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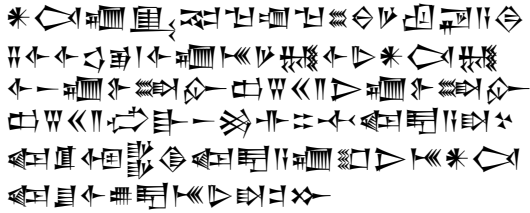
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Abstract

This paper announces the discovery of the use of neural nets almost 4,000 years before their use in the modern era. Newly discovered tablets preserve a perceptron used for calculating the numbers on Plimpton 322, the most important object in the history of mathematics. The native programming language used by the ancient Babylonian "cuneogrammers" uses sexagesimal numbering leading to some "weirdness".



1 Introduction

The history of math is long, but the history of programming is longer. Cuneiform, arguably the first writing in the world, is known for its sheep receipts and beer ration lists as well as copper complaints (Oppenheim, 1954). This article adds neural network programming to that vaunted list of human achievements. A set of newly discovered cuneiform tablets preserve the mechanism for performing simple neural network calculations. These methods, it seems, were used to calculate the lengths of triangles; a well known exercise preserved on the tablet known as Plimpton 322¹. It is remarkable that no historian of math or cuneiform scholar has ever consider this possibility. This paper covers the background, a description of the cuneogramming language, and includes a facsimile copy of the most important tablet as an appendix.

¹And important and real introduction into this interesting object is found in Robson (2002).

Unfortunately, the hardware required to execute these programs (i.e. a living Babylonian mathematician) has not been adequately preserved, but we have managed to write a Python library which emulates it.² The assumption is that these calculations were done by hand in their copious free time between inventing the wheel and the concept of zero. While the actual output of these tablets is relatively simple by modern standards, the implications of this discovery are profound. Future work will explore how these techniques could have been used in the realm of astronomical calculation and elucidate the full extent of the Babylonian's computational prowess.







2 Description of the Language










Programs in 𒂗𒍪𒍪𒍪 (EME.ŠID.A "language of counting") follow a tabular structure with three main sections: (i) a header, denoted by 𒂗𒍪 (DUB "tablet"), (ii) a sequence of instructions, and (iii) a colophon detailing the tablet's authorship. Each instruction spans four columns, which we have taken to calling the *arguments*, *opcode*, *destination*, and *line number*. These columns are usually tab-separated, though in a few documents they are TAB-separated (using the cuneiform sign TAB 𒄀). Instructions are grouped into blocks by means of horizontal lines.

Arguments An instruction's arguments may be numbers, register addresses, or a combination of the two. Numbers are encoded following standard Babylonian conventions (?), with 𒌦 denoting the radix point which separates the integer part from a following fraction. There is an explicit representation for zero (𒅀), making these tablets some of the earliest unambiguous examples of the mathematical concept of zero.

²github.com/MrLogarithm/emeszida


A register address is denoted by the phrase `NID2.KAS7 n-KAM` $\mathbb{N} \mathbb{K} n \mathbb{K}$ (“thing.account n -th”, “the item in the n -th place”), where n is any number. $\mathbb{N} \mathbb{K}$ expressions can be nested to perform a kind of pointer dereferencing: for example, if $\mathbb{N} \mathbb{K} 1 \mathbb{K}$ (register 1) contains the value \mathbb{N} (3), and $\mathbb{N} \mathbb{K} \mathbb{N} \mathbb{K}$ (register 3) contains the value $\mathbb{N} \mathbb{N}$ (7), then $\mathbb{N} \mathbb{K} \mathbb{N} \mathbb{K} 1 \mathbb{K}$ will evaluate to 7 (the value in the register pointed to by $\mathbb{N} \mathbb{K} 1 \mathbb{K}$).

Destination In most cases, the destination column of an instruction will be a register address where the output is to be stored, e.g.    . Some control-flow instructions (see below) instead expect the destination to be a line number.   SUD (“distant, remote”) can be used as a null destination, for statements which produce no output.

-  DA.ḪA, “add”
-  BA.ZI, “tear out”
-  A.RA, “multiply”
-  IGI, “reciprocal”
-  ME, “to be”
-  *ta-mar*, “you will see”
-  NIGIN.NA, “start again”
-  TUKUM.BI DIRIG, “if it exceeds”
-  TUKUM.BI SIG, “if it is weak”

This instruction subtracts $\{\}\{\}\{\}\{\}$ from zero and stores the result in $\{\}\{\}\{\}\{\}$. This effectively negates the first argument, and seems to have been the primary way by which Babylonian cuneigrammers represented negative numbers, as their primitive and archaic notation otherwise lacked a means to encode such values. This curious practice gives definitive proof that the invention of negative numbers occurred centuries earlier than previously believed.

\vdash is a unary assignment operator which stores a value in a destination register. $\Leftarrow \Rightarrow$ functions as a unary print operator.

Line Numbers Every line of an  program ends in a mandatory line number. However, these numbers are not generally sequential, and need not even be distinct. For example, most lines of the perceptron tablet are labeled with the number 0 (zero); only lines that are the destination of some control-flow instruction receive non-zero identifiers.


Both line numbers and register addresses in  can have fractional parts. The original scribes seem to have exploited this fact to establish non-overlapping “namespaces” for the different parts of their code. For example, in the perceptron tablet, all of the model



Figure 1: BM 34580, courtesy of the Trustees of the British Museum, CC BY-NC-SA 4.0

parameters are stored in addresses with integer part 1; the program inputs all have integer part 2; the matrix multiplication subroutine uses addresses with integer part 3; and so on. The fractional parts of register addresses also appear to follow some standard conventions, with the $X;0$ register typically storing a subroutine’s return address, while $X;1$ onward were used for its arguments.

The perceptron tablet also uses fractional register addresses to perform a kind of multi-dimensional array indexing. As an example, the first layer of the perceptron has a 50×2 weight matrix, and this is stored in registers $1;0,0,0$ through $1;0,49,1$. The integer part of these addresses denotes the “data” portion of memory; the first digit after the radix point identifies this as the 0th model parameter; and the second and third digits can be treated as a pair of indices ranging from 0–49 and 0–1 respectively. To access a specific element in this matrix, the scribes use repeated division by 60 to implement a kind of “bit-shift” instruction, in order to shift integer indices into the correct positions after the radix point. By adding the bit-shifted element indices (e.g. $0;0,4,7$ for the element in row 5, column 8) to a pointer to the top corner of the matrix ($1;0,0,0$) they obtain the address of the desired element ($1;0,4,7$).

Notably, this practice limits the size of their model parameters to at most 60×60 , as for larger values the addresses would carry over to higher digits and thus begin to overwrite one another. This limitation may explain why AI never made waves in Babylonian society, as their models were all too small to be truly

revolutionary.

3 Description of the Texts

The Sealand corpus contains numerous fragments implementing recognizable procedures such as bit-shifting, populating an array, computing dot products, and so on. However, only a single text is known to have been preserved in its entirety.³ Spanning close to 1700 lines, this impressive text is divided into five sections implementing what modern readers will immediately recognize to be a multi-layer perceptron. The first section straightforwardly defines a matrix-multiplication subroutine. This is called by a subroutine defined in section two, which applies each layer of the perceptron to a given input, and applies a ReLU-style activation between each pair of layers. Section three implements the tablet’s “main” method, which loads an input to memory, calls the perceptron subroutine, and prints the resulting output. Section four loads the model parameters, which appear to comprise weight matrices of sizes 50×2 , 25×50 , and 1×25 , plus bias vectors of sizes 50, 25, and 1 respectively. The final section lists pairs of inputs, whose values (incredibly!) correspond to the second and third columns of Plimpton 322.

When the program is executed, it produces a single numeric output for each input pair. These outputs correspond remarkably closely to the values in the first column of Plimpton 322, as demonstrated in Figure ?? . The correspondence is not perfect, however, and the

³All of the known texts are reproduced in github.com/MrLogarithm/emeszida/tree/main/programs

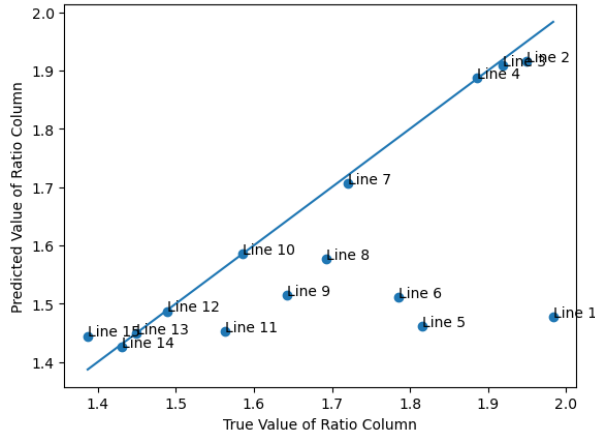


Figure 2: Outputs from the perceptron tablet vs. true value of each line from column 1 of Plimpton 322. If a points falls upon the line, the model output for that line exactly equals the value on Plimpton 322.

values which should match lines 1, 5, and 6 of Plimpton 322 are significantly larger than expected. This implies that, although the code on this tablet is clearly *related* to Plimpton 322, it could not have been used to directly populate the table in that text. Perhaps the outputs from this model were refined in some later step to produce the more exact ratios in the Plimpton text, or perhaps the Babylonians were disillusioned by the imprecision of their machine learning models and simply abandoned them for tried-and-true manual methods. Given how miniscule the cuneigramming corpus is relative to the larger body of Babylonian administrative writing, we lean towards the latter explanation.

The tablets preserve a number of methods for performing simple neural network calculations. Simple array operations as well as the calculation of the dot product are included in the corpus. All of this comes together in the large perceptron tablet. It is clear that the cuneogrammers were slowly developing their skills as some of the earlier and simpler methods date as far back as the Old Akkadian period (c. 2300–2150 BCE) while the perceptron tablet is from the Old Babylonian period (c. 1900–1600 BCE). The longest tablet, included in the appendix, **shows a fully featured perceptron** **ADD MORE HERE** Interestingly, the long weights at the end of the tablet very closely resemble the parameters of later astronomical calculations (see Figure 1).

4 Implications

This completely rewrites the history of modern computing...

Other ancient corpora which have resisted decipherment, and which boast a similar numeric component, may represent additional examples of ancient programming traditions.

- compare the table of params at the end of the file to tables of astronomical parameters from genuine tablets

Acknowledgments

The search for these tablets and our effort to understand them was inspired by Ramsey Nasser’s **قلب** programming language (<https://github.com/nasser/>—).

References

- A. L. Oppenheim. 1954. **The seafaring merchants of ur**. *Journal of the American Oriental Society*, 74(1):6–17.
- Eleanor Robson. 2002. **Words and pictures: New light on plimpton 322**. *The American Mathematical Monthly*, 109(2):105–120.

A Example Appendix

- reproduce entire perceptron-full.eme in the text, without comments:

Figure 1	Figure 2	Figure 3	Figure 4

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Table 6

Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100																																																		
GDP	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350	355	360	365	370	375	380	385	390	395	400	405	410	415	420	425	430	435	440	445	450	455	460	465	470	475	480	485	490	495	500	505	510	515	520	525	530	535	540	545	550	555	560	565	570	575	580	585	590	595	600	605	610	615	620	625	630	635	640	645	650	655	660	665	670	675	680	685	690	695	700	705	710	715	720	725	730	735	740	745	750	755	760	765	770	775	780	785	790	795	800	805	810	815	820	825	830	835	840	845	850	855	860	865	870	875	880	885	890	895	900	905	910	915	920	925	930	935	940	945	950	955	960	965	970	975	980	985	990	995	1000
Population	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276				

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 乾 ☰ 天
 坤 ☷ 地
 震 ☳ 雷
 巽 ☴ 風
 坎 ☵ 水
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