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Singing minstrel robots, a means for improving social behaviors

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***Abstract*— *Bertsolaritza*, Basque improvised contest poetry, offers another sphere to develop robot body language and robot communication capabilities, that shares some similarities with theatrical performances. It is also a new area to work on social robotics. The work presented in this paper makes some steps forward in designing and implementing the set of behaviors the robots need to show in the stage to increase, on the one hand robot autonomy and on the other hand, credibility and sociability.**

I. INTRODUCTION

Basque, euskara, is the language of the inhabitants of the Basque Country. And *bertsolaritza*, Basque improvised contest poetry, is one of the manifestations of traditional Basque culture that is still very much alive (see Fig. 1). Events and competitions are very common in which improvised verses, *bertso*-s, are composed. In such performances, one or more verse-makers, named *bertsolari*-s, produce impromptu compositions about topics or prompts which are given to them by an MC (theme-prompter). Then, the verse-maker takes a few seconds, usually less than one minute, to compose and sing a poem along the pattern of a prescribed verse-form that also involves a rhyme scheme. Melodies are chosen from among hundreds of tunes. Xabier Amuriza, a famous verse-maker that modernized and contributed to the spread out of the bertsolaritza culture, defined bertsolaritza in a verse as:

Neurriz eta errimaz	**Through meter and rhyme**
kantatzea hitza	**to sing the word**
horra hor zer kirol	**that is what kind of sport**
mota den bertsolaritza.	**bertsolaritza is.**

Fig. 1. 2009 national championship

Computer-based poetry has been paid attention to in the research community for the last years (see [8] and [21] for a review), but among the several differences that exist between poetry and *bertsolaritza*, mainly the later belongs to the oral genre, and the public performance is extremely important. Therefore, it is not enough the development of an automatic verse generation system, the created poem has to be part of a performance. Thus, a real body that interacts with the public and sings the improvised verse with a proper melody is needed. The interaction with the robot should be speech-based; thus, on the one hand the system should be able to receive the verse requirements to generate the most appropriate verse according to the given instructions and to sing it with the proper melody. On the other hand, the robot must show the same degree of expressiveness Basque troubadours, *bertsolari*-s, do. And all those tasks must be accomplished concurrently in an extemporaneous performance.

We believe that the *BertsoBot* project provides a huge opportunity to join together the capabilities of autonomous robots to sense their environment and interact with it, and the natural language processing tools devoted to automatic verse generation.

II. RELATED WORK

Human-robot interaction (HRI) is the study of interactions between humans and robots. HRI is a multidisciplinary field with contributions from human-computer interaction, artificial intelligence, robotics, natural language understanding, design, and social sciences. A considerable number of robotic systems has been developed in the last decade showing HRI capabilities [6][9].

But social robots are beyond HRI. According to Breazeal [3], sociable robots are socially intelligent robots in a human like way, and interaction with them is like interacting with persons.

Verbal communication is a natural way of interaction among humans. However, non-verbal expression is key to understand sociability [14]. A bunch of work focuses on facial expressiveness [10][13]. Breazeal's Kismet robotic head represents itself a milestone as how the human voice affects expressiveness. Besides, the advent of humanoid robots has launched researchers to investigate and develop body language expression in robots. Aldebaran's *Pepper* [22] is surely the commercial robot with the highest bodily expression capabilities right now. It has no legs, but it uses its waist and arms to show human like expression while talking.

Robot performances have shown to be a window display for disclosing the state of the art of social robots to the general public, and as such, to measure social acceptance of robots. Although everything is rehearsed beforehand, theater

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offers an invaluable sphere to research and develop social behaviors in robots, to work and extent the expression of emotions and the natural communication among humans and robots [18][5]. No need to mention that the term Robot was first used in a play entitled RUR (*Rossum's Universal Robots*) [4]. A review of robot performances can be found in [20]. Little by little robots are bursting into theaters motivated by researchers as a means, but also by artists [17].

However, social robots require to be autonomous. Synthetic replicates are mostly teleoperated or preprogrammed robots; the degree of autonomy shown by performer robots is still far from showing human like behavior (see [19] for a categorization and classification of robots acting in theaters). In our opinion, *Bertsolaritza* offers another sphere to develop robot body language and robot communication capabilities, that shares some similarities with theatrical performances, but also a new area to work on social robotics.

Joxerra Gartzia [7] enumerates the communication act in 5 steps: "*Inventio* (create the message), *dispositio* (give the message the correct form, think how to transmit that message), *elocutio* (how to say the previously prepared message, manage space and time), *memoria* (keep in mind previous work) and *actio* (the action itself)". Acting needs *elocutio*, *memoria* and *actio*. However, *bertsolaritza* needs to go through the five steps, *inventio* and *dispositio* are mandatory. We'll try to enumerate the main differences between theatrical performances and *Bertsolaritza*:

- Theater plays have predefined scripts, and thus, the improvisation required is very little. The acting person might occasionally change the structure of a sentence but not the meaning. On the other hand, the singed verses must be created in just a moment, according to the requirements imposed by the emcee. There is a strong link to the required form (rhythm, rhymes). As a consequence, a performance is never repeated, it never happens twice the same.
- Plays require dialogues, actors talk to each other or to the public. *Bertsolari*-s mainly sing, but they also need to maintain dialogues with the emcee. Even more, they can interchange messages in form of *bertso*-s with other contestants.
- The scene on the stage changes with the play, but in a verse impromptu performance the verse maker will always find some reference elements like the microphone or the resting chair.
- During a theater play, the public does not participate further than showing the degree of satisfaction with the played stage. On the contrary, in *bertsolaritza* the public can condition the response of the improviser at each moment.

Thus, from the point of view of developing social behaviors in robots, both theater and *bertsolaritza* offer a rich scenario to develop robot expressiveness. The former may require more demanding body language, and the later is better suited to develop human-robot conversation systems. But singing minstrel robots entail social behaviors, robots must react to perceptions and show to be autonomous. The messages (the verses) need to be created on the spot, based on current perceptions, and the robot needs to adapt to the current situation, to respond to the happening events. But to respond in a natural, human-like manner.

The contribution of this paper relies in designing and implementing the set of behaviors the robots need to show in the stage to increase, in one hand robot autonomy and in the other hand, credibility and sociability.

III. VERSE GENERATION

When constructing an improvised verse (*bertso*) a number of formal requirements must be taken into account. Rhyme and meter are inseparable elements in improvised verse singing. A person able to construct and sing a *bertso* with the chosen meter and rhyme is considered as having the minimum skills required to be a *bertsolari*. But the true quality of the *bertso* does not only rely on those demanding technical requirements. The real value of the *bertso* resides on its dialectical, rhetorical and poetical value. Thus, a *bertsolari* must be able to express a variety of ideas and thoughts in an original way while dealing with the mentioned technical constraints. In this balance lies the magic of a *bertso*.

A. *Generating the* bertso

Bertso-s can be composed in a variety of settings and manners. For instance, *Zortziko Txikia* (see Fig. 2) is a composition of eight lines in which odd lines have seven syllables and even ones have six. The union of each odd line with the next even line, form a strophe. Each strophe has 13 syllables with a caesura after the 7th syllable (7 + 6) and must rhyme with the others. In the basic scenario (the one we'll focus on), the four rhymes to compose a *bertso* are received as input, and the verse generator module should give as output a novel and technically correct verse, and (hopefully) with coherent content. There are other modes but are out of the scope of this paper.

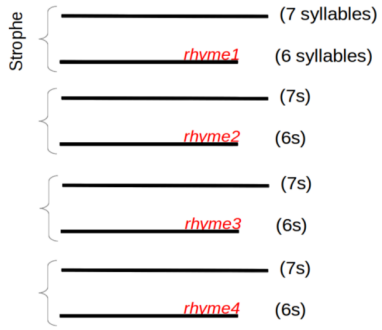

Fig. 2. Structure of a verse in the *Zortziko txikia* meter (8 lines, 4 strophes)

According to Laborde [16], human verse makers have three main tools for improvising verses:

1) Learned improvising techniques and rules, mandatory for generating verses metrically correct.

2) Memory to store and classify previously listened verses, visual and lexical information.
3) The sensorial stimuli that are input in the instants prior to the generation of the verses.

BertsoBot has only available the first two tools, the improvisation process is then the result of a set of rules that, given a metric, produce a technically sound verse. And a huge memory, a stored corpus of ordered Basque sentences extracted from a Basque newspaper. Complete sentences need to be stored because they are basic structures that ensure a minimal coherence.

The verse generation process then consists of the following steps:

1) Receive as input the four rhymes to compose the verse
2) Find sentences in the corpus that rhyme with the input words and have the correct number of syllables
3) Generate the verse with the highest textual coherence

See [1] for a more detailed explanation.

B. Audio processing and singing

In order to generate the verse, the robot needs to identify the proposed exercise and the given rhymes first. The audio is captured via SOX[1] and afterwards, the Google Speech service is used (hopefully available for Basque Language) as ASR to convert the audio to text. Once the text is received, it is analyzed to verify whether the words are available in a local dictionary (list of words with synonyms). If, as a consequence of the analysis no word is recognized, then the robot tells the emcee that it has not understood the sentence and asks to repeat the exercise.

To be able to communicate with the emcee, the robot makes use of AhoTTS, a speech synthesizer for Basque Language developed by AhoLab [11].

But, besides of talking, the robot must sing. The generated verse must be translated to a song in an audio file that will afterwards be reproduced by the robot. To get such audio, first the utilized metric is analyzed and, then, a melody is randomly chosen from an available database and, using a modified version of the AhoTTS that changes the duration and intonation of the syllables, among other features, produces the audio file with the singed verse.

IV. FIRST PUBLIC PERFORMANCE

At the very beginning of this project we were invited to make a public demonstration: a duel between robots and human *bertsolari*-s. It was a big challenge at the state of the art, and it was an invaluable opportunity not only to make a didactic demonstration of what a real robot could do in *bertso* composition, but also to see how the real *bertsolari*-s, and the illustrated audience will behave and react when faced with synthetic replicates. Fig. 3 shows a snapshot of the event.

The performance aroused great interest, and almost every local newspaper, radio and television covered the event (see [23], [24]). However, that first performance was a little bit daring, the system development was naive. The verses were improvised, with more or less meaning depending on luck, but the rest of the show, i.e. the robot movements and actions were mostly preprogrammed or teleoperated with a joystick.

Fig. 3. Verse-duel between one *bertsolari* and two robots

Several lessons were extracted from that event. The employed robots, a Pioneer 3DX and a PeopleBot both from MobileRobots, were not very suitable for body language, due to their limited expressiveness. The PTZ unit was used mainly for simulating changes in gaze direction, and small oscillations were implemented to emulate dancing movements while singing.

Beyond the robot morphology, that first performance showed us that a bunch of work was needed before confronting again with human *bertsolari*-s. On the one hand, regarding the verse creation, methods for enhancing verse coherence were needed. On the other hand, the autonomy level of the robots in the stage should be increased and, more important, the way the robots behave on the stage should be humanized. If the robots are meant to participate in such contests, they must show a higher level of expression, much more like human actors do. Next sections show the steps forward being made to improve those behavioral aspects.

V. BODY LANGUAGE DEVELOPMENT

The *BertsoBot* requires certain capabilities to sing improvised verses to the public, dramatizing the eloquence (gesture repertoire) that a human *bertsolari* shows at the stage. Thus, it should be capable of communicating in a natural way with the emcee and the other contestants, but also to identify some key elements on the stage.

The first decision we made was to change the robotic platforms used. Well, the shape might be not so important but a higher number of degrees of freedom clearly helps. Now, NAO humanoid robots from Aldebaran Robotics are being used.

The verbal and gesture communication capabilities with the new platforms were tested in an initiative named *ZientziaClub* or Club of Sciences that aims to disclose science and technologies to the society. A dialogue with NAO of approx. 10 minutes was presented (Fig. 4). The robot was required to give some explanations about itself, and to produce a verse given the rhymes. The robot was teleoperated by human gestures captured by a Kinect sensor (see [27]); NAO

[1]Sound eXchange, a cross-platform command line utility to process audio files

gesticulated while chatting, and moved around the stage according to the teleoperator commands (video available at [25]).

Fig. 4. Dialogue at ZientziaClub. The teleoperator is placed on the same stage, visible to the public

Next subsections explain the modules developed to remove the teleoperation to improve robot autonomy and to supply it with a decent expressiveness. The underlying software architecture is depicted in Fig. 5.

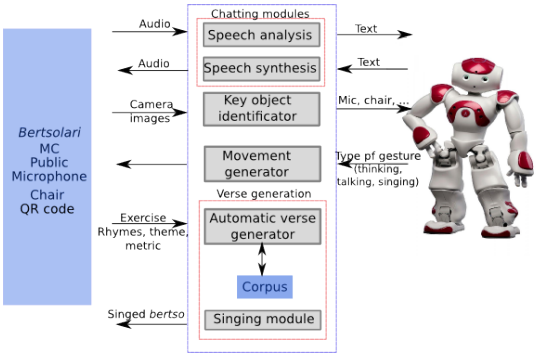

Fig. 5. Software architecture. The modules work in parallel and are activated by different stimuli.

A. Behavior repertoire

Based on the usual flow of a contest, the robot should be able to:

1) Await its turn to sing, until the emcee calls it.
2) Approach the microphone and listen to the exercise being proposed to it by the emcee.
3) Generate the verse and sing it.
4) Observe the public reaction that will allow to feed future verses
5) Reach back its chair, or attend to the next exercise according to the emcee's decision

The robot pays attention to different elements at different states. The mic location is a reference point for the robot, and also is the chair. For the time being, those elements, as well as being adapted to the robot morphology, they have labels to make it easier the identification processes. They all have color tags that make them distinguishable; chairs have been painted with different colors and, similarly, the microphone has a blue tag on its base. No location information in form of odometry or frame of reference is used because the location of those elements with respect to the robots varies depending on the scenario. Thus, a color tracking procedure enhanced with a Kalman Filter is used to produce a more robust behavior against illumination conditions and the robot balancing while walking.

For the microphone tracking, both cameras on the robot head are used. The top camera is used to locate the mic and approach to it. Once the lower camera reaches the view of the microphone, the robot stops forwarding and uses its visual information to correct its position with respect to the microphone.

Besides, for the chair tracking, only the top camera is used to approach it until breast sonars detection alerts that the chair is close enough. Then, the robot turns and uses a yellow line on the floor to center its position with respect to the chair so that it can execute the sitting exercise.

Although most of the time the *bertsolari*-s act individually, sometimes they need to react to other contestant actions. For instance, after one contestant is sent to its chair, and the next one is called, they cannot collide on their trajectories. Humans will naturally do it waiting for the robot or human or letting them pass. But as the system must contemplate the situation with more than a single *bertsolari* robot in a show, the robots need to coordinate among them. At the current state, this coordination is hard coded, there are prefixed timing values set that allow robots to act without pouring into trajectories.

B. Gesture repertoire

Five different gesture sets have been identified and implemented, using *Choregraphe*[2], or by modifying some of the movements available within the robot's libraries:

- Thinking gestures: those gestures that, unconsciously, we make while standing up in front of the microphone and thinking the verse. They are movements to unstress, to relax tension like put one's hands back, swing the hip, scratch one's head, ... There is one gesture extremely important while thinking: reach and maintain a neutral pose. The robot needs to move, needs to reproduce some gestures but it cannot be continuously gesturing like a puppet; improvising a verse is a very hard mental process that requires extreme concentration and that is reflected in the body language of the improvisers.
- Talking gestures: humans don't stay still while talking, we naturally gesticulate moving the hands or nodding.
- Singing preamble gestures: just after the improvisation process finishes and before the *bertsolari* starts singing, he/she needs to accommodate the body and/or clear the throat, look around and probably stare off into space, above the public.
- Singing pose: oddly, and probably due to the extreme concentration effort that must be maintained, the bertsolari stands still while singing. Of course, not everyone maintains the same pose, sometimes they keep the hands on their pockets, or on their back, or just have their arms down, but that pose does not vary significantly from one *bertsolari* to the other.

[2]A multi-platform desktop application created by Aldebaran for monitoring and controlling NAO humanoid robots

- Sitting gestures: humans are not designed to be motionless while being awake, and so, it is not appropriate to have a robot sat inert in the stage. Humans stretch or cross their legs, drink water or move the head to change the gaze while being sat. No need to said that our robots' movements are very limited in that position, and that most of the mentioned moves cannot be replicated. But they can change their arms' position and make movements with their heads. Again, the neutral pose is often required to be maintained.

As Guy Hoffman underlines in [12], when you want to arose emotions, it does not matter so much how something looks like, it is all in the motion, in the timing of how the thing moves. If public attention and interest are to be maintained, gestures cannot be predictable. Even for the robotic enthusiastics, it becomes extremely boring to see the robot doing exactly the same thing once and again. Thus, after identifying the main different states of the global behavior and generating the gesture libraries for each state, we chose to randomly select all, the number of gestures (between a delimited interval), the gesture set and the order in which they must be reproduced, at each state as the performance progresses. The neutral positions while thinking and being sat have a higher probability to be selected due to their importance, and the time to maintain that pose also varies randomly (again within a hard coded time interval).

Regarding the talking and singing states, the duration of the audio file can be measured in advance. Hence, the duration of the associated movement set is adapted to the duration of the audio file.

This solution may seem a little naive, but it has shown to be effective to increase the spontaneity of the robot, from the perspective of the observer and thus, the empathy with the robot.

VI. DEMOS

We have not had the opportunity to make a public demonstration with the evolved system in a real scenario yet, but the performance of the system can be appreciated in several videos that can be found on our YouTube channel [26]:

a) Gesture repertoire: this video reflects different scenes of a play. On the one hand, sitting gestures are demonstrated by two robots that remain sat while gesticulating with different timings and in a different manner. On the other hand, thinking gestures show how the robot behaves while thinking the verse, while talking. Lastly, the singing preamble gestures somehow warn the public it is going to sing.

b) Behavior repertoire: this video shows how the robot moves around the stage, when the MC calls it or sends it back to rest.

c) Chatting and singing behaviors: the video shows the kind of dialog the robot maintains with the MC in different cases, for instance when it has not been able to understand what the MC has said or how it asks the MC for the rhymes again when it misunderstands them. Besides, the video shows the robot humming when it is not able to compose a strophe with a given rhyme.

d) Global behavior: in a rehearsal recorded at the lab, two NAO act as *troubadors* and the roll of the MC is performed by a third robot, a Pioneer 3DX. The robotic MC then establishes the rules of the duel: who starts, the exercises and the flux of the performance. QR codes are used by the emcee to distinguish the two NAO robots (Fig. 6). Versemaker robots communicate among them sharing messages and each one acts when demanded.

Fig. 6. *BertsoBot* demo

VII. SHORTAGES AND FURTHER WORK

It is not easy to objectively evaluate the performance of the proposed system. However, the ontology of robot theater proposed by Lu [19] shall be used to measure the state of the *BertsoBot*. Lu's ontology is based on the automation level and the required control the robots depend on (see figure 7).

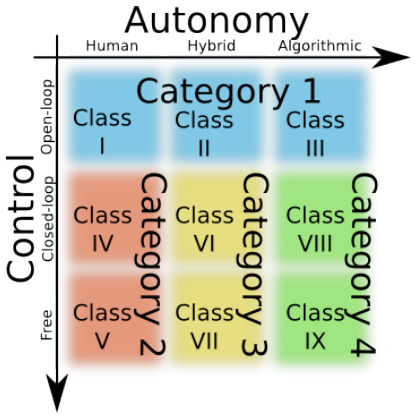

Fig. 7. Ontology of robot theater proposed by David Lu

Analyzing the evolution of the *BertsoBot*, the first prototype utilized in our first performance could be categorized as a Category 1 Class II robot, an open-loop with a hybrid control, hybrid in the sense that behavior was partially specified by the human, but there were also algorithmicaly specified behaviors. The second approach, settled with the new platforms and the gesture-based teleoperation could be classified as Category 2 Class IV, a closed-loop system with human input where the performance changes according to some conditions on the stage but not arbitrarily.

The current state of the project locates the *BertsoBot* at Class VIII, behavior produced algorithmicaly in a closed-

loop control. The robot generates its behavior via computation, without explicit human intervention further than the oral instructions given by the (robot or human) emcee. But the behavior depends on its own perceptions.

Regarding the behavior of the *BertsoBot* as a single unit, besides improving the verse coherence (some steps forward have been made in [2]), many aspects need to be developed and integrated:

- No many robots show self-awareness of the mistakes they have done (see [28]) and the *BertsoBot* is not an exception. Up to now, if for any reason the robot cannot generate a strophe, the robot hums during that piece of the verse. But the failure is not reflected on the behavior nor in the body expression. We must give the human the sense that the robot knows what it is doing reflecting the errors or the poor actuation sensation on its behavior.
- If the *BertsoBot* is to be trustworthy, public reaction must feedback the robot somehow. For example, in [15] the public is invited to participate showing colored paddles that hints the robot with the kind of jokes the audience (dis)likes.

There is another aspect that affects the coordination of several *BertsoBot*-s acting together that should be improved. Regularly, when it is a human actor that interacts with a robot, she/he tends to adapt to robot timing, filling pauses with her utterances, and helping to conceal delays and robot limitations. But for instance when it is a robot the one that acts as the emcee, the delays (produced by the internet access and the computational units used, but also because of the hard coded timings fixed on the programs) remain. Communication among robots must be extended and more basic behaviors must be integrated.

Summing up, we're still far from having autonomous free robotic *bertsolari*-s (Class IX in Lu's ontology) but we are little by little making steps forward.

Appendix: Communication among robots

The *BertsoBot* project is being fully developed using ROS (`www.ros.org`), that offers a modular structure. Related packages are available at RSAIT's GitHub (`github.com/rsait/rsait_public_packages`). Including a third robot as the MC required to distribute the computation processes and thus, the communication among them. To solve that issue we chose to use `multimaster_fkie`, available in the ROS wiki that allows stabilizing the communication among two or more machines that are running their own roscore.

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