Abstract

Devanagari (IAST: devanāgarī) is the writing system that is adapted by various languages like Sanskrit (IAST: sanskrit). International Alphabet of Sanskrit Transliteration (IAST) is a transliteration scheme for romanisation of Sanskrit language. IAST makes use of diacritics to represent various characters. On a computer, these are represented using Unicode standard which differs from how the Sanskrit language behaves at a very fundamental level. This results in an issue that is encountered while designing typesetting software for devanāgarī and IAST. We hereby discuss the problems and provide a solution that solves the issue of incompatibilities between various transliteration and encoding schemes. Implementation and source code available at https://github.com/dhruvildave/uast

Keywords

Human-Computer Interaction, Interaction Techniques, Text input

1 Handling Unicode characters in IAST

1.1 Pros and Cons of IAST

International Alphabet of Sanskrit Transliteration (IAST) is a popular transliteration scheme used by Sanskrit language for the romanisation of Devanagari script that has seen adaptation amongst scholars. IAST has many benefits:

- Closely follows the original scripts
- Unambiguous
- Intuitive
- No problems of case-sensitivity

IAST uses various diacritics with letters. When it comes to typesetting Sanskrit with IAST, we have to use non-ASCII Unicode characters which creates a problem of having to use non-standard key bindings and/or packages to input those characters. Figuring out those key bindings and setting up IAST input has been a pain point for scholars and students alike. For example, depending on the operating system, package, or editor one might be using, r can be entered via Ctrl + r, Alt + r, or any other key binding in that case. This hugely hinders portability.
1.2 Alternate Syntax for handling Unicode

We suggest a new syntax for representing the characters that use diacritics that are used in IAST:

- Any non-ASCII character should be entered between \( /x/ \) as per Table 1 where \( x \) should be replaced with ASCII replacement for the corresponding Unicode character
- All other ASCII characters should be entered as-is

For example: \( rōma \) should be entered as \( r/a/ma \) as the corresponding entry for \( ā \) is \( a \). Similarly, \( rameśa \) should be entered as \( rame/su/a \) as the corresponding entry for \( ś \) is \( su \). In the same way, \( krṣṇa \) would become \( k/r//sl//nl/a \).

Table 1: Unicode diacritic to ASCII mapping

| unicode | ascii |
|---------|-------|
| ā       | a     |
| ā       | au    |
| ī       | i     |
| ū       | u     |
| ṛ       | r     |
| Ṛ       | ru    |
| ķ        | l     |
| ķ        | lu    |
| ℓ        | ll    |
| ṭ        | t     |
| ṭ        | d     |
| ṇ        | n     |
| ṇ        | nu    |
| ṇ        | nl    |
| ś        | su    |
| ś        | sl    |
| Ṣ        | m     |
| Ṣ        | h     |
| I        | .     |
| I        | ..    |
| ś        | '     |
| śō       | om    |
Table 1 can be summarised up as follows:

- If a diacritic appears above of a character, the character is appended with a `u` where `u` stands for "upper". If a diacritic appears below of a character, the character is appended with a `l` where `l` stands for "lower". For example, ś becomes su, ṇ becomes nu, ṣ becomes sl and ṇ becomes nl.
- For characters that only have a single diacritic, we mention the character directly as it is unambiguous by default. For example, ḍ becomes d, ṭ becomes t, ṁ becomes m, and ḥ becomes h.
- For diacritics of a, the frequency of ā exceeds that of ã by orders of magnitude so ā becomes a and ã becomes au. This can be similarly applied to other cases where Ṱ becomes r, ṭ becomes l, ṷ becomes ru, and ṭ becomes lu.
- Since there is only one remaining diacritic for ṇ, ṇ becomes n unambiguously.
- The remaining characters are simply mapped to the simplest possible representation that are closest to its IAST counterparts.

This mapping is intended for replacement of non-ASCII characters only. Thus, dhā should be written as /dha/ and not /dh/a as only the former would be a correct mapping while latter would be an invalid case as there is no mapping defined for dh but only d.

The benefits that arise from doing this is that now we have a standard way of representing unicode glyphs without having to worry about keyboard layouts and key bindings.

There are two main reasons why we use a new syntax, as inspired by LaTeX, and not resort to other techniques that are adopted by other schemes and encodings.

- Using a mix of lowercase and uppercase would make the scripting and typesetting case-sensitive which tends to be error-prone, harm readability, and involve lot of extra invisible key-pressing in form of Shift or Caps Lock. Our system makes typing those extra characters completely explicit and remove the problem of case-sensitivity altogether.
- The only new character which gets introduced is / (front-slash / Unicode: U+002f) which would explicitly demark the character boundary. Adding other non-alphanumeric characters like & or . would involve invisible key pressing. A suitable competitor to / would be _ (underscore / Unicode: U+005f) but it involves pressing Shift key. We could equivalently use - (dash / Unicode: U+002d) but we reserve it for a special purpose that we present in the next section.

2 devanāgarī and Unicode

2.1 Problems with existing systems

The previous section handled the problem of handling input of Unicode characters when using IAST. The situation doesn't improve when we move from IAST to devanāgarī. We have the same problems mentioned earlier.

We already have many systems that make use of ASCII characters to input devanāgarī script. A very popular system is Harvard-Kyoto convention. It uses a mix of lowercase and uppercase ASCII characters. In this case, rāma in IAST would become rAma in Harvard-Kyoto.
The comparison of various systems is best done by formalising the requirements for a good typesetting system:

- Case-insensitive
- Uses only ASCII characters
- Does not involve invisible key-pressing like Shift or Caps Lock
- Follow IAST
- The character entered should be intuitive and follow the pronunciation

Table 2: A demonstration of how devanāgarī gets encoded in various transliteration schemes or encodings

| | राम: | कृष्ण: | प्रज्ञा |
|---|---|---|---|
| IAST | rāmaḥ | kṛṣṇaḥ | prajñā |
| Harvard-Kyoto | rAmaH | kRSNaH | prajJA |
| SLP1 | rAmaH | kfzRoH | prajYA |
| Velthuis | raama.h | k.r.s.na.h | praj-naa |
| ITRANS | rAmaH | kRRiShNaH | praj-nA |

All the other encodings fall short in atleast one of the criterias. But the problems amplify.

2.2 Unicode Aware Sanskrit Transliteration

We suggest the following system for typesetting devanāgarī:

- The typesetting should follow IAST
- Any unicode diacritics to be entered in IAST should follow the system presented in Section 1.2 and all ASCII characters should simply be entered as-is
- Put an explicit - (dash / Unicode: U+002d) to represent a halant (IAST: halanta / Unicode: U+094d). Thus, unlike IAST, k would become k- to signify lack of an inherent vowel
- a after a consonant is redundant but supported. So, kamāla and kmāl would both mean the same
- To place an explicit vowel instead of a vowel sign, follow it with a \ (back-slash / Unicode: U+005c). It is also used to explicitly mark character boundary. dh would be parsed as ध. To treat them individually, place a like dah which would be parsed into दह.
- The typesetting should be case-insensitive. Thus, both p and P should be treated in the same way.

We call this the **Unicode Aware Sanskrit Transliteration (UAST) system**. Any system which implements UAST will be able to unambiguously transpile it to IAST and devanāgarī using an algorithm with linear space and time complexity. The primary purpose of UAST is to bridge the gap between how typesetting of IAST and devanāgarī is done.
Here are a few examples to exemplify the above principles:

1. **rāma**
   राम
   The only unicode diacritic here is ā. We replace it as per Table 1 with /a/. The remaining characters stay the same. Since a is redundant, we can also remove it.
   UAST = r/a/ma | r/a/m

2. **rāmaḥ**
   रामः
   Replace ā with /a/ and ḡ with /h/. Redundant a can be removed as well.
   UAST = r/a/ma/h/ | r/a/m/h/

3. **krṣṇa**
   कृष्ण
   Replace ṛ with /r/, ṣ with /sl/, and ṇ with /nl/. The final a is redundant. Since ṣ is part of consonant cluster, we need an explicit -.
   UAST = k/r//sl/-/nl/

4. **jānāmi dharmam**
   जानाम धर्मम्
   Replace ā with /a/. r and m at end is half so it is followed by -. Redundant a after dh and m can be removed.
   UAST = j/a/n/a/mi dhr-mm-

5. **kasya**
   कस्य
   No unicode diacritics to replace here. Add - after the s. Redundant a can be removed.
   UAST = ks-y | kas-ya

6. **agniḥ**
   अग्निः
   Replace ḡ with /h/. Add \ after a to place a vowel literal instead of vowel sign. Add - after g.
   UAST = a\g-ni/h/

7. **dhanena**
   धनेन
   Redundant a can be removed.
   UAST = dhnen | dhanena

8. **dahana**
   दहन
   Add a between d and h to treat them individually.
   UAST = dahn | dahana | dahan | dahna
9. *agnimīle*

The vedic accents can be represented using ‘‘ and ‘‘.

UAST = a\`g-nim/i/l/l/e

The following benefits arise from using UAST:

- It is case-insensitive.
- All the key-presses are explicit. There are no use of keys like Shift or Caps Lock.
- The only non-alphanumeric characters are / (Unicode: U+002f), \ (Unicode: U+005c), and - (Unicode: U+002d).
- It is highly intuitive as it does not deviate from IAST and follows character sounds.

### Table 3: A demonstration of how UAST compares with other transliteration schemes and encodings for *devanāgarī*

|          | सा:     | कृषण:   | प्रज्ञा   |
|----------|---------|----------|---------|
| Harvard-Kyoto | rAmaH   | kRSNaH   | prajJA  |
| SLP1     | rAmaH   | kfzRaH   | prajYA  |
| Velthuis | raama.h | k.r.s.na.h| praj-naa|
| ITRANS   | rAmaH   | kRRiShNaH| praj-nA |
| IAST     | rəmaḥ   | kṛṣṇaḥ   | prajnā  |
| UAST     | r/a/m/h/ | k/r//sl/-/nl//h/ | p-rj/-n//a/ |

### 2.2.1 Design Decisions

There are a few decisions that were involved and inspired the design of UAST.

#### 2.2.1.1 Following IAST

The main problem with certain encodings and keyboard-layouts is that they map many *devanāgarī* characters to key-bindings that are non-intuitive. They distance themselves from IAST. IAST is widely used for many reasons:

- Its mapping is unambiguous and exact. For example, ड is always mapped to थ.
- Related sounds have related mappings. For example, ड is always mapped to ढ and ध is always mapped to ढ to consider the point that ढ is an aspirated version of ढ. Similarly, all nasal characters ङ, च, छ, and ज are all mapped to ऋ, ऋ, ऋ, and ऋ respectively. This makes IAST a very logical and intuitive mapping to use. As a result, IAST bridges the gap between Sanskrit and English phonetics.
- Follows original script as-is.

This makes it arguably the most popular transliteration scheme used by scholars and students alike. Since IAST so closely follows the language, it would make sense that the *devanāgarī* typesetting also follow IAST to prevent confusion and remove ambiguity. We believe that a person trying to learn or use
a language and interact with it via a typesetting system should be more concerned with “what to write” rather than “how to write”.

The more an encoding or transliteration system distances itself from IAST, the less intuitive it becomes. Other systems work well in isolation but only add to more confusion when it comes to dealing with them alongside IAST.

2.2.1.2 Avoiding mix of lowercase and uppercase characters

There are major disadvantages involved with the use of both lowercase and uppercase characters. The first is slowing down of reading\(^1\) and writing speeds. Consider the following example. \(\text{pitā}\) in IAST would be written as \(\text{pitA}\) in Harvard-Kyoto and \(\text{pit/a/}\) in UAST. The first three characters stay the same in both. The difference occurs at the end. Ignoring any user-specific or system-specific changes, there are two possible sequences to enter \(\text{A}\) after \(\text{t}\):

- Shift + a
- Caps Lock, a, Caps Lock

The former involves two key-presses while the latter does three. Thus, to write \(\text{pitA}\), we would have to do 5 or 6 key-presses. For writing \(\text{pit/a/}\), there is no uppercase involved. Thus it would be completed in 6 key-presses. So at the cost of additional key-presses, we end up with two major benefits:

- All the key-presses are now explicit. Infact, since we are now using all lowercase characters on a standard ASCII keyboard, number of key-presses = length of string. So a user writes what a user sees. The errors arising due to that are no longer a problem.
- The problem of case-sensitivity is completely eliminated. In conventions like Harvard-Kyoto, change a character to lowercase even by mistake would incur significant penalty on accuracy and precision of transliteration.

2.2.1.3 Avoiding use of non-ASCII Unicode diacritics

The main problem involved with IAST is entering non-ASCII Unicode diacritics. There are a lot of problems as discussed in Section 1.1 involved with entering non-ASCII Unicode diacritics as used in IAST. It might involve finding a specific package or even manually setting up key-bindings. This brings up a problem of portability. There is no standard syntax for \(\text{devanāgarī}\) or even IAST in case of absence of unicode diacritics on keyboard. In UAST, we address that problem by the solutions suggested in Section 1.1.

2.2.2 Explicit Halant (halanta) and Choice of character set

Sanskrit (\textit{sanskṛta}) language and computers have a difference that is very fundamental to the entire problem of encoding, transliteration, and typesetting.

\textit{sanskṛta} language is written using IAST or \textit{devanāgarī} script. Computers use Unicode\(^2\) encoding.

In \textit{sanskṛta}, the consonants are inherently without a vowel and vowels including \(\text{a}\) are added later on.

Thus for \textit{sanskṛta},

\[\text{कृ + अ = क}\]

Since IAST directly follows the language,

\[k + a = ka\]
But this is not the case in Unicode. There is a very subtle but very important distinction. In Unicode Standards, consonants are inherently with an ə and halanta is added later on to signify the absence of any vowel.

Thus for unicode,

\[ \text{k} + \text{ə} = \text{k} ə \]

For example,

In language,

\[ \text{पूर्व} = \text{प} + \text{ू} + \text{र} + \text{व} + \text{ी} \]

In computer,

\[ \text{पूर्व} = \text{प} + \text{ू} + \text{र} + \text{ृ} + \text{व} + \text{ी} \]

This means that Unicode is fundamentally incompatible with how the language and IAST function. There is no explicit representation of the halanta in IAST as it is not needed after all. But then parsing IAST and converting it to devanāgarī means we have to look for those additional and missing ə. For example, on pressing a k, IAST assumes that IAST equivalent of k安静 (क) is entered but Unicode assumes that IAST equivalent of ka (का) is entered. Now a person using IAST will press an a. At this point, for the user, IAST equivalent of ka should have been entered. But what one really ends up with is IAST equivalent of kaa. This occurs frequently with every consonant that IAST has to fight with Unicode for removal of that extra ə to make things work as per standards. This addition and removal of characters makes it completely unintuitive to use IAST directly while typesetting devanāgarī. This is a problem because at this point, we are directly working with unicode glyphs of devanāgarī rather than a romanised representation. It won’t be a problem if IAST or even devanāgarī were to function in isolation. Things get more confusing when going to both of IAST and devanāgarī as various encodings add new characters that aren’t a part of IAST which leads to unintuitive key-bindings in devanāgarī.

To resolve this issue, UAST prefers the use of an explicit halanta to bridge this very gap between devanāgarī/IAST and Unicode. Since IAST is already the standard to work with, the entire character set of UAST is same as that of IAST with added - for a halanta as it very much resembles a dash.

So under UAST, when k is entered, IAST equivalent of ka will be entered to take Unicode into consideration more closely and be in center of the spectrum between the two. This makes ə redundant. This little detail can be very easily parsed and it now comes with an added benefit that since the inherent vowel is now explicit, we can easily use UAST to directly parse it into devanāgarī directly and to IAST with very little to no modification. UAST uses no diacritics and hence there is no problem of either of missing characters, non-standard key-bindings, or case-sensitivity.

This makes UAST the single typesetting system and solving multiple encoding problems for representing Sanskrit in computers by mixing the good parts of both IAST and Unicode while being intuitive, fast, and easy to learn, use, and remember at the same time.
3 References

Babayigit, Özgür. 2019. "The Reading Speed of Elementary School Students on the All Text Written with Capital and Lowercase Letters." *Universal Journal of Educational Research* 7 (2): 371-80.

Unicode Consortium. 2021. "Unicode - The World Standard for Text and Emoji." *Unicode*. https://home.unicode.org/.

Templin, David. 2013. "The Devanagari script." *Hindilanguage.info*. https://hindilanguage.info/devanagari

Ruppel, A. M. 2017. *The Cambridge Introduction to Sanskrit*. New York, New York: Cambridge University Press.

1. Babayigit (2019)
2. Unicode Consortium (2021)