Efficiency of International Standard Serial Number Code as an Error Correcting Scheme

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Abstract: Error correcting coding is an effective technique of detecting and correcting errors which may occur due to environmental interference or physical defects such as human errors in the communication channels. The International Standard Serial Number code is internationally used for identifying the title of serial publications. This paper analyzes the efficiency of the international standard serial number code as an error correcting scheme. Moreover, the paper explores on the factors which affect the efficiency of any error correcting scheme. The study utilizes weight checksum technique to detect and correct error(s) in a code word. It is clear that ISSN code is not an efficient error coding scheme. ISSN code is only reliable in error detection. ISSN code can detect any error in the code iff the weight checksum equation does not hold. However, the code does not detect silent errors. The study develops a new efficient and robust modified ISSN code that is efficient in error detection and correction capabilities. The code has dual mechanism for error detection and correction in a code word. If the weight checksum equation does not hold and secondly, if the conditions for the generating equation do not hold. Modified ISSN code can detect and correct silent errors in a code word. Modified ISSN code is an efficient error coding scheme for it is efficient in error detection and correction capabilities.

Keywords: ISSN, Modified ISSN, Efficient, Error, Coding, Scheme

1. Introduction

Different communication channels have different error correcting coding schemes depending on the types of errors expected in a particular communication channel. An effective error coding requires an efficient scheme which is selected based on the characteristics of the specific communication channel.

1.1. Factors Affecting the Efficiency of an Error Coding Scheme

1.1.1. Durability of the Entire Error Coding Scheme

Durability of error coding scheme depends on the duration of time the entire coding system can stay before being exhausted. An efficient error coding scheme should last for a long period of time. The dictionary of the coding scheme should be large enough to be used for a longer period in its utilization.

1.1.2. Precision of Code Words in an Error Coding Scheme

The total number of digits in a code word in an efficient coding scheme should not be too large so as to lose its immediate utilization. A good (n, q) error correcting code should have a considerable length (n) for fast transmission of messages and large field q to ensure wide transmission of a variety of information (to ensure big dictionary). The code words of the coding scheme should have little similarities to each other. A good (n, q) error correcting code should have a well define field q to ensure precision in its usage. The length of all code words should be same.

1.1.3. Reliability in Utilization of the Error Coding Scheme

The primary principle of an error coding scheme is to assist the receiver of a message to get the true information intended

by the sender, therefore, an efficient error coding scheme should guarantee high probability of accuracy of the messages received by the receiver. An error coding scheme can only guarantee a high probability of accuracy of the message if and only if it can be able to detect and correct error(s) which may occur. An efficient error coding scheme should, therefore, detect and correct all errors that may occur from the original message.

1.2. Efficiency of the ISSN Code in Error Detection and Correction

1.2.1. Durability of the ISSN Code

The International Standard Serial Number (ISSN) is a code that is internationally accepted for identifying the title of serial publications. From ISSN network statistics by January 2019, more than 2.5 million ISSNs had been issued. The number increases by approximately $60,000$ to $70,000$ ISSNs annually. However, about $130,000$ ISSNs are changed and corrected annually. ISSN is only associated with the title of the publication. Therefore in case a publication is modified appreciably, a new ISSN has to be assigned. This means that if a publication title changes ten times the same publication has to be assigned ten new ISSN. It is clearly evident that the number of ISSNs changed and corrected is about double the number of ISSN increase per year.

Additionally, the entire ISSN coding scheme has a relatively small dictionary. The dictionary of $10,000,000$ code words and currently more than 2.5 million ISSNs has been issued by January 2019. This implies that with about 70,000 code words issued per year and $130,000$ ISSNs changes and correction annually, the remaining $ISSN$ code words can last for maximum of 35 years. With high number of publications increase, currently ISSN coding scheme is not durable.

1.2.2. Precision of the ISSN Code Words

ISSN code is computed modulo 11, therefore the code is a finite field. ISSN code being a finite field of order 11, each element of the code word is supposed to be chosen from the set $F_{11} = \{0, 1, 2, ..., 9, 10\}$ but the element 10 has two digits 1 and 0 , therefore, not applicable as an element of the code word. However, in the case when the check digit is 10, an alphabetic letter is used. An alphabetic letter is used to ensure that the length of the ISSN codes remains eight. The usage of the alphabetic letter only in the check digit but not is an element of the entire code word makes the ISSN code to loss its brevity and precision. ISSN uses numeric digits except in check digit where alphabetic digit is used. Therefore, there is a lot of similarities of the elements from one code word to another.

1.2.3. Reliability in the Utilization of the ISSN Code Words

From the properties of ISSN code [12], it is clear that the following deductions holds;

1. ISSN code can detect any error in a code word if and only if the weight check sum equation does not hold.

2. ISSN code can detect and correct all single error in a code word if and if the position of the error is known.

3. ISSN can detect and correct all transposition errors in a code word even if the position of errors is unknown.

4. ISSN can detect and correct all double errors in a code word if and only if the position of errors in known.

5. ISSN cannot detect and correct silent error(s) in a code word.

6. ISSN code cannot correct jump transpose error, double error, jump twin error, phonetic error, twin error, omission, and insertion error in a code word.

Corollary 1.1. ISSN code is not an efficient error coding scheme.

Proof. It is clear that ISSN code is neither durable nor precise error correcting scheme. Moreover, it is clear that ISSN is not reliable in error correction for it only corrects a single error and a transposition error in a code word. Therefore, ISSN code is not efficient in error correction.

2. Modified ISSN Code

The Modified ISSN code is developed and generated by the use of functions, permutations and the properties of the existing ISSN code. The code is developed on the basis of a good communication channel and an efficient error coding scheme.

2.1. Development and Generation of Modified ISSN

1. The Modified ISSN code is an alphanumerical code, that is, it is made of alphabetical digits and numerical digits.

2. The Modified ISSN code is a finite field of order 31 where each digit is chosen from the set F_{31}. The set F_{31} is the set $\mathbb{Z}_{31} = \{0, 1, 2, ..., 30\}$. Each code word of the modified ISSN code has a length of 8 digits, where each digit chosen from the set F_{31}. Alphabetical digit O and I are omitted, for O resembles numerical digit 0 and I resembles 1 hence to avoid confusion. Thus the set $F_{31} = \{0, 1, 2, ..., 8, 9, A, B, C, ..., U, V, W\}$ without alphabetical digits I and O. The main reason of using alphabetical digits is to replace two digits numerical digits hence avoiding confusing and enhancing preciseness.

3. The elements in each code word is generated by the generating equation defined by $x_{i+1} = 3x_i + 5 \, (mod \, 31)$, $i = 1, 2, ..., 6$ except the last digit of the code word. The last digit of code word is the check digit hence is computed. The first term(digit) of the generating equation is chosen randomly from the $F_{31} \cong \mathbb{Z}_{31}$.

4. It is not a must for the generating equation defined by $x_{i+1} = 3x_i + 5 \, (mod \, 31)$, $i = 1, 2, ..., 6$ to start at the beginning of a code word. The sequence generated by of the generating equation can also be terminated in a code word. In the case where the sequence is terminated, digit 0 is inserted after the last digit of the terminated sequence and before the first digit of the other generating

equation . The first term(digit) of the other generating equation is also chosen randomly from the $F_{31} \cong \mathbb{Z}_{31}$.

5. The digit 0 does not have to necessarily be used when a sequence generated by the generating equation has been terminated, it may be used as an element of the code word itself. That is, digit 0 may be generated by the generating equation or may be at the beginning of the generating equation. In this case, digit 0 acts as a neutral digit. This implies that the generated sequence does not necessarily terminate once there is a digit 0.

6. In the case where the generating equation does not start at the beginning of a code word, the first digit of sequence is repeated from the beginning of a code word until where the start digit of the generating equation starts. Moreover, it is not a must for the generating equation to start at the beginning immediately after digit 0 in case the generated sequence had been terminated.

In the case where the generating equation does not start after digit 0, the first digit of the new sequence is repeated after digit 0 until where the start digit of generating equation starts.

7. ISSN codes are only associated with the title of a publication, in case changes and corrections are made to the title of a publication, the code word will have an extra digit called a blind digit. A blind digit is separated from the check digit by a hyphen. A blind digit does not affect the weight check sum of the entire code word. It is given depending on the number of changes made in the title of a publication. Importance of the blind digit is to help to know the number of times the changes and corrections have been made to a title of a publication.

8. The eight digits of the modified ISSN code must satisfy

$$\sum_{i=1}^{8} \sum_{j=9-i} jx_i \equiv 0 \, (mod \, 31).$$

Examples of modified ISSN code;

$1 \; 8 \; V \; W \; 2 \; B \; 7 \; N$
$B \; B \; B \; B \; B \; 7 \; R \; 0$
$S \; M \; 0 \; V \; W \; 2 \; B \; 3$

$1 \; 1 \; 1 \; 1 \; 8 \; V \; W \; C$
$3 \; E \; G \; N \; 9 \; 1 \; 8 \; L - 2$
$V \; W \; 2 \; B \; 0 \; T \; Q \; D$

$L \; 3 \; 0 \; R \; J \; U \; 0 \; U$

Where

Table 1. Elements of modified ISSN code.

0	1	2	3	4	5	6	7	8	9
A=10	B=11	C=12	D=13	E=14	F=15	G=16	H=17	J=18	K=19
L=20	M=21	N=22	P=23	Q=24	R=25	S=26	T=27	U=28	V=29

2.2. Number of Code Words in Modified ISSN Code

Proposition 2.1. Modified ISSN code has a dictionary of upper bound of 28, 644, 217.

Proof. The Modified ISSN code is finite field of order 31 where each digit is chosen from the set $F_{31} \cong \mathbb{Z}_{31}$. Each code word of the modified ISSN code has a length of 8 symbols,where each symbol is chosen from the set F_{31}. Moreover, the eighth digit of the modified ISSN code is the check digit which is computed on the basis of weight checksum equation.The elements in each code word is generated by the generating equation defined by $x_{i+1} = 3x_i + 5 \, (mod \, 31) \, i = 1, 2, 3, ..., 6$. It is not a must for the generating formula for the generation of the elements of a code word to start at the begin of the code word. Total numbers of the code words depends on the generating equation and digit 0 for the termination of the generated sequence. Digit 0 for the termination of the generating equation can occur from the second digit of a code word to the seventh digit of a code word. There are 31 ways of choosing the first digit of a code word, two ways of choosing the second digit, that is, through generating equation or repetition if generating equation does not start in the beginning of a code word. From the third

digit to the seventh digit there are three ways of choosing each digit. There is only one way of choosing the eighth digit for it is computed to satisfy the weight checksum equation. Moreover, if there is a digit 0 in second digit, there are 31 ways of choosing the third digit, similar to the fourth digit until the seventh digit. Therefore there are $31 \times 2 \times 3^5$ or 31^5 ways of choosing a code word, hence the dictionary of the modified ISSN code is $15066 + 28, 629, 151 = 28, 644, 217$.

2.3. Calculation of the Check Digit in a Modified ISSN Code Word

Let the code word for modified ISSN be $X = x_1, x_2, ..., x_7$ without the check digit. To compute the check digit, x_8, since the code word digits $x_1, x_2, ..., x_7$ are known, calculate $\sum_{i=1}^{7} \sum_{j=9-i} jx_i$. Let $\xi = \sum_{i=1}^{7} \sum_{j=9-i} jx_i$ then $x_8 + \xi \equiv 0 \, (mod \, 31)$. Now since 0 is additive identity of $\mathbb{Z}_n$, therefore x_8 is the additive inverse of $\xi (mod \, 31)$. Thus $x_8 \equiv -\xi (mod \, 31)$.

Example 2.1. Calculate x_8 for the ISSN code word $1 \; 8 \; V \; W \; 2 \; B \; 7 \; x_8$. To compute x_8, calculate $\xi =$

$$\sum_{i=1}^{7} \sum_{j=9-i} jx_i = 443\,(mod\,31) = 9\,(mod\,31)\ .$$ Hence $x_8 = 9^{-1}(mod\,31) = 22 = N$.

3. Error Detection in Modified ISSN Code

Modified ISSN code is an improved error coding scheme in term of error detection and correction capabilities. Let $X = x_1, x_2, ..., x_8$ be the code word for modified ISSN, then the weight checksum is computed $\sum_{i=1}^{8} \sum_{j=9-i} jx_i \equiv mod\,31$.

If $\sum_{i=1}^{8} \sum_{j=9-i} jx_i \neq 0\,(mod\,31)$ then the code has detected error(s). Moreover, Let the code word for modified ISSN be $X = x_1, x_2, ..., x_8$, then $x_2 = (3x_1 + 5)\,(mod\,31)$, $x_3 = (3x_2 + 5)\,(mod\,31)$, $, ...x_7 = (3x_6 + 5)\,(mod\,31)$. If $x_i \neq (3x_{i-1}+5)\,(mod\,31), i = 2, 3, .., 7$ then the code has detected error(s). An ISSN code word has a length of only eight digits unless there is change of the title of the publication where the code word has nine digits, therefore, if the code has a length of more or less than eight then there is an error.

Remark 3.1. if $x_i \neq (3x_{i-1}+5)\,(mod\,31)$, $i = 2, 3, .., 7$ does not necessarily indicate an error in the code word for there are two occasions where $x_i \neq (3x_{i-1}+5)\,(mod\,31)$, $i = 2, 3, .., 7$ will occur but no error has occurred in the code word:

a. In case there is a digit 0 indicating the termination of the generating equation $x_{i+1} = 3x_i + 5\,(mod\,31), i = 1, 2, ..., 6$

b. In case there is repetition of a digit indicating that the generating equation $x_{i+1} = 3x_i + 5\,(mod\,31), i = 1, 2, ..., 6$ has not begun in the beginning of the code word or after digit 0 when there is termination of the generating equation. The code word has to satisfy the checksum weight equation $\sum_{i=1}^{8} \sum_{j=9-i} jx_i \equiv 0\,(mod\,31)$.

3.1. Single Error Detection in a Modified ISSN Code Word

Proposition 3.1. The Modified ISSN code detects any single error in the Modified ISSN code word.

Proof. Suppose $X = x_1, x_2, ..., x_8$ is the modified ISSN code word and $Y = x_1, x_2, ..., x_{\tau-1}, y_\tau, x_{\tau+1}, ..., x_8$ with $y_\tau = x_\tau + \alpha \quad \alpha \neq 0$ is the modified ISSN code word with a single error that has occurred in digit x_τ, $1 \leq \tau \geq 8$. Then

$$(\sum_{i=1}^{8} \sum_{j=9-i} jy_i)$$
$$(\sum_{i=1}^{8} \sum_{j=9-i} jx_i) + (9 - \tau)\alpha \neq 0\,(mod\,31)$$
$$(9 - \tau)\alpha \neq 0\,(mod\,31)$$

Moreover, $y_\tau \neq (3x_{\tau-1}+5)\,(mod\,31)$. Therefore the single error is detected.

Proposition 3.2. The Modified ISSN code detects silent error in a code word.

Proof. Suppose a single error has occurred in a modified ISSN code word but $\sum_{i=1}^{8} \sum_{j=9-i} jx_i \equiv 0\,(mod\,31)$. Then if $Y = x_1, x_2, ..., x_{\tau-1}, y_\tau, x_{\tau+1}, ..., x_8$ with $y_\tau = x_\tau + \alpha \quad \alpha \neq 0$ is the modified ISSN code word with a single error that has occurred in the position x_τ then

$$(\sum_{i=1}^{8} \sum_{j=9-i} jy_i)$$
$$(\sum_{i=1}^{8} \sum_{j=9-i} jy_i) + (9 - \tau)\alpha \equiv 0\,(mod\,31)$$
$$(9 - \tau)\alpha \equiv 0\,(mod\,31)$$

This implies that either $9 - \tau$ or α is a multiple of 31 or 0. Since $9 - \tau$ cannot be a multiple of 31 or 0 for $1 \leq \tau \leq 8$ hence $\alpha = 0$ and no error. However, there is a single error in the code word then there exist a digit of the code word $x_i \neq (3x_{i-1}+5)\,(mod\,31)$. Therefore $x_\tau \neq (3x_{\tau-1}+5)\,(mod\,31)$ and hence the silent error detected. Conversely, Suppose a single error has occurred in modified ISSN code but $x_i = (3x_{i-1}+5)\,(mod\,31)$ for $i = 2, 3, .., 7$ then $\sum_{i=1}^{8} \sum_{j=9-i} jx_i \neq 0\,(mod\,31)$ then the silent error is detected.

Proposition 3.3. The Modified ISSN code corrects the single errors in a code word.

Proof. Suppose $X = x_1, x_2, ..., x_8$ is the modified ISSN code word and $Y = x_1, x_2, ..., x_{\tau-1}, y_\tau, x_{\tau+1}, ..., x_8$ with $y_\tau = x_\tau + \alpha \quad \alpha \neq 0$ is the modified ISSN code word with a single error that has occurred in digit $y_\tau, 1 \leq \tau \geq 8$. The most important thing is the code to detect the position of the digit with error. From second digit to the second last digit of the code word is generated by the generating equation $x_{\tau+1} = 3x_\tau + 5\,(mod\,31)$ unless there is a repetition of digits or digit 0 indicating termination of the generating equation. By use of the generating equation $x_{\tau+1} = 3x_\tau + 5\,(mod\,31)$ the digit $y_\tau = x_\tau + \alpha \quad \alpha \neq 0$ is detected by $y_\tau \neq (3x_{\tau-1}+5)\,(mod\,31)$. After the position of y_τ is detected, the error is corrected by the computing $y_\tau = (3x_{\tau-1}+5)\,(mod\,31)$ and $y_\tau = (\frac{x_{\tau+1}-5}{3})\,(mod\,31)$. In case $x_{\tau+1} < 5$ or $(x_{\tau+1}-5)$ is not divisible by 3 then

$$3y_\tau \equiv x_{\tau+1} - 5\,(mod\,31)$$
$$3^{-1}y_\tau = 3^{-1} \times ((x_{\tau+1} - 5)\,(mod\,31))$$
$$y_\tau = 21 \times ((x_{\tau+1} - 5)\,(mod\,31))$$

when $x_{\tau+1} < 5$

$$y_\tau = 21 \times ((31 + (x_{\tau+1} - 5))\,(mod\,31))$$

Then the weight checksum equation $\sum_{i=1}^{8} \sum_{j=9-i} jx_i \equiv$

$0 \, (mod \, 31)$ is tested whether it holds. Additionally, when the error has been detected and the position of the error is known. Then the error can be corrected by

$$\sum_{\substack{i=1 \; i\neq\tau \\ j=9-i}}^{8} jx_i + (9-\tau)y_\tau \equiv 0 \, (mod \, 31)$$

$$(9-\tau)y_\tau \equiv - \left[(\sum_{\substack{i=1 \; i\neq\tau \\ j=9-i}}^{8} jx_i)(mod \, 31) \right]$$

$$y_\tau = (9-\tau)^{-1} \times - \left[(\sum_{\substack{i=1 \; i\neq\tau \\ j=9-i}}^{8} jx_i)(mod \, 31) \right]$$

Since $y_\tau = x_\tau + \alpha, \alpha = 0$ hence $y_\tau = x_\tau$ yielding the original modified ISSN code word $X = x_1, x_2, ..., x_8$.

Example 3.1. Let $1 \; 8 \; V \; W \; 2 \; B \; 7 \; N$ be the modified ISSN code word and $1 \; 8 \; V \; W \; C \; B \; 7 \; N$ be the modified ISSN code word with a single error at x_5. By

$$\sum_{\substack{i=1 \\ j=9-i}}^{8} jx_i \neq 0 \, (mod \, 31)$$
$$505 \neq 0 \, (mod \, 31)$$
$$9 \neq 0 \, (mod \, 31)$$

therefore the single error is detected. By use of the generating equation $x_{i+1} = (3x_i + 5) \, (mod \, 31)$ the position of the error is found. The error is at x_5 for

$$C = 12 \neq (3W + 5) \, (mod \, 31)$$
$$12 \neq 95 \, (mod \, 31)$$

the error is corrected by the computing $y_\tau = (3x_{\tau-1} + 5) \, (mod \, 31)$ and $y_\tau = (\frac{x_{\tau+1}-5}{3}) \, (mod \, 31)$

$$x_5 = (3x_4 + 5) \Rightarrow x_5 = (3V + 5) \, (mod \, 31)$$
$$x_5 = (90 + 5) \, (mod \, 31)$$
$$x_5 = 2 \; and$$
$$x_5 = (\frac{B-5}{3}) \, (mod \, 31)$$
$$x_5 = (\frac{11-5}{3}) \, (mod \, 31)$$
$$x_5 = 2$$

Hence the error is corrected.

Remark 3.2. The Modified ISSN is more efficient in single error detection and correction than ISSN code.

3.2. Transposition Error Detection and Correction in a Modified ISSN Code Word

Proposition 3.4. The Modified ISSN code detects all transposition error in a code word.

Proof. Suppose $X = x_i, i = 1, 2, ..., 8$ is the modified ISSN code word and $Y = x_1, x_2, ..., , x_\beta, x_\tau, ..., x_8$ with x_τ and x_β

be exchanged digits of the modified ISSN code word. Then

$$(\sum_{\substack{i=1 \\ j=9-i}}^{8} jy_i)$$

$$(\sum_{\substack{i=1 \; i\neq\tau,\beta \\ j=9-i}}^{8} jx_i) + (\tau - \beta)x_\tau + (\beta - \tau)x_\tau \neq 0 \, (mod \, 31)$$

$$(\tau - \beta)(x_\tau - x_\beta) \neq 0 \, (mod \, 31)$$

provided $\tau \neq \beta$ and $x_\tau \neq x_\beta$. Therefore, transposition error of digits x_τ and x_β is detected. Alternatively, Suppose $X = x_i, i = 1, 2, ..., 8$ is the modified ISSN code word and $Y = x_1, x_2, ..., , x_\beta, x_\tau, ..., x_8$ with x_τ and x_β be exchanged digits of the ISSN code word. Then

$$x_\beta \neq (3x_\tau + 5) \, (mod \, 31) \;\; and$$
$$x_\tau \neq (\frac{x_\beta - 5}{3}) \, (mod \, 31)$$

but

$$x_\tau = (3x_\beta + 5) \, (mod \, 31) \;\; and$$
$$x_\beta = (\frac{x_\tau - 5}{3}) \, (mod \, 31)$$

Therefore transposition error of digits x_τ and x_β detected.

Corollary 3.1. The Modified ISSN code corrects all transposition errors in the code word.

Proof. From the above prove (detection of transpose error) it is clear that

$$x_i = (3x_{i-1} + 5) \, (mod \, 31) \, i = 2, 3, ..., 7$$
$$x_\beta \neq (3x_\tau + 5) \, (mod \, 31)$$
$$x_\tau \neq (\frac{x_\beta - 5}{3}) \, (mod \, 31)$$

but

$$x_\tau = (3x_\beta + 5) \, (mod \, 31)$$
$$x_\beta = (\frac{x_\tau - 5}{3}) \, (mod \, 31)$$

Thus implying there is a transpose error which can be corrected by exchanging the digits x_τ and x_β.

Example 3.2. Let $1 \; 8 \; V \; W \; 2 \; B \; 7 \; N$ be the modified ISSN code word and $1 \; 8 \; V \; W \; B \; 2 \; 7 \; N$ be the modified ISSN code word with adjacent transposed error at x_5 and x_6 . Consider the new modified ISSN code word $1 \; 8 \; V \; W \; B \; 2 \; 7 \; N$, the weight checksum equation $\sum_{\substack{i=1 \\ j=9-i}}^{8} jx_i \neq 0 \, (mod \, 31)).\tau = 5, \beta = 6, x_\tau = 11, x_\beta = 2(\tau - \beta)(x_\tau - x_\beta) \neq 0 \, (mod \, 31) \Rightarrow (5-6)(11-2) = -9 \neq 0 \, (mod \, 31)$. Moreover, $2 \neq (3 \times 11 + 5) \, (mod \, 31)$ for $(3 \times 11 + 5) \, (mod \, 31) = 38 \, (mod \, 31) = 7$ and $11 \neq (\frac{2-5}{3}) \, (mod \, 31)$ but $11 = (2 \times 3 + 5)(mod \, 31)$ and $2 = (\frac{11-5}{3})$. Hence the transposed error detected. Since the transposed error is detected the code can be corrected by transposing the digits yielding $1 \; 8 \; V \; W \; 2 \; B \; 7 \; N$ by which the weight checksum equation holds. Hence the error

corrected.

Remark 3.3. The Modified ISSN is more efficient in transpose error detection and correction than ISSN code.

3.3. Jump Transposition Error Detection and Correction in Modified ISSN Code

Proposition 3.5. The Modified ISSN code detects all jump transposition error in a code word.

Proof. Suppose that $X = x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$ is a modified ISSN code word and $Y = x_1, x_2, x_5, x_4, x_3, x_6, x_7, x_8$ be modified ISSN code word with jump transposition error. The check sum of X and Y are $8x_1 + 7x_2 + 6x_3 + 5x_4 + 4x_5 + 3x_6 + 2x_7 + x_8$ and $8x_1 + 7x_2 + 6x_5 + 5x_4 + 4x_3 + 3x_6 + 2x_7 + x_8$ respectively. Assume that X and Y are multiple of 31 that is both are $\sum_{i=1}^{8} \sum_{j=9-i} jx_i \equiv 0\,(mod\,31)$. Consider $X - Y$. After cancellation

$$X - Y = 6x_3 - 6x_5 + 4x_5 - 4x_3$$
$$= 2x_3 - 2x_5 = 2(x_3 - x_5).$$

Since $x_3 - x_5$ is $-30 \le x_3 - x_5 \le 30$. The only multiple of 31 between -30 and 30 is zero. Therefore $x_3 - x_5 = 0$, then $x_3 = x_5$ meaning no error has occurred. This is a contradiction. Alternatively, Suppose that $X = x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$ is a modified ISSN code word and $Y = x_1, x_2, x_5, x_4, x_3, x_6, x_7, x_8$ be the modified ISSN code word with jump transposition error. Consider $Y = x_1, x_2, x_5, x_4, x_3, x_6, x_7, x_8$ then the error can be detected by $x_4 \neq (3x_5 + 5)\,(mod\,31)$, *and* $x_4 \neq (\frac{x_3-5}{3})mod\,31$ but $x_4 = (3x_3 + 5)\,(mod\,31)$ and $x_4 = (\frac{x_5-5}{3})\,(mod\,31)$. Hence jump transposition error detected.

Corollary 3.2. The Modified ISSN code corrects all jump transposition error in a code word.

Proof. It is clear that once the jump transposition error has been detected can be corrected. Suppose that $X = x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$ is a modified ISSN code word and $Y = x_1, x_2, x_5, x_4, x_3, x_6, x_7, x_8$ be the modified ISSN code word with jump transposition error. Consider $Y = x_1, x_2, x_5, x_4, x_3, x_6, x_7, x_8$ once the error is detected by $x_4 \neq (3x_5 + 5)\,(mod\,31)$, $x_4 \neq (\frac{x_3-5}{3})\,(mod\,31)$ but $x_4 = (3x_3 + 5)\,(mod\,31)$ and $x_4 = (\frac{x_5-5}{3})\,(mod\,31)$. This implies that the error can be corrected by transposing x_3 and x_5 and then test whether the weight checksum equation holds and the generating equation $x_i = (3x_{i-1} + 5)\,(mod\,31)\,i = 2, 3, ..., 7$ holds.

Example 3.3. Let $1\,8\,V\,W\,2\,B\,7\,N$ be the modified ISSN and $1\,8\,2\,W\,V\,2\,7\,N$ be the modified ISSN code word with jump transposed error at x_3 and x_5. The error is detected by the fact that $x_4 \neq (3x_5 + 5)\,(mod\,31)$, *and* $x_4 \neq (\frac{x_3-5}{3})\,(mod\,31)1$ but $x_4 = (3x_3 + 5)\,(mod\,31)$ and $x_4 = (\frac{x_5-5}{3})\,(mod\,31)$ therefore the jump transposition error can be corrected by exchanging x_3 and x_5 yielding $1\,8\,V\,W\,2\,B\,7\,N$ in which both $x_i = (3x_{i-1} + $

$5)\,(mod\,31)\,i = 2, 3, ..., 7$ and $\sum_{i=1}^{8} \sum_{j=9-i} jx_i \equiv 0\,(mod\,31)$ hold.

3.4. Double Error Detection and Correction in Modified ISSN Code

Proposition 3.6. The Modified ISSN code detects and corrects all double error in the code word.

Proof. Suppose $X = x_i, i = 1, 2, ..., 8$ is the modified ISSN code word and $Y = x_1, x_2, ..., x_{\tau-1}, x_\tau, x_\beta, x_{\beta+1}..., x_8$ be the modified ISSN code word with double error in digit x_τ and x_β. Without loss of generality $Y = \sum_{i=1}^{8} \sum_{j=9-i} jx_i \neq 0\,(mod\,31)$ and error detected in the code word Y. Suppose there is no error in the Y then $Y = \sum_{i=1}^{8} \sum_{j=9-i} jx_i \equiv 0\,(mod\,31)$ and $x_i = (3x_{i-1} + 5)mod\,31\,i = 2, 3, ..., 7$ but this not the case. Since there is an error in Y, the double error is detected by

$$x_\beta \neq (3x_\tau + 5)\,(mod\,31)$$
$$x_\tau \neq (\frac{x_\beta - 5}{3})\,(mod\,31)$$

moreover,

$$x_\tau \neq (3x_{\tau-1} + 5)\,(mod\,31)$$
$$x_\beta \neq (\frac{x_{\beta+1} - 5}{3})\,(mod\,31)$$

but the rest $x_i = (3x_{i-1} + 5)\,(mod\,31)$ holds. Since $x_{\tau-1} = (3x_{\tau-2} + 5)\,(mod\,31)$ and $x_{\beta+1} = (\frac{x_{\beta+2}-5}{3})\,(mod\,31)$, the twin error in Y is corrected by making $x_\tau = (3x_{\tau-1} + 5)\,(mod\,31)$ and $x_\beta = (\frac{x_{\beta+1}-5}{3})\,(mod\,31)$ then test whether the weight checksum equation holds.

Example 3.4. Let $1\,8\,V\,W\,2\,B\,7\,N$ be the modified ISSN code word and $1\,8\,V\,5\,C\,B\,7\,N$ be the modified ISSN code word with double error at x_3 and x_4. Since the weight checksum equation does not hold, the error is detected in the code word. The double error is detected by

$$C \neq (3 \times 5 + 5)\,(mod\,31) \qquad C = 12 \neq 20\,(mod\,31)$$
$$5 \neq (\frac{C-5}{3})\,(mod\,31) \qquad 5 \neq (\frac{12-5}{3})\,(mod\,31)$$
$$5 \neq (3 \times V + 5)\,(mod\,31) \qquad 5 \neq 30\,(mod\,31)$$

and

$$C \neq (\frac{B-5}{3})\,(mod\,31)$$
$$12 \neq (\frac{11-5}{3})\,(mod\,31)$$

Since

$$V = (3 \times 8 + 5)\,(mod\,31)$$
$$29 = (3 \times 8 + 5)\,(mod\,31)$$

and

$$B = (\frac{7-5}{3}) \, (mod \, 31)$$
$$11 = 3^{-1} \times 2 \, (mod \, 31)$$
$$11 = 21 \times 2 \, (mod \, 31)$$
$$11 = 42 \, (mod \, 31)$$

then

$$x_\tau = (3 \times V + 5) \, (mod \, 31)$$
$$x_\tau = (3 \times 29 + 5) \, (mod \, 31)$$
$$x_\tau = 30 = W$$

and

$$x_\beta = (\frac{B-5}{3}) \, (mod \, 31)$$
$$x_\beta = (\frac{11-5}{3}) \, (mod \, 31)$$
$$x_\beta = 2$$

Therefore the code has detected and corrected double errors in the code word.

4. Efficiency of the Modified ISSN in Error Detection and Correction

Proposition 4.1. Modified ISSN code is an efficient error coding scheme.

Proof. Without loss of generality, modified ISSN code is efficient in error detection and correction. Moreover, modified ISSN has a blind digit which shows the number of corrections and modification done of the title of publication. ISSN coding scheme is only associated with the title of the publication. Therefore in case a publication is modified appreciably, only the blind digit changes. This means that if a publication is modified ten times the modified ISSN code shows that the title of the publication has being changed ten times. Moreover, modified ISSN code is a finite field where its elements are precisely selected and therefore an efficient coding scheme.

5. Conclusion

The study has shown that ISSN code is not an efficient error coding scheme. ISSN code is only efficient in error detection for it only reliable in error detection. ISSN code can detect any error in the code iff the weight checksum equation does not hold. However, the code does not detect silent errors. Modified ISSN code is efficient in error detection and correction capabilities. The code has dual mechanism of detection of errors in a code word. First, if the weight checksum equation does hold and secondly, if the generating equation does not hold. Modified ISSN code can detect and correct silent error in a code word. Modified ISSN code is an

efficient error coding scheme for it is efficient in error detection and correction capabilities. Moreover, the code has a relatively big dictionar.

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