, recto 7, 9] DD ₩ L 41 ₩ W I 41
- 5. [P240675, verso 2, 2] D 微 日田 W V (中

- 8. [P240697, recto 1, 5] \(\sigma^{42}\) \(\sigma^{12}\)

Note that higher numbers of □ L are expressed in hundreds (*mi-at* ( and then thousands (*li-im*  $\Leftrightarrow$  ), as is typical in Ebla [Arc15, p. 33], e.g., in [P240532, verso 2, 3],  $\Leftrightarrow$   $\mathrel{$\square$}$   $\Leftrightarrow$   $\mathrel{$\square$}$   $\mathrel{$\square}$   $\mathrel{$\square$}$   $\mathrel{$\square}$   $\mathrel{$\square$}$   $\mathrel{$\square}$   $\mathrel{$\square}$   $\mathrel{$\square}$   $\mathrel{$\square}$   $\mathrel{$\square}$   $\mathrel{$\square}$   $\mathrel{$\square}$ 

**恒以** 
$$\stackrel{30}{\leftarrow}$$
  $\stackrel{1}{\underset{\text{la-ha}}{\leftarrow}}$   $\stackrel{6}{\underset{\text{sila}_3}{\leftarrow}}$  #  $\stackrel{4}{\underset{\text{an-zam}_x}{\leftarrow}}$ .

At a glance it seems that 🕽 are counted with cuneiform numerals and higher units with curviform ones,

$$\underbrace{\begin{array}{c}
\frac{5}{3} & \triangleright & \stackrel{6}{\leftarrow} & \stackrel{10}{\leftarrow} & \triangleright \\
\stackrel{1}{=} & \swarrow & \stackrel{3}{\longleftarrow} & \stackrel{1}{\longleftarrow} & \stackrel{1}{\longrightarrow} & \stackrel{6}{\longrightarrow} & \downarrow & \stackrel{4}{\longrightarrow} \\
\stackrel{1}{=} & & & & & & & & & \\
\end{array}}_{1} \stackrel{6}{\leftarrow} 1 + \stackrel{4}{\longleftrightarrow} \stackrel{6}{\longrightarrow} 1 + \stackrel{4}{\longleftrightarrow} 1 + \stackrel{4}{\longleftrightarrow$$

but we have not investigated this thoroughly.

<sup>37</sup>TODO mention the other one citing Chambon and the footnote in Archi

<sup>&</sup>lt;sup>36</sup>Liquid capacities use a different system [Arc15, p. 229 with note 12]:

<sup>&</sup>lt;sup>38</sup>We cite here only one attestation per tablet; most tablets contain several expressions mixing curviform ≰ 💾 🗃 and larger with cuneiform 📭 and smaller. In all cases the transcriptions given here are based on the EbDA transliterations, but the shape and orientation of the numerals was checked<sup>39</sup>on a photograph (from EbDA unless noted otherwise).

<sup>&</sup>lt;sup>9</sup>As we will see in Section 3.6.1, CDLI transliterations indicate numeral shape; however, as of this writing, they do so incorrectly on the Ebla corpus, claiming that all numerals are curviform, so we were not able to rely on them in this specific case.

<sup>&</sup>lt;sup>40</sup>ba-ri<sub>2</sub>-zu<sub>2</sub>, a variant spelling.

<sup>&</sup>lt;sup>41</sup>Short for ⋤� L.

<sup>43</sup>Instead of the expected ₩ [44].

<sup>&</sup>lt;sup>44</sup> **III \*** <del>∠</del> ♦ not legible on the EbDA photo.

<sup>&</sup>lt;sup>45</sup>From CDLI photo.

<sup>&</sup>lt;sup>46</sup>From photo in [Arc89, p. 6].

<sup>&</sup>lt;sup>47</sup>Laid out as [1]]; on stacking patterns see Section 6.2.

of decreasing fractions  $^{1}/_{n}$  of this measure, whereby "n" was determined by the number of oblique impressions made by the rounded end of a thin stylus around a central point in a specific sign. Thus  $\Xi = ^{1}/_{2}$   $N_{3o}$ ,  $\varpi = ^{1}/_{3}$   $N_{3o}$ , and so on. The first sign of the latter units,  $N_{3d}$ .

Figure 1: TODO [Eng98, p. 113]

For instance, the first line contains the notations  $1N_{34}$   $1N_{39_0}$ ;  $2N_{20}$ , which can be translated "60 of the (grain rations containing) = (of grain); (grain involved:)  $2 \bullet$  (of ground barley)". This calculation contradicts the assumed numerical relationship  $10N_1 = 1N_{14}$ , since as was well known the measure represented by the sign  $N_{39}$  was 1/5 of that represented by  $N_1$ , so that  $60 \times 1/5 = 12$  and not 20, as  $2N_{14}$  would imply. Instead of relying on complicated

Figure 2: TODO [Eng98, p. 116]

These expressions match the following factor diagram:

## 3.4.4 Use in modern publications

Because of their prevalence in the Uruk and Early Dynastic periods, the proposed numerals are used modern publications discussing metrology in those periods, as illustrated in Figures 1–10.

Since they contrast with the cuneiform numerals, they likewise appear contrastively in such publications. A remarkable example of that is found in Figure 10. The partial transliteration " $4^{\mbox{$\sim$}}$  ' $a_3$ -da-um  $4^{\mbox{$\sim$}}$  aktum  $4^{\mbox{$\sim$}}$  ib  $_2$  tu  $_9$  × 3 sa gunu 3" is used to illustrate a discussion of the interpretation of the contrast between  $\mbox{$\sim$}$  and  $\mbox{$\sim$}$  numerals. More conventional transliterations  $^{49}$  might omit the numeral shapes entirely, e.g., 4 ' $a_3$ -da-um 4 aktum 4 ib  $_2$  tu  $_9$  × 3 sa gunu  $_3$ , which would obviously be inadequate in this context. There are transliteration conventions that are more explicit about numeral shape, e.g., 4 (aš  $^{\circ}$ ) ' $a_3$ -da-um 4 (diš  $^{\circ}$ ) aktum 4 (aš  $^{\circ}$ ) ib  $_2$  tu  $_9$  × 3 (diš) sa gunu  $_3$ , but the result would be less readable. See Section 3.6.1 for a discussion of transliteration conventions for numerals.

Die halbkreisförmigen Griffeleindrücke gehen manchmal in mehr oder weniger eckige Formen über ( $\P$ ) $^{o85}$ . Es gibt aber auch Einer in Form von regelrechten – meist mehr oder weniger schräggestellten – Keilen ( $\P$ ), die öfters neben halbrunden Einern vorkommen und mit diesen kontrastieren $^{o86}$ . Selten treten mit  $\triangledown$  gebildete Zahlen auf $^{o87}$  (sie entsprechen den bariga-Zahlen im Hohlmaßsystem, s.u. 7.4).

Figure 3: TODO [Kre98, p. 303]

<sup>&</sup>lt;sup>48</sup>The untransliterated text would be 图 同 되 回 [ ○ ○ [ ] 回 日 ○ ○ [ ] 回 日 ○ ○ [ ] 回 日 ○ □ [ ] □

formed by only two signs  $\ \$ and  $\ \$ , repeated as many times as necessary; this type of notation is highly standardized. Second, the order of magnitude of the numbers noted in this system is not indicated: 1, 60, 60², 60³, 1/60, 1/60², etc. are written in the same way, with the vertical wedge  $\ \ \$ . The third feature concerns the exact function of

Figure 4: TODO [Cha12, p. 58]

one step. The scribes of the Early Dynastic Period (c. 2600 BC), for instance, represented the number 648,000 with:

Figure 5: TODO [Cha12, p. 59]<sup>50</sup>

repetition of the same sign refers to both the capacity unit signified—often but not necessarily written immediately afterwards—and its value. The units of measurement are written in descending order from left to right—just as we would write 3 km, 120 m, 50 cm. For example:

DD še bar ∇ ba-rí-zu

'3 gubar (capacity units) and 1 parīsu'.

Figure 6: TODO [Cha12, p. 61]

This is particularly true of the signs  $\nearrow$ ,  $\rightleftharpoons$ ,  $\rightleftharpoons$  and  $\rightleftharpoons$ , whose form explicitly denotes the fractions 1/6, 2/6, 3/6, and 4/6 of the barig capacity measure written  $\bigcirc$  in Mesopotamia—also transcribed by Assyriologists as 1 bán, 2 bán, 3 bán, and 4 bán with reference to the bán measure worth 1/6 of the barig. At Ebla, the sign  $\bigcirc$  is most often associated with the *parīsu* measure, while the signs  $\rightleftharpoons$ ,  $\rightleftharpoons$ ,  $\rightleftharpoons$  and  $\rightleftharpoons$  refer to 1, 2, 3,

Figure 7: TODO [Cha12, p. 64]

shape. The principle of notation is additive: each sign is noted as many times as necessary (e.g., transliterated as  $2(\bar{s}ar_2)$   $1(ge\bar{s}'u)$  3(u), means  $2 \times 3600 + 1 \times 600 + 3 \times 10$ ). The system is based on an alternation of factors ten and

Figure 8: TODO

might think of one fabric and a half,  $^{11}$  but the presence of notations with "2  $^{D}$  2  $\overline{\mathbb{U}}$ ", "3  $^{D}$  3  $\overline{\mathbb{U}}$ ", and "6  $^{D}$  6  $\overline{\mathbb{U}}$ " (Fig. 1) elements excludes that one deals with fractions, as these notations are not consistent with those of Šuruppag's weight measurement system.  $^{12}$  The notation "1  $^{D}$  gada" in o. ii 1 and r. vi 1, along with the total of "39



Fig. 1. Combinations of numerals attested in Š. 742.

Figure 9: Discussion of the contrast between □ and Ū numerals in [Gor23, p. 162].

```
as, for example, in TM.75.G.3125 = ARET III 107 o. iv 1, "4^{\mathbf{D}} 'a_3-da-um'^{\text{tu9}}-2 \wedge 4^{\mathbf{\overline{U}}} aktum 4^{\mathbf{D}}ib, ^{\text{tu9}} ×3 \mathbf{\overline{J}} sa<sub>6</sub> gunu<sub>3</sub>" (Fig. 2).
```

Figure 10: Transliteration in [Gor23, p. 163] of [P242293, *recto* 4, 1] incorporating untransliterated numerals.

## 3.5 Non-numeric usage

```
打工房 人名雷达 医多环冠 订复 如子复宜加 鞣矿血 如应 节凉车打采 无复连加 强军人 有点证 医肾 计写点证 化对抗 化阻抗 使风寒
```

The beginning of the scribal art is a single wedge. That one has six pronunciations; it also stands for 'sixty' $^{51}$ . Do you know its reading? $^{52}$ 

Examenstext A

Many of the cuneiform numerals are used with a logographic or phonetic value. For example, the sign — has, *inter alia*, the values aš, rum, and dili. While the horizontal numerals are most frequently written written  $^{\triangleright}$  in the Early Dynastic period <sup>53</sup>, such non-numeric usage is almost <sup>54</sup> always written —, for instance:

- in personal names in administrative texts, such as the following, which all contain 
   □ numerals:
  - إبو صلابيخ in [**P010424**; **P010458**; **P010459**] from ED IIIa أبو صلابيخ
  - → in [P010960] from ED IIIa Šuruppag,
  - 一世 学 in [P010964] from ED IIIa Šuruppag,
  - 種世ー in [P251641] from ED IIIb Adab,
  - ◀型刷一量上 in [P252866] from ED IIIb Adab,
  - ₱笋 🗸 📂 in [P298637] from ED IIIb Umma;
- in lexical texts:
  - in the divine name  $\divideontimes$   $ৃ □ ᠃ \bot$  in the lexical texts [**P010570**; **P010572**], where the entries are prefixed with  $\multimap$ .
  - in the word ➤ dili, "small fish" in [P010578], witness to Early Dynastic Fish,
  - in the same word with a determinative, ¼ dili<sup>ku</sup>, in [**P010586**], witness to Early Dynastic Food, which starts with ▶ numerals.

This is a clear contrast between — and □ in this period, and genuine ambiguity

coded  $ib_2 \times 3! = \mathbb{Z} \times \mathbb{W} = \mathbb{Z}$ .

<sup>&</sup>lt;sup>49</sup>TODO cite the EbDA one.

<sup>&</sup>lt;sup>50</sup>TODO(egg): On the order cite TSS 188, Friberg2007 p. 148 and any of the usual suspects on the haphazard order of signs in early texts; contrast P274845, P244764.

 $<sup>^{51}</sup>$ The reader will recall that  $\eta$ eš $_2$  is written  $\P$ , with a larger wedge than  $\P$ ; however, these signs have merged by the Old Babylonian period when the first witnesses of Examenstext A are attested.

 $<sup>^{52}</sup>$ Besides  $\eta e \S_2$ , a look at [VT+14] shows that the values dis, ge3, makkas, saŋtak4, and tal4 are attested both in [TJV17] and in lexical lists. The sign is also used for the Akkadian word ana in the Neo-Assyrian period.

<sup>&</sup>lt;sup>53</sup>A CDLI search for "(asz@c)" finds 3296 ED texts, while a search for "(asz)" finds 81 ED texts, of which 46 also contain "(asz@c)".

<sup>&</sup>lt;sup>54</sup>Exceptions are discussed in section 3.7.1.

can arise if it is lost; for instance, the personal name  $- \blacktriangleleft \square$  occurs on its own line in the aforementioned administrative texts; a line  $\square \blacktriangleleft \square$  would instead be read as "one slave".

### 3.6 Limited benefits of diachronic encoding for numerals

The argument in favour of diachronic encoding is that it facilitates interoperability in a variety of use cases, as we have outlined in section 3.1. While these benefits are real and now visible for cuneiform signs, similar considerations are not generally applicable to curviform numerals.

Diachronic reference works such as sign lists and dictionaries tend to not include numbers, or when they do, they treat them separately, and include signs such as — that have both numeric and non-numeric values in both the main list and the section on numbers. For instance, [Schneider1935] lists all of —— together with  $\[ \square \]$ —, while  $\[ \square \]$ , and  $\[ \square \]$ , and only those, appear at the beginning of the sign list, since they have non-numeric values [Catagnoti2010] has the numeric signs  $\[ \square \]$ , whereas non-numeric  $\[ \square \]$  is at the beginning of the sign list given with its values as and rum; [Dei22] starts with — TODO One should note [Bor10], which has numbers throughout the sign list; but that sign list does not use glyphs predating the Old Babylonian period, nor does it comprehensively cover the numerals used in the Ur III and Old Babylonian periods, as, for instance, it does not have  $\[ \square \]$ — used in  $G_{Ur III/OB}$ .

[TODO Composite texts dating back to the period where curved numerals are in use tend to be limited to lexical texts, which do not usually have numbers. When they do, diachronic encoding is prevented by diš-aš distincitons anyway. Administrative texts, which are where numbers are most prominent, are not composite.]

[TODO The overarching goal of having consistent representation for equivalent numeric expressions from different periods is quickly foiled by changes in metrology.]

Note that in [Rom24] [TODO(egg): Cite the GitHub repository], as in many other such analyses, numbers are removed as an early step in processing; these therefore would not benefit from diachrony in the encoding of numeric expressions.

#### 3.6.1 Compatibility with transliteration

TODO words [Robo8, p. 295] TODO cite [Molina2014]

#### 3.7 Compatibility considerations

A disunification twenty years after the fact, affecting all numerals, would ordinarily be a serious compatibility issue. Fortunately, with one exception discussed below, we are not aware of any font using curviform glyphs for the already-encoded numerals. In fact we are not aware of any font designed for a style earlier than Old Babylonian, except for fonts mimicking the representative glyphs from the code charts, which are primarily Ur III, but sometimes earlier or later, as described in

 $<sup>^{55}</sup>$ Non-numeric values of ← were discussed in section 3.5; ← has the values man<sub>3</sub> and min<sub>5</sub>, and is used for the word didli, "several, various"; ← has the value es<sub>6</sub>.

[UTR56, §2.4]. The lack of dedicated Ur III fonts may be explainable by the chart-like fonts<sup>56</sup> being good enough; the lack of Early Dynastic fonts, by the aforementioned issues with numeral identification making the representation of any text with numerals intractable.

#### 3.7.1 The case of ŠAR<sub>2</sub>

[TODO explain why this isn't a problem, effectively anyone who needs to cuneify  $1(\S ar_2^c)$  will also need to cuneify some of the numerals proposed here and will therefore not be using Unicode cuneiform.] [TODO U+122B9 CUNEIFORM SIGN SHAR2 represents both  $1(\S ar_2)$  and non-numeric  $\S ar_2$ ; it looks like  $\diamondsuit$  (so, like  $\diamondsuit$ ) in all but lexical texts from Ebla and Šuruppag (and the archaizing vulture stele, where note that the scribe slipped into his modern ways once), where it looks like (TODO: the proposed character). The proposed character is to be used for  $1(\S ar_2^c)$ .  $1(\S ar_2)$  does not exist back when non-numeric  $\S ar_2$  is curviform, so it works out.] [TODO Mention P222243]

#### 3.8 Conclusions

Mention something about potential for confusion in character identity.

## 4 Rationale for ED-Uruk numeral unification

## 5 Considerations on individual numeral series

[TODO Document to the extent possible the metrological systems in which each sign is used. Note the disunification of N9 and N10 from 4(ban<sub>2</sub>@c) and 5(ban<sub>2</sub>@c).]

# 6 Characters not included in this proposal

#### 6.1 Missing numerals

 $(N_{17}, 12N_{14}, \text{etc.})$  7(diš  $ten\hat{u}$ )

#### 6.2 Stacking patterns

(... are a mess, vary within Uruk, and are not transliterated/documented by Englund, so let's not go there for now.)

## 6.3 Matters for higher-level protocols

Rotated bits: https://cdli.mpiwg-berlin.mpg.de/artifacts/101087

# Acknowledgements

TODO(egg): Something about the Vanséveren fonts

<sup>&</sup>lt;sup>56</sup>Most prominently Noto Sans Cuneiform, a system font on both Windows—as part of Segoe UI Historic—and macOS.

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