Granular Learning Objects for Instrument Design and Collaborative Performance in K-12 Education

Ivica Bukvic
Virginia Tech
Department of Music
DISIS, ICAT
Blacksburg, VA (USA)
ico@vt.edu

Liesl Baum
Virginia Tech
School of Education
IDEAS, ICAT
Blacksburg, VA (USA)
lmbaum@vt.edu

Bennett Layman
Virginia Tech
Department of Music
DISIS, ICAT
Blacksburg, VA (USA)
blay12@vt.edu

Kendall Woodard
Virginia Tech
School of Education
IDEAS, ICAT
Blacksburg, VA (USA)
kwoodard@vt.edu

ABSTRACT
In the following paper we propose a new tiered granularity approach to developing modules or abstractions in the Pd-L2Ork visual multimedia programming environment with the specific goal of devising creative environments that scale their educational scope and difficulty to encompass several stages within the context of primary and secondary (K-12) education. As part of a preliminary study, the team designed modules targeting 4th and 5th grade students, the primary focus being exploration of creativity and collaborative learning. The resulting environment infrastructure - coupled with the Boys & Girls Club of Southwest Virginia Satellite Linux Laptop Orchestra - offers opportunities for students to design and build original instruments, master them through a series of rehearsals, and ultimately utilize them as part of an ensemble in a performance of a predetermined piece whose parameters are coordinated by instructor through an embedded networked module. The ensuing model will serve for the assessment and development of a stronger connection with content-area standards and the development of creative thinking and collaboration skills.

Keywords
Granular, Learning Objects, K-12, Education, L2Ork, Pd-L2Ork

1. INTRODUCTION

With the rapid development of new technologies, the primary and secondary education (K-12) models are increasingly struggling to adapt to the ever-changing skill sets students will require as they prepare to engage in the world around them. Recently, a survey conducted by IBM, revealed common belief that "more than rigor, management discipline, integrity or even vision -- successfully navigating an increasing complex world will require creativity." [10] It appears the students' success will increasingly depend on their ability to continually adapt to and creatively engage with the newfound technologies. Projects like *Scratch* [9] and *Alice* [6] seek to address this challenge by exposing children to computer programming through age-appropriate user-friendly tools coupled with engaging contexts (e.g. story telling). While powerful visual environments, such tools provide limited audio support, and consequently limited applicability in music-centric scenarios. There is a need for a tool with similar level of age-appropriate creativity potential within the music domain.

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1.1 Granularity
The scalable approach to complexity of computer programming has made real-time graphical programming environments for audio, video, and graphical processing - such as Max [11] and Pure-Data (Pd) [8] - favorites among college-level educators, multimedia artists, and researchers. One of the key advantages of such programming environments is their rapid prototyping potential made possible through varied granularity (externals or objects of variable complexity), interoperability, and reusability. Max ad Pd are essentially tools built around a "good" learning object - or rather, an element "of computer-based instruction grounded in the object-oriented paradigm of computer science." [7] Even though both tools are developed using C programming language, their design promotes the understanding of self-contained and self-sufficient units typical of object-oriented programming environments and as such within the context of this paper we view them as object-oriented software development environments. In addition, we treat their individual objects (a.k.a. externals) as synonymous to learning objects because they can be regarded in the traditional sense of the definition as both members of a larger instructional repository of information and as an applied learning tool for students. Both Max and Pd are therefore built around the learning object model and, as such, have tremendous potential as educational tools. It is therefore curious that neither tool has seen significant uptake in the primary and secondary (K-12) curriculum. For the purpose of further discussion, based on granularity, we define two kinds of learning objects, those with fine-grained or higher-tier (basic operation, low impact, e.g. an arithmetic operator) and coarse-grained or lower tier of granularity (complex operation, high impact, e.g. munger1~ a.k.a. disis_munger~ [3]). One possible explanation is that the granularity level among objects is too varied, requiring a larger amount of prerequisite knowledge as well as a steeper learning curve, both of which limit their potential usefulness in K-12 scenarios. It appears, however, that this problem can be circumvented by providing a consistent set of coarser-grained abstractions that better cater to the needs of the target population. If we apply the onion peel metaphor to the Max/Pd abstraction, one could envision a complex coarse-grained abstraction built on increasingly finer-grained abstractions until eventually the system arrives at the finest-grained basic learning objects (or as fine as the system permits/supports). Such an approach would not only offer for a much better instructional tools appropriate for K-12 education but would

also provide instructors with more adaptive instructional materials to match the evolving educational models and skill level of the target student population.

2. IMPLEMENTATION

This study builds on the foundations of the Boys & Girls Club of Southwestern Virginia Satellite Linux Laptop Orchestra project, that engaged 4th and 5th grade students as performers as part of an afterschool program. Using the real-time graphical programming environment paradigm, the research team set out to design a collection of coarse-grained learning objects that would enable the target student population to expand their engagement to building their own original instruments. Using the resulting tools students were given an opportunity to design their own instruments. Through a series of rehearsals, they developed an in-depth knowledge of the instrument, with the ultimate goal of having the group perform a piece that would be specifically written for the ensemble utilizing new performing forces.

Considering the proposed project targets K-12 education, careful consideration was given to identifying technologies that will require minimal cost overhead. By leveraging existing hardware resources developed specifically for the Boys & Girls Club Satellite Linux Laptop Orchestra [2], in conjunction with the software resources of the Linux Laptop Orchestra (L2Ork) [7], this project was able to abate all costs associated with the infrastructure for this particular phase of research. More specifically, the research team chose to base the platform on Pd-L2Ork [10], a L2Ork-centric fork of the Pd-Extended [12] that focuses specifically on improving stability, editor features, and adding new GUI-centric functionality. The latest iterations of the tool vary significantly from the original system, providing over two hundred bug-fixes and new features, offering a robust and cost-efficient platform.

As part of this study our goal was to design the lowest-tier of coarse-grained abstractions with the expectation they will enable students with limited programming skills to immediately engage with the system. The anticipated outcome was for students to design a working instrument that meets the following conditions:

- Either a short (attack-based) or sustained
- Pitched or non-pitched (noisy)
- Controllable via Wiimote [13]
- Network-enabled

We chose to rely on the Nintendo Wiimote, the core input interface in L2Ork setup. Furthermore, we utilized MotionPlus [13] extension that allowed for a more accurate measurement of continuous motion. Based on the experience with the design and development of works for the L2Ork ensemble, we decided to forego the integration of Nunchuk [13] in order to maintain student focus on the exploration of virtuosity attained through a balance between a number of digital controller states and analogue body motion.

The objects were designed iteratively using granular modeling approach, starting with the central (core) objects first [1]. These were categorized into input, sound generation, effects, logic, arithmetic, and output. Input consisted of Wiimote and three Wiimote input filters (attack-based and sustained models, and button filters). The initial sound generation objects included two pitched and unpitched. The effects consisted of a low pass filter, multitap delay, and a reverb. The logic object selection was limited to a cross-fading gate mechanism, while arithmetic object provided means for modulating signal strength. The signal output included a limiter and (re)profiler to ensure all instruments performed consistently in terms of audio amplitude. Starting with a complete, albeit limited set of core objects gave the team an opportunity to engage students at the outset while the remaining objects were added as the project developed. All object outlets and inlets were marked to allow for users to better understand how objects could be connected to provide meaningful results. To minimize potential level of confusion, students' computers were provided with a simplified version of Pd-L2Ork; the library of objects supplanted the standard set of objects. Likewise, the remaining application menus were stripped of unnecessary features that could potentially confuse its users.

Each computer instrument was classified by the student as pitched or non-pitched. This information was embedded in the networked module that will be utilized at a later stage to coordinate performing forces from the instructor's computer. Based on reported instrument properties, pitched instruments will therefore receive only pitched event information, while non-pitched instruments only non-pitched information. In the absence of the networked module, the primary expectations of the ensuing coarse-grained *techosystem* were engagement of the target student population, promotion of creativity through the design of live interactive hyperinstruments, as well as system's overall ease of use. Such data was collected by capturing student's desktop activity in conjunction with students' verbal descriptions of their instruments and their understanding of how the said instruments functioned. We are currently in the process of compiling and analyzing the collected data.

3. CHALLENGES

As expected, one of the greatest challenges of the preliminary study is striking a balance between creative potential and ease of use. Introducing too coarsely-grained object designs, while improving ease of use, also limits variance among designs and consequently creativity. On the other hand, too finely-grained objects tend to increase complexity, resulting in a steeper learning curve. With promising pilot study results, there is clearly a need for a more quantifiable analysis of project's impact. Another challenge of the design approach is defining learning processes associated with the activity and identifying specific areas within the K-12 education where such learning can be integrated.

4. CONCLUSION & FUTURE WORK

The proposed coarse-grained approach to creativity has clearly shown promise in engaging 4th and 5th graders. It has also provided them with an integrated approach to design, development, testing, as well as professional use of musical artifacts, a process that has also essentially integrated all STEM (science, technology, engineering, and math) components.

With the coarsely-grained layer now ready for production, as part of our future work the team will focus on expanding the granular approach to provide multi-tiered learning objects. We envision such objects being built on an intermediate layer of more finely-grained abstractions whose granularity may make them appropriate for use in higher grades. The team will also explore more quantifiable ways of assessing and optimizing granularity for the target populations. Finally, the team will continue exploring quantifiable ways to integrating the proposed learning model in the K-12 curriculum.

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