Building an Intelligent Tutoring System for Learning Polysemous Words in *Mooré*

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***Abstract*—This paper presents the results of our research carried out as part of the building of an Intelligent Tutoring System (ITS) to learn *Mooré*, a tone language. A word in tone language may have many meanings according to the pitch. The system has an intelligent tutor to personalize and guide the learning of the transcription of polysemous words in *Mooré*. This learning activity aims both to master the transcription and also to distinguish the lexical meaning of words according to the pitch used. A first step of this research has been the specification of the processes, inference and knowledge of the system. In this work we present the implementation and pedagogical assessment of the system. We designed the architecture of the ITS, the diagnosis of transcription errors and remediation approach. Then, we used the Petri net formalism to model the system dynamic in order to analyze its states and fix deadlocks. We developed the system in java and we evaluated its educational value by an experimentation with learners. This shows that the learning objectives can be achieved with this system.**

Keywords*—Intelligent tutoring system; petri network; evaluation; Mooré language

I. Introduction

An Intelligent Tutorial System (ITS) is a computing environment for human learning that integrates artificial intelligence techniques and cognitive theories in order to provide guided and personalized learning to learners [1], [2]. It consists of four main modules: domain, student, tutoring and communication [26], [27]. In the literature, ITS for learning language research are mostly on European and Asian languages such as English, Japanese, Chinese [5], [10], [11], [12]. Our research contributes to the development of ITS for language learning. We aim to build an ITS to learn polysemous words in *Mooré* through transcription activities. *Mooré* is a tone language, the most spoken in Burkina Faso. This language is also spoken in some neighboring countries such as Côte d'Ivoire, Ghana, Mali and Togo.

The contribution presented in this paper follows a previous one where we presented a specification of an intelligent tutoring system to learn tone language [13]. We used CommonKADS a knowledge engineering method to specify the knowledge and processes of the system. The specification provides a common framework for the development of transcription-based ITS for any tone language.

In Burkina Faso, the learning of local languages is part of the non-formal education program of the government. So, only with the training centers, often of short-term projects, provide learning programs for local languages. Therefore, building an ITS for Mooré learning is a significant contribution in the field of local languages ilearning in Burkina Faso. The building of such IT tools could not only help meet the needs to learn local languages in sub-Saharan Africa but also to ensure the continuity of local language learning during periods of pandemic such as COVID-19.

The rest of the paper is organized as follows. Section II presents the background. It contains important concepts used in this article. In Section III we present the architecture of the system and describe the approach to diagnostic transcription errors and the remediation to provide. Section IV shows the development framework and an overview of the system. Section V presents the evaluation results of the system experimentation. In Section VI we summarize the work done and gives some perspectives.

II. Background

In this section, we present important concepts that we used and related work on tone language. These concepts are the Petri net, Bayesian network widely used in the field of ITS research.

A. Tone Languages

A Tone language includes pitch phonemes in addition to consonants and vowels, and pitch differences are used to distinguish one lexical item from another [15]. Tone languages are characterized by two types of tones: punctual tone and melodic tone. In punctual tones, only one aspect of the melodic curve is considered (highest or lowest) whereas in modulated tones, they are distinguished by successive directions of the melodic curve [16]. *Mooré* and most of the languages spoken by sub-Saharan African are languages with punctual tones [4]. The Mooré language has three tonal patterns:

- the high tone, represented by the acute accent (´)
- the medium tone, represented by the dash sign (¯)
- the low tone, represented by the grave accent (`)

The Non-respect of tones leads to confusion, misinterpretation or nonsense.

The learning activities of the ITS are based on transcription tasks of polysemous words in *Mooré* language at the example of Fig. 1. To do this, taking account the tone in the transcription is very important because it allows us to distinguish the lexical meaning of words according to the pitch.

(a) bread (*búrì* in *Mooré*) (b) fall (*bùri* in *Mooré*)

Fig. 1. Example of Two Words(Bread and Fall) Represented in Images. The First Image is Transcribed by the Word *Búrì* and the Second Image by the Word *Bùri*. The Word *Buri* in *Mooré* without the Pitch, it' is Unclear whether that Word Alludes to the First Image or to the Second Image.

B. Petri Networks

The Petri networks in short Petri nets is a mathematical modeling formalism introduced by Dr. Carl Adam Petri in 1962. This modeling tool is used to represent the dynamics of discrete distributed systems in computer science, engineering and so forth [8]. The petri nets formalism is borrowed from graph theory. Therefore, a Petri nets is a directed bipartite graph that has two types of node: places and transitions. Place is represented by circle and transition by bar or box. Places and transitions are connected by directed edges. Place represents system states, condition or resources that must be met before an action can be performed. Transition represents actions.

A mathematical definition of Petri net is a tuple $PN = (P, T, Pre, Post)$ where:

- $P = \{p1, p2, ..., pn\}, n > 0$ a finite set of places;
- $T = \{t1, t2, ..., tm\}, m > 0$ a finite set of transitions;
- The places P and transitions T are disjoint ($P \cap T = \emptyset$);
- $Pre : (PxT) \rightarrow \mathbb{N}$ is an input function that defines directed edges from places to transitions;
- $Post : (TxP) \rightarrow \mathbb{N}$ is an output function that defines directed edges from transitions to places.

A marked Petri net is a five tuple $G = (P, T, Pre, Post, M)$ where M can be viewed as a function, which assigns a natural number with each place, i.e. $M : P \rightarrow N$. M can also be viewed as a vector given by M_k = $\{M_1, M_2, ..., M_i, ..., M_n\}$ where the i^{th} entry of M is M_i, which is the marking of the place p_i. The execution of a Petri net causes its marking to change by removing tokens from its input places and depositing into each of its output places.

A transition is said to be enabled when each one of its input places is marked with at least one token. In mathematical terms, a transition, $t \in T$, is enabled if $M(p) \succeq Pre(p, t); \forall p \in P$. If an enabled transition t fires then it causes a change in marking from $M(p)$ to $M'(p)$ given by the equation:

$$M'(p) = M(p) - Pre(p, t) + Post(p, t); \forall p \in P.$$

As for the usefulness of the Petri net, this approach is used to diagnose modeling errors of an application [9], [6]. In the field of ITS, Petri nets have been used to model systems and to verify their consistency [7]. Thus, for our study, we used graphical representation of Petri net to model the operations(actions) ans states of our system. The reachability graph will allows to represent the different firings of the marked Petri net. The purpose of the reachability graph is to remove possible deadlock states of the system.

C. Bayesian Network

The Bayesian network is a graphical and probabilistic model for representing uncertain or incomplete knowledge of the learner in the field of learning [3]. It is a technique of artificial intelligence initiated by Corbett and Anderson in 1994. The graphical model is represented by two parameters {N, A}. N represents the set of nodes or vertices and A the set of arcs. The probabilistic representation of the Bayesian network is based on Bayes' theorem [28]. Bayes' theorem is translated by the following mathematical formula:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

In other words, this equation means: for two events A and B, what is the probability that A will occur given B.

In the field of ITS, the Bayesian network approach can be used to [17]: update the learner model [18]; diagnose the causes of learner errors [19]; or predict the actions of the learner in a problem-solving process [20]. Diagnosing misconceptions requires collecting and checking for buggy rules, which sometimes leads to overwhelming and impractical numbers of buggy rules, even for simple domains such as fractions [21]. Modern approaches, such as algorithmic debugging [22], automatically distinguish buggy rules. With reference to the study on the specification of knowledge and processes, the authors have determined two inference structures in the context of the design of ITS for tone languages learning [13]. These two inference structures are: the inference structure for Assessment and the inference structure for Diagnosis. The following Task-descomposition diagram (see Fig. 2) presents the different inferences used by the inference structure for Assessment.

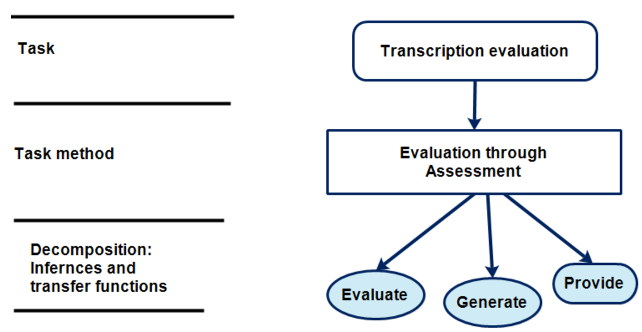

Fig. 2. Task-Decomposition Diagram.

For this present study, we use the Bayesian network approach to trace transcription errors. This is a very suitable approach for the diagnosis of cognitive knowledge.

III. System Design

In this section of our study, we first describe the different components of the intelligent tutoring system to learn *Mooré* polysemous word, then we show the approach used for the knowledge diagnosis and finally we present the approach used to design the operation of the system.

A. Architecture of the ITS

As most intelligent tutors, the intelligent tutoring system for learning transcription of polysemous words in *Mooré* language consists of four components namely the domain module, the student module, the tutoring module and the communication module. However, for the modeling of the components of our system, it was made taking into account the specificity of the domain of learning. Fig. 3 presents this architecture.

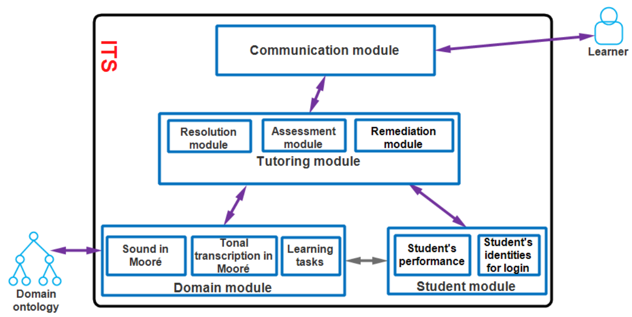

Fig. 3. Architecture of the System.

The different modules in Fig. 3 correspond to the following description:

- Domain module

The role of the domain module is to provide the system with all the information related to the knowledges of the learning area. The domain module consists of the learning tasks, transcriptions corresponding of learning tasks in *Mooré* and sounds in *Mooré* corresponding to the learning tasks. The Learning Tasks component of the domain module consists of all the learning tasks in the system. These tasks are presented in the form of images. The Tonal transcription in *Mooré* component contains the ideal transcriptions of the learning tasks. As for the Sound in *Mooré* component, it consists of sounds corresponding to ideal transcriptions in *Mooré*. The tutoring module uses this component of the domain module to provide didactic aid to learners. The didactic aid of our system allows learners to listen to the sound corresponding to the task selected in order to transcribe correctly.

- Tutoring module

The pedagogical strategy of the system is represented in the tutoring module. This module consists of the resolution, evaluation and remediation modules. With reference to the Petri network of our system represented by Fig. 6 in subsection III-C, the Resolution module is responsible for executing actions t_3, t_4 and t_5 of the Petri network. As for the Assessment module, it is responsible for executing actions t_6, t_7, t_8, t_9 and t_{10}. For the Remediation module, it is responsible for executing actions t_{11}, t_{12}, t_{13}, t_{14}, t_{15}, t_{16}, t_{17}, t_{18}, t_{19} and t_{20} of the Petri network.

- Student module

It is composed of the learner's performance states in relation to his tasks solved and the data for the system login. The student module is responsible for managing all the information of learner's profile. It updates the profile of the latter, in particular the Student's performance component, after each resolution of a task.

- Communication module

The communication module consists of the different interaction windows between the system and the user. It allows the system to interact with users and vice versa.

We consider that the domain module and the tutoring module represent the most important modules of our ITS because domain module contains the knowledge that the system should taught and tutoring module the strategies that the system should use to evaluate learning and provide assistance.

B. Diagnostic

In the domain of ITS, some authors limit remediation to feedback [23], [24] and others perceive it as a process consisting of cognitive diagnosis and feedback [25]. We consider remediation as a process that consists of first detecting the sources of errors and then generating the appropriate feedback in relation to the error committed. So, for the diagnosis of knowledge, we have, using the graphic model of Bayesian network method, first proceeded to the representation of the uncertain and incomplete knowledge of the learners. This representation allowed us to make the causal links between this knowledge. We then developed the different algorithms for tracing transcription errors based on the Bayesian network representation. Fig. 4 below represents the Bayesian network model that we designed.

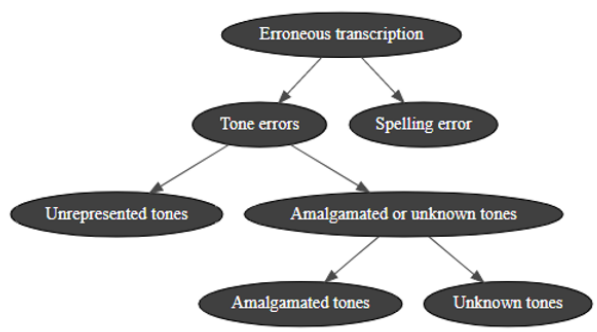

Fig. 4. Bayesian Network for Knowledge Diagnosis.

Fig. 4 presents the diagnosis of transcription errors. When the transcription evaluation made by the learner returns an erroneous transcription, the system performs tracing based on the above Bayesian network in order to detect the transcription error and generate the suitable feedback.The probable transcription errors listed in the graphical model of the Bayesian network above have been identified in collaboration with the *Mooré* language trainers The flexibility of the Bayesian network approach allowed our collaboration non-computer scientists to easily understand the graphical model shown in Fig. 4. Also, this representation allowed the trainers of the *Mooré* language to participate in the validation of the study. Fig. 5 presents the flowchart model of our Bayesian network.

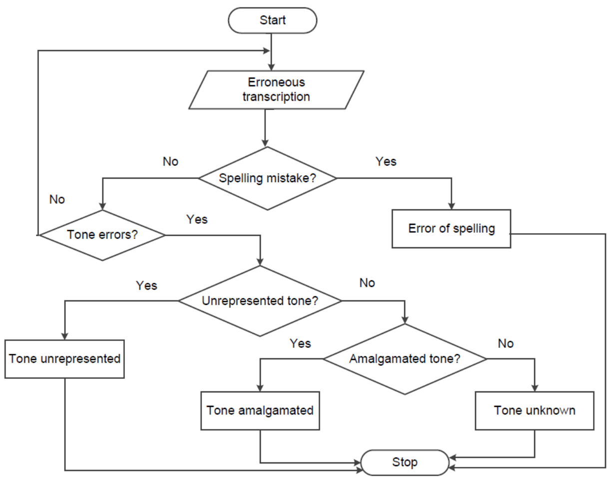

Fig. 5. Flowchart of Knowledge Diagnosis. This Represents the Bayesian Network Algorithm.

Fig. 5 shows a flowchart of the remediation algorithm that generates adaptive feedback according to the learner.

C. Verification of the System Consistency

The Petri Network is an efficient tool for the verification of discrete event systems [14]. Since an ITS is a discrete event system, we use the Petri net formalism to model our system. This model is important to ensure that the system does not have any action or operation that would put it in a deadlock situation. Therefore, we can simulate the operation of the system and resolve possible blockage situations before implementation step.

Fig. 6 presents the Petri net of the system which models its different states.

In Fig. 6, the transitions (t_i) represent the different actions performed by the system and the places (p_i) represent the input or output data of the actions of system. Table I describes the different actions and states of the system.

Based on the description of places and transitions in Table I, the task solving, for example, is described as follows. The system first executes the action (t_3). The learner selects one of the tasks presented (p_4) and the system then executes the action (t_4). From the data (p_5), the system finally executes the action (t_5).

To correct the possible blockages of the system, we made the reachability graph in order to analyze the different firings of the transitions. Fig. 7 presents the reachability graph of the Petri net.

The analysis of Fig. 7 shows that for each firing of t_i, the input place p_i goes from 1 to 0 and the output place p_{i+1} goes

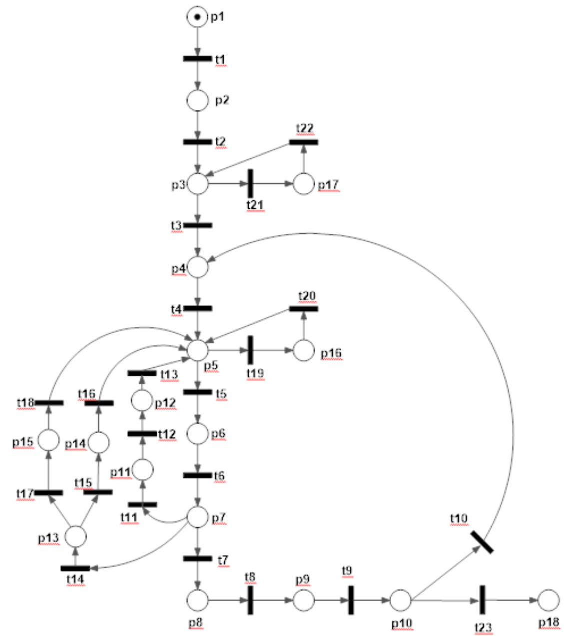

Fig. 6. Petri Net Representation of the System States(Places) and Actions(Transitions).

TABLE I. DESCRIPTION OF THE PLACES(STATES) AND TRANSITIONS(ACTIONS) OF THE PETRI NET.

Places (p_i)	Transitions (t_i)
p_1 : app icon	t_1 : display login screen
p_2 : login screen	t_2 : check login and password
p_3) : home screen(Main)	t_3 : load tasks
p_4 : tasks presented	t_4 : load image and audio
p_5 : task selected, image	t_5 : read transcription
and audio loaded	
p_6 : transcribed word read	t_7 : produce success feedback
p_7 : transcribed word assessed	t_8 : mark task solved
p_8 : success feedback generated	t_9 : update learner's profile
p_9 : task solved marked	t_{10} : return to tasks presented
p_{10} : learner's profile updated	t_{11} : detect spelling mistake
p_{11} : spelling mistake detected	t_{12} : display spelling mistake
p_{12} : feedback spelling mistake displayed	t_{13} : transcribe again
p_{13} : tones error detected	t_{14} : detect tones error
p_{14} : feedback amalgamated	t_{15} : detect amalgamated
tones displayed	tones and produce feedback
p_{15} : feedback tones error displayed	t_{16} : transcribe again
p_{16} : sound emitted	t_{17} : produce tones error feedback
p_{17} : learner score displayed	t_{18} : transcribe again
p_{18} : system ended	t_{19} : emit sound
	t_{20} : end sound emitted
	t_{21} : display score
	t_{22} : return to the main menu
	t_{23} : stop the system

from 0 to 1. From these results, we can say that the Petri net is 1-safe (or binary) which means that the system is deadlock-free. We can conclude that the designed system is coherent.

IV. SYSTEM OVERVIEW

We implemented the system on the Java environment. We present in this section an overview of the system functionalities. An user can use this application to learn *Mooré* language by transcription tasks. Fig. 8 presents the system dashboard view.

Fig. 8 presents the system dashboard which provides main menu. A click on the *"TACHES"* button leads to the resolution

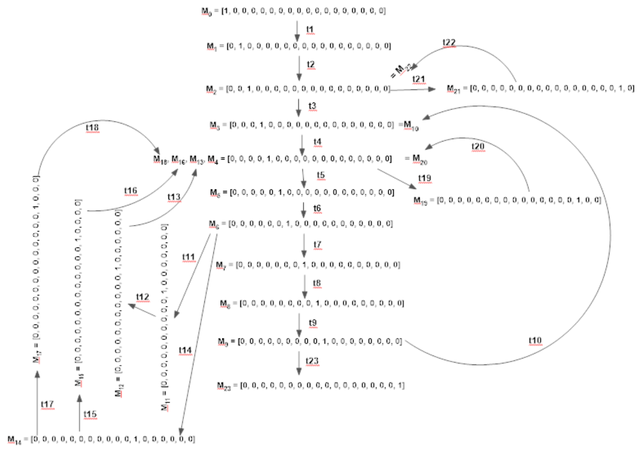

Fig. 7. Reachability Graph Corresponding to the Petri Net of Figure 6.

Fig. 8. System Dashboard.

interface and user can select a task to transcribe, see Fig. 9.

The resolution interface displays a list of tasks to be solved by the learner. In Fig. 9, the selected task (number 2) is displayed as an image to be transcribed in *mooré*.

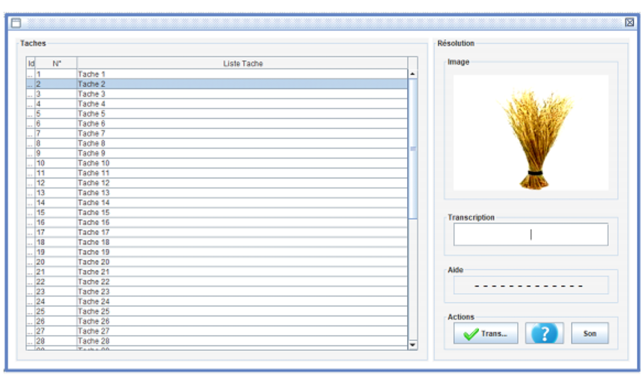

Fig. 9. Resolution Interface Presenting the Tasks. Each Task Corresponds to an Image to be Transcribed.

Fig. 10 gives an illustration of a resolution of task. The selected task shown in Fig. 9 consist of an image of broom. We suppose the user entered *saaga* in *Mooré* as the answer. We use this wrong answer that will allows to show some feedback generated by the system.

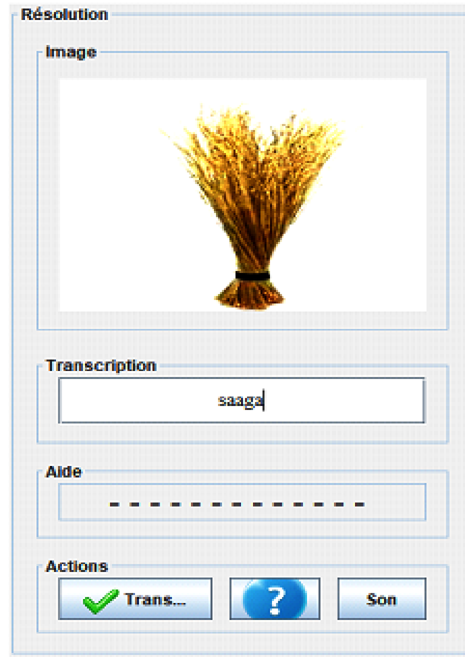

Fig. 10. An Example of Transcription. The Task Number 2 of Broom Image is Transcribed in *Mooré* by *saaga*.

A click on the button *"Transcrire"* will trigger the evaluation module and produce the corresponding feedback, see Fig. 11. It shows that the spelling is correct but confusing because the word refers to different meanings. We say that the word is amalgamated. One must use the tone to distinguish which sens is.

(a) Feedback of the Amalgamate

Fig. 11. Feedback Generated by the System when the User Enters the Word *saaga* as Answer. In this Case the Answer is Wrong Even if the Spelling is Correct.

The correct answer should be *saagà* with low tone on the last vowel.

V. Pedagogical Assessment

To do the pedagogical assessment of our system, we proceeded with the experimentation of the application. A total of four *Mooré* trainers and seventeen learners were able to do the experimentation. For the questionnaires, we developed them via Google Forms.

The formulation of the questions addressed to the learners and the trainers aimed to verify the following aspects:

- The conformity between the content of the Knowledge Base (KB) of the system developed and the content of the corpus of *Mooré* language, namely, the transcriptions and the sounds:

- The relevance of the learning tasks.
- The clarity of the resolution steps.
- The relevance of the feedback generated.
- The relevance of the sounds loaded.
- The ease of use of the system.
- And the contribution of the system in the field of the *Mooré* language learning.

Fig. 12 and Fig. 13 give an overview of some results of the users' feelings after the experimentation of the application.

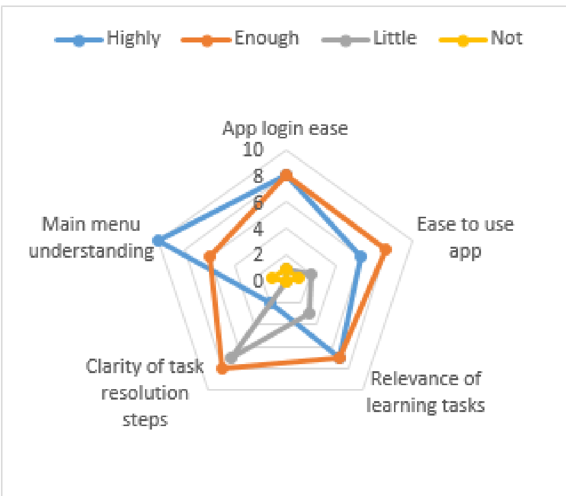

Fig. 12. Learners' Opinions on the System

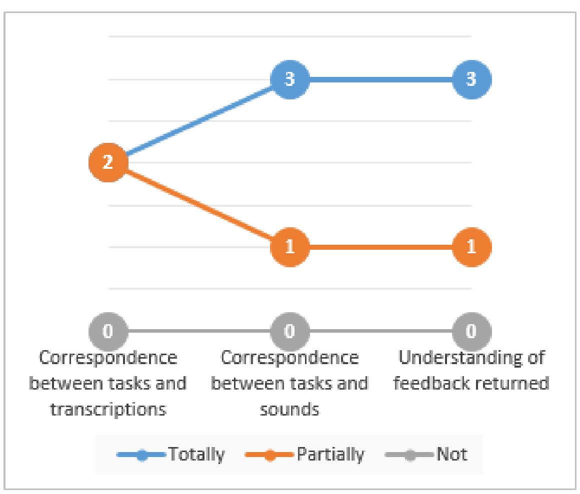

Fig. 13. Trainers' Opinions on the System.

We analysis the collection of the users' opinions and we present here some results in Fig. 12 and Fig. 13 for both learners and trainers.

For the verification of the conformity between the content of the Knowledge Base of the developed system and the content of the corpus of the *Mooré* language, the four trainers found an almost total conformity between the two contents. For the relevance of the learning tasks, fourteen out of seventeen learners found the different tasks at least enough relevant. For the clarity of the resolution steps, ten out of seventeen learners found the steps of resolution at least enough clear. As for the relevance of the feedback generated and the sounds loaded, fourteen learners affirmed that the feedback generated help in the correction of transcription errors and sixteen affirmed that the sounds emitted really help in transcription. And for the contribution of the system in the field of the *Mooré* language learning, all trainers answered in the affirmative that the system allows learning without human assistance.

Based on these results, we can say that the pedagogical assessment of the system allowed to show that the use of it could made it possible the learning of the transcription in *Mooré* without human assistance. Similarly, this system would be a great contribution in the field of education for local languages learning in Burkina Faso.

VI. Conclusion and Perspectives

In this paper, we presented the work on system design, the implementation of the system and the pedagogical assessment of the system. In the system design, we showed the architecture of the ITS, we described the Bayesian network approach that we used to trace the errors of transcription and we presented the Petri net approach that we used to design the operation of the system. The architecture proposed allowed to define the different modules of the system. The Bayesian network model made it possible to represent the uncertain knowledge and to develop the algorithms for tracing errors. As for the Petri net approach, it allowed to simulate the operation of the system and to correct the possible blockages. In relation to the implemenation of the system, we presented some views of the system implemented. And as for the pedagogical assessment of the system, the experimentation of the application made it possible to collect the users' feelings. The analysis of these feelings shows, among other things, that our system is a great contribution for *Mooré* learning. For the future, we expect to develop a speech recognition activity to integrate into our system. This speech recognition activity will learn phonetics in Mooré. We also expect to develop a WordNet ontology for the *Mooré* language. The WordNet ontology for the *Mooré* language is a particularly promising avenue. It will constitute an online knowledge base and will be interoperable with our system and with other applications.

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