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Editorial

We are glad to publish this new issue of Comunicações em Informática one month earlier than usual. These papers were submitted during the year of 2020. Some of them are related to two thematic calls conducted with focus on Computing Education and on Virtual and Augmented Reality Groups. We would like to thank the associated editors that contributed to the success of these calls.

This edition presents fifth papers, thirteen submitted for thematic calls. The first two papers are the abstract "Using the Duolingo Tool to Support English Classes" relates a pedagogical and technological intervention with the Duolingo tool to support the English classes of a Brazilian high school. The authors observed a motivation improvement in students and suggest that this type of gamified intervention can be useful to help in memorizing words and increasing participation. The second paper is "Previsão em sistemas dinâmicos caóticos com ruído" and presents how to use dynamic systems with differential equations to model natural and artificial behaviors. The author demonstrates as example the Lorenz systems to show a way to develop algorithms that can simulate approximated solutions.

It is worth to mention that Comunicações em Informática had its first issue published in December of 2007. It is known by the Brazilian scientific community that Qualis, the Brazilian official system developed by CAPES with the purpose of classifying scientific production, has guided the publishing option of several researchers in Brazil. In 2017, the Qualis-CAPES had started a new quadrennium that is being concluded this year of 2020 with a new classification list. We received the notice that Comunicações em Informática will be listed in this next Qualis. This is a good new, but there is much work to be done! The goal now is to encourage authors to make their papers final versions in English language in order to enhance reach and impact of the papers published.

Finally, it is important to highlight the collaboration of the reviewers that make possible to this journal to provide constructive feedback for authors and also have allowed the approval of quality works. With this in mind, we would like to thank all reviewers and associated editors that have collaborated since 2017.

Liliane S. Machado
Editor in Chief

Special Section: Computing Education

This issue of Comunicações em Informática brings another special section Educomp – "Educação em Computação". Research in this section includes current and important topics such as robotics, games and gamification.

Knowledge can be assimilated more effectively when it is possible to integrate the theoretical concept into practice. In this sense, games and robotics can be identified as strategies to enhance the learning process. In this proposal to align theory and educational practices, there is the gamification technique, which is using game-based mechanics, aesthetics and game thinking to engage and motivate, in order to stimulate actions that promote learning.

The articles in these lines contribute to the improvement of quality in the educational process with their experiences.

In this sense, this special section presents three articles with this focus. In the article "Tecnologia robótica e problem based learning aplicada para o ensino de lógica e programação", the authors present activities with robotics for teaching programming logic and the importance of Problem Based Learning as an active methodology to promote learning. The article "ThinkTank: um jogo construtivista para ensino de pensamento computacional" shows the development of the game for teaching computational thinking and programming, based on block programming. The article "Improving Students' Motivation and Focus Through the Gamification in the Computer Science Peer Instruction Methodology (CSPI)" presents the initial assessment of the gamification adoption into the CSPI with positively impacts participants' motivation and focus.

We appreciate the dedication of the reviewers for the selection of these works in this special section. The suggestions, comments and analyses have ensured the quality of the journal's manuscripts.

We hope that the studies covered in the articles would encourage further researches in the field of Computer Education. A good reading to all!

Thaíse K. L. Costa
Pasqueline D. Scaico
Guest Editors

Special Section: Virtual Reality Laboratories

This section brings papers submitted to the Labs presentation track of the XXII Symposium on Virtual and Augmented Reality. From ten works it is possible to research and development groups, laboratories and companies in Brazil and abroad that produce virtual reality, augmented reality and mixed reality. Some of them develop their projects in partnership with companies and make an interesting connection between scientific development and commercial products.

- HandOns is a company whose partner is the Compsi lab at Centro Universitário Eurípides de Marilia (Univem), both in Brazil. They use virtual reality and augmented reality to create solutions for industry, market and health.
- Corollarium is a Brazilian company specialized in web and mobile development, image processing, virtual and augmented reality. Its expertise encompasses the full development process - from design, production and installation.
- labICE is an interdisciplinary laboratory at Federal University of São Paulo (Unifesp) in Brazil which has a multi-institutional basis for carrying out research projects in areas such as virtual reality, augmented reality, health, and distributed systems.
- The OE@FEUP is a laboratory at University of Porto in Portugal which has a set of experimental resources based on augmented reality, virtual reality and haptic systems to support education.
- MarineVerse is a company based in Australia that aims to promote and share the sport of sailing by virtual reality providing engaging, interactive sailing experiences that motivate people to try the real sport.
- LApIS is a research laboratory at University of São Paulo (USP) in Brazil which aims to develop multidisciplinary research involving computer science areas and other knowledge fields such as physiotherapy, psychiatry, radiology, and cardiology.
- Voxar Labs at Federal University of Pernambuco in Brazil develops multidisciplinary research in spatial computing, tackling the inner areas of extended reality, computer vision, and natural interaction.
- BioxLab is a design, testing and improvement of health application from the State University of Campinas (UNICAMP) in Brazil. Their focus in assisting motor and neurofunctional recovery processes.
- LabTEVE is a research and development laboratory at Federal University of Paraíba (UFPB) in Brazil which has a multidisciplinary focus on virtual and augmented reality subjects such as training simulators and serious games for several areas.
- VISLab at Federal University of Rio Grande do Sul (UFRG) in Brazil develops projects mainly on rendering, and animation. Its main focus is on researches in human-computer interaction, with emphasis on non-conventional interaction.

These laboratories are places to work, have the formation and improvement of students (undergraduate, graduate, and post-doctoral levels) and professionals. We hope the reading of those works could inspire and stimulate new connections among researchers, industry, and developers. Enjoy!

Marcelo de Paiva Guimarães (Guest Editor)
Liliane S. Machado

Journal Reviewers (since December, 2017)

Using the Duolingo Tool to Support English Classes: Intervention and Experience

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Keywords: *Educational technology; English learning; Duolingo*.

Introduction: Several studies show that most students believe that their learning might be improved by integrating technology into classrooms [1][2]. Currently, there are several types of educational tools that can be use in the teaching-learning process, such as Kahoot!, ClassDojo, and Google Classroom. In addition, there are other more specific resources that can help to explore a certain subject more deeply. This abstract relates a pedagogical and technological intervention carried out by a group of students who attend an undergraduate program in computer science teaching. In order to support the English classes of a Brazilian high school, localized in Mamanguape city, Paraiba, they performed instructional activities focused on presenting a new learning and motivational resource. Methodology: Initially, the entire school was observed. Students, faculty, and staff were interviewed. While gathering some initial data, the researchers learned from the 12 th grade students about their struggles with comprehending English. Also, because English is one of the mandatory courses for those who apply for the National Secondary Education Examination (ENEM), an exam to be taken by students finishing their senior year who intend to enter most Brazilian universities, the 12th class was chosen for further study. Duolingo was selected as the central learning resource because it is the most popular software to support second language education (used by more than 300 million learners), it is free, and, mainly, it is a technology that runs in smartphones [3]. In total, 36 students participated in this study using Duolingo. To evaluate how the use of Duolingo might have impacted students' learning, a set of activities was developed based on a digital game. The logic is as follows: after some tips were presented to students, they had to figure out what word was being formed (Figure 1). As an example, a house and a bed that appear on the screen are the tips to identify the word WAKE UP. Discussion: According to the high school's English teacher, students who spent a great deal of time using Duolingo increased participation in classes. As Duolingo was installed in their smartphones, it can be credited for the increased participation. About the activities, most of the students assessed and utilized them to fix some words learned through Duolingo, such as verbs. Conclusions: This intervention was an excellent practical experience for future teachers because it was possible to follow up closely the learning process of students. Therefore, it reinforces the potential of technology to have a positive effect on knowledge acquisition. We believe that Duolingo might make learning more interesting, pleasant, and interactive in English classes as [4] as well. Furthermore, online tools increase the motivation to learn, especially in public schools where there are, unfortunately, fewer resources.

Figure 1:Example of applied activity.

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Previsão em Sistemas Dinâmicos Caóticos com Ruído

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Resumo: Um modelo muito comum para sistemas dinâmicos é que sua evolução seja dada por uma equação diferencial. Entretanto, a ocorrência de caos determinístico dificulta a aplicação deste modelo para fazer previsões em sistemas reais. Caos determinístico é um fenômeno com dependência sensível a perturbações, o que causa imprevisibilidade a longo prazo. Mostramos como usar dados de séries temporais de um sistema para estimar as equações diferenciais que determinam sua evolução. Usamos como exemplo o sistema de Lorenz e métodos numéricos que incluem o uso de funções polinomiais para ajustar as velocidades das variáveis do estado, e assim determinar um modelo para a sua evolução temporal. Mostramos também que pode ser usado mesmo na situação de dados com ruídos observacionais.

Palavras-chave: *caos determinístico; regressão linear; previsão em sistemas dinâmicos.*

1. Introdução

Muitos comportamentos naturais e artificiais podem ser modelados matematicamente como sistemas dinâmicos de equações diferenciais em que determinam a evolução temporal do estado do sistema. No entanto, às vezes é complicado determinar qual o modelo matemático capaz de reproduzir um determinado comportamento físico desejado, especialmente quando tratamos de dados limitados ou de sistemas complexos, onde há a presença da não-linearidade, caos e de ruídos observacionais [1].

Nesse contexto, torna-se interessante desenvolver uma técnica que procure determinar um sistema de equações diferenciais equivalentes ao sistema desconhecido. Uma vez descoberto este sistema existe a possibilidade de se resolver as equações a partir do vetor de estado atual, conhecido, e desta forma fazer estimativas sobre o seu estado futuro [2,3,4].

Técnicas modernas de inteligência artificial, tais como aprendizagem de máquina, amostragem compressiva, e computação em reservatório, têm se revelado eficazes em situações de alta complexidade, resolvendo problemas que constituem desafios para a computação até há pouco. Neste trabalho, usamos algumas dessas técnicas para testar os limites da previsão em um sistema [2,3,5].

Para tentar realizar essas técnicas em dados de sistemas desconhecidos, escolhemos como base um sistema dinâmico simples e caótico, conhecido como *sistema de Lorenz*. Nossa metodologia consiste em gerar dados observacionais, correspondendo às séries temporais do sistema de Lorenz, usar estes dados para estimar a equação diferencial, bem como os seus parâmetros, que regem a evolução do sistema. Isso é feito com o uso de funções polinomiais, capazes de se ajustar à dinâmica desconhecida. Em seguida, usamos este modelo para prever o estado futuro durante um certo horizonte de previsão. Esta previsão pode ser comparada com o estado verdadeiro do sistema original para testar a precisão da técnica [6].

O objetivo é desenvolver algoritmos capazes de se adaptar ao sistema, com parâmetros flexíveis, que simulem e apresentem soluções aproximadas dos dados coletados.

2. Metodologia

Os métodos são implementados em linguagem de programação Python, fazendo uso de módulos pré-existentes para análise numérica e ajuste de funções. Usamos as bibliotecas Numpy, Scipy, Random e Matplotlib.

Dado o sistema de Lorenz na equação (1),

$$\begin{cases} \dot{x}_1 = f_1, \\ \dot{x}_2 = f_2, \\ \dot{x}_3 = f_3, \end{cases}$$

$$\begin{cases} f_1 = \sigma(x_2 - x_1), \\ f_2 = r x_1 - x_2 - x_1 x_3, \\ f_3 = x_1 x_2 - b x_3, \end{cases} \tag{1}$$

onde σ = 10, r = 28 e b = 2,667. Encontramos soluções numéricas para este sistema através do método de Runge-Kutta de quarta ordem (RK4) com as condições iniciais adequadas, mas genéricas. A partir desse momento vamos supor que esses dados, considerados como observações exatas, tenham se originado de um sistema dinâmico desconhecido, o qual desejamos estimar e prever.

Temos o objetivo de recuperar a dinâmica do sistema a partir das velocidades desses dados (suas derivadas com respeito ao tempo). A metodologia pode ser dividida em três etapas:

1) Calculamos funções polinomiais unidimensionais de grau G que aplicadas ao tempo se ajustem aos dados observados. Definimos estas como $\boldsymbol{P}(t[n])$, onde

o tempo foi discretizado. Para encontrar estas funções usamos o método de B-Spline [7].

2) Realizamos uma derivação com relação ao tempo dessas funções polinomiais unidimensionais, chamando a derivada temporal de $\boldsymbol{V}(t[n])$, como mostra na equação (2).

$$\dot{\boldsymbol{P}}(t[n])=\boldsymbol{V}(t[n]). \quad (2)$$

3) Usando o método de Mínimos Quadrados [8], calculamos funções polinomiais multidimensionais $\boldsymbol{F}$, de grau G, aplicadas aos dados ajustados, tais que estas funções expressem as velocidades como função das variáveis de estado, como na equação (3).

$$\boldsymbol{F}(\boldsymbol{P}(t[n]))=\boldsymbol{V}(t[n]). \quad (3)$$

Em situações reais, é inevitável que haja erros nos dados, que chamamos de ruído. Para simular a situação de ruído observacional nos dados, acrescentamos a uma cópia dos dados, valores aleatórios com distribuição gaussiana. Isso será feito com a equação (4).

$$\boldsymbol{x}_r=\boldsymbol{x}+\boldsymbol{r}, \quad (4)$$

onde $\boldsymbol{x}_r$ são os dados contaminados por ruído, $\boldsymbol{x}$ são os dados exatos e $\boldsymbol{r}$ são os valores aleatórios produzidos com a distribuição especificada.

3. Resultados

Resolvemos a equação (1), com o método RK4, usando as condições iniciais da equação (5).

$$\begin{cases} x_1[0]=0{,}1, \\ x_2[0]=0{,}1, \\ x_3[0]=0{,}1, \end{cases} \quad (5)$$

em um tempo discretizado sobre um passo constante $\Delta t=10^{-2}$. Inicialmente, com $t[0]=0{,}0$ e $t[N]=100{,}0$, onde N é o índice final da série. Isso produzirá séries temporais, onde os dados finais estão fora do transiente inicial. Logo em seguida, usamos os dados finais dessas séries como sendo as novas condições iniciais e novamente solucionamos o sistema no mesmo intervalo. Assim obtemos os dados mostrados na Figura 1.

Acrescentamos ruído observacional $\boldsymbol{r}$, com distribuição normal de média $\mu=0$ e desvio padrão $\boldsymbol{D}=\text{máx}(\boldsymbol{x})$. Só então partimos para a recuperação do sistema usando os dados das séries temporais com ruídos.

Aqui é preciso ter cautela ao se ajustar as funções polinomiais sobre os dados contaminados por ruído. Não queremos que as equações estimadas acompanhem as oscilações rápidas causadas pelo ruído, mas apenas a dinâmica original do sistema, que varia em uma escala de tempo mais lenta. Sendo assim, usamos funções polinomiais unidimensionais $\boldsymbol{P}_r(t)$ de grau G que se ajustam com o método B-Spline usando um parâmetro de suavização s. Esse método usa um ajuste de mínimos quadrados de modo que tenta filtrar o ruído, admitindo um resíduo no ajuste de valor s, de acordo com a equação (6).

$$\sum_{i=1}^{n}(\boldsymbol{P}_r[n]-\boldsymbol{x}_r[n])\leq s, \quad (6)$$

onde $\boldsymbol{P}_r[n]$ é o vetor de funções que desejamos, $\boldsymbol{x}_r[n]$ é vetor de dados conhecidos.

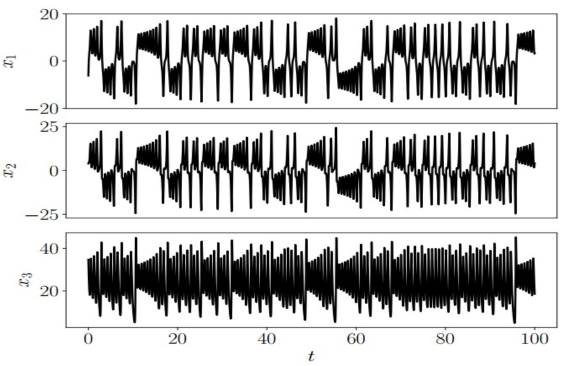

Figura 1. Séries temporais do sistema de Lorenz.

Usando os dados conhecidos, testamos diversos valores de s a fim de chegar ao menor resíduo possível com respeito aos dados exatos, livres de ruído. Sendo assim, acompanhamos a dependência em s do valor do *desvio médio* ao *valor exato Q*, como na equação (7).

$$Q=\frac{1}{N}\sum_{i=1}^{n}|\boldsymbol{P}_r[n]-\boldsymbol{x}[n]|\simeq 0. \quad (7)$$

Como o sistema de Lorenz é tridimensional, fazemos o uso de três funções polinomiais. O grau G dessas funções polinomiais variando de 3 a 5. Nossos testes mostraram o melhor valor de s encontrado para cada grau analisado no Quadro 1.

Quadro 1. Análise da escolha do valor de *s*. FONTE: os autores.

Função	Grau		
	3	4	5
P_1	$s=300$	$s=300$	$s=300$
P_2	$s=540$	$s=530$	$s=530$
P_3	$s=1800$	$s=1800$	$s=1800$

Com o uso desses valores de s, seguimos as etapas da metodologia. Na primeira etapa precisamos saber qual o melhor grau para o ajuste dos polinômios e na terceira etapa precisamos saber qual a melhor norma para o ajuste, sempre visando o melhor saldo de previsão. Para definir um critério numérico para a capacidade de previsão arbitramos o tempo (ou horizonte) de previsão como sendo aquele no qual o erro percentual das séries temporais originais e recuperadas diante de ruídos atinge 10% do valor máximo da série. Fizemos uma análise estatística baseada em 10 realizações em que a cada realização mudamos os valores aleatórios de ruídos. Esta análise, mostrando os efeitos do grau e da norma no tempo de previsão, é mostrada na Figura 2.

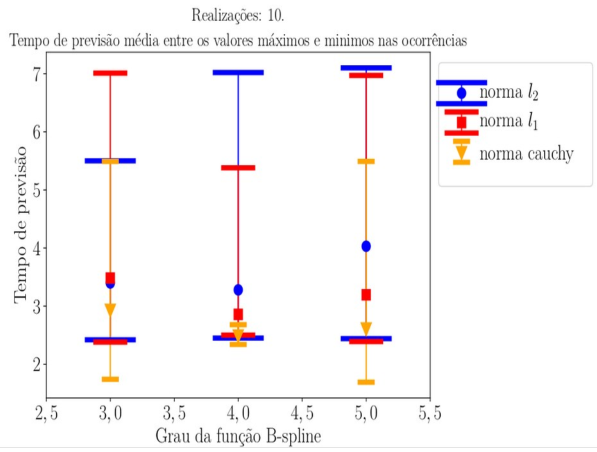

Figura 2. Análise sistemática do grau e norma.

Além disso, sabemos que o tempo de previsão pode ser fortemente influenciado pela condição inicial, pois o tempo de previsão máximo teórico depende do expoente de Lyapunov local observado no espaço de fase, o qual é determinado pelo tempo de observação e pela condição inicial. Fizemos, então, o teste com diferentes condições iniciais, mas fixando os valores de ruído, apresentado na Figura 3.

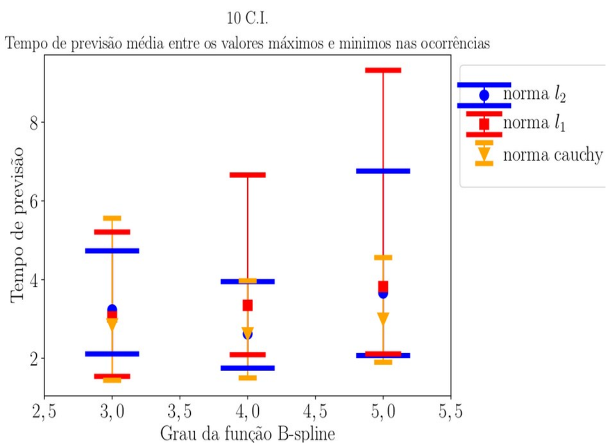

Figura 3. Análise sistemática do grau e norma.

Em seguida, fixando valores de ruídos e com o resultado da análise, fizemos, na primeira etapa, o uso de funções polinomiais unidimensionais de grau 5. Na segunda etapa, fazemos uma derivação com relação ao tempo dessas funções e obtemos funções polinomiais unidimensionais de grau 4. Na terceira etapa, fazendo o uso de funções polinomiais multidimensionais de grau 2 e usando a norma l_1, temos o resultado para os coeficientes dos polinômios, mostrado no Quadro 2.

Sabendo que as funções do sistema de Lorenz são também polinômios, é possível realizar a comparação com os valores exatos. Tratando agora nosso sistema dado por essas novas funções polinomiais, realizamos uma solução numérica através do método RK4.

Quadro 2. Valores resultantes para os coeficientes diante de ruído.

parcela	equação		
	$\dot{x}_1 = f_1$	$\dot{x}_2 = f_2$	$\dot{x}_3 = f_3$
1	-1	-0,9	-1,7
x_1	-10,2	27,8	-0,5
x_2	10	-0,8	0,4
x_3	-0,2	0	-2,4
$x_1 x_2$	0	0	1
$x_1 x_3$	0	-0,9	0
$x_2 x_3$	0	0	0
x_1^2	0	0	0
x_2^2	0	0	0
x_3^2	0	0	0

A Figura 4 apresenta o comparativo das séries do sistema de Lorenz e as séries do sistema aproximado. A Figura 5 apresenta o tempo de previsão de aproximadamente 2,61 unidades de tempo considerando o critério de 10% do erro percentual das séries temporais originais e recuperadas diante de ruídos.

4. Discussão

A análise da Figura 2 e da Figura 3 mostra que para a primeira etapa o melhor grau é 5 e para a terceira etapa a melhor norma é l_1. Não testamos que efeitos podem ter nesta análise a variação do intervalo de tempo entre os dados temporais e o acréscimo do ruído. O nível de ruído usado foi de apenas 1% do valor máximo da série temporal Para outros dados, provavelmente os resultados de *s*, graus das funções e normas serão outros. Entretanto, a metodologia é a mesma, o que nos assegura sua eficácia. Também em situações reais, onde não conhecemos o sistema, a tarefa de encontrar o valor de suavização torna-se mais complicada, pois não podemos calcular *Q*, o desvio do valor exato, mas o uso de B-Spline ajustada possibilita estimar um valor de *s* adequado de modo a não ajustar o ruído dos dados.

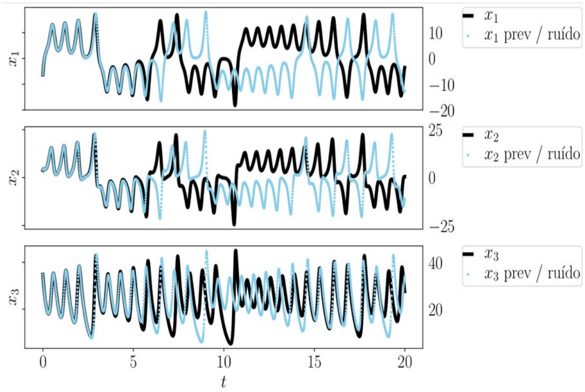

Figura 4. Comparação entre as séries temporais originais e as séries recuperadas diante de ruído.

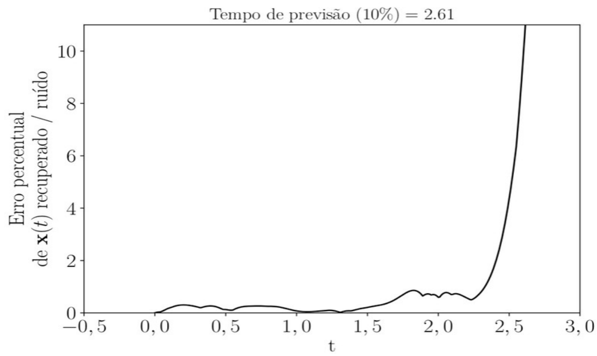

Figura 5. Erro percentual das séries temporais originais e recuperadas diante de ruídos. FONTE: os autores.

5. Conclusões

Usamos o sistema de Lorenz como exemplo para aplicar e desenvolver o nosso método de previsão em sistemas dinâmicos. Mostramos que o conhecimento de séries temporais de dados oriundos do sistema pode ser usado para recuperar a dinâmica que origina o comportamento observado. Em seguida, usando a dinâmica recuperada, e abordamos o problema da previsão do estado futuro.

Desenvolvemos uma técnica de inteligência artificial utilizando funções polinomiais para calcular as velocidades de evolução das variáveis de estado do sistema e com isso, recuperamos suas equações diferenciais e finalmente realizamos a previsão. O algoritmo proposto é capaz de se adaptar ao sistema, com parâmetros flexíveis, extraídos a partir dos dados coletados em observações. Sendo assim, os resultados são eficazes diante de um sistema caótico e o método ainda pode ser ajustado e aplicado a outros sistemas. Exploramos algumas situações que se espera encontrar em problemas reais, no intuito de mostrar que sua aplicabilidade prática é viável.

Para reduzir o efeito do ruído, fizemos testes com diferentes valores de um parâmetro de suavização e conseguimos encontrar valores que fazem uma filtragem nos dados com ruídos de modo a aproximá-los cada vez mais dos dados considerados exatos.

Em geral, conclui-se que as aproximações por funções polinomiais são eficazes para recuperar as equações governantes dos sistemas. Logo, conforme temos os métodos para a previsão de um sistema caótico, então é possível sua aplicação a dados reais de sistemas desconhecidos, desde que tenham características similares, tais como determinismo e baixa dimensionalidade.

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Tecnologia Robótica e *Problem Based Learning* Aplicados ao Ensino de Lógica

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Resumo: O artigo descreve o desenvolvimento de uma solução baseada em robótica educacional para promover o ensino de lógica e programação. As atividades envolveram a criação do *hardware* e a implementação da integração com Snap!, além da geração do material didático. No decorrer do desenvolvimento da solução, observou-se a necessidade de unir a aplicação do sistema robótico, a uma metodologia de ensino que pudesse apoiar o processo de disseminação junto aos professores e alunos da educação básica, especificamente, o sexto ano do ensino fundamental II. Diante disso, foi utilizada metodologia ativa, especificamente, *Problem Based Learning* (PBL) para a construção do material didático.

Palavras-chave: *robótica educacional; problem based learning; Snap!; ensino de lógica*.

1. Introdução

A robótica educacional é a aplicação da tecnologia na área pedagógica, sendo mais um instrumento que oferece aos alunos e professores, a oportunidade de vivenciar experiências semelhantes às que terão na vida real, dando a estes, a chance de solucionar problemas mais do que observar formas de solução. A robótica tem grande potencial como ferramenta interdisciplinar, visto que a construção de um novo mecanismo, ou a solução de um novo problema, frequentemente extrapola a sala de aula. A robótica assume o papel de uma ponte que possibilita religar fronteiras anteriormente estabelecidas, agindo como um elemento de coesão dentro do currículo das escolas do ensino básico [1].

Contudo, ainda persiste o desafio de implementar e promover corretamente a adoção da robótica educacional no Brasil. O primeiro problema está na falta de professores familiarizados com a sua aplicação em sala de aula. Posteriormente, ocorrem a existência de equipamentos sem manutenção, outros com tecnologia ultrapassada, além de quantidade insuficiente para atender o número de alunos [2]. Diante disso, é fundamental entender como realmente construir uma solução aplicando robótica educacional que tenha foco, metodologia de aprendizagem clara e que permita ao professor conduzir uma atividade de forma satisfatória para grande parte dos alunos e não somente para um grupo pequeno de interessados pelo assunto. O desafio está em como atingir a maioria dos alunos, incluído os desinteressados. Para isto, as plataformas educacionais envolvendo robótica devem se aprofundar no processo das metodologias ativas e encontrar o equilíbrio correto para atender os interesses tanto dos alunos quanto dos professores. No emprego da metodologia ativa [3], em oposição à aprendizagem passiva baseada na transmissão de informação, o aluno assume uma postura mais ativa, na qual ele resolve problemas, desenvolve projetos e, com isto, cria oportunidades para a construção de conhecimento.

Entre as metodologias ativas, a utilizada no projeto foi *Problem Based Learning* (PBL). Trata-se de uma proposta pedagógica que consiste no ensino centrado no estudante e baseado na solução de problemas, reais ou simulados. Os alunos, para solucionar esse problema, recorrem aos conhecimentos prévios, discutem, estudam, adquirem e integram os novos conhecimentos. Essa integração, aliada à aplicação prática, facilita a retenção do conhecimento. Portanto, o PBL valoriza, além do conteúdo a ser aprendido, a forma como ocorre o aprendizado, reforçando o papel ativo do aluno neste processo, permitindo que ele aprenda como aprender.

O PBL oferece diversas vantagens, como o desenvolvimento da autonomia, a interdisciplinaridade, a indissociabilidade entre teoria e prática, o desenvolvimento do raciocínio crítico e de habilidades de comunicação. Além disso, à medida que estimula uma atitude ativa do aluno em busca do conhecimento e não meramente informativa, como é o caso da prática pedagógica tradicional, o PBL caracteriza-se como uma metodologia formativa onde o elemento central é o aluno [4]. Os alunos são apresentados a um problema, pré-elaborado, e com a facilitação de um professor/tutor, são estimulados a discutir e elaborar hipóteses. Esta situação motivadora nos grupos leva a definição de objetivos de aprendizagem, que serão os estímulos para o estudo individual [5].

Ademais, o protagonismo dos estudantes no processo de aprendizagem é um importante fator motivacional, levando a busca ativa do conhecimento e gerando um aprendizado mais eficaz. A interdisciplinaridade é outra importante vantagem do PBL sobre o ensino tradicional. A substituição de conhecimento fragmentado, oferecido em disciplinas, por situações reais, que envolvam vários aspectos do conhecimento, favorece uma aprendizagem significativa, contextual e, ainda, promove a integração dos conteúdos curriculares do ciclo básico [6].

Com relação ao Snap! trata-se de uma linguagem de programação educacional e ferramenta de autoria multimídia baseado no Scratch (*https://scratch.mit.edu*) [7]. O Snap! é uma linguagem visual que utiliza características de arrastar e soltar (*drag and drop*). O principal aspecto desse ambiente está na implementação de algoritmos por intermédio de blocos construtivos.

Essas ferramentas são adequadas para introduzir os estudantes na área de ciência da computação, visto que o processo de desenvolvimento de programas computacionais se torna mais intuitivo e direto. Um detalhamento sobre a utilização do Snap! pode ser encontrado no manual de referência acessado pelo *link*: *https://snap.berkeley.edu/snap/help/SnapManual.pdf* Todos os componentes do sistema de programação Snap! são gratuitos e de código aberto, sob uma Licença Pública Geral.

2. Metodologia

O desenvolvimento foi dividido em atividades relacionadas à criação do *hardware* do robô SuperKid (projeto mecânico, eletrônico e do software embarcado), construção de um *middleware* para realizar a integração dele com o Snap! e a transmissão de comandos via *bluetooth*. Além disso, paralelamente, foi realizada a criação do material educacional para apoiar o uso do kit por parte de alunos e professores.

Baseado nas especificações do SuperKid (levantadas na fase de visão e validadas na fase de concepção) foi realizado um planejamento dos custos de produção por lotes. Utilizou-se a eletrônica do robô Kid (*http://www.xbot.com.br/educacional/kid*) como base para iniciar a criação do Super Kid. A meta era trabalhar com um microcontrolador de baixo custo para suportar o *software* embarcado responsável pelo controle tanto dos motores (mobilidade) quanto dos sensores (infravermelho) e atuadores (leds e buzina). A meta era que o robô tivesse um custo de fabricação baixo já prevendo um carregador e baterias no lugar das pilhas e a presença de uma carenagem. Essas características não existem no Kid.

Durante o projeto chegou-se a pesquisar a utilização do Arduino com o objetivo de trocar o processador original do Kid (microcontrolador PIC 16F876A). O Arduino é uma plataforma de prototipagem eletrônica de *hardware* livre, projetada com um microcontrolador Atmel AVR de placa única, com suporte de entrada/saída embutido que utiliza uma linguagem de programação C/C++. Uma típica placa Arduino é composta por um controlador, algumas linhas de E/S digital e analógica, além de uma interface serial ou USB, para interligar-se ao hospedeiro, que é usado para programá-la em tempo real. Ela, em si, não possui nenhum recurso de rede, porém é comum combinar com extensões chamadas de *shields*. Um desses *shields* poderia permitir a comunicação via *bluetooth*. Contudo, devido ao custo financeiro envolvido, a decisão final foi manter o *hardware* do Kid, acrescentando um *chip bluetooth* na eletrônica embarcada. A placa fabricada pelo Kid com a modificação era mais barata que a aquisição do Arduino + *shield* para comunicação via *bluetooth*. O projeto também considerou a questão da autonomia da bateria do *hardware* que deveria durar pelo menos entre seis a oito horas. Foi modificada a placa original do Kid para ser capaz de conectar um carregador de tomada para carregar a bateria que substituiu o "case" de pilhas.

Posteriormente, o foco foi na construção da biblioteca com as funções de controle do robô como, por exemplo, movimentar para frente, para trás, parar, ligar e desligar buzina, acender e apagar leds. Dessa forma, os blocos desenvolvidos podem ser utilizados dentro do ambiente de programação do Snap! Os comandos que representam cada bloco são enviados via *bluetooth* para o robô executar. Para isto foi necessário realizar um estudo sobre o Snap! e entender de que forma a plataforma executada via *browser* poderia ser comunicar com o meio externo. Durante essa revisão foi identificado um caso de uso com o lego *mindstorm* (*https://scratch.mit.edu/ev3*) que serviu com o referência. Também foi encontrado um *site* que relata experiências de como realizar a conexão com o Scratch (*https://education.lego.com/en-us/support/mindstorms-ev3/scratch*), porém na época da pesquisa, não foi encontrado material para integração com o Snap!

Foi definida uma arquitetura que privilegiou a menor quantidade de interações para evitar consumo de energia no robô e problemas de erro de comunicação que poderiam desestimular o aluno a interagir com o kit educacional. Na Figura 1 é exibido o robô SuperKid. Na Figura 2 é apresentada a interface do Snap! com os comandos que foram criados (lado inferior esquerdo da figura – blocos construtivos em azul).

Figura 1. Visão geral do robô construído (SuperKid).

Inicialmente, foram montados manuais de uso que permitem, tanto o aluno quanto o professor, manipular os comandos do robô, instalar o sistema e executar exemplos de exercícios com os blocos construtivos. Também foram montadas videoaulas explicando detalhadamente cada atividade. Além disso, os professores envolvidos tiveram um *workshop* presencial de 16 horas (dois dias) para aprender a trabalhar com o material em sala de aula. Entendia-se que seria o suficiente para que pudessem utilizar o ferramental e montar suas próprias atividades, ou mesmo, utilizar aquelas que já tinham sido construídas. Contudo na fase de validação com três turmas do sexto ano do ensino fundamental II (total de 72 alunos), o processo de adoção da tecnologia não ocorreu de forma satisfatória com baixos índices de adesão por parte dos alunos.

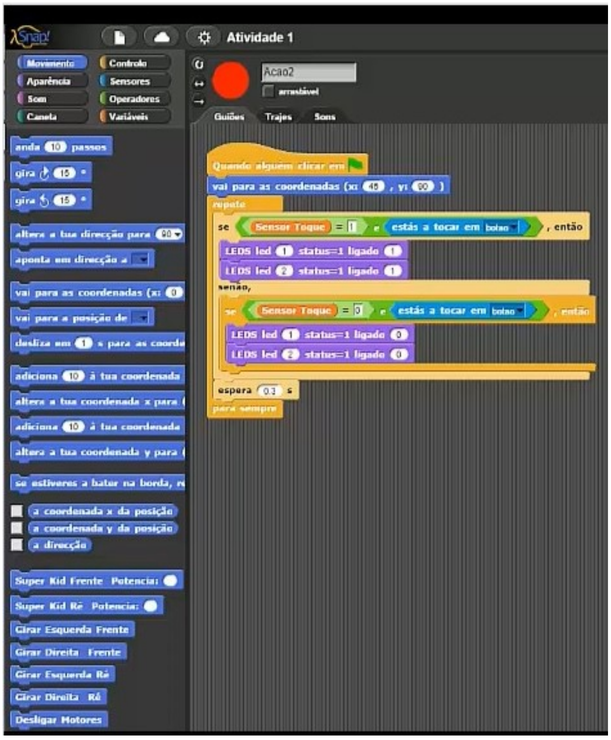

Figura 2. Interface do Snap! com os comandos desenvolvidos.

Diante dessa situação e baseados na experiência de um projeto de aprendizagem para disciplina de Introdução à Computação (IC) para graduação [8], que trabalhou com fuga de labirinto e conceitos envolvendo PBL, foram criados Planos de Aulas (PAs) com conteúdos para que os alunos pudessem utilizar o kit educacional desenvolvido. Além disso, eles serviram de base para os professores gerarem novas atividades que pudessem ser utilizados nos laboratórios de informática ou espaço *maker* das escolas. Os PAs foram montados com tempo estimado para serem realizados durante uma aula padrão (45 minutos). Cada PA tem um tema (disciplina) e um subtema. Para etapa de validação foram criados PAs com o objetivo de ensinar linguagem de programação com o subtema relacionado à instrução condicional. No caso do ensino de lógica foi montado um PA sobre aprendizagem de conjuntos (união, intersecção, etc).

3. Resultados

Neste projeto foi construída uma biblioteca de comandos para o controle do robô: (1) movimentar para frente, (2) para trás, (3) parar, (4) ligar buzina, (5) desligar buzina, (6) acender leds e (7) apagar leds. Esses blocos são utilizados dentro da programação normal do Snap! e os comandos que representam cada bloco são enviados via *bluetooth* para o robô executar. Os comandos foram criados no formato “xml”. A seguir é apresentado um exemplo: no caso o comando “Girar Esquerda Frente”:

```
<blocks app="Snap! 4.0, http://snap.berkeley.edu"
version="1"><block-definition s="superkid parar
motores" type="command" category="other">

<code></code><inputs></inputs><script><block
s="doRun"><block s="reportURL"><l>
localhost:3611/parar</l></block><list></list>
</block></script></block-definition>

<block-definition s="Girar Esquerda Frente"
type="command" category="motion"><code></code>
<script><block s="doReport"><block s="reportURL">
<block s="reportJoinWords"><list><l>
localhost:3611/gef</l><l>-</l></list></block>
</block></block></script></block-definition>
```

Com relação ao servidor de comunicação, foi desenvolvido um aplicativo que realiza a conexão ponto a ponto via *bluetooth* entre o robô e computador instalado com Snap! Este aplicativo é responsável por realizar o pareamento com o robô antes de iniciar as atividades didáticas. A Figura 3 mostra a interface desse aplicativo. O usuário deverá escolher uma porta serial previamente definida em uma lista disponibilizada pelo computador e salvar. Depois, basta clicar no botão “iniciar servidor” para ligar a comunicação, e posteriormente, clicar no botão “finalizar servidor” para desligar essa comunicação.

Figura 3. Aplicativo “porta.exe” responsável por habilitar o servidor de comunicação entre o robô e o Snap!.

Ao iniciar o servidor, o robô exibe um sinal visual quando o mesmo está conectado ao computador. Dessa forma, facilita ao usuário saber se a comunicação está funcionando corretamente. O aplicativo desenvolvido é responsável por encapsular as palavras e transmitir os comandos seguindo um protocolo de comunicação robusto que evita perda de comandos e sobreposição da pilha de execução. Ele é capaz de interpretar os comandos vindos do Snap! e traduzir para este protocolo. A comunicação é bidirecional, isto é, do Snap! para este programa e vice versa. Isto se deve aos comandos condicionais que necessitam da resposta do robô. Não basta apenas enviar os dados, o Snap! precisa também recebê-los para executar a programação em tempo real.

Foram realizadas 10 sessões com atividades para testar os PAs criados com um grupo de oito alunos. O objetivo era verificar se a nova abordagem pedagógica surtiria efeito positivo no engajamento dos alunos e no aprendizado do conteúdo em si. Os testes foram realizados com o subtema: Instrução Condicional. A seguir, exemplos de atividades para os alunos:

1. Utilizando os blocos construtivos, faça com que o robô, ao ser iniciado, verifique todos os seus sensores de distância. Se houver algum obstáculo próximo a algum destes sensores, o robô deverá girar para o lado oposto e "fugir" do obstáculo. Não utilizar instruções de laço.
2. Utilizando os blocos construtivos e somente o sensor frontal construa uma solução para que o robô possa sair do labirinto o mais rápido possível e no menor número de interações.

4. Discussões e Conclusões

Este trabalho buscou aplicar tecnologia robótica para promover o engajamento não somente dos alunos, mas dos professores, inclusive aqueles que não são da área de informática/computação. Os primeiros testes com o público alvo (fase de validação) demostraram nitidamente que se não fosse adaptada uma metodologia ativa para promover as atividades, qualquer ferramenta construída padeceria de adoção da mesma em sala de aula, entende-se, laboratório de informática. Algumas vezes, por conta do aluno, e quase sempre, por conta do próprio professor/ instrutor.

Mesmo contando com o arcabouço do conceito da Hora do Código (*https://hourofcode.com/br*), o mesmo não se mostrou suficiente para promover o envolvimento dos professores no processo educacional, pois muitos deles não eram da área de informática/ computação ou não estavam imbuídos da mesma doutrina. Diante disso, foi necessário estudar as metodologias ativas e identificar de que forma elas poderiam auxiliar no processo de adoção e engajamento da tecnologia educacional proposta.

As principais vantagens pedagógicas da robótica, principalmente associada ao método PBL que puderam ser observadas estão relacionadas ao desenvolvimento do raciocínio e na lógica da construção de algoritmos e programas para controle dos mecanismos. É importante salientar que nos anos escolares iniciais devem ser trabalhados conceitos relacionados às estruturas abstratas necessárias à resolução de problemas no eixo do "Pensamento Computacional". É importante que o aluno tome consciência do processo de resolução de problemas, e compreenda a importância de ser capaz de descrever a solução em forma de algoritmo. Nesta etapa, os alunos são expostos à noção básica de algoritmos quando, por exemplo, ensinam-se as operações aritméticas básicas. A expectativa é que isso seja enfatizado, de forma que os alunos entendam noções básicas de algoritmo, sendo capazes de, a partir de conjuntos de instruções diversas, conseguir elaborar algoritmos para solucionar diferentes tipos de problemas.

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ThinkTank: Um Jogo Construtivista para Ensino de Pensamento Computacional

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Resumo: Este artigo discute e apresenta o desenvolvimento do jogo Thinktank, com base construcionista, para o ensino de pensamento computacional e programação. O jogo faz uso de programação em blocos em uma mecânica de fácil entendimento para atingir públicos variados, com pouco ou nenhum conhecimento em programação. Um diferencial deste jogo é a competição multijogador em tempo real pela internet, que permite a aprendizes se desafiarem e jogarem em arenas competitivamente, estimulando-os a melhorar e aprender continuamente novos algoritmos e estratégias para ganhar a partida. É apresentado um protótipo inicial do jogo, bem como futuras direções de pesquisa e melhorias.

Palavras-chave: *construcionismo; pensamento computacional; jogos sérios*.

1. Introdução

Os algoritmos, as tecnologias de comunicação e informação, além da inteligência artificial permeiam cada vez mais a vida cotidiana. Essa ubiquidade da tecnologia resultará em uma mudança no ambiente de trabalho e na sociedade do futuro. Nesse contexto, se faz necessário preparar a população para novas demandas e oportunidades, seja oferecendo a crianças a possibilidade de ter experiências com essas tecnologias, seja capacitando adultos a trabalhar em um ambiente de trabalho permeado por elas. Esse novo cenário requer um pensamento crítico e inovador para resolver problemas cada vez mais complexos, com pessoas habilitadas a pensar computacionalmente e algoritimicamente, fluentes no uso e concepção de novas tecnologias [1].

Pensar computacionalmente é uma forma de encarar problemas análoga ao questionamento em um pensamento científico [1]. O Pensamento Computacional (PC) é uma “abordagem para resolver problemas, projetar sistemas e entender comportamentos humanos que se baseia em conceitos da ciência da computação” [2]. O PC fundamenta-se em grande parte em conceitos de programação, porém não é definido somente por isso [3].

O desenvolvimento do PC não deve se limitar ao ambiente escolar formal; ele deve ser mais pervasivo, ubíquo e não diretamente associado a uma sala de aula e outros espaços formais de ensino. Uma forma de construir esse conhecimento é através do uso ou construção de jogos digitais (JD). Em particular, o uso de jogos para a educação promove maior engajamento e imersão (*flow*) nos estudantes, o que, por sua vez, relaciona-se a um maior aprendizado, absorção de conceitos e desempenho criativo em ambientes profissionais [4].

Com base nessa necessidade do desenvolvimento do PC em diferentes ambientes, e as vantagens inerentes a jogos digitais quanto à imersão e retenção de informação, este artigo apresenta a proposta do desenvolvimento de um protótipo de jogo digital construcionista online de estratégia e ação, denominado ThinkTank, com foco no desenvolvimento de PC de forma ubíqua. O jogo traz inspirações de títulos similares como *Robobuilder* [5] apresentando diferenciais quanto à imersão de seus jogadores, bem como facilitando o desenvolvimento de conceitos de PC através de mecânicas lúdicas.

Este artigo se encontra organizado da seguinte forma: a Seção 2 descreve e fundamenta os conceitos teóricos usados. A Seção 3 descreve as práticas pedagógicas, os conceitos de PC e as mecânicas de imersão aplicados no desenvolvimento do jogo. A Seção 4 descreve a implementação do jogo e suas implicações no aprendizado de PC, bem como suas atuais limitações. Finalmente, a Seção 5 ilustra perspectivas futuras para este projeto.

2. Fundamentação Teórica

2.1 Construtivismo e Construcionismo

O construtivismo é uma teoria pedagógica proposta pelo filósofo Jean Piaget, afirmando que o ser humano não recebe conhecimento de fontes externas e o compreende/aplica diretamente; o aprendiz primeiro constrói seu próprio conhecimento [6].

Outra abordagem pedagógica é a teoria sociocultural proposta por Vygotsky. Relacionada ao construtivismo (construtivismo social), ela difere-se por ter maior ênfase à construção do conhecimento através de interações e aspectos sociais como a família, comunidades, e cultura [7].

O paradigma construcionista foi criado por Papert como uma forma de descrever a construção do conhecimento através do computador [8]. Baseado no construtivismo, essa teoria se diferencia ao afirmar que o aprendizado ocorre ao construir um objeto; ela ainda difere-se do construtivismo social e piagetiano por ser mais situacional e pragmática [10], bem como por um maior envolvimento afetivo do aluno no aprendizado [9].

Neste trabalho, o jogo construído assemelha-se mais à prática construcionista de Papert, principalmente pelo uso do computador como ferramenta e pela construção de robôs; o próprio jogo, neste caso, toma o papel de mediador do aprendizado.

2.2 Pensamento Computacional

O conceito de PC está intimamente ligado ao construcionismo proposto por Papert e possui muitas interpretações distintas, sendo definido de forma abrangente como uma forma de resolver problemas usando o computador como uma ferramenta para tal [1]. Desta forma, pode ser utilizado para o ensino e aprendizado das mais diversas habilidades e competências, como matemática, física e áreas relacionadas. Mesmo havendo pouco consenso entre as competências que envolvem PC, é possível entendê-las como um conjunto de habilidades a serem adquiridas. Neste trabalho, optou-se por definir PC como o seguinte conjunto de habilidades: coleta de dados (H1), análise de dados (H2), representação de dados (H3), abstração (H4), decomposição de problemas (H5), algoritmos e procedimentos (H6), Automação (H7), Simulação (H8) e paralelismo (H9) [11]. A escolha desta definição em detrimento de outras se deve a uma maior número de categorias específicas ligadas à análise de dados, bem como uma separação entre o uso de algoritmos, paralelismo e resolução de problemas.

3. Metodologia

ThinkTank é um jogo desenvolvido como uma forma de aplicar a prática construcionista para o aprendizado de PC, possuindo modos de jogo multiusuário (*multiplayer*) e monousuário (*singleplayer*). Para o desenvolvimento deste jogo, foi escolhida a *engine* de jogos Unity e a linguagem de programação C#, por serem tecnologias muito usadas em programação de jogos e possuírem uma vasta gama de tutoriais e suporte.

Em *Thinktank*, em vez de comandar um personagem diretamente através de comandos do teclado/console, o aprendiz/jogador deve codificar e construir a lógica de programação de um robô, colocado em uma arena para competir com robôs de outros jogadores; o jogador deve gerenciar, a partir de sua programação, uma reserva de energia do robô e com ela administrar sua movimentação e ações. Vence o jogador que conseguir melhor resultado sem esgotar suas reservas de energia.

O jogador programa o robô através de linguagem visual de blocos, similar à usada no software educacional *Scratch* [12], como ilustra a Figura 1. A programação visual foi escolhida por diminuir as barreiras de aprendizado de PC, além de ser mais compreendida por alunos quando comparada a uma linguagem tradicional [13]. Além disso, o uso de programação visual resulta em um aprendizado mais relevante por alunos com baixa confiança em suas próprias habilidades [14]. Finalmente, o uso dessa ferramenta aumenta a motivação e engajamento dos aprendizes [15]. Assim, essa escolha de interação traduz-se em uma forma mais igualitária, autônoma, motivadora e eficiente de aprendizado de PC.

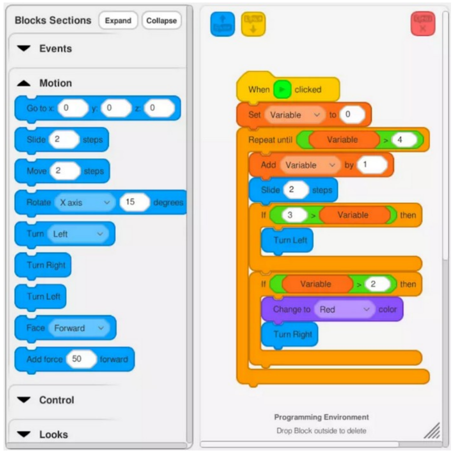

Figura 1. Programação em blocos usada no jogo [16].

A escolha do cenário e a estruturação como uma competição entre robôs já foi abordada na literatura, devido aos seguintes motivos [5]:

- facilidade na tradução entre os algoritmos abstratos e ações do robô no ambiente de jogo;
- o ato de programar robôs para executar tarefas simples é divertido e motivador em ambientes educacionais;
- o contexto (disputas de robôs) e objetivo do jogo (ganhar dos demais oponentes) são claros o suficiente para serem auto explicativos, auxiliando a prática construcionista.

Para tornar a experiência do jogo mais lúdica, foram desenvolvidos elementos de som e arte que remetem a consoles de jogos eletrônicos mais antigos e tradicionais (elementos nostálgicos): optou-se por um estilo de arte baseado em pixels (*pixel art*), em um cenário repleto de doces, no qual uma civilização altamente tecnológica, também feita de açúcar, está testando sondas robô para explorar um mundo feito de água (o principal combustível dessa civilização). Um exemplo do espaço de disputa e seus elementos de design é ilustrado na Figura 2.

Figura 2. Exemplo de cenário de disputa. Próprio(s) autor(es).

O modo monousuário foi desenvolvido de forma a executar o papel de *scaffolding* [7], ao mesmo tempo em que mantém o jogador aprendiz imerso na prática de programação. O jogo oferece uma série de robôs pré-programados, executados de forma autônoma, que servem para o jogador testar a lógica de seu próprio personagem e desafiar-se individualmente. Além disso, foi desenvolvida uma série de desafios (*puzzles*) para o aprendiz resolver usando técnicas de PC. Esse design particular dos modos de jogo foi feito para ser usado de forma não competitiva, com os jogadores desafiando a si mesmos, disputando contra versões robóticas automatizadas, buscando ter novas experiências e ideias de melhorias nos algoritmos que estão implementando.

O modo multijogador usa a competição como forma de motivar jogadores a desenvolver algoritmos cada vez mais complexos, que possam competir satisfatoriamente com outros jogadores na Internet.

O jogo difere-se de outros na literatura, como *Robobuilder* [5] ou *Robocode* [17], por possuir modo de *multiplayer* online, enquanto essas plataformas se resumem a partidas com múltiplos jogadores de forma local, inserindo os robôs jogadores manualmente em uma partida. Em termos do modo *singleplayer*, as plataformas existentes focam somente na simulação de partidas com o uso de robôs autônomos, construídos por inteligência artificial ou disponibilizados por outros jogadores; em *Thinktank*, além de fazer uso desta mesma mecânica, foram desenvolvidas fases de tutorial e quebra-cabeças (*puzzles*) para estimular o jogador a programar de forma mais eficiente e trabalhar a sua competência em resolução de problemas. *Thinktank* traz também elementos de jogos comerciais, objetivando um maior engajamento do jogador e uma maior abrangência de público; entre esses elementos se encontra a própria estética do jogo, usando *pixel art* e uma perspectiva isométrica, diferente dos jogos analisados na literatura, que apresentam perspectiva *top-down* e pouca preocupação com a estética. O jogo ainda oferece mecânicas únicas de jogabilidade, como poderes especiais e itens de customização do robô, que permitem ao jogador adaptar seu robô com disparos mais fortes, melhor movimentação, etc; outra característica importante é a arena na qual os jogadores batalham, que possui obstáculos gerados aleatoriamente aumentando o nível de desafio da programação do robô e gerando uma diferenciação entre cada partida.

Devido à facilidade de uso e abrangência de habilidades de PC trabalhadas, é possível utilizar o jogo com alunos do ensino fundamental, médio e superior, tanto de forma autônoma quanto para ensino de áreas correlatas como ciência, tecnologia, engenharia e matemática (STEM). O jogo também pode vir a ser usado em dinâmicas de aprendizado de conceitos de física (trajetória de projéteis), matemática (usando a movimentação geral do robô), e até mesmo economia (escassez de recursos/gerenciamento de energia).

4. Conceitos de PC em *Thinktank*

O jogo ThinkTank permite a aprendizes de diversos níveis e formações desenvolverem o PC de forma lúdica e interativa. Ele trabalha pelo menos seis diferentes habilidades de PC:

- H1/H2: coleta de dados sobre o robô, como nível de energia restante, posição dos demais competidores no cenário, bem como sua posterior análise para tomada de decisão;
- H4/H5: redução da complexidade do contexto de programação para somente movimentações em uma arena pré-demarcada, permitindo ao aprendiz abstrair conceitos técnicos de forma mais simples e visual;
- H6/H7: embora não sejam trabalhadas diretamente, espera-se que os melhores jogadores proponham e testem diferentes algoritmos e procedimentos, visto que devem usar comandos visuais para realizar todas as ações de movimentação e estratégias de vitória de seu robô. A H6 em particular é praticada a todo instante pelo aprendiz jogador ao programar seu robô.

Desta forma, o jogo abrange a maior parte do que se considera como PC na literatura.

5. Conclusões e Perspectivas Futuras

Este artigo apresentou um protótipo inicial do jogo de disputa de robôs ThinkTank, com o objetivo de desenvolver o PC e conceitos de programação de forma lúdica e motivadora. O objetivo do jogo é atingir diversos públicos, podendo ser usado no ensino fundamental, médio e superior. O jogo pode ser usado individualmente, mas também possibilita a disputa entre participantes em uma forma multijogador com objetivo de tornar a atividade motivadora. É possível ainda usar o jogo como base para ensinar conceitos de STEM.

O primeiro protótipo do jogo foi desenvolvido, e algumas funcionalidades descritas neste texto ainda não estão disponíveis. Pesquisas para o desenvolvimento de modelos de avaliação do aprendizado de PC com base no jogo são importantes trabalhos futuros. Além disso, seria importante adaptar as mecânicas de programação, para permitir o uso do jogo em *smartphones* ou *tablets*, tornando-o mais responsivo. Finalmente, poder-se-ia explorar alternativas aos modos de jogo, abrindo novas possibilidades para professores usarem o jogo em sala de aula.

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Improving Students' Motivation and Focus Through the Gamification in the Computer Science Peer Instruction Methodology (CSPI)

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Abstract: The Peer Instruction (PI) is an active learning, student-centered approach designed to engage students through the administration of conceptual questions. On its turn, the CSPI is an adaptation of the PI to the computer science area, mainly Introductory Programming (CS1) courses. In this work, we present the initial assessment of the gamification adoption into the CSPI. Two CSPI/CS1 courses were administered, one without gamification (control experiment) and one with it. We identified that, although participants originally didn't expect that gamification would affect their experience, results suggest that gamification positively impacts participants' motivation and focus. Future work involves the analysis of collaboration and interaction variables through learning analytics tools.

Keywords: *Gamification; active learning; peer instruction; Computer Science peer instruction; CS1; assessment; motivation.*

1. Introduction

In contrast to the traditional instructor-focused classes, in 1991, Bonwell & Eison [1] explained that students must do more than just listen: they should read, write, discuss, and be actively involved in solving problems, which is known as Active Learning.

One of the most adopted Active Learning approaches, the Peer Instruction (PI), was born in the physics area. As described by Kelly, M. [3], the PI is a student-centered teaching method designed to engage students through the administration of conceptual questions, which help resolve misconceptions related to the class content.

In a typical PI class, the theoretical content is interspersed with questionnaires, usually multiple-choice. As explained in [3], students have two opportunities to answer each question, the first after a round of individual reflection and then again after a discussion round with a peer. Based on the number of right answers, the instructor can make adjustments to address students' issues.

We have designed a PI adaptation to the scope of computer science, mainly focusing on CS1 courses [4], and defined as Computer Science Peer Instruction (CPSI). In the same way as the PI, at some point in a CSPI class, the instructor administrates a set of multiple-choice questions to the students. The main difference is that, on the CSPI, students have only one chance to answer each question. Initially, students work alone for 1 minute, having access only to the question statement. Then, they work in groups of 2 or 3 students, having 2 minutes to think together and select one of the available choices for the question. The instructor can extend the time if required. Finally, the instructor, considering the number of right answers, explains the solution.

In both PI and CSPI, technology can support the automatic submission, correction, and display of the responses. In the current study, we adopted the clickers (iClicker brand [6]), small remote-control devices that have 5 buttons (letters from A to E). The clicker device can submit in real-time the answer (letter) pressed by a student, which is received by a base connected to the instructor's notebook. A software then shows a consolidated chart of answers from all participants.

On its turn, as described by Klock *et al.* [8], the concept of gamification relates to a set of techniques that extend game design elements to other contexts, like electronic commerce and learning environments. Related to the latter, the authors state that the adoption of gamification *"is justified as a way to motivate and engage students"* [8].

Moreover, Feldbusch *et al.* [2] explain that gamification is a wide approach, supported by the adoption of a variety of game elements, like a scoring system, badges, achievements, level systems, and so on.

On this work we are focusing on the competition aspect, in a PI learning environment, supported by the adoption of a public score system. The contributions are the initial assessment of the inclusion of the gamification approach into the CSPI. We want to identify whether gamification is a positive factor and whether it can affect the students' motivation, focus, and social collaboration.

2. Methodology

Lazar *et al.* [6] explain that *experimental research* normally starts from a preformed theory, usually organized as one or more hypotheses, which supports the design of experiments to collect and analyze data that will ultimately prove (or not) the original hypothesis. The cycle then repeats itself, being the hypothesis updated from the previous results, leading to new experiments, data collection, and so on. Figure 1 shows a diagram, based on Lazar experimental methodology [6, pp-305, Figure 11.1], illustrating how this research is organized.

On this research, preformed theory (Figure 1, item 1) was organized as the following **Research Questions:**

- **RQ1:** Does gamification affects students' motivation and focus in CSPI classes?
- **RQ2:** Does gamification affects students' social interaction and collaboration in CSPI classes?
- **RQ3:** Overall, is gamification a positive factor to support CSPI classes?

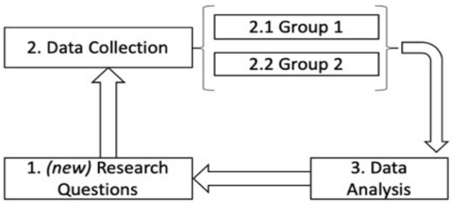

Figure 1. Experimental research methodology adopted in this study. Based on Lazar [6, pp-305, Figure 11.1].

Then, the **Data Collection** step (Figure 1, item 2) was organized as two experiments, defined as Groups G1 and G2. The Group G1 experiment was held at the Programming Week (PW), an annual event organized by the Brazilian Computer Society (BCS). In the PW, the *"Introduction to the Computational Thinking in Python"* course was taught by one of the researchers using the CSPI methodology. Participants (N=6) were all K-12 instructors.

The course had a total of 25 hours, with 20 "theoretical" hours in the classroom, in which theory content (*e.g.* PowerPoint slides) were interspersed with multiple-choice questions that should be answered through the clickers system. Participants were divided into 3 pairs, sharing one clicker per pair. The other 5 hours were freely used by the participants to solve problems in the laboratory. These lab hours were supervised by a TA. The CSPI methodology was not employed in the laboratory classes.

In the course's last day, participants from the Group G1 took a survey composed of 4 Likert scale questions (questions Q1 to Q4, as presented in Table 1) and an open-ended question, in which they could freely express themselves about the course, CSPI methodology, usage of the clickers, *etc.*

Table 1. Question statements (Likert scale questions).

Q1	*I would be more motivated to participate and use the clickers if it were adopted the idea of gamification.*
Q2	*I prefer competitions with prizes.*
Q3	*I usually talked to my colleagues when solving the exercises.*
Q4	*I liked the classes with clickers and I would like the teacher to continue with this approach in the future.*
Q5	*Gamification was a positive approach to increase students' motivation and focus.*

The Likert scale questions were designed to map the research questions in the following way: RQ1 (questions Q1 and Q2); RQ2 (question Q3) and; RQ3 (question Q4).

On its turn, the Group G2 experiment was held at a PW event at a different year than the Group G1. Participants (N=8) were all K-12 instructors, except by one, that was a K-12 student. The course organization was the same as the Group G1, except by the number of participants pairs (4) and by the adoption of a modified CSPI gamified version.

The CSPI gamified version was the same as the traditional CSPI methodology, except by the fact that the instructor added a score table in the blackboard. The table was used to publicly record the scores for each group, being updated after students answered the questions through the clickers. As the submission is anonymous, the instructor publicly asked which groups had correctly answered the question.

In the same way as Group G1, in the course's last day participants from Group G2 took a survey composed of 4 Likert scale questions (questions Q2 to Q5, as presented in Table 1) and an open-ended question. The Likert scale questions mapped the Research Questions in the following way: RQ1 (questions Q2 and Q5); RQ2 (question Q3) and RQ3 (question Q4).

The **Data Analysis** step (Figure 1, item 3) was conducted considering the *quantitative* data extracted from the 5-point Likert scale questions' answers and the *qualitative* data extracted from the open-ended questions' answers. Results from the Likert scale questions were initially converted to the numbers 1 (strongly disagree) to 5 (strongly agree), respectively. Then, for each question, it was calculated the *mean* of these values.

The next step was to assess whether the differences from both groups (G1 and G2) were statistically significant. We decided to adopt the nonparametric Mann-Whitney U test, as the data was collected from two independent groups of participants [6]. As explained by Nachar [7], the Mann-Whitney U test null hypothesis (H_O) stipulates that the two independent groups are homogeneous and have the same distribution. The nonparametric tests results are presented in subsection 3.3.

Finally, closing the cycle described by Lazar [6], the research follow-on (Figure 1, item 1) is presented in the discussion section (Section 5).

3. Results

3.1 G1 Group (without gamification)

Table 2 presents the results from the Likert scale questions related to the G1 Group:

Table 2. N= 6 participants. *SD* stands for "Strongly Disagree"; *D* for "Disagree" and so on. Questions are presented in Table 1.

	SD	*D*	*N*	*A*	*SA*
Q1	0	0	4	2	0
Q2	2	0	3	1	0
Q3	0	0	2	3	1
Q4	0	0	0	2	4

As showed in Table 2, related to the research question **RQ1**, participants had a slightly higher than neutral agreement with the Q1 statement, related to the adoption of a gamification approach to enhance their motivation (M=3.33, SD=0.51). The gathered qualitative data supports this view as, from the 3 students that answered the open-ended question, a participant reported that *"Gamification would be to support students' motivation"*, another one affirmed that *"I don't know how favorable the competition would be"* and the last one that *"I think it is unnecessary to create competitiveness"*. On its turn, in Q2, participants tended to disagree that the prize would be relevant in such hypothetical competition (M=2.5, SD=1.22).

Related to **RQ2,** results from Q3 indicate that students usually talked to their colleagues when answering the exercises (M=3.83, SD=0.75). Finally, related to **RQ3,** results from Q4 indicate a highly positive acceptance of the CSPI methodology (M=4.55, SD=0.51).

3.2 Group G2 (with gamification)

Table 3 presents the results from the Likert scale questions related to the G2 Group:

Table 3. N = 8 participants. Statements are presented in Table 1.

	SD	*D*	*N*	*A*	*SA*
Q2	0	0	3	4	1
Q3	0	1	1	3	3
Q4	0	0	0	1	7
Q5	0	0	0	1	7

As showed in Table 3, related to the research question **RQ1**, participants strongly agreed with the Q5 statement, expressing that the adoption of a gamification approach enhanced their motivation and focus (M=4.87, SD=0.70). In the Q2 statement, participants tended to agree with the importance of prizes in competitions (M=3.75, SD=0.70). Related to **RQ2,** results from Q3 indicate that students usually talked to their colleagues when answering the exercises (M=4.0, SD=0.75).

Finally, related to **RQ3**, almost all students strongly agreed that they liked the CSPI classes and would like the instructor to continue with this approach in the future (M=4.87, SD=0.70). All participants answered the qualitative open-ended question, with all answers being positive towards the adoption of gamification. Answers were classified as the ones that stated that gamification supports students' motivation (4), competition is fun (2), and participants that liked the prizes (2).

3.3 Nonparametric Tests

Overall, as presented in subsections 3.1 and 3.2, considering questions that were administered to both groups (Q2, Q3, and Q4), results from group G2 were always higher than group G1. Also, when comparing the question that assessed whether the gamification would support/supported the student's motivation (respectively Q1 and Q5), results were also higher in the G2 group. These data suggest that gamification was positively accepted and also a factor that potentially supported students' collaboration, motivation, and focus.

Nonetheless, as described in Section 2, specific nonparametric statistical tests would be essential to assess the specifics and whether the results would be or not significant. A two-sided Mann-Whitney U Test ($W=1$, $P < .05$) comparing Q1 (G1) and Q5 (G2) answers found, indeed, that although participants in group G1 were skeptical about the potential benefits that gamification could bring to the CSPI classes, participants in group G2 considered the gamification a positive approach to increase students' motivation and focus on the learning process.

However, similar two-sided Mann-Whitney U Test did not find statistically significant differences when comparing G1 and G2 answers for the other questions: Q2 ($W=9.5$, $P=.053$); Q3 ($W=20$, $P=.632$); and Q4 ($W=19$, $P=.414$). This suggests that, although gamification could bring a positive impact on participants' motivation and focus, it does not affect the collaboration between participants, neither the overall acceptance of CSPI classes.

4. Discussion

4.1 Research Questions' Answers

Related to **RQ1**, results suggest that gamification positively affects students′ motivation and focus in CSPI classes. Moreover, it was identified that, in regular, not gamified classes, students did not wonder or expect that gamification would bring such benefits. A possible explanation for this could be that the adoption of clickers would be, *per se*, a great novelty. Therefore, in G1, students would still be adapting to the PI approach and clickers technology, not willing, or even considering that gamification could also be included in this scenario. Similarly, in G2, students could not differentiate the benefits of the CSPI approach and gamification, considering both approaches as one unique “whole package”. In order to mitigate this, future research could consider a extended period of time, ideally a semester.

On its turn, related to **RQ2,** results suggest that the adoption of gamification does not affect social interaction and collaboration in CSPI classes. This result supports the CSPI original proposal that participants, regardless of gamification be or not be present, should always discuss their answers with peers before submitting them.

The difference observed between the not gamified (G1) and gamified (G2) CSPI version was that the former supported a *cooperative* scenario, in which groups communicated and helped each other, exchanging information and possible solutions. On its turn, the latter supported a *competitive* scenario, with virtually no interaction among different groups.

Future work could investigate the pros and cons of each scenario, including the impact of these approaches on students' learning and individual participation. For example, shy students may feel more comfortable in the *cooperative* environment, interacting only with colleagues in their group. Additionally, they would possibly feel embarrassed to have their responses and performance publicly exposed in the *competitive* scenario. On the other hand, this competition and exposure could force students to focus more on classes, having a positive impact on their learning.

Finally, related to **RQ3**, results (Q4) from G1 and G2 were highly positive and not statistically different, suggesting that students equally appreciated both the non-gamified and gamified CSPI versions.

However, when considering not only the Likert scale related question (Q4) but also the findings already discussed from RQ1 and RQ2 and also the qualitative data, it is fair to consider that, overall, gamification was a positive factor to support CSPI classes.

From the instructor's point of view, however, it is relevant to consider that the gamified classes required additional efforts, such as managing the scoreboard and also the prizes. This, added to the already required overhead for the CSPI adoption, like the design of questions and content redesign, can be an obstacle for the large-scale adoption of this methodology.

Regarding the prizes, it is natural for participants to feel enthusiastic about winning them (as detected in the G2 group), but its adoption does not seem to be a required feature for a good gamification experience.

4.2 Comparing results to previous works in the area

Klock *et al.* [8] organized a literature survey comparing and evaluating gamification studies through variables like interaction, performance, and user experience. The authors identified that, overall, *"gamification has proved more effective at enhancing student interaction than at increasing engagement and motivation" [8]*. This is, indeed, an opposite result as the findings of this current study (*cf.* Section 4.1).

A possible explanation is that the effects of gamification vary accordingly to the context in which it is used, as each study has its particularities. Therefore, it seems not possible to generalize the gamification outcomes to any context.

Particularly in the CSPI approach, students are encouraged from the beginning to interact with each other. Thus, at least about this factor (interaction), the positive outcomes that could arise from the gamification adoption seem to be limited.

5. Threats to Validity

The main data collected in this study comes from a set of Likert scale and open-ended questions. These questions were mapped to the research questions and then the results analyzed to assess whether variables like motivation, focus and collaboration were reached.

Although this is a typical and literature supported assessment approach [6], it is limited, as the assessment is performed only through questionnaires administered to participants. For example, question Q3 statement relates to assessing whether participants talked to their colleagues when solving exercises. In this case, a determined participant could strongly agree with the statement, but, in practice, had barely communicated with their colleagues. This does not mean that the participant had purposely provided misinformation, but that their perception may eventually be away from reality.

Therefore, it would be interesting to consider and measure more specific and objective data, like the number of interactions between students (from the same group and different ones); the number of correct answers in the CSPI questions; whether students were distracted browsing internet or performing other tasks, etc.

Related to the employed Mann-Whitney U Tests, the study's sample sizes (N1=6 and N2=8) can lead to a minimum *p-value* of .0007 [9], which is inferior to the adopted level of significance (.05), meaning the results are up to a point valid and reliable.

However, as any statistical test, the greater the number of participants the greater the reliability of the results. For example, the reported Mann-Whitney U Tests result from Q2 had a *p-value of .0536*. Therefore, even the result was slightly above the adopted significance level, it was reported as not statistically significant – what could be different with a greater sample size. In this way, further works could consider larger sample sizes for a more accurate analysis of the data. Also, the participants of this study were mostly instructors from K-12 schools. Future works could be organized in undergraduate CS1 courses.

6. Conclusions

In this work, we present the initial assessment of the gamification adoption into the CSPI. We identified that, although participants originally didn't expect that gamification would affect their experience, overall results did suggest that gamification positively affects participants' motivation and focus, being a positive factor to support CSPI classes. Results also suggest that gamification does not affect social interaction and collaboration. Future works involve the analysis of interaction variables through learning analytics tools.

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HandsOn e Compsi:
Parceria em Projetos de Realidade Virtual para Indústria, Comércio e Saúde

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Resumo: A empresa HandsOn, em parceria com o laboratório de pesquisa Compsi do Centro universitário Eurípides de Marília – Univem, foi criada para atender demandas de sistemas de interfaces computacionais. Ela originou para desenvolver um sistema de apoio a interação médico-paciente, mostrando de forma visual doenças e tratamentos. Em sequência ela se envolveu na área de construção civil, criando um sistema para lojas de construção usarem com seus clientes para montarem sua casa na Realidade Virtual. E por fim ela desenvolveu um sistema de treinamento para operadores de fábrica, que permite rápida construção de procedimentos de treinamentos por gestores. Como principal contribuição, a empresa publicou o *framework* de código aberto Project Team, que acelera o ciclo de desenvolvimento da Realidade Virtual.

Palavras-chave: *realidade virtual; treinamento; interação médico-paciente.*

1. Introdução

A empresa HandsOn nasceu com o propósito de produzir tecnologias que sejam de fácil acesso e interação para seus usuários.

Desde a sua fundação ela tem uma forte relação com o laboratório de pesquisa Compsi do Centro universitário Eurípides de Marília - Univem, localizado na cidade de Marília.

A empresa atua produzindo softwares de Realidade Virtual (RV), Realidade Aumentada (RA) e Computação Gráfica de forma geral, principalmente na indústria, comércio e saúde.

2. Principais Projetos

A seguir serão apresentados os principais projetos da HandsOn em parceria com o laboratório de pesquisa Compsi da Univem de Marília.

2.1 Treinamento de operadores de indústria alimentícia

Com a presença cada vez mais frequente da tecnologia na indústria e seu aumento aplicado em processos internos, tecnologias como a RV e RA tem se tornado cada vez mais presentes [1, 2, 3, 4], sendo utilizada para treinamentos [2], monitoramentos [3] e simulações [4].

Devido a isso, a informatização – sendo em partes automatização e virtualização – de processos tem se tornado cada vez mais habitual, dando origem ao termo conhecido como indústria 4.0 [5].

Nesse sentido, o sistema para treinamento de operadores em ambiente virtual foi desenvolvido por uma demanda de uma fábrica na área de alimentos da cidade de Marília.

Os operadores da fábrica passam atualmente por um processo de treinamento teórico, seguido de um treinamento in loco. Porém cada linha de produção possui equipamentos diferentes, produz produtos diferentes, e, portanto, necessita de habilidades e conhecimentos diferentes.

Mesmo considerando operadores já treinados, é necessário fazer a reciclagem do treinamento periodicamente, garantindo que o procedimento continua sendo seguido e que o operador não adquira vícios (desvio) na sua execução do procedimento.

O sistema visa contribuir na automatização, facilitação, melhora na interatividade e *feedback* sobre o treinamento do operador em seu procedimento de fabricação de produtos.

Além disso, devido ao sistema ser totalmente digital, sempre que o treinamento for aplicado, não há a necessidade de interagir com os equipamentos do meio físico da fábrica, possibilitando fazer o treinamento quando quiser sem que prejudique a produção dos produtos.

Visando essas dificuldades, foi construído um sistema de treinamento em ambiente virtual. Esse sistema pode ser usado nas plataformas PC e RV. Todas as ações de interação da RV foram abstraídas no PC para serem "*point and click*", permitindo uma experiência similar para operadores que sintam desorientação na RV.

Para garantir a escalabilidade do sistema, foi desenvolvido uma ferramenta de modelagem de treinamentos, usada inicialmente por designers e futuramente pelos gestores da fábrica aderindo ao End-User Development [6].

Essa ferramenta permite modelar treinamentos no ambiente virtual através da construção de uma máquina de estados das ações que o usuário deve fazer durante o treinamento. Conforme mostrado na Figura 1, cada estado representa uma etapa do treinamento com uma ação (um verbo) e um objeto.

Outro recurso do sistema é a possibilidade de criar "fases" com diferentes níveis de dificuldade para cada procedimento. Esse recurso proporciona variabilidade, facilitando na repetição necessária para transformar a habilidade do treinamento em conhecimento.

Com o recurso de fases temos a pontuação e placar. Cada fase de um procedimento realizado gera uma nota para o usuário, calculada com base no tempo de execução e quantidade de erros cometidos. Essas notas servem primariamente como avaliação de competência, como trava para fases mais avançadas, e também são expostas em um placar para estimular competição entre colaboradores.

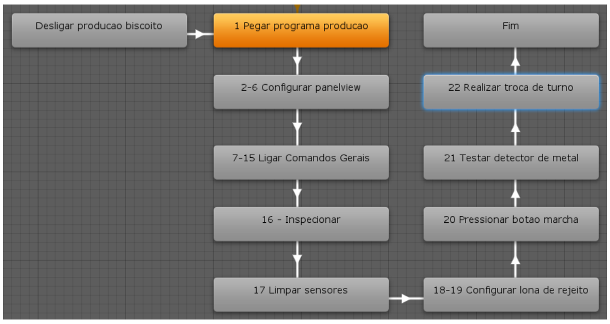

Figura 1. Máquina de estados definindo etapas do treinamento.

Outro recurso do sistema é um NPC colaborador. O NPC pode receber um comando para cada estado do procedimento, de forma que ele simula um colaborador real fazendo um procedimento com várias pessoas. Ele se comunica com o usuário através de um conjunto de gestos, como na Figura 2 em que ele está fazendo um gesto de “jóia”.

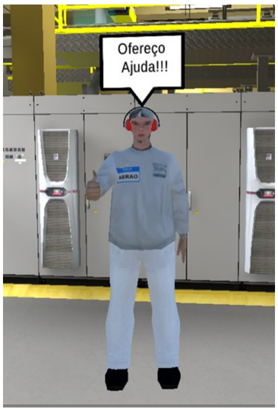

Figura 2. NPC colaborador fazendo gesto de prosseguir (jóia) para o usuário.

Um dos possíveis erros que o usuário pode cometer é justamente fazer uma ação antes do NPC estar pronto. O NPC também serve como um tutorial para ajudar usuários que esqueceram do procedimento.

Por fim, o sistema também tem um *dashboard* gráfico para gestores acompanharem o resultado dos treinamentos e avanço da equipe operacional, assim como identificar *hotspots* de dificuldade dos colaboradores para remodelar o treinamento.

2.2 <u>Sistema de apoio a interação médico-paciente</u>

Na área da saúde temos um problema que ocorre com muita frequência, que é a não-adesão aos tratamentos das doenças. Essa não-adesão é um dos principais motivos do insucesso a terapêutica/terapia [7].

Pacientes adoecidos necessitam entender a sua condição e sua terapêutica, sendo de fundamental importância a interação comunicativa entre o médico e o paciente [8]. Porém, a dificuldade no não entendimento do paciente pode levá-lo a se desviar do tratamento ou não entender a importância do tratamento e a gravidade de sua situação. Nesse caso temos um problema educacional, que diversos projetos [9, 10] provam que o auxílio de imagens e vídeos melhoram a absorção do conhecimento.

Com essa finalidade nasceu o HandsOn Medical Support, um sistema para apoiar a interação médico-paciente. Se trata de um sistema web interativo que permite visualizar o corpo humano em 3D (Figura 3). Atualmente o sistema possui somente a especialidade da oftalmologia mapeada e está aberto a acesso no link: https://handsonmedical.com/oftalmo/

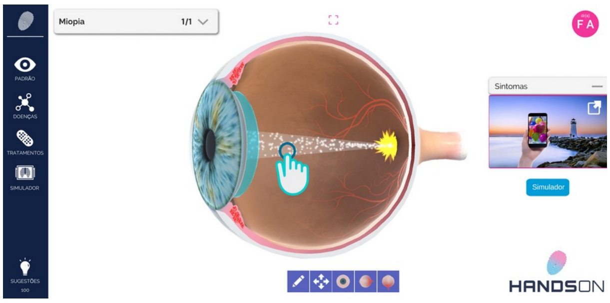

Figura 3. Sistema de apoio a interação médico-paciente da HandsOn.

Esse sistema apresenta como a enfermidade altera o paciente (como por exemplo, miopia), como ela pode progredir e ficar cada vez pior, além do resultado após o tratamento.

Ele mostra patologias e tratamentos através de animações 3D ou interações do usuário. Por exemplo, doenças mais complexas como o glaucoma são mostradas em animações, enquanto doenças mais simples como a miopia permitem que o usuário clique e interaja com o olho humano para ver seu efeito.

O objetivo é auxiliar na interação médico-paciente, apoiando o médico no consultório em sua explicação ao paciente, e aumentando a adesão ao tratamento. Para isso ele também permite que o médico desenhe na tela sobre as doenças, usando o mouse ou monitor que suporte toques.

Além da simulação 3D de doenças e tratamentos, o sistema tem um simulador de efeitos na visão humana, que permite simular algumas das principais doenças oculares. A Figura 4 mostra no simulador a visão em um estado avançado de Degeneração Macular.

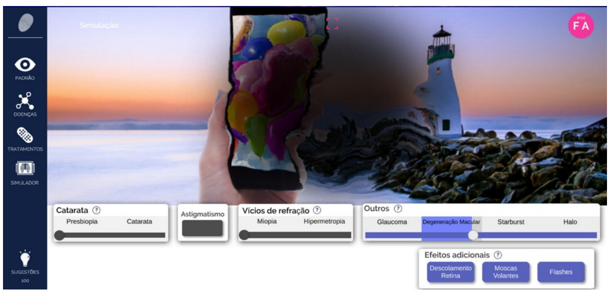

Figura 4. Simulador de visão mostrando estágio avançado de Degeneração Macular.

2.3 CivilRV

O sistema CivilRV foi desenvolvido para atender uma demanda de lojas de construção civil. Clientes dessas lojas tem dificuldade de escolha de produtos e de imaginar como a combinação de produtos que eles desejam ficam em um ambiente real. O sistema foi criado justamente para permitir configurar, em um ambiente virtual, cada produto que o cliente deseja comprar.

O sistema, que funciona em RV ou PC, permite ao cliente configurar o seu cômodo com os produtos da loja. Por exemplo na Figura 5 o usuário na RV está selecionando um modelo de vaso sanitário.

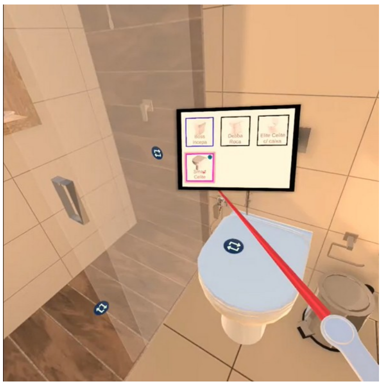

Figura 5. Seleção do modelo de vaso sanitário na Realidade Virtual por um usuário.

3. Contribuições da HandsOn e Compsi

Cada projeto tem suas contribuições sociais, ao facilitar e agilizar processos existentes, ajudando o operador de fábrica, o paciente e o comprador.

O sistema de treinamento gera alguns benefícios sociais como possibilidade de geração de um vídeo de treinamento e vídeo de marketing institucional, limitação na exposição de operadores não treinados a linha e até facilidade em aplicar reciclagens.

O sistema de interação médico-paciente também gera contribuições sociais, visando que a atenção visual contribui com redução de esforço cognitivo [11], além do auxílio ao entendimento, diminuindo a taxa de abandono a terapêutica.

O sistema CivilRV ajuda compradores em suas decisões, para que consigam visualizar o resultado das suas compras antes da aplicação dos produtos.

Em termos de contribuição científica, o destaque é o sistema de interação médico-paciente, que envolveu diversos alunos de Iniciação Científica, e está produzindo no momento um trabalho de mestrado no qual é realizado a comparação de seis softwares para resultar em qual tecnologia é mais efetiva na interação médico-paciente, para por fim, ter um *framework* que inclui as melhores tecnologias como resultado.

Em termos de contribuição tecnológica, os projetos produziram o *framework* de código aberto no topo do *engine* Unity para desenvolvimento de Realidade Virtual, denominado Project Team: https://bitbucket.org/allancaixeta/projectteamframework

3.1 *Framework* de RV Project Team

O *framework* Project Team é voltado para a engine Unity e para os equipamentos Oculus Go e Oculus Quest. Ele tem dois objetivos, acelerar o desenvolvimento de sistemas de RV e permitir desenvolvimento multiplataforma com dois tipos de interação: *point and click* e 6DoF.

O desenvolvimento multiplataforma permite criar sistemas que são de RV e usam a interação 6DoF ou PC e usam a interação *point and click*. Dessa forma o mesmo sistema funciona de forma similar em duas plataformas diferentes, requisito não funcional importante pois nem todos os usuários se adaptam bem a RV. O *framework* também promove a não necessidade de ter um capacete (HMD) de RV para realizar testes iniciais.

O *framework* possui três recursos principais: objetos prontos (prefabs); *scripts* de interações em objetos (Selectors); *scripts* gerais.

Os objetos prontos são, por exemplo, câmera e personagem prontos para funcionar na RV e PC, com funcionalidades de locomoção, mira e interação já preparadas. Assim como canvas de interfaces prontas para serem usados na tela (modelo HUD) no PC ou fixo nas mãos do avatar na RV.

Em termos de *scripts* de interação, chamados de *Selectors* no *framework*, eles são seletores responsáveis por realizar diversas interações em objetos 3d tendo alguma alteração em cena como resultado.

Por fim, o *framework* tem alguns *scripts* para uso geral no desenvolvimento de sistemas de RV, como *scripts* para gerenciar as mãos e ações de pegar e soltar, *scripts* para realizar ações a partir de botões do controle, e outros de uso geral.

4. Conclusões

Há um grau de dificuldade elevado para levantar, avaliar e aplicar os procedimentos que são aplicados na fábrica, pois além da necessidade de fidelizar o ambiente o mais próximo possível da realidade, também é necessário abstrair e inserir *feedbacks* instantâneos ao colaborador, para que o mesmo possa ver sua evolução e entender a necessidade do treinamento em um ambiente virtualizado.

Assim como no sistema da interação médico-paciente, é necessário que o paciente possa ver o mais próximo possível do mundo real a sua atual situação, trazendo um melhor entendimento.

Por fim, com a possibilidade de visualizar da forma mais palpável possível de como ficarão os cômodos da casa, o sistema Civil RV traz a imersão necessária para que o cliente possa se sentir dentro do seu próprio cômodo mobiliado, trazendo uma maior satisfação e *feedback* de como ficará futuramente.

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Corollarium Technologies

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Abstract: Corollarium is a company that specializes in web and mobile development, image processing, virtual and augmented reality. Its expertise encompasses the full development process - from design to production to installation, aiming to offer customized solutions of the highest quality and lowest maintenance. This paper goes briefly over what we have been researching and creating over the last years.

Keywords: *virtual reality; augmented reality; image processing; simulators*.

1. Introduction

Focused on technology for data visualization, Corollarium is a company that specializes in image processing, virtual and augmented reality, with desktop, web and mobile development. Its expertise encompasses the full development process–from design to production to installation, aiming to offer customized solutions of the highest quality and lowest maintenance. Corollarium has partnerships with international academic institutions and develops state-of-the-art research and technology. It has also developed projects and sold software licenses in Brazil, Europe, Asia and the Americas.

The company has a long history of its projects being approved for relevant and well recognized grants. It was approved for a FAPESP PIPE grant in 2009, with a low cost immersive projection system project. In 2010 it was approved in the PRIME project of FINEP, as well as the XPTA.lab project of the Ministry of Culture, in partnership with UFSCar, UNESP, UFPA, UFPB and Abútua Tecnologia. In 2011, it received a RHAE grant from CNPq that lasted until 2013, and was renewed for a second phase from 2015 until 2017. It was chosen to be part of the Brazilian delegation at the Museum Connections world fair, which took place in Paris in 2016.

Corollarium has always researched and developed with universities. Its partnerships over the last few years have included UFSCar, UNESP, UNICAMP, UFSJ and UNIFESP, with labICE [1]. We believe that these partnerships benefit both the company and the university, exchanging experience, technology and helping to bridge the gap between the commercial market and academic research.

Over the years our projects have often handled problems of real-time synchronization, on image acquisition, data processing and display. These are challenging problems, dealing with all usual issues from distributed processing, and facing the difficulties of running in unexpected venues where there is little control of the environment. We have learned to design and implement robust solutions, understanding that customers want not only a plug-and-play solution, but a zero-config, zero-maintenance that just works, even with sketchy networks, faulty internet connections and unusual hardware. As a result our products have evolved and run on many operating systems (Linux, Windows, OSX, Android, iOS) and processor architectures (ARM, x86) and networks (WiFi, Ethernet, 4G).

2. Main Projects

Ever since it was created, Corollarium designed and developed expert software for a multitude of customers. Our expertise in XR led us to develop technology for multi-projection systems, including the design, project and installation of mini CAVEs with commodity and low cost devices. Our knowledge allows us to perform the entire flow of a VR system implementation, both hardware and software.

Being hired by customers to develop projects has always been a mainstay of the company. These projects fall under non-disclosure agreements and therefore cannot be exposed here. But the research and development made through the years led us to create a considerable amount of technology, which besides allowing us to be faster and more efficient, it also enabled us to develop our own products, some of which are described below.

2.1 Camera360

Camera360 is a multi-camera system that takes photos in synchrony [2]. With one click you have images from every angle and all details. Camera360 captures an image around an object with multiple cameras. The photos are captured and processed in seconds and immediately available in the cloud, on a site with its own domain, using the customer's logo and visual identity, ready to be shared on social networks. We have used Camera360 for photogrammetry as well, generating 3D content from pictures and using it for augmented and mixed reality. It is a cost-effective system that uses smartphone cameras or modular computers, improving the traditional technique of using high-cost cameras and complex electronics for synchronization. Camera360 systems of up to 80 cameras have been built.

Camera360 can be used for 360 degree photos, panoramas, bullet time, promotional events, interactive catalogs, fashion, art, 3D reconstruction and more. Figures 1 and 2 show real deployments of the system.

Figure 1. A Camera360 installation using Android.

Figure 2. Another installation of Camera360 made by a customer.

Synchronization of cameras has first been done by Edward Mulbridge, and the bullet-time effect became famous through the Matrix movies. It entails high speed synchronization and capture of images, usually through special hardware. We have evolved our solution from point-and-shoot cameras to Android and Raspberry Pi devices, understanding the void in the market for low and mid-range solutions. The lack of a dedicated electronic trigger, which has near zero latency, is a challenge. Wifi networks have considerable jitter, delays and lack of multicasting, and even with Ethernet one has to take into account a number of delays: the network layers, operating system, camera shutter etc.

We have also taken great care of the usability: a Camera360 installation at a large venue, such as our installation in the Coachella festival in California, generates a line of people interested in taking pictures. We needed a fast, reliable system that took pictures from many cameras, gathered them into a single server, processed them for alignment, color correction, watermarking, generated GIFs and videos and uploaded them to the cloud with a single click.

2.2 Multiselfie

Multiselfie is a mobile and web app to take photos with multiple devices at the exact same time [3]. Only one person clicks and all the phones take pictures together. It's a consumer version of Camera360.

With Multiselfie phones from several people are used to take pictures at the exact same time. Everyone gets their phone out and gets ready, and a single person creates a room, just like creating a chat room. They get a link that is shared among everybody, and only the person that created the room needs to click a button to shoot a picture. You have multiple photos of a single moment, and instead of a logistic problem you have fun taking the picture. Figure 3 shows three phones running Multiselfie.

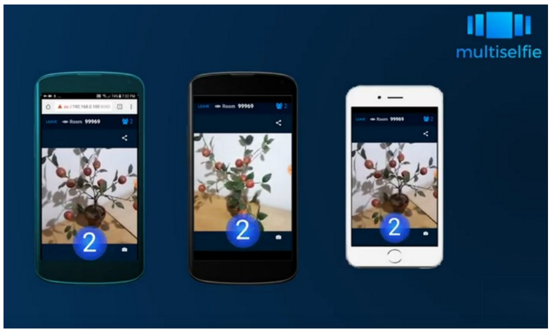

Figure 3. Multiselfie over three different phones.

In larger events we can integrate Multiselfie into other apps or sites, and give a more fine grained control to the responsible person, as well as information about the pictures and analytics. Multiselfie added new challenges to an already difficult problem. How to synchronize several - perhaps dozens, perhaps hundreds - phones over different 3G, 4G and Wifi networks? How to deal with the ensuing upload flood? We developed special synchronization algorithms that wouldn't need an immediate trigger signal, which is unfeasible in these circumstances. Edge computing came to the rescue, processing as much as possible on the phones before uploading data to the cloud.

2.3 Video wall

Our video wall controller software is an inexpensive and robust video wall solution with a friendly web interface and an excellent cost/benefit ratio [4]. It handles multiple screens with all kinds of content: videos, images, camera, window and desktop streaming.

We support clients in Windows, Linux and Android, including x86 and ARM architectures. Using Raspberry Pis as zero-clients makes our solution one of the most cost-effective in the market, with trivial deployment.

The visual design mode, as shown in figure 4, enables any transformation on the screens: they can be arbitrarily spaced and rotated, with real time updates. The software automatically applies the transformations, and even traditional matricial arrangements are benefited by the fine screen positioning, compensating for borders, as shown in figure 5. There's a very fine video synchronization algorithm that compensates for differences in timing with a smooth speed scaling function, avoiding sudden frame jumps.

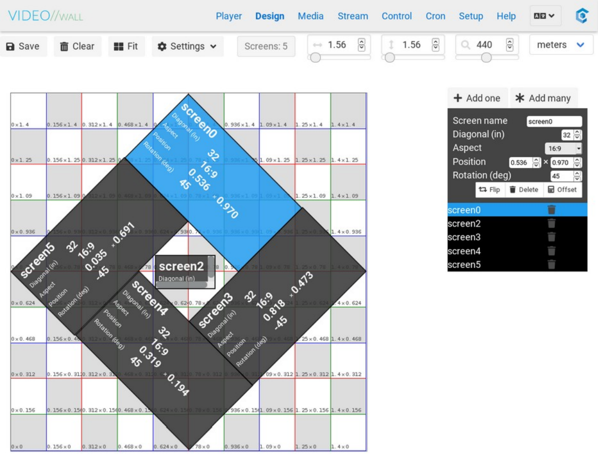

Figure 4. The design system for videowall screens.

We provide several features useful for both marketing applications and operation centers. These include scheduling of operations (such as turning the screens on and off), streamcasting of applications and the whole desktop of other machines with zero software installation, displaying messages and more.


Figure 5. One of our deployed video walls.

2.4 Virtuactor

Virtuactor is an interactive 3D simulator application for industrial, commercial and risky operations.

It is a completely customizable solution for training and evaluating people using a simulated computer environment. Its goal is both to provide rapid, risk-free initial training and ongoing user assessment, to ensure that processes are being followed and to provide tools for optimizing bottlenecks.

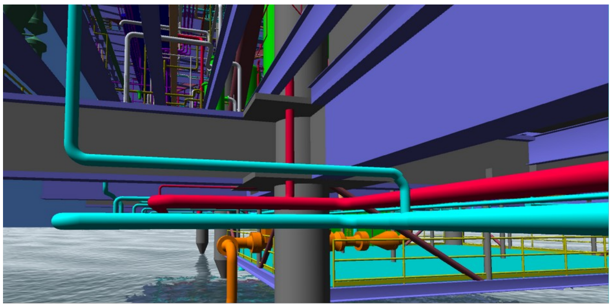
Figure 6. Virtuactor simulating an oil platform.

Risky operations, production training, optimization and evaluation of people – Virtuactor allows you to simulate common or emergency situations and complex and delicate operations, as is the case of oil platforms (figure 6). The results reports are generated by a simple web interface for human analysis, with automatic evaluation of performance through artificial intelligence. Simulations save time and money and also avoids damages that could occur in equipment due to irregular operation. Virtuactor can be used on screens, with virtual reality glasses or even in immersive virtual reality environments.

2.5 LajeVR

This project uses virtual reality to simulate a dive on a 3D model of the Laje de Santos State Marine Park [5]. It includes the island above water and the submerged area, allowing people from all over Brazil and the world to visit the park virtually, do simulated virtual dives, learn about the fauna that inhabits or migrates through the park and the marine environment.

The Laje de Santos State Marine Park (PEMLS) is the first Marine Park among the Conservation Units of the State of São Paulo, created on September 27, 1993, through State Decree nº 37.537. It has the objective of protecting marine biodiversity, and conserving biological diversity on the coast of the state of São Paulo. It is located about 40km from the coast of the city of Santos.

As there are no other rock formations or islands nearby, it has a large concentration of fish in passing and reefs, being one of the main diving and underwater photography spots in the country. The Park also has a wreck. It can be visited by boats, but landing on the island is forbidden. The navigation is long, about 1h30 to 2h in speedboats or 6h to 8h in slow boats, which makes the visit difficult and of considerable cost, being basically restricted to accredited scuba divers. With that few people have access to a place of enormous beauty and diversity of fauna.

Figure 7. Laje de Santos in our 3D simulation.

Since we aimed for a large audience, the project is available at a public website and we used WebGL for the 3D and VR parts (figure 7). The project is sponsored by a Proac grant from the State of São Paulo. It is an ongoing project, delayed due by the COVID pandemic. The entire project is being released as open source, and the current version can be visited at https://corollarium.github.io/lajevr/.

3. Social, technological and/or scientific contributions

Most of our internal research has been in better technology for distributed computing, particularly concerning synchronization under different circumstances. Our technology for simultaneous image processing has been used for several applications, including entertainment, marketing, culture and industry.

We have also created a considerable amount of technology on image and video processing, which has been applied on several projects for our customers. An automatic alignment and color calibration software is integrated with Camera360. Other applications include automatic recognition of patterns and entities, often using machine learning.

Our usage of commodity hardware for VR environments results in installations that cost five to ten times less than high end solutions available on the market, making it affordable to universities and companies that would not be able to have it otherwise.

Our continuous collaboration with universities led to a two-way transference of technology, both bringing academic research to the market and helping academic projects to be implemented.

On the social side, we are particularly proud of the LajeVR project, since we can take people to see a marine park which is not easily accessible. We can take millions of people to see a preserved underwater area which is seen by only a few hundred people each year, and for free. We have often collaborated with open source projects, writing bug fixes and improvements. We have also released our own, most of which are available at our Github page [6].

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labICE – Laboratório de Inovações Computacionais e de Engenharia

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Resumo: Este artigo apresenta o labICE (laboratório de Inovações Computacionais e de Engenharia), que é um laboratório interdisciplinar que tem como objetivo o desenvolvimento de pesquisas acadêmicas alinhadas a inovação, em áreas como Realidade Virtual, Realidade Aumentada, Saúde, Sistemas Distribuídos e Internet das coisas. O laboratório é voltado para o ensino, pesquisa e extensão. Para isso, conta com uma forte característica multi-institucional para realização de projetos, principalmente, os de pesquisa. Como resultado apresenta formação e aprimoramento de mão-de-obra qualificada em nível de graduação, pós-graduação e em estágio de pós-doutoramento. Isso é solidificado por diversas publicações em veículos nacionais e internacionais, registros de software e prêmios recebidos.

Palavras-chave: *realidade virtual; realidade aumentada; laboratório; sistemas distribuídos*.

1. Introdução

O labICE (laboratório de Inovações Computacionais e de Engenharia) é um grupo de pesquisa interdisciplinar com base na Ciência da Computação e Engenharia, com foco em novas descobertas em áreas como Realidade Virtual, Realidade Aumentada, Saúde, Sistemas Distribuídos e Internet das coisas. Este laboratório é coordenado pelo Prof. Dr. Marcelo de Paiva Guimarães, professor da Universidade Federal de São Paulo (Unifesp).

A figura 1 mostra o logo do laboratório, que é representado pela Coruja das Neves (ou do Ártico), um animal majestoso, com belos olhos e pelagem magnífica, que vive na região do Ártico. A coruja foi escolhida porque, segundo a mitologia grega, é o símbolo de Atena (deusa da sabedoria e da justiça), também conhecida como Minerva. A palavra ICE no nome do laboratório significa gelo em inglês, sendo então uma referência ao habitat da Coruja das Neves.

Figura 1. Logo do labICE.

Os trabalhos do laboratório envolvem ensino, pesquisa e extensão. Então, forma mão de obra qualificada (graduação e pós-graduação) por meio de projetos científicos e tecnológicos, resultando em dissertações de mestrados e projetos de conclusão de curso. Além disso, atua como local de estágio de pós-doutoramento. O labICE realiza ações de extensão para qualificação de pessoas, por exemplo, cursos voltados para ensinar professores a desenvolverem aplicações de realidade virtual e realidade aumentada no contexto educacional.

As atividades do laboratório se originaram em pesquisas relacionadas com o desenvolvimento de aplicações de realidade virtual com alto grau de imersão e interação para dispositivos de multiprojeção, como os CAVEs (*Cave Automatic Virtual Environment*) e mini-Caves. Este contexto envolveu desde trabalhos relacionados aos equipamentos físicos (clusters de computadores, dispositivos de entrada e saída) e a parte de software, questões associadas a sistemas operacionais, como *drives* para as placas gráficas, a comunicação e sincronização de sistemas distribuídos, até bibliotecas para facilitar o desenvolvimento das aplicações.

O labICE continua trabalhando com estas questões na atualidade, mas abriu novas frentes, como, por exemplo, trabalhos voltados para o armazenamento de prontuários eletrônicos de pacientes com Blockchain, sendo que os dados são oriundos de sensores de movimentos. Estes dados também são representados em ambientes de realidade virtual. Essa pesquisa é voltada para auxiliar os profissionais de fisioterapia durante as sessões com pacientes.

A figura 2 mostra uma nuvem de palavras formada a partir do título dos artigos publicados entre 2017 e 2020. Destaca-se nela palavras como Realidade Virtual, Realidade Aumentada, Game, 3D, Simulador e Imersão.

Figura 2. Nuvem de palavras formadas a partir do título de artigos de 2017 a 2020.

O restante do artigo está organizado da seguinte forma: a seção 2 apresenta o aspecto multi-institucional do labICE, então cita os principais parceiros. A seção 3 mostra os principais projetos de pesquisa já desenvolvidos e em desenvolvimento e, por fim, a seção 4, mostra as conclusões que discutem as ações correntes e futuras do laboratório.

2. Parceiros

As ações do laboratório foram se solidificando desde o princípio pelo fato de buscar a multi-institucionalidade, por acreditar que quanto mais pessoas de localidades e com conhecimentos diferentes ou não se unirem, melhores resultados poderão ser atingidos. Esse fato fortaleceu o desenvolvimento dos trabalhos, desde atividades intelectuais, como o debate científico até o compartilhamento de equipamentos, colaboração em editais de pesquisa e de atividades nos mesmos projetos.

A figura 3 ilustra o esforço multi-institucional do labICE, mostrado as várias instituições e a parcela delas nos trabalhos científicos. O gráfico foi criado considerando os artigos do labICE que foram publicados em parceria com outros 13 laboratórios de 2017 a 2020. Assim, por exemplo, pesquisadores da UFSJ (Universidade Federal de São João del Rei) estiveram envolvidos em 24,0% dos trabalhos, enquanto os do Mackenzie em 18,67%.

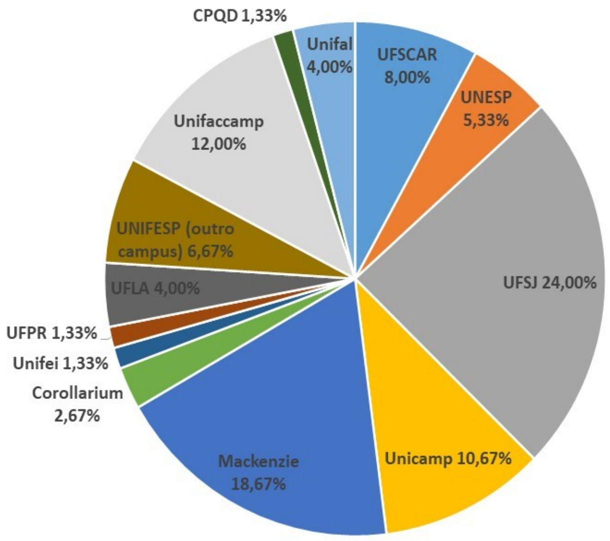

Figura 3. Parceria multi-institucional do labICE.

Esta característica multi-institucional teve como origem o interesse comum de desenvolvimento de aplicações de realidade virtual em ambientes de multiprojeção com baixo, depois foi expandindo para outras áreas. A seguir são ilustrados alguns dos parceiros e as colaborações do labICE com os outros laboratórios:

- Prof. Dr. Diego Roberto Colombo Dias da Universidade Federal de São João de Rei (UFSJ): contribui com pesquisas relacionadas a sistemas de multiprojeção, o que inclui trabalhos que abordam a comunicação e sincronização de clusters de computadores. Além disso, temos pesquisas em conjunto referente a uso de sensores de movimento em pacientes, em especial, para a apoiar a reabilitação [1], [2]; e também pesquisas que aplicam técnicas de inteligência artificial [3].
- Prof. Dr. José Remo Ferreira Brega professor da Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP): colabora com projetos voltados para redes de computadores e no desenvolvimento de aplicações de realidade virtual e de visualização [4], por exemplo, na visualização de modificações que ocorrem em *software* [5] e no desenvolvimento de *serious game* [6];
- Profa. Dra. Valéria Farinazzo Martins da Universidade Presbiteriana Mackenzie (Mackenzie): colaboramos, principalmente, em pesquisas relacionadas a avaliação (por exemplo, usabilidade, funcionalidade e motivacional) de aplicações de realidade virtual e realidade aumentada. Assim, muitas vezes trabalhos [7] com heurísticas, como as de Nielsen;
- Prof. Dr. Luís Carlos Trevelin professor da Universidade Federal de São Carlos (UFSCar): laboratório parceiro em assuntos de redes de computadores e no desenvolvimento de aplicações para mini-CAVEs, como em sistema imersivo de controle aéreo para drones [8]. Atualmente, o professor está aposentado e continua contribuindo de forma pontual;
- Prof. Dr. Alexandre Brandão, pesquisador da Universidade de Campinas (Unicamp): colaboramos em pesquisas relacionadas a reabilitação de pacientes, tanto no desenvolvimento de *software* [9], quanto em desenvolvimento de *hardware* para rastreamento corporal [10];
- Corollarium Tecnologia representada por Msc. Bruno Barberi Gnecco: colaboração em assuntos referentes a ambientes e soluções com realidade virtual e realidade aumentada, como o uso a que investiga o uso da realidade virtual na web [11].

Estas parcerias têm sido de grande valia para todos os envolvidos e já gerou resultados de destaque. Por exemplo, neste ano de 2020, pesquisadores do labICE em parceria com os outros laboratórios receberam o Prêmio Inventores 2020 na categoria Tecnologia Licenciada, com o software para reabilitação motora e cognitiva denominado e-House, da Agência de Inovação da Unicamp. Além disso, ganhamos um Best Paper Award no 20th International Conference on Computational Science and its Applications (ICCSA), cujo artigo tratava de uma solução de *hardware/software* para rastreamento de pacientes por fisioterapeutas [10].

3. Principais projetos de pesquisa do labICE

As principais linhas de projetos desenvolvidos nos últimos cinco anos até a atualidade são as seguintes:

- Rastreamento corporal: os movimentos físicos dos usuários (por exemplo, pacientes e trabalhadores) podem ser usados como entradas para soluções, desde tratamento de reabilitação até sistemas de ergonomia. Nessa linha estão sendo desenvolvidos subprojetos com sensores inerciais e ópticos. Este projeto é realizado no contexto do CEPID/Fapesp Brainn (*Brazilian Institute of Neuroscience and Neurotechnology* – Instituto Brasileiro de Neurociência e Neurotecnologia). A figura 4 ilustra o rastreamento e o gráfico de movimentação do ombro direito no eixo transversal de um paciente;

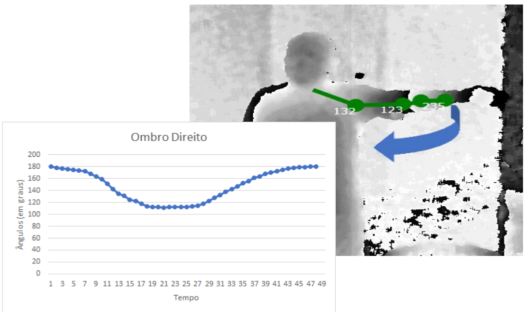

Figura 4. Movimento do ombro direito no eixo transversal.

- Odor: visão e audição são os sentidos comumente usados em aplicações de realidade virtual e realidade aumentada. Esse projeto tem como objetivo pesquisar o desenvolvimento e o uso de display olfativos [12], para isso já foi desenvolvido um protótipo que está em fase de aprimoramento. A figura 5 mostra um usuário usando o *display* olfativo desenvolvido;

Figura 5. Display olfativo móvel desenvolvido.

- Simuladores: desenvolvimento de simuladores para os mais variados contextos, como educação e treinamento. Por exemplo, simuladores de realidade virtual para apoiar o processo de ensino-aprendizagem de gerência de memória (figura 6), gerência de processos e escalonamento de discos em sistemas operacionais.

Figura 6. Simulador de gerenciamento de memória.

- Avaliação de aplicações: faz parte do processo de desenvolvimento dos projetos do laboratório a avaliação do produto resultante, como de usabilidade, de atendimento de requisitos, desempenho e de aprendizagem. A figura 7 mostra uma aplicação educacional voltada para crianças que foi avaliada pelos alunos e professores;

Figura 7. Aplicação de Realidade Aumentada para apoiar o ensino de formas geométricas.

- Sistemas distribuídos: o labICE foi impulsionado inicialmente por volta do ano de 2010 com o desenvolvimento de bibliotecas para controlar ambientes de multiprojeção com alto grau de imersão e interação, como os CAVEs e mini-CAVEs, assunto que ainda é investigado até hoje, principalmente com questões referentes a inserção de atividades colaborativas nestes ambientes. Para isso, algumas pesquisas foram direcionadas para resolver problemas de comunicação e sincronização inter-*clusters* de computadores, que estão em localidades remotas (por exemplo, Brasil e Alemanha). A figura 8 mostra um ambiente 3D sendo executado em uma mini-CAVE;

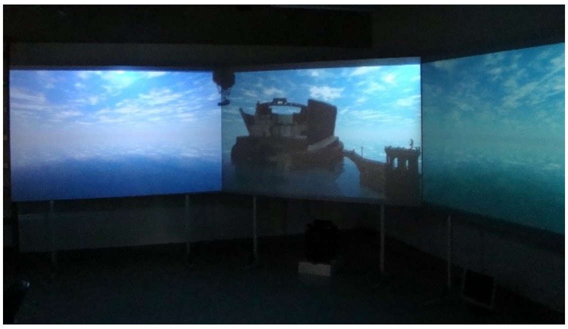

Figura 8. Mini-CAVE executando aplicação 3D.

4. Conclusões

O labICE foi impulsionado inicialmente por pesquisas voltadas para o desenvolvimento de ambientes de realidade virtual com alto grau de imersão e interação com baixo custo. Logo após, com o envolvimento de outras pessoas (professores e alunos) e instituições, novos interesses foram surgindo.

Atualmente o laboratório mantém uma regularidade de produção, publicando em veículos científicos nacionais e internacionais; e registro de *software*. Além disso, tem contribuído com a formação de mão de obra e realizado cursos de extensão aberto para a comunidade.

O caminho a ser fortalecido pelo laboratório nos próximos anos é a parceria com laboratórios internacionais no desenvolvimento de pesquisas. Além disso, é necessário também mais ações referentes a criação de patentes e a criação de produtos com qualidade próxima ao necessário para serem licenciados.

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Online Experimentation @FEUP: Five Years of Evaluations

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Abstract: The Online Experimentation @FEUP lab gathers a set of experimental resources based on Augmented Reality, Virtual Reality and Haptic Systems. The design, development and implementation of those resources are guided by the following main goals: familiarizing students with the referred technologies, complement hands-on experimentation, motivate students and promote knowledge gain. A brief presentation of the online experimental activities most utilized and evaluated in the past five years in context of different undergraduate courses and at the K12 level is presented. In all the studies conducted, the strategies adopted involve pre- and post-testing to assess knowledge gain, experimental group activities, and individual response to surveys to assess student reaction. The results published in journals, conferences proceedings and book chapters are discussed.

Keywords: *augmented reality; virtual reality; haptic systems; experimentation; engineering education; conceptual knowledge gain.*

1. Introduction

For the past three decades, remote experimentation (RE) [1-3] where simulation, data collection and analysis are assisted by instrumentation and computers, has been increasingly used. More recently, Virtual Reality (VR), Augmented Reality (AR) and haptic interactions, are being incorporated in collaborative platforms. Together with RE they constitute what is called Online Experimentation (OE) [4].

Although one should not look at OE as a replacement of hands-on experimentation, there are certain characteristics of OE that can enhance learning. The phenomena and concepts involved in most engineering areas are complex, described by intricate mathematical relationships, requiring most of the times high level of abstraction skills that can take a long time to acquire. These difficulties can result in lack of motivation, frustration and undesirable knowledge gaps.

The advantages of using the referred technologies in education are manifold. On one hand VR and AR allow for the visualization of abstract concepts and complex spatial relationships and, in the case of haptic interaction systems, they involve the sense of touch through tactile feedback. Moreover, they make it possible to test the theoretical limits of the physical models, something not often feasible in real experiments. In addition, the virtual nature of the technologies is very suited for exploring dangerous environments and destructive tasks. On top of that, these different ways of exploring the senses contribute to enhance engagement and interactivity, thus having a positive impact on student motivation to learn and on academic performance [5-12].

Other advantage includes suitability for e-learning and b-learning, and flexibility to provide additional time to perform the experiments. However, using OE in Engineering Education (EE) is not only driven by those advantages. AR, VR and haptic systems play an increasingly important role in many of areas of engineering expertise. Industries like the automotive, aircraft, and manufacturing, among others, are using such technologies for many purposes like for instance training, maintenance, assembly and repair. Therefore, it is pertinent that students get in contact with such technologies while learning.

Furthermore, the current pandemic situation has stressed the need to have available diverse online experimental resources in order to avoid in the future possible lack of experimental training in science and engineering education.

The Online Experimentation@FEUP (OE@FEUP) project (https://remotelab.fe.up.pt/) is active since 2003 and is a repository of 42 multidisciplinary online open experimental resources. They are based on the use of different technologies in remote sensing, monitoring and actuation, virtual simulators, virtual/augmented reality and sensorial devices like haptic interfaces, data gloves, 3D glasses, among others.

In this paper, a brief presentation of the available resources is given, with a description of the target populations that used them, publications in journals and conference proceedings, and summarize the conclusions from studies conducted to evaluate their potential as promoters of motivation and conceptual knowledge gain.

2. Description and methodologies of OE implementation

2.1 <u>Resources at OE@FEUP</u>

OE@FEUP integrates experiments based on six main types of technologies, or associations: Remote Experiments (RE) (15), Augmented Reality Experiments (ARE) (8), Virtual Experiments with Haptic Interaction (VE&Haptics) (7), Virtual Reality (VR) (3), Simulators (4) and Instrumented Devices (OID) (5), that are represented in percentage in Figure 1.

In this report, the focus is on the ARE, VE&Haptics and VR resources that have been extensively used over the past five years in the context of undergraduate engineering programs and K12 level non formal learning. They cover areas from physics, civil, electrical, mechanical and environmental engineering.

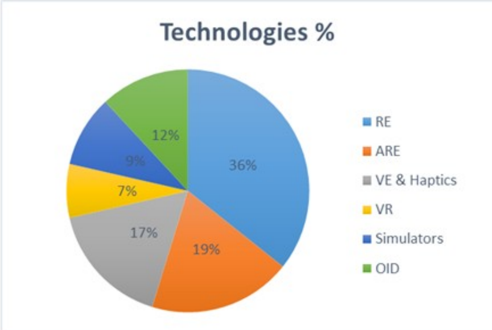

Figure 1. *OE@FEUP for all technologies*.

The experimental tools offered were designed, developed and implemented with the following main objectives:

- to facilitate the understanding of basic science and engineering concepts;
- to engage and motivate students to learn
- to complement hands-on experimentation
- to be accessible for everyone, everywhere, anytime
- to familiarize engineering students with technologies that they might encounter in their professional future.

Table 1 presents the most used online resources in the past five years available in the OE@FEUP platform.

It shows the type technology, the name of the experimental resource, the context in which they were used and the number of students that had the opportunity to engage in experimental activities with them. The publications containing the description of the resources and of the conducted studies to evaluate them as promoters of motivation and knowledge gain are also depicted. Not all of the studies involve the number of students reported in the table and that corresponds to those who worked in the lab with the OE resource. The experimental activities took place in the framework of several undergraduate courses of different integrated master engineering programs and in the context of the Junior University program of the Porto University [13]. This program brings every years K12 students to the university for different non formal learning activities.

2.2 <u>Strategies used to evaluate the OE resources</u>

For the past five years, the OE resources have been evaluated as promoters of motivation and conceptual knowledge gain. These evaluations are linked to the objectives referred above that guide the design, development and implementation of the OE tools.

To evaluate how using the OE influences conceptual knowledge, pre and posttesting is implemented and measures such as normalized gain and Cohen's *d* effect size are calculated to provide a quantitative estimate of knowledge gain (see [17] and references therein).

Table 1. Online experimentation technologies, resources, target population, number of students and references.

Technology	Name of the Resource	Target Population	Approx. number of students	References
ARE	"AR DC circuit puzzle"	ME,CE, IEM,K12	900	[14], [15], [16], [17], [18], [19]
	"AR straightness evaluation"	IEM	160	[19]
	"Groundwater flow on a small scale embankment dam"	CE	170	[19]
VE&Haptics	"Elastic constant of Coil Springs"	EVE, K12	170	[20]
	"Mechanical Characterization of Materials"	CE (Brazil)	20	[21],[22]
VR	"Mechanics 3D virtual lab"	K12	80	[23]

ME – Mechanical Engineering, IEM – Industrial and Management Engineering, CE – Civil Engineering, EVE – Environmental Engineering, K12 – High school students

The purpose of the pre- test is to engage students in thinking about the physical phenomena they are about to observe and for possible explanations of the phenomena. Having observed and experimented, they can check whether their prediction is confirmed. This procedure also permits instructors to get a clear idea of the most common misconceptions. The post- test allows for establishing how students changed their view due to experimenting using virtual system environments. The change from incorrect to correct answer may affect memory and on understanding of the underlying concept.

Before the experimental activity, students answer individually to a set of conceptual multiple-choice questions about the most relevant concepts addressed in the experiment. Then, working in groups, they explore the resources. Immediately after that, they answer again individually to the same set of questions. Whenever possible, sometime after the experimental activity, they answer to the same set of questions and to others related to the same concepts, which allows for assessing knowledge retention. Calculation of the normalize gain and of effect size of mean's differences provide measurements of the efficacy of the activity to correct possible prior misconceptions.

To investigate students' reaction to the use of the OE resources, questionnaires are used. They are based on existing questionnaires in the literature and are intended to measure relevant psychological traits known to be connected with motivation as well as performance [26, 27]. Examples of latent variables considered are self-efficacy in using new technologies, interest, perceived value of OE in the context of engineering training, ease of use of the resources, attitude towards using OE and behavioral intention to use the technologies in the future [27]. Analysis of the surveys include descriptive statistics and, for large enough samples, multivariate techniques such as regression analysis and structural equation models are applied. They allow for investigating the influence that the psychological traits described have on each other.

3. Discussion

The evaluation of the resources is performed over the years using the same methodology involving different students. The results of the several studies reported in the references shown in Table 1 are very consistent. They indicate that the OE learning tools have a good impact on conceptual knowledge gain and that students view them as interesting, valuable for the learning process, easy to use, and their attitude towards using OE to learn is very positive.

Although no direct evidence emerges from the studies, they suggest that associating OE with the pre- and post- testing might condition the affective and cognitive response of the students. Students interact with the resources guided by the questions they are trying to answer. They have the goal of observing certain phenomena and to understand the concepts addressed in the questions. This might influence their interest and their perception of the utility of the OE tools to learn.

The fact that large number of students from different engineering programs and from K12 level respond similarly in different years, indicates the relevance of exposing them to such tools.

Moreover, the results also indicate that the resources proved to offer a good instructional design, fulfilling the goals behind their conception.

Other important conclusion taken from the studies performed is that there are no significant gender differences, both in students' reaction and in knowledge gain.

The results encourage the authors to continue using the OE resources in their teaching practices as they have shown a consistent potential to promote student engagement and conceptual knowledge gain.

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MarineVerse Enables More People to Sail!

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Abstract: MarineVerse wants to promote and share the sport of sailing with the world by providing sailing education, growing as a sailor, socializing, and having entertainment using virtual reality technology. Current VR sailing applications are designed for Valve Index, HTC Vive, Oculus Rift, and Oculus Quest, and flagship products are MarineVerse Cup and VR Regatta.

Keywords: *sailing; virtual reality; exergaming.*

1. Introduction

MarineVerse (MV) started in January 2016. The idea was first tossed around in Hobart, Tasmania. The team had a chance to see the yachts finishing Sydney to Hobart race and relax in a peaceful apartment in North Hobart. After a brainstorming session, the project officially started.

Greg Dziemidowicz is the Lead Developer and grew up with sailing and technology. He started programming when he was eight years old and joined a sailing club when he was 12. Over the years, many people have contributed to MarineVerse and its various projects like VR Regatta, Big Breezy Boat, and others. A full list of credits is available inside the press-kits of individual projects.

MarineVerse aims to promote and share the sport of sailing with the world. MV is doing it by providing sailing education and entertainment using virtual reality (VR) technology, building VR sailing applications for Valve Index, HTC Vive, Oculus Rift, and recently, Oculus Quest.

Also, as a vision, MarineVerse aims to promote sailing every day by providing engaging, interactive sailing experiences that motivate people to try the real sport. Besides, allowing senior sailors (Figure 1) to stay connected to the competition and their sailing friends by providing an accessible VR environment that offers ample social opportunities and facilitates rehabilitation. The use of VR technology in the areas of rehabilitation and therapy continues to grow, with encouraging results being reported for applications that address human physical, cognitive, and psychological functioning [1-4].

When everyone is using VR on a daily basis, MV also wants to be a safe harbor, where you can meet like-minded people, sail together, socialize and learn, growing as a sailor. One of the first researches involving sailing and virtual reality is reported on the work from Walls [5], where the ability of fourteen competitive helmsman of different skill levels to sail a standard course towards the wind (upwind) was assessed using a virtual reality sailing simulator. The results indicate that the test used can differentiate between variations in upwind sailing performance over a wide range of ability.

Figure 1. Screenshot from Marine Verse website. Allowing seniors to stay connected to the sport and their sailing friends.

2. Main Projects

MarineVerse flagship products are Marine Verse Cup [6] and VR Regatta - The Sailing Game [7] (Figure 2).

Figure 2. Screenshot at Yatch mode inside Marine Verse Cup Alpha.

VR Regatta was the debut project where it brings entertainment and education together through virtual reality. The idea is to create experiences to enable more people to sail through the creation of games, training experiences, and more. It is the leading VR sailing game for HTC Vive since 2016.

MarineVerse Cup is a competitive VR sailing game that brings multiplayer sailboat racing to every VR headset owner. Available to be joined daily and on weekly races (Figure 3), with varying wind conditions and courses that will test your sailing and racing skills.

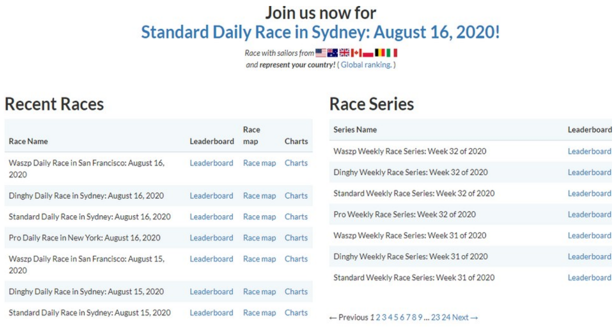

Figure 3. Screenshot at a racing board from MarineVerse Cup website.

Both simulation projects aim to promote engagement in the sporting spirit of sailing, encouraging exercise, a true exergame. Exergames are known as digital games combining training with gameplay, which can improve youths' health status and provide social and academic benefits [8] [9] [10].

However, it is perceived the potential of adults 50+ and seniors also to improve health status, as another project from MV provides. Big Breezy Boat (B3) [11] is the first mobile project aiming to democratize sailing by bringing it to affordable virtual reality, and it complements the debut project - VR Regatta - The Sailing Game that brought sailing to high-end PC VR.

3. Social and scientific contributions

Virtual reality sailing enables MV to provide sailing training and education at your home, more cheaply, and quickly. The company considers it a fun and engaging tool to reinforce what you are already learning on the water. As a newbie, advantages are that you can go at your own pace, focusing on a given subject for as long as necessary. On top of that, an instructor will be able to join you in the virtual world, if you need anything specific explained.

In the case of an advanced sailor, all of the projects can connect you with experts from around the world while VR offers a unique learning environment. In the last five years, MV took place in seventeenth events to explore possible applications of virtual reality for promotion of the sport and potential future training applications, as recently as a partner in VR Fitness Summit 2020, presented by Virtual Athletics League (VAL).

As a social contribution, MarineVerse projects also have a high potential for social exergames to persuade seniors to increase physical activity [12]. The authors highlight that many elderly suffer from loneliness, making social interaction within exergames very important. In 2020, due to the pandemic situation, the number of adults 50+ and seniors players at MV doubled during the lockdown period.

For instance, the experience of one of the virtual sailors' race, who started sailing in real life at eight years old and is now 54 and recently started playing on B3: "*immediately after involved my 80 year old mother too on her own Go, living not far from each other but during COVID time, in BBB relaxing, feeling like we used to feel when we were sailing, chatting and relaxing and being amazed!*". When asked, "Who and why should try MarineVerse Cup?", the same sailor did not hesitate to say: "*Just anyone who has the slightest thing with watersports/sailing because it is just very realistic amazing immersive competitive feeling, incl relaxing and escape into VR (...) The sailing, the behavior of the boat it is like in real life, you can learn how to sail here and or just continue or start a hobby that gets you involved for a lifetime.*".

MV projects could eventually support research into these research areas, of how exergames can help to motivate the elderly to exercise more, focusing on possible social interactions in online exergaming and persuasive technologies. Enhancement of presence in a VR Sailing environment can also be conducted studies, as the work of [13] developed with a virtual training track with a large-scale visualization, rudder input, and haptic feedback on the mainsheet line.

Finally, MV also has plans to improve the Quality of Experience of participants using the system. Employing testing and using virtual questionnaires research for applied measurements that include not only game concepts such as flow, presence, video quality, and well-being but also sailing learning data analytics to attempt to identify success factors to guide designers of water exergaming systems.

4. Partners & Friends

Marine Verse partners and supporters cannot fail to be mentioned [14]. MarkSetBot is the world's first robotic sailing mark. Led by a team of passionate sailors and innovators, MarkSetBot strives to grow the sport of sailing and improve the quality of race management through all that they do. MarkSetBots use GPS technology to hold position and zero in on a specific location, which may be dictated through an app or webpage. Changing courses becomes simple as marks are moved by dragging a waypoint and pressing a button. All this can be accomplished with precision greater than that of traditional marks.

MySail - Go Sailing is a crew finding and management platform for yacht racing. With MySail, skippers can easily organize and communicate with their regular race crew and find new sailors to join when they are short-handed. For sailors looking for their next - or first - crewing position, MySail provides a platform to connect with skippers and get out on the water more often.

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Virtual Reality, Augmented Reality and beyond: Laboratory of Computer Applications for Health Care at University of São Paulo

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Abstract: The Laboratory of Computer Applications for Health Care at University of São Paulo develop multidisciplinary research involving Computer Science areas and other knowledge fields such as Physiotherapy, Psychiatry, Radiology, and Cardiology. Most studies use concepts besides Computer Science, by aggregating knowledge to solve real problems. In this paper we present the main projects in Virtual Reality and Augmented Reality areas, highlighting serious games, computer-aided diagnosis and therapy, simulation and training. Besides the social and scientific impact inherent to the type of the developed research, some systems are available to health professionals in order to allow technology transfer and consequent technological and economic impact in daily activities of health tasks.

Keywords: *health care; simulation and training; serious game; virtual reality; augmented reality; computer-aided diagnosis.*

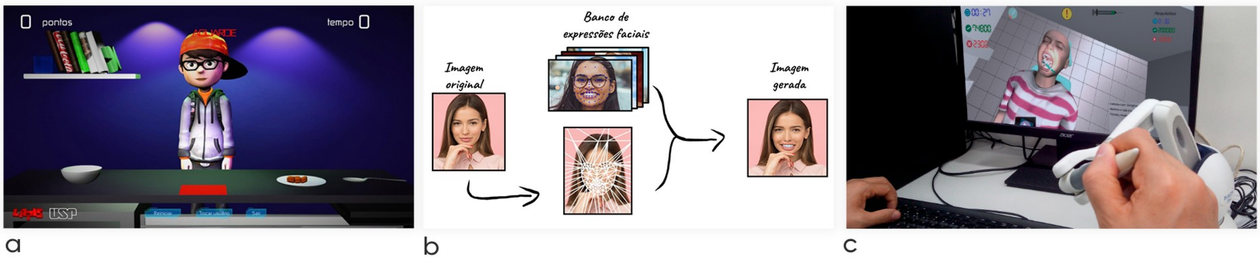

Figure 1. Some projects developed by LApIS members: (a) serious game for virtual rehabilitation; (b) facial emotion synthesis; (c) simulation for dental anesthesia.

Figure 2. Computer-aided diagnosis in Autism Spectrum Disorder: (a) Patient during eye tracking process; (b) frame of a video used as stimulus; (c) Saliency map obtained from processing of eye tracking signals.

1. Introduction

LApIS is an abbreviation in Portuguese for "Laboratory of Computer Applications for Health Care". The laboratory aggregates nine full time advisors from School of Arts, Sciences and Humanities at University of São Paulo (USP), with background in the Computer Science areas, which teach and supervise graduate and undergraduate students. Most of the projects of LApIS are multidisciplinary because their members believe that solution of real problems requires knowledge of several areas. Then, the development of such research requires effective participation of professionals from other areas, who know the application deeply. Thus, besides the advisors above mentioned, LApIS has collaboration with researchers from Brazilian and foreign institutions, with backgrounds not only in Computer Science areas, but also in Psychiatry, Cardiology, Physiotherapy, Odontology, Radiology, among others.

Research developed at LApIS aims to solve some real problems, by answering research questions such as:

- How to develop efficient and engaging systems for virtual rehabilitation?
- How do aid diagnosis and therapy of different anomalies and disorders?
- Using emotions recognition in simulation, games, and computer-aided diagnosis can contribute to the efficiency of these systems?

- Is it possible to generate intuitive visualization in three-dimensional (3D) environments to decrease the cognitive effort required to understand abstract information?
- Virtual games can present the same efficiency like real games?

In order to answer these and other questions, we put together several areas of Computer Science, such as Graphical Processing, Machine Learning, Computer Theory, Software Engineering, Information Retrieval, and Human-Computer Interaction. Other areas are also studied in order to aggregate useful concepts for the research. Among these, the most recent are studies about characteristics of disorders like Autism Spectrum, Alzheimer, and Mild Cognitive Impairment. Anomalies like cardiomyopathies and breast cancer are also explored in some research. Finally, concepts that involve studies from Psychology and Education, like cognitive skills, affective computing and visual attention have been included in some of the research developed at LApIS.

2. Main Projects

The projects developed at LApIS can involve different concepts within Computer Science areas. Most of them use Graphical Processing, considering Virtual Reality (VR) and Augmented Reality (AR), Image Processing and Content-Based Image Retrieval. In this paper the projects more directly related to VR and AR are highlighted (Figure 1). Other projects can be seen at: https://lapis.each.usp.br/.

2.1 Serious games

In partnership with physiotherapists, LApIS has developed serious games to aid training and motor rehabilitation processes. In [1], a VR serious game is described for the motor rehabilitation of patients considering the performance of daily activities. Also in this context, Funabashi et al. [2] proposed a serious game whose task is to associate images, involving cognitive and motor challenges. The correspondence between virtual and real games is also investigated [3].

Aiming to provide greater engagement in serious games, some researchers have investigated the automatic adaptation of these applications based on the user's emotional state. In [4], an Affective Computing framework was proposed for the automatic adaptation of serious games aimed to aid motor rehabilitation processes.

In addition to reducing the cost of implementation to the developer, this approach allows the physiotherapist to configure the adaptations to be defined for each patient. Figure 1a illustrates one of the games used in this research.

A PhD research currently developing aims to not only provide the automatic adaptation of serious games of general purpose, but also to include the analysis of the user's personality in this context [5]. In this sense, a systematic review was developed in order to analyze how the user's personality traits imply the experience of using VR systems [6], as well as a systematic literature review to identify emotion recognition techniques [7].

2.2 Computer-aided diagnosis and therapy

Collaboration with Psychiatric Institute at USP and Instituto de Computação (Unicamp) is advancing the state-of-art in computer-aided diagnosis and therapy of Autism Spectrum Disorder (ASD), Alzheimer, as well analysis of Psychotherapy sessions. Initial results obtained by processing anthropometric facial measurements extracted from two-dimensional (2D) images [8,9] are promising.

Using machine learning methods to process eye tracking signals [10] has shown the potential of an approach under development, illustrated by Figure 2. Some of the psychiatric disorders can limit an individual's ability to recognize facial expressions of emotions. To aid training of this skill, recognition of emotions is explored. LApIS has developed tools for generation of synthetic facial images [11] and caricatures [12] representing emotions to be used in this context (Figure 1b).

Radiology and Cardiology are other two fields of knowledge investigated by some LApIS research. The former is related to aid diagnosis of breast cancer using Computer Theory [13]. Regarding the later, a partnership with Heart Institute at USP allows 3D objects to be reconstructed from Magnetic Resonance Imaging and used to retrieve the most similar objects from a database [14]. Thus, physicians can analyze the retrieved objects to compose their decision about the diagnosis. Figure 3 shows the developed system.

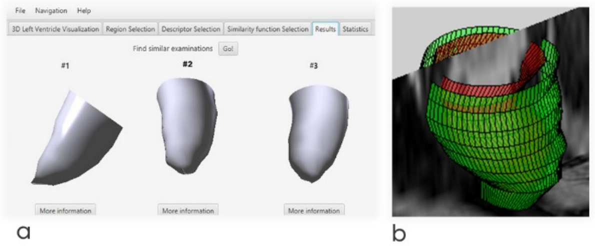

Figure 3. Computer-aided diagnosis in Cardiology by using 3D objects retrieval: (a) Ventricle wall reconstruction; (b) 3D environment used for retrieval.

Information Visualization has being explored as a tool to aid diagnosis. Currently, LApIS has explored the visualization of temporal data in 3D space, associating VR concepts to Visual Attention and Machine Learning. Thus, we seek to advance the visualization of temporal data in 3D space, through personalized visualizations based on capturing the users' preferences. While in [15] the use of rule-based learning is discussed in the personalization of visualization of temporal data, in [16] the results of a controlled experiment carried out with health professionals are presented. The proposed approach is extensible to other domains that share data that can be organized into informational clusters.

2.3 Simulation and training

VR simulators for training medical procedures can provide a low cost environment while provide greater safety for students. With this point of view, LApIS has developed VR systems for process simulation and medical training.

In order to reduce the high failure rates in the dental anesthesia procedure, the VR Vida Odonto haptic simulator [17] (Figure 1c) has been developed by LApIS in collaboration with the Faculty of Dentistry of Bauru (USP) and the Interactive Technologies Laboratory of the Polytechnic School (USP). Gamification techniques were incorporated into this simulator to promote engagement and provide student assessment metrics [18], making it a serious game. In another work [19], a method of learning haptic trajectories was added to the game, favoring the learning of trajectories performed by an expert.

In [20], a simulator for the medical procedure of breast palpation with force feedback is presented. This application was built using the ViMeT (Virtual Medical Training) framework, also developed by LApIS [21]. In this simulator, techniques and force feedback parameters are implemented to simulate different features useful to train the palpation exam, such as size and stiffness of nodules, and parameters related to breast composition.

LApIS has also studied methods for simulating physiological processes related to health areas. In [22], partial results of a method for simulating blood flow in arteries are presented. In it, a method joining Smoothed Particle Hydrodynamics and elastic deformations in meshes representing arteries is proposed. The objective is to offer greater realism in the creation of 3D simulators that require a reliable representation of blood flow in the human body.

3. Impacts and final remarks

Results of research developed at LApIS have been published in high impact journals and conferences, cited along this paper, which can show the scientific impact of the researchers. Besides this, some awards have been achieved [8,23,24,25], which ratify the quality of the research.

Regarding technological and social contributions, the results of the applications related to diagnosis are currently being tested by the partners in order to include them in the routine of health professionals aiming at aiding ASD, Alzheimer and Cardiology diagnosis. Simulator of dental anesthesia, as well as its gamification, is also being validated aiming at its insertion in the student's routine.

Members of LApIS are always open to exchange experiences with other laboratories. All the projects cited in this paper have opportunities to establish collaboration and include new students.

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Voxar Labs

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Abstract: Voxar Labs is a research group focused in augmenting experiences through research, innovation and collaboration with academia and industry. It develops cutting-edge multi-disciplinary research in the large area of Spatial Computing, tackling the inner areas of Extended Reality, Computer Vision and Natural Interaction. The laboratory aims to create impact through R&D&I, technology transfer, scientific publications, patents and human-resources formation. It is one of the most productive Augmented Reality research groups in the Latin America, also being recognized with seven best papers and ten first-place competitions' prizes over the nine years of its existence. Voxar Labs is part of the Informatics Center of the Federal University of Pernambuco, located in Recife – Pernambuco, Brazil.

Keywords: *extended reality; augmented reality; spatial computing; computer vision; natural interaction.*

Figure 1. Voxar Labs collaborators and laboratory headquarters at CIn-UFPE.

1. Introduction

Voxar Labs [1] is a research group founded in 2011, which develops research, development and innovation in the fields of Spatial Computing, with focus on Extended Reality (AR, MR, VR), Computer Vision and Natural Interaction. The name is coined as a reference to these areas, being a junction of "Voxel", as the fundamental unit of a spatial world that we want to build or understand, and Augmented Reality acronym "AR".

The Voxar Labs mission is to develop people by augmenting experiences. Based on this mission, its projects and research challenges arise from a problem focused environment. The values representing its core culture principles are creativity, cooperation, reliability, responsibility, flexibility, and enjoyment.

The group leadership arises from a network of professors and researchers, from UFPE and other institutions from Pernambuco, headed by Dr. Veronica Teichrieb (lab director and associate professor at CIn-UFPE), and includes Dr. Francisco Simões (Federal Institute of Pernambuco - IFPE), Dr. João Paulo Lima (Federal Rural University of Pernambuco - UFRPE), Dr. João Marcelo Teixeira (Electronics and Systems Department of UFPE), Dr. Lucas Figueiredo (Senior Research Scientist), Dr. Rafael Roberto (Senior Research Scientist), and Dr. Alana Da Gama (Biomedical Engineering Department of UFPE). This partnership reinforces the interdisciplinary importance for the group, in addition to establishing important alliances with other research institutions from the state.

The Voxar Labs team also includes one postdoctoral research fellow, one Ph.D. researcher, seven Ph.D. candidates, five master's students and 18 undergraduate students. There are a total of 48 members, including professors, researchers, engineers, Ph.D. candidates, students (MSc. BSc.), and staff from computer sciences and other fields, such as design, education, and physiotherapy. Some of these members can be seen in Figure 1, as well as the current headquarters of the lab.

Despite being relatively young, the lab has already won several prizes, including seven best papers (five from SVR), and ten first-place competitions' prizes. The laboratory also contains the only researcher from Latin America to appear in the list of the top 160 authors in Augmented Reality (AR) worldwide, Veronica Teichrieb. More information about Voxar Labs is presented in the following sections.

2. Surroundings and context (State, City and University)

The state of Pernambuco, in the northeast coast of Brazil, is famous for its beaches and cultural attractions. In addition to its continental area, it holds the Fernando de Noronha archipelago, a natural site on UNESCO's World Heritage list. It also unites culture and development, being one of the leading technology centers in the country.

The capital of Pernambuco is Recife. It is the oldest capital in Brazil, maintaining a set of mansions from colonial times that are still preserved, especially in its downtown area (Figure 2). Recife is famous for its strong culture, with dance, manual arts, theater, and cinema. People are very friendly and welcoming, sharing a unique passion for their hometown.

Figure 2. Recife downtown area with preserved colonial buildings. The area holds Porto Digital, an important technological park for Latin America

In the last 15 years, the city has come to have a great national and international prominence as an important hub for IT technology and creative economy. Much of this is due to Porto Digital [2], one of the most important technological parks in Latin America in terms of revenue and number of companies.

The main university in Pernambuco is the Universidade Federal de Pernambuco (UFPE), with its main campus located in Recife (Figure 3). Founded in 1946, UFPE aggregates more than 40 thousand people, including teachers, staff, and students. It ranks 10th nationwide and 45th in Latin America according to QS World University Rankings [3]. Rankings such as CSRankings point the Center of Informatics of UFPE in the South American leadership in the last 3 years in scientific production in the areas of Visualization, Robotics and Artificial Intelligence, among others, with UFPE in 5th position.

Among its centers, one that stands out is the Center of Informatics (CIn-UFPE), one of the most renowned centers in Brazil and Latin America (Figure 4). The CIn-UFPE Graduate Program stands out among the seven best in Brazil, and its courses include academic master's and Ph.D. programs, professional master's and PhD programs, and specializations. Also, the Program has the title of “Center of Excellence and Reference” in teaching and research, with national and international renown, achieving the grade “7” (the highest) in the evaluation of the Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES). In this field, CIn-UFPE maintains a significant and growing production, with the annual publication of about 40 articles in indexed international journals and more than 100 articles in national and international conferences, in addition to books and book chapters.

Figure 3. Universidade Federal de Pernambuco (UFPE).

Figure 4. Center of Informatics of the UFPE (Cin-UFPE).

3. Representative projects

Voxar labs uses an YouTube account (youtube.com/user/voxarlabs) to showcase its main results in research, development and innovation [4]. As examples of the lab effort in long term research, two are very representative: the 3D Tracking area and the Sicure project (Figure 5). The 3D Tracking research area has powered international cooperation projects (i.e., INRIA/UChile/UFPE and TUGraz/Kyushu/UFPE), industry projects and patents, various collaborative PostDoc and Ph.D.’s (e.g., with Microsoft Research, EPFL, TUGraz), research papers and prizes in high quality venues (ISMAR [5][6], ICRA [7], C&G [8][9], IJCNN[10], Sensors [11]).

The project called Sicure (former Ikapp project), shows how the interaction of real-world challenges and multidisciplinary applied research can produce impactful results, focusing on at home safe physiotherapy. This project boosted an international cooperation (TUMunich), PhD.s and master’s, multidisciplinary cooperation with physiotherapy and biomechanical engineering researchers, a spin-off creation, and many high-quality papers and prizes (C&G [12], 3DUI [13]).

4. Innovation through research

Amongst the development strategies adopted by research laboratories, the Voxar Labs approaches the research activity as a means to achieve innovation, and therefore deliver impactful results to the society. The core vision is to bridge the gap between research findings on Spatial Computing (from our works and others’) and its applications.

Figure 5. Sicure project (former Ikapp project).

This way, research methodologies within the Voxar Labs include innovation strategies, tailored Design Thinking processes to identify relevant use case scenarios and partners, to then solve problems within our society. For instance, internal processes such as the Foresight method (iftf.org/foresightessentials/), developed by Institute for the Future (IFTF), are conducted to steer the research towards non-trivial problems that in some cases may even not be yet revealed. Therefore, the approach of conception and development of researches is twofold: reactive, receiving demands from industry partners; but also proactive, analyzing exposed needs in society, and forecasting future opportunities.

Initiatives conducted in this direction include hosting hackathons, using as base ready-to-transfer technologies from the research, publicizing the contributions, and fostering the creation of competitive startups from the start, given the advanced technical background that will be used as core for their products (Figure 6). At last, the Voxar Labs also works with innovation hubs (e.g., SOFTEX - softexrecife.org.br), hosting events to promote collaboration with local and national industry partners. Grounded on developed models for technology transfer and licensing, the laboratory elaborates and engages on match-making strategies to relate companies needs to families of technologies developed by the lab, enabling partners to tackle unsolvable problems otherwise.

5. Social, technological and scientific contributions

In recent years, the Voxar Labs has stood out for carrying out high impact research, having, in the year 2019 alone, published five articles in indexed international journals, 12 papers in national and international conferences, generated two patents, and is in the process of creating its first two spin-offs. This is the result of research done by its members, as well as partnerships with companies and other universities, including HP, Samsung, Harvard GSE, Université de Montréal, Kyushu University, to name only a few.

Since its foundation, Voxar Labs won the best paper in five of the last eight editions of SVR, which is the main Brazilian event in the area. Among the awards, some highlights are the first place in the @Home category of the Latin American and Brazilian Robotics Competition - LARC/CBR, and the first place in the Offsite Tracking Competition of the IEEE ISMAR, both in 2015. Voxar Labs also won innovation prizes such as the Sports Hack Brazil of the IBM Hackathon (held at Campus Party Recife), Layar creation challenge in 2011, Metaio Developer Contest in 2013, and competitions at SVR and the Brazilian Symposium on Computer Games and Digital Entertainment (SBGames).

Figure 6. Hackathon promoted by the Voxar Labs to give opportunity to the birth of startups with cutting-edge technologies.

In a recent review [14], prof. Mark Billinghurst systematically searched Scopus papers to find the top 160 authors in Augmented Reality (AR) and the institutions that they come from (Figure 7).

Figure 7. Where in the world is AR Research Happening? Medium publication from prof. Mark Billinghurst in 2018 [14].

The list is based on the number of publications produced by each author. Veronica Teichrieb is the only researcher from Latin America to appear in that list. When using the same criteria for Latin America, 5 from the top 10 researchers belong to the Voxar Labs team.

In 2020, Voxar Labs CIn-UFPE is proud to organize IEEE Symposium on Mixed and Augmented Reality (ISMAR) [15]. In addition, the three major Brazilian conferences in VR/AR, CG/CV and Digital Games. These conferences, sponsored by the Brazilian Computer Society (SBC) are the Symposium on Virtual and Augmented Reality (SVR) [16], the Conference on Graphics, Patterns and Images (SIBGRAPI) [17] and the Symposium on Games and Digital Entertainment (SBGames) [18]. All conferences were planned to be hosted in the Recife area before COVID-19. However, to preserve the safety and well-being of all participants, they are going to be held as virtual conferences. The Voxar labs team can be seen in Figure 8.

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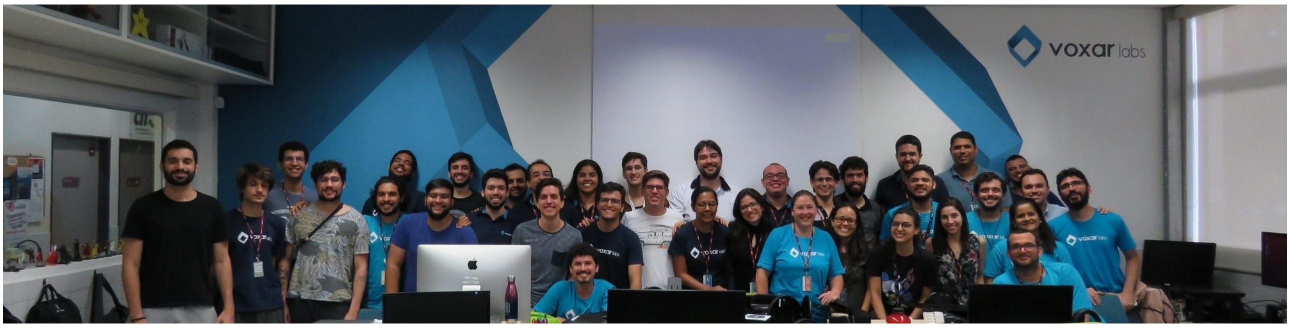

Figure 8. The Voxar Labs team in 2019/2020 closing year meeting.

BioxLab: Laboratório de Informática em Saúde – Bioxthica

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Resumo: Sistemas de Realidade Virtual (RV) têm sido utilizados na ciência como ferramentas de ensino e aprendizagem, formação técnica e entretenimento. No campo da reabilitação neurofuncional, a RV oferece uma oportunidade real para complementar e estimular a terapia convencional em pessoas que convivem com limitações físicas e cognitivas. Pertencente ao BRAINN (um Cepid FAPESP), o BioxLab consiste em um laboratório de design, testes e aprimoramento de soluções de Informática em Saúde para aplicações em recuperação motora e neurofuncional. Estas aplicações são controladas a partir dos movimentos captados por um dispositivo de reconhecimento de gestos (de desenvolvimento próprio) que consiste em um sonar (ultrassom) e Arduino ou pelo Microsoft Kinect (dispositivo comercial) que digitaliza o corpo do usuário e cria coordenadas espaciais de suas articulações, permitindo a interação gestual.

Palavras-chave: *reconhecimento corporal; realidade virtual; recuperação neurofuncional; dispositivos vestíveis*.

1. Introdução

O Instituto Brasileiro de Neurociências e de Neurotecnologia – BRAINN [1] foi criado em 2013 como um Centro de Pesquisa, Inovação e Difusão da FAPESP [2], está sediado na Faculdade de Ciências Médicas da Universidade Estadual de Campinas – UNICAMP, e busca desenvolver novos métodos e técnicas voltadas à prevenção, diagnóstico, reabilitação e tratamento de doenças cerebrais debilitantes, especialmente a epilepsia e o acidente vascular cerebral (AVC).

Entre os projetos orientados à criação e testes de novas tecnologias para neuroreabilitação, há uma linha de pesquisa voltada à realidade virtual (RV) e recuperação neurofuncional, que é responsável por três áreas complementares: 1. desenvolvimento de dispositivos vestíveis para o reconhecimento corporal e controle de ambientes virtuais (a partir de interação gestual); 2. softwares de análise do movimento e; 3. aplicativos para interação dos pacientes com ambientes virtuais imersivos e não imersivos voltados ao contexto da reabilitação física e neurofuncional.

Neste contexto, foi estruturada a Bioxthica (Spion-off do BRAINN) e o BioxLab – Laboratório de Informática em Saúde da Bioxthica (figura 1), designado a liderar projetos de inovação nas áreas de informática em saúde e a interagir com Clínicas de Reabilitação, Centros de Saúde e Institutos de Ciência e Tecnologia (ICTs) para a transferência de tecnologia, capacitação de profissionais (especialistas em cinesiologia) e na colaboração em projetos científicos [3,4].

O BioxLab é coordenado pelo Dr. Alexandre Brandão, Pesquisador Associado do BRAINN e do Instituto de Física Gleb Wataghin (IFGW) da UNICAMP.

Figura 1. BioxLab.

2. Projetos e contribuições tecnológicas e científicas

Os projetos do laboratório estão subdivididos em 4 competências:

2.1 Desenvolvimento de *software* para o registro e mensuração de amplitude do movimento (ADM) [5,6]

O *software* (figura 2) oferece uma opção aos especialistas da área da saúde acerca do estudo do movimento humano (cinesiologia), representa uma alternativa de baixo custo sendo um recurso de avaliação não invasivo.

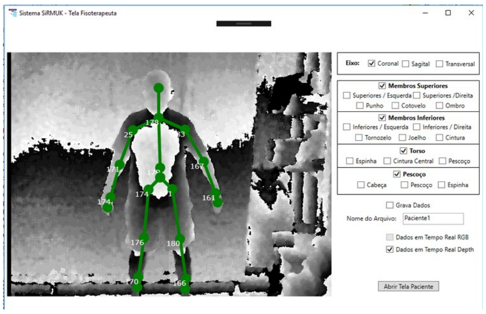

Figura 2. Interface do *software* de mensuração e registro de ADM.

2.2 Desenvolvimento de aplicativos de realidade virtual imersiva e não imersiva

A interação gestual do usuário com o ambiente de RV ocorre de forma intuitiva, fisicamente ativa e essencialmente lúdica, por meio de gestos motores pré-determinados para cada aplicativo. O reconhecimento destes gestos, que permite esta interação gestual com o ambiente de RV, ocorre em duas etapas: 1º) o corpo de uma pessoa deve ser identificado por um sensor que o distingue dos demais objetos presentes no mesmo ambiente; 2º) os segmentos corporais, da pessoa identificada, devem ser agora atribuídos de características que possam servir de controle a um sistema computacional.

Os aplicativos GestureCollection (figura 3) oferecem ao usuário/paciente uma forma de interação fisicamente ativa, com controle motor a partir dos membros superiores e inferiores [7-11].

Figura 3. Interface dos aplicativos (não imersivos) GestureCollection.

Os aplicativos e-House e e-Street (figura 4), simulam um ambiente residencial e urbano, respectivamente, e foram modelados a partir do motor de jogo Unity3D, com o propósito de oferecer aos usuários desafios de navegação (orientação espacial) e simulação de situações de risco (prevenção de quedas e travessia de ruas) [12].

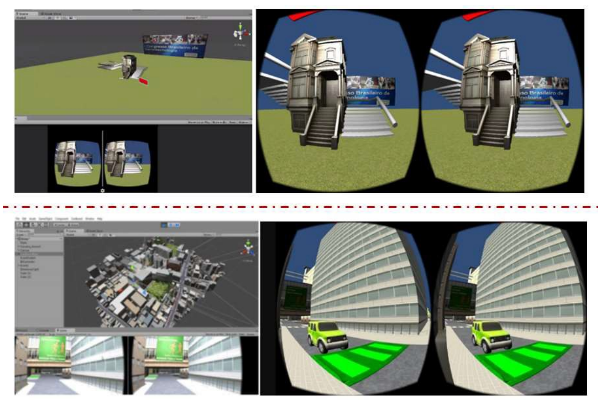

Figura 4. Interface e ambiente de desenvolvimento dos aplicativos (imersivos) e-House (imagem superior) e e-Street (imagem inferior).

2.3 Desenvolvimento de dispositivos vestíveis para Interação Humano-Computador (IHC) a partir de interação gestual

Para controlar o ambiente virtual a partir dos movimentos de marcha estacionária, foi construído um dispositivo (*hardware*) a partir de sensores ultrassom (sonar) conectados fisicamente (*wired*) à uma placa controladora (Arduino); os sinais de entrada consistem da diferença de altura (ΔS, considerando a posição inicial S0) do sonar, e enviados ao Arduino (figura 5). O Arduino envia o sinal (via *bluetooth*) para o *software* que está sendo executado em um smartphone (inserido em óculos de RV), o qual permite o controle de navegação (por interação gestual) dos ambientes e-House e e-Street pelo usuário [13,14].

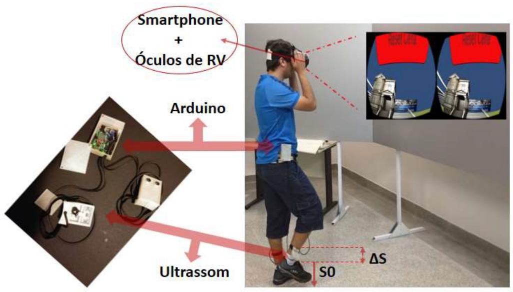

Figura 5. Dispositivo de interação para marcha estacionária.

2.4 Aplicação das tecnologias desenvolvidas em testes de usabilidade com voluntários/pacientes em terapias de recuperação motora e neurofuncional

A fim de evidenciar o aumento de conectividade cerebral durante a interação com as soluções descritas anteriormente, foram realizados exames de Imagem de Ressonância Magnética funcional – fMRI (do inglês, functional Magnetic Resonance Image), que consiste em uma técnica de neuroimagem, não invasiva, utilizada para encontrar áreas cerebrais ativas mediante a execução de diferentes tarefas (motoras ou cognitivas) ou mesmo quando o indivíduo está em repouso (*resting-state*).

Para estudar a conectividade cerebral (figura 6), são analisadas as relações entre as diversas áreas cerebrais durante experimentos de estado de repouso (resting-state fMRI), os quais são realizados antes e após a interação com um ou mais dos aplicativos [15].

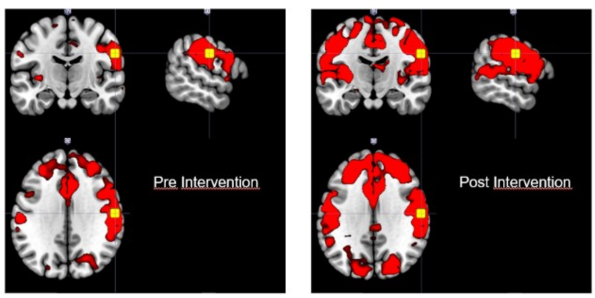

Figura 6. Mapa de correlação da atividade cerebral antes a após a interação com os aplicativos não-imersivos.

3. Parceiros

São parceiros do BioxLab, pesquisadores das ICTs:

- UNICAMP: Prof^a^ Dr^a^ Gabriela Castellano, Instituto de Física Gleb Wataghin (IFGW) | Prof. Dr. Li Li Min e Dr^a^ Sara Regina Meira de Almeida, Faculdade de Ciências Médicas (FCM) | Prof^a^ Dr^a^ Paula Teixeira Fernandes, Faculdade de Educação Física (FEF) | Dr. Thomas Beltrame, Instituto de Computação (IC); * publicações em colaboração [5-7,11-16].
- USP: Prof. Dr. Cláudio Fabiano Motta Toledo, Instituto de Ciências Matemáticas e de Computação (ICMC); * publicações em colaboração [17].
- UFSJ: Prof. Dr. Diego Roberto Colombo Dias, Departamento de Computação (DComp); * publicações em colaboração [5,6,7,12,13,14].
- UNESP: Prof. Dr. José Remo Ferreira Brega, Departamento de Computação;
- UNIFESP: Prof. Dr. Marcelos de Paiva Guimarães, Reitoria/UAB; * publicações em colaboração [6,7,12,14,18].
- UFES: Prof^a^ Dr^a^ Ester Miyuki Nakamura Palacios, Centro Biomédico, Departamento de Ciências Fisiológicas;
- UFOP: Prof^a^ Dr^a^ Gilda Aparecida de Assis, Departamento de Computação; * publicações em colaboração [15,19,20].
- UFSCAR: Prof^a^ Dr^a^ Daniela Godoi Jacomassi, Departamento de Educação Física e Motricidade Humana (DEFMH) | Prof^a^ Dr^a^ Paula Regina Mendes da Silva Serrão, Prof Dr Maurício Jamami e Prof. Dr. Nivaldo Antônio Parizotto, Departamento de Fisioterapia (DFisio) | Prof. Dr. Daniel Marinho Cezar da Cruz, Departamento de Terapia Ocupacional (DTO) | Prof. Dr. Luis Carlos Trevelin, Departamento de Computação (DC); * publicações em colaboração [5,7,8,9,10,11,12,13].

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Innovative Technologies to Support Education and Training: Researches by LabTEVE

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Abstract: Training systems based on virtual reality, serious games, assessment methods, systems to support learning, assessment methodologies and technologies to extend interaction with educational content have been the focus of researches at LabTEVE. The interdisciplinarity can be observed in each project, highlighting the need for dialogue between areas for the production of solutions and technologies that can be used today as well as prospected for the future.

Keywords: *virtual reality; augmented reality; innovative research; educational technology.*

1. Introduction

The Laboratory of Technologies for Virtual Teaching and Statistics (LabTEVE) was created in 2000 to research and develop innovative methodologies and techniques to provide and support the learning by systems that allow information access any time and anywhere as well as training of individuals to deal with new technologies. Each project involves multidisciplinary teams that combine their expertise to provide consistent solutions to real problems. Thus, researchers from several academic centers of the Federal University of Paraíba take part in LabTEVE, specifically from the departments of Statistics, Computer Science, Psychology, Nursing, Medicine, Education, Engineering, Information Sciences and Chemistry. Nowadays, the group is composed by 27 researches and collaborators, including under graduation, master and PhD students. Additionally, there are partnerships with researchers and institutions from Brazil, Canada, France and Portugal.

The focus on education is the master line of the LabTEVE researches, that can be categorized in:

- Training Simulators based on Virtual Reality
- Methodologies for Real Time Skills Assessment
- Serious Games
- Virtual and Augmented Reality Applications

2. Main Projects

The innovative methodologies for education consider new ways to interact with the information, extending the reality possibilities. Since education processes are present in different stages of life, the researches of LabTEVE include since basic to professional (and permanent) education.

2.1 Training simulators and methodologies for real time assessment

Virtual Reality (VR) has been adopted in the proposal and development of simulators for medical training as a demand of medical education. In order to provide realistic manipulation of human body structures, haptic systems have been adapted and included in the simulators. The purpose is provide practice in virtual environments, free of risk, and fill the gap between theory and real practice for health students. The research also include the study and proposal of metrics that consider psychomotor skills. Those metrics are necessary to allow the use of interaction data, besides other virtual environment information, as input of assessment modules.

The simulators developed at LabTEVE include an intelligent assessment model. Intelligent models for real time assessment of users' skills are online (real time) systems able to monitor users' movements and environments variables, to provide a feedback about the procedure performed. This is a relevant area of research at the laboratory, with several methodologies proposed to provide feedback in real time, coupled to the VR simulator. These methodologies for real time assessment can consider one or more users acting in the simulator at the same time [7]. In the first case, they are named Single User's Assessment System (SUAS) [10] and in the second one Multiple Users' Assessment System (MUAS) [9]. This last one is able to assess each user in the system as well as, their interactions to complete a task (figure 1). Each assessment system is developed according to the specificities of the problem: the variables and the knowledge related to the task simulated.

The practice of incisions for surgical procedures is an example of simulator integrated to an assessment module. The incisions simulator brings a SUAS an assessment system based on the use of Support Vector Machine and rules of classical logic [11]. Other example is the simulator for training administration of drugs by needle (SIMTAMI), that included the proposal of metrics [5] and a SUAS to evaluate user's choice of tools and needle manipulation data, among other tasks, to produce an assessment report able to indicate right/wrong and acceptable/ unacceptable movements and choices. In both simulators, the tool manipulation data is provided by a haptic device.

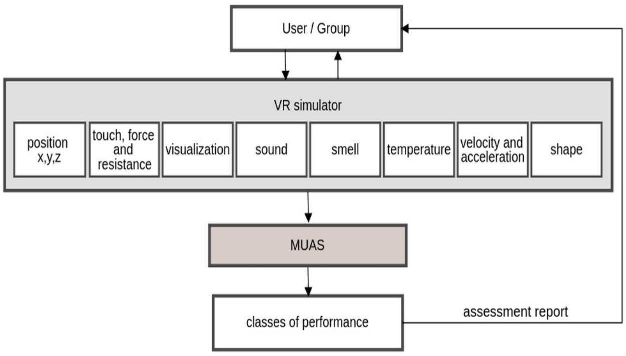

Figure 1. MUAS interaction with VR simulator.

The simulator for Gynecological Exam named SITEG (Figure 2) uses a SUAS based on the fusion of several fuzzy assessment methods. In this system, each method assesses variables according to their respective statistical distribution of data and aggregates these results using granularity computing [15]. SIMCEC is a collaborative simulator for surgical education of health professionals that will integrate surgical teams. In it, users can perform the simulation in one of the 3 available profiles:surgeon, surgical technician and anesthetist. Together, they must execute a preoperative phase of a maxillary surgery. A MUAS based on classical logic monitor each user activities and interactions to compute successes and mistakes [13].

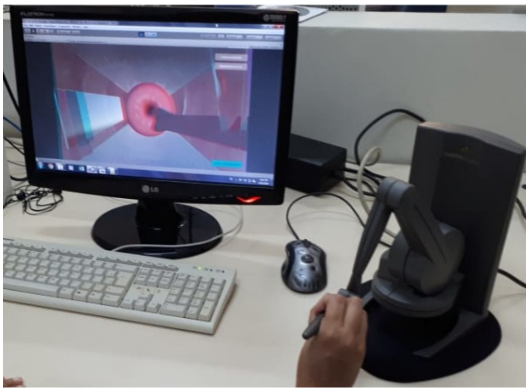

Figure 2. Haptic manipulation with SITEG.

There is another way of assessment for cases where training must be carried out continuously to improve the user's skills. The continuous assessment aims to assess the user in the repetition of tasks in a simulator in order to produce reports with notes, graphs and tables to illustrate the evolution of user's skills [8].

2.2 Serious games

The proposal of innovative Serious Games is also present in the LabTEVE researches. Some of those games include VR approaches to improve players' sense of presence and enjoyment. The design of serious games at LabTEVE have been focused on player engagement and include studies about presence, natural interaction and automatic balancing of difficulty level. The content is always the kernel of the game design process.

An example of those serious games is the FarMyo, a game to rehabilitation of patients pos stroke that uses an electromyography device to capture player movements [3] by natural interaction. Specific gestures in this rehabilitation game were recognized by neural networks. The game is in the final stages of testing for clinical evidence (Figure 3).

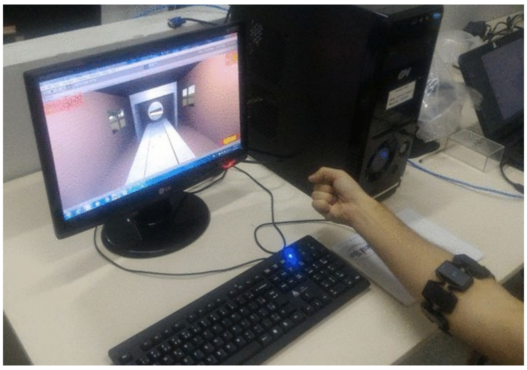

Figure 3. Playing FarMyo using an electromyographic device.

The Caixa de Pandora game was developed in 2015 as a tool for the qualification of health professionals about the violence against women [1]. The game was reformulated for mobile and general public in 2018[12]. Since 2019 has been conducted a redesign of the game for a VR approach with a 360º environment [4].

The intelligence models are also present in the serious games. Their goal is to monitor player actions to identify their comprehension of the game subject and 1) modify the game progress, 2) reinforce a content presented, or 3) extract measures. The third case can be seen in the Paki Mirabolândia, a game dedicated to identify player personality traits [14] (figure 4). Paki Mirabolândia is a serious game that integrates a decision making model based on the Item Response Theory to relate the choices and actions of players to their trace latent.

Figure 4: The Paki Mirabolândia game to identify user trait of personality.

2.3 Virtual and Augmented Reality Applications
Several other researches have been conducted in the LabTEVE and use virtual and augmented reality as a way to approximate content to people and improve learning processes.

In project Interactive Archaeology was developed an immersive and multiplatform environment of the archaeological site of Ingá Stone, one of the most important of Brazil. The environment have a set of historic and archaeological information found in the site and in the literature. By VR technology it was possible to visit the site in a three side display (figure 5) system [6]. The environment was rebuild using HTML5 to provide 3D view and navigation by web at: http://www.de.ufpb.br/~labteve/download/inga/.

More recently, the design and integration of augmented reality to didactic material was presented in the AminoViewer project (figure 6). In this project was proposed and developed a book and an application to explore aminoacids in undergraduation courses [2]. Further developments include the design of a game for collaborative activities in this subject.

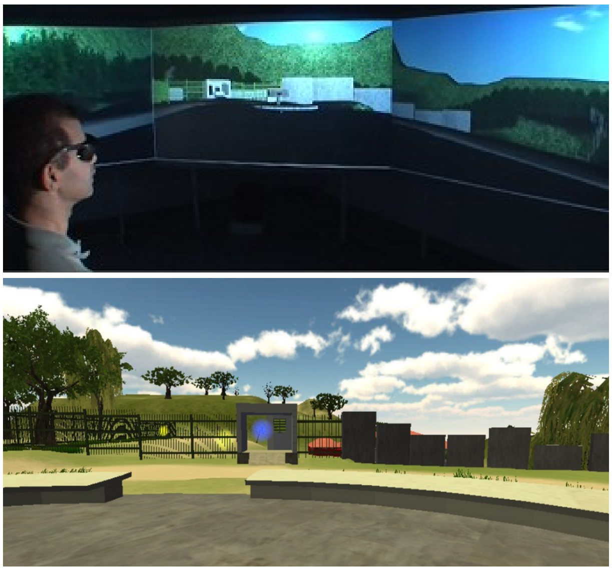

Figure 5. The virtual Ingá archeological site in a three side display and online at web.

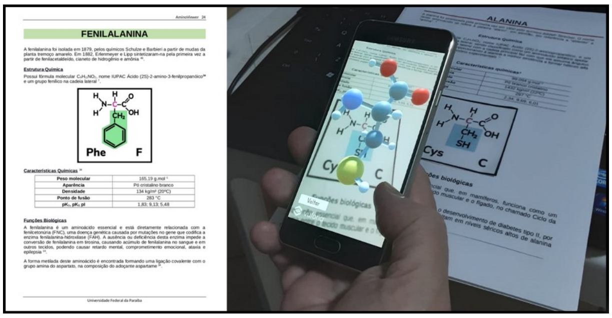

Figure 6. The AminoViewer didactic material.

3. Social, Technological and Scientific Impact
LabTEVE has contributed to the advancement of research related to educational technologies, with regional, national and international impact. In this context, it has also contributed to the technological production of solutions, made available to society, and to the training of human resources. Next, the main impacts are highlighted.

3.1 Scientific impact
The projects and research developed at LabTEVE have been published in regional, national and international scientific journals and conference proceedings. It is a constant goal of the group to disseminate this research in order to collaborate with the advancement of science. In the last 10 years, the group has produced 59 papers in journals and more than 100 in conferences.

3.2 Social impact
As a way of reaching society, the research group is present at major national scientific events. Particularly, since the year 2014, the group has participated annually in state technology fairs, exposing its results to society. It is also important to remember that several of the products developed by LabTEVE are available to society free of charge, reaching schools and educational institutions, collaborating with training processes.

3.3 Technological impact
The technological production of LabTEVE has an institutional impact, since the group has ensured the registration of this production with the National Institute of Industrial Property through the Technological Innovation Agency (INOVA) at the university, with incentives from this agency. From its creation, LabTEVE has already registered 29 computer programs and required patent for four inventions. Since 2016 the LabTEVE team receives annually from INOVA inventor awards for their software products.

3.4 Impact on Human Resources Training
The training of human resources at LabTEVE has taken place from undergraduate and graduation works. The doctorate and master degree works are carried out by the Postgraduate Program in Decision and Health Models and have an interdisciplinary character, while by the Postgraduate Program in Informatics there are master's orientations that, although they are in Computing, are integrated with multidisciplinary projects of the laboratory. In its 20 years of operation, LabTEVE has received more than 50 students, including undergraduates, master's and doctoral students.

4. Final Considerations
This paper presented the main research lines of LabTEVE and some projects developed in the last ten years. Previous works can be seen on the laboratory pages and in a previous publication about the group [16].

Since 2009, LabTEVE is member of the Brazilian Institutes of Science and Technology, through the research network of Medicine Suported by Scientific Computing (INCT-MACC), which involves more than 20 Brazilian and international institutions.

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Visualization, Interaction and Simulation Lab at UFRGS

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Abstract: The Visualization, Interaction and Simulation Laboratory (VISLab) is part of the Computer Graphics, Image Processing and Interaction research group, which started its activities in 1978 developing projects mainly on rendering and animation. Along the years, as new researchers joined the group, new research fields such as image acquisition and analysis, virtual reality, non-conventional interaction, and visualization of complex data started to be investigated. Within this group, VISLab is majorly concerned with research on human-computer interaction, with emphasis on non-conventional, 3D interaction and haptics, and immersive visualization in the context of virtual and augmented reality applications. In this paper, we present the VISLab research focus and the strategy we use to achieve its main goal: to enhance the human with computers, extending the perception capabilities, and improving the human power of action in a natural way. We also briefly describe and illustrate some recent works developed in the lab.

Keywords: *non-conventional interfaces; virtual and augmented reality; immersive visualization*.

1. Introduction

In a quest for mechanisms to enhance the human with computers, we have been investigating new technologies and techniques that may contribute to extend the human perception and to enlarge our power of action. This strategy is coupled with the concepts of calm and natural interfaces, where computers become ubiquitous and users live in a fully connected world, being constantly updated through their senses and acting in a precise and natural way. To accomplish our goals, we are conducting research on human computer interaction (HCI) in a broad sense, which includes non-conventional and 3D interaction, haptics, and the use of mobile and wearable devices to allow the implementation of these concepts everywhere. Moreover, our research on HCI is heavily influenced by virtual and augmented reality (VR/AR) setups, which also implies studies on immersive and situated visualization. Results contribute to real applications (e.g., data visualization and health care) and are tested with final users whenever possible.

Our research focus is built on the assumption that human-computer communication should go beyond the eyes to include the touch and the auditory systems. This implies in using the most out of the computational resources available to enhance human activity with all helpful sensory (not only visual) information in harmony with our living environment, while bearing in mind the human tasks the systems are entitled to support. Our goals touch a number of computational and human aspects, which are covered by the projects in the different research lines conducted by the VISLab members.

2. Recent results

In this section we provide an overview of some results that illustrate our research focus. The complete list of projects can be found at the lab's web page.

<ins>HCI and 3D interaction</ins>

Earlier, we have proposed a family of 3D interaction techniques based on smartphones for 3D selection and manipulation [1][2]. The use of such devices presents two advantages: they are equipped with a rich set of sensors and fit greatly as pointing devices (1); almost everyone has a smartphone and carries it always and everywhere like an extension of their body.

We have successfully applied smartphone-based 3D interaction techniques for collaborative manipulation of virtual objects in VR and AR. Such novel paradigm for 3D manipulation supports smooth and intuitive collaborative actions. The approach coordinates and combines the multiple users rotations, translations and scales, as well as the camera control [3] (see Fig. 1). It has been proved advantageous for sharing the interaction complexity among many users. When applied in AR [4] this approach combines touch gestures and device movements for fast and precise control of 7-DOF transformations. Moreover, the interface creates a shared medium where several users can interact through their point-of-view and simultaneously manipulate 3D virtual augmentations (see Fig. 2).

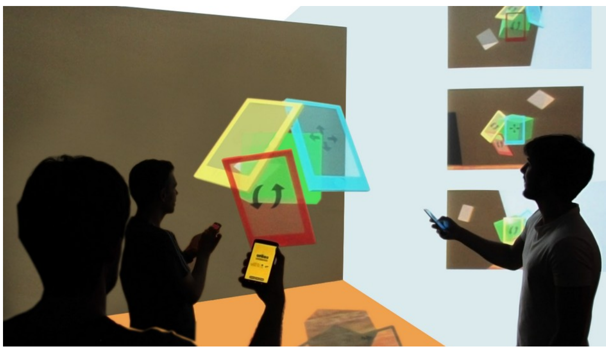

Figure 1. Three users simultaneously driving the object through the virtual environment. The colored rectangles indicate the position and orientation of each user in the VE. The three windows at the right-side show the three personal views.

Figure 2. Overview of three persons using our mobile interface to collaboratively manipulate objects in an augmented reality environment.

Haptic interaction

Touch and force feedback are know to increase immersion and to enrich the sensorial experience in VR. But tactile signals can also be used to communicate ad hoc information in several human-to-human and human-computer scenarios. While short vibrations that signalize an incoming call or message by a cell phone are ubiquitous, we have worked to extend such simple vibratory notifications so that they are modulated in sets of lexical tactile elements (so called tactons) that put together in sentences compose very expressive languages. One thing we found out is that to increase the language expressiveness without increasing the number of ad hoc tactons, modifier tactile patterns can be used [5]. Perceptual and cognitive factors such as stimuli type and location on the body are some current foci of study.

We explored the actuator density and precision in vibrotactile displays and the acuity for vibration of the head's skin when using such devices [6, 7]. We have also designed and assessed haptic guidance techniques for 3D environments. We designed and assessed a vibrotactile HMD to render the position of objects in a 3D space around the user by varying both stimulus loci around the head and vibration frequency. This combination of stimuli convey respectively direction parallel to the ground and elevation [8].

More recently, we have been investigating the potential uses of other haptic devices like the EXOS Wrist DK2 [9], which is wearable and ungrounded, but still provides rotational stimuli around the wrist. Such stimuli, when combined with the visual information in a virtual environment, can potentially convey a suitable model for balance stimulation and weight perception. The system could have impacting applications for health, with rehabilitation exercises in physiotherapy, to improve or recover one's sense of equilibrium, and to improve general VR metrics such as embodiment and presence.

Immersive analytics and situated visualization

Current immersive technologies, which combine stereoscopic displays and natural interaction, are being progressively used for information visualization and data analyses. This has been called immersive analytics.

We have investigated the use of an HMD-based environment for the exploration of multidimensional data, represented in 3D scatterplots as a result of dimensionality reduction. We proposed a new modeling for assessment, accounting for the two factors whose interplay determine the impact on the overall task performance: the difference in errors introduced by performing dimensionality reduction to 2D or 3D, and the difference in human perception errors under different visualization conditions. Instead of the traditional interaction we implement and evaluate an alternative data exploration metaphor where the user remains seated and viewpoint change is only realisable through physical movements. All manipulation is done directly by natural mid-air gestures, with the data being rendered at arm's reach. The virtual reproduction of the analyst's desk aims to increase immersion and enable tangible interaction with controls and two dimensional associated information [10, 11, 12]. More recently, the VirtualDesk approach has been used to evaluate an immersive space-time cube geovisualization for exploring trajectory data [13] (see Fig. 3).

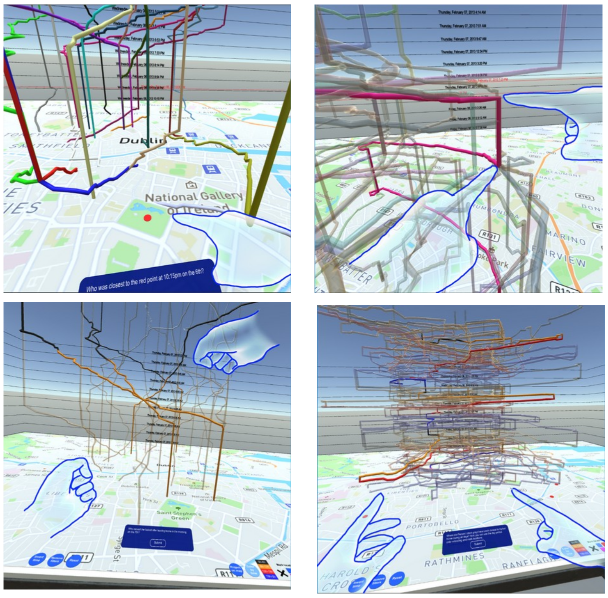

Figure 3. Different tasks being performed in the Immersive condition with Dense data: comparisons of instant distance (top left), stop durations (top right), movement speeds (bottom left) and event locations (bottom right). Blue hand contours added for clarity.

When using augmented reality devices, such as the HoloLens, we refer to such applications as situated visualization or situated analytics. We have also investigated the potential benefits of situated visualization in proof-of-concept applications. For example, an augmented reality user interface was developed to provide information for users to define the most convenient location to sit down in a conference room. This accounts for different sets of arbitrary demands by projecting 3D information directly atop the seats. Qualitative and quantitative data collected from a user study indicated that the augmented reality solution is promising in some senses and may help users to make better decisions [14]. Previously, in another work, we used virtual holograms placed on a terrain to guide user navigation instead of the usual heads-up display approach where the augmentations follow the line of sight [15]. More recently, we conducted a study with electromagnetic compatibility (EMC) data, where a user of AR glasses visualize, in a situated fashion, the EM fields around the physical devices that generate them. Situated interaction allows performing data readings accurately and efficiently.

Realistic Simulators

A great motivator for research in VR in the lab is surgery simulation. We have first worked on techniques for modeling organ shapes, joint motion and tissue deformation. Then, we explored collision detection and instrument-tissue interaction, and put that all together in a software framework based on game engines [16]. Currently, the main challenges reside on: creating customized patient models for surgery planning, improving physics-based behavior to simulate real tissue, and proposing new interaction techniques to manipulate medical data.

We have come up with a novel method that uses position-based dynamics for mesh-free cutting simulation. Simulations of cuts on deformable bodies have been an active research subject for more than two decades. However, previous works based on finite elements methods and mass spring meshes cannot scale to complex surgical scenarios. Our solutions include a method to efficiently render force feedback while cutting, an efficient heat diffusion model to simulate electrocautery, and a novel adaptive skinning scheme based on oriented particles [17] (see Fig. 4).

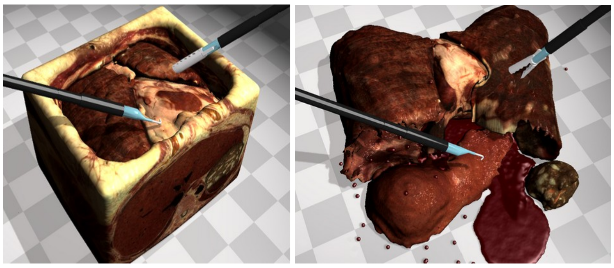

Figure 4. Visual results from a fully dynamic cutting simulation with multiple materials. Thorax organs and other anatomical structures are shown. Nearly 10,000 particles and 30,000 constraints were simulated at haptic framerates.

In another work, we proposed the analysis of videolaparoscopy data to compute the Bidirectional Reflectance Distribution Function (BRDF) of living organs as an input to physically based rendering algorithms, and applied this technique in a case study around the liver with patient-specific rendering under global illumination [18].

Simulating the modeling of virtual dynamic objects in immersive VR is another challenging research topic. While sketching was traditionally a 2D task, and even the new generation of VR devices allowed to sketch in 3D, the drawn models remained essentially static representations. We have developed a new physics-inspired sketching technique built on the top of position-based dynamics to enrich the 3D drawings with dynamic behaviors. A particle-based method allows interacting in real time with a wide range of materials including fluids, rigid bodies, soft bodies and cloths [19] (See Fig. 5).

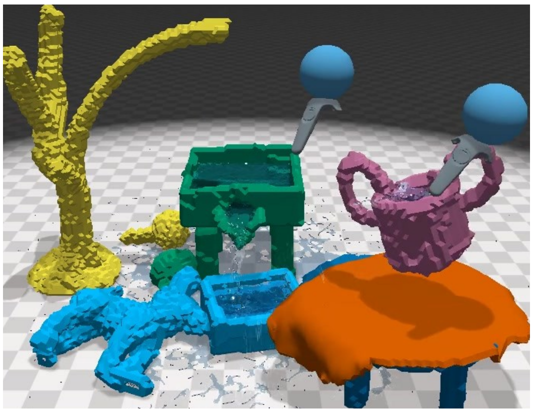

Figure 5. Different dynamic bodies (soft, rigid, fluid) interacting in the same VR scene and with the user controller.

3. Uniqueness and final comments

Several factors collaborate to compose our uniqueness in the region and our potential to produce excellent research comparable to top-ranked international institutions. According to the Brazilian Ministry of Education, UFRGS is ranked among the top 5 research universities in Brazil. Its Computer Science (CS) undergraduate program is reputed as number one by the same ministry and recognized by the industry for the excellent education provided. Our Graduate Program in Computer Science is among the best ones and covers most of the CS areas. This entitled us to count on excellent infrastructure and a significant number of undergraduate and graduate research scholarships. Currently, eight faculties and around 40 undergraduate, MSc, and PhD students compose the Graphics, Image Processing and Interaction group. The eight faculties have a varied background for having obtained their PhD or having spent sabbatical leaves in different, highly qualified institutions worldwide, with which they have maintained cooperation projects with international reference groups over the years. As for VISLab, around 16 students work in our lab on a daily basis, exchanging experiences and taking advantage of the same facilities.

Due to these characteristics, VISLab welcomes students with varied backgrounds but with strong evidence of a research-oriented profile, and also seeks collaboration with other groups to broaden research opportunities.

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