

Report on the 2nd Digital Ludeme Project Workshop

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The 2nd Digital Ludeme Project (DLP) Workshop, on the topic of *Game AI Applications for Historical Games Research*, was held at Maastricht University's Department of Data Science and Knowledge Engineering (DKE) over 11–14 April 2022. The aims of this workshop were twofold:

1. To bring together experts on both the historical/cultural study of games as well as the computational study of games and Game AI, in order to foster discussion and the exchange of ideas between fields that do not often meet.
2. To educate participants in the use of the Ludii general game system (Piette et al. (2020)) through lectures and practical hands-on tutorials, and solicit feedback on what functionality might be added to Ludii to increase its usefulness for practitioners in the field.

This workshop follows on from the earlier 1st DLP Workshop on the topic of *Foundations of Digital Archaeoludology (DAL)* held at the Leibniz Centre, Schloss Dagstuhl, Saarbrücken, Germany, over 10–12 April 2019 (Browne et al. (2019)). The 1st DLP Workshop was attended by 17 participants.

The 2nd DLP Workshop was held as a hybrid event due to Covid restrictions and travel difficulties, although most participants attended in person (see Fig. 1). There were a total of 36 participants from 17 countries, and 32 talks (in addition to round table and open discussions) from 22 speakers including 14 × invited speakers, 5 × DLP team members and 3 × DKE Honours students.¹ Each day covered a broad theme split into four specialised sessions, as follows.

1. DAY 1: DIGITAL ARCHAEOLOGUDODOLOGY

The first day of the Workshop was a general introduction to the DLP in general and the Ludii general game system (Piette et al. (2020)) in particular, to give participants a useful context for the Workshop.

1.1. Session 1. The Digital Ludeme Project (DLP)

The very first session of the Workshop was an introductory session about the DLP and the DLP team.

- C. Browne *Introduction and Update on the DLP*: Principal Investigator Cameron Browne kicked off with an update on the DLP and progress since the 1st DLP Workshop in 2019 (Browne et al. (2019)), especially in the context of the ongoing Covid pandemic.

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¹The workshop schedule is available at: <https://ludii.games/workshop.php>.



Fig. 1. The 2nd Digital Ludeme Project Workshop in session.

- É. Piette, W. Crist, D. Soemers and M. Stephenson *Overview from the DLP Team*: The DLP team members then briefly introduced themselves and explained their roles and responsibilities in the project. Éric Piette (Workshop organiser) explained the Workshop format and important logistical details before asking participants to introduce themselves.

1.2. Session 2. Interpreting the evidence

This session focussed on the evidence for the traditional games of the world—the artifacts, artistic representations, texts, and ethnographic observations that provide information about which ludemes were contained in a specific place and time. Identifying these can be a challenge, but they can provide not only the ludemes themselves but other information about specific games that can help guide the process of game reconstruction.

- W. Crist *Rules, Etiquette and Gameplay*: After introducing the conceptualization of evidence in our database, the discussion around identifying what are definitively rules and what are social practices, or etiquette, relating to games was discussed by archaeologist and project member Walter Crist. Because of the way that games are learned and taught verbally, and especially the way they are documented by anthropologists, all possible scenarios in these games which are allowed by the basic rules are not always documented or encountered. In practice, etiquette guides the way people play in these situations, as well as in the way that people play, which is in contrast to the way artificial intelligence agents play games.

- T. Depaulis *An Exploration of Pre-Columbian Andean Games*: This talk by games and cards historian Thierry Depaulis focused on some analysis of archaeological evidence from the Andes, a region where traditional games are not as well documented as other places. Documents from Spanish chron-

iclers as well as archaeological and ethnographic evidence was discussed to highlight some of the games that can be identified in this part of the world.

- J. Schmidt-Madsen *Beyond the Board: Experiential Analysis in Digital Archaeology*: Turning to South Asia, which has a wealth of evidence for board games throughout history, Jacob Schmidt-Madsen, a postdoctoral researcher and historian at the University of Copenhagen presented challenges and opportunities for computational games research. His talk brought up the fact that people play for different reasons, and that understanding these reasons and the social context of play can help to form expectations about gameplay in particular games.

1.3. Session 3. Ludii for education

This session focussed on educational uses of the Ludii system.

- E. Duggan *What has the Digital Ludeme Project Done For Us? From Where We Were to Where We Are*: Eddie Duggan, Senior Lecturer at the University of Suffolk, discussed the evolution of the Ludii software and of the DLP since the 1st DLP Workshop in 2019 (Browne et al. (2019)). He gave feedback on what is still missing in Ludii to make it more accessible to non-programmers, and the benefits of this software to various game-interest communities.

- M. Tibaldini *Using Ludii in the Classroom*: Marco Tibaldini, a historian at the Free University of Bozen-Bolzano, Italy, then presented a brief analysis of the Digital Ludeme Project and its pedagogical implications, followed by its potential in the classroom.

- F. Parlak *Teaching Historical Games with Ludii*: Fatih Parlak, Assistant Professor at the University of Cappadocia in Turkey, outlined the potential benefits of the data collected during the DLP for courses he teaches on games in cultural history. This included examples of interesting DLP games implemented in Ludii used as support for the students, and the use of Ludii for students to create their own games as their final project.

1.4. Session 4. Practical issues

The first day concluded with a session on practical concerns about to Ludii and the DLP in general.

- DKE MaRBLLe Students *A Visual Game Editor*: Three DKE students from the Maastricht Research Based Learning initiative (MaRBLLe) – Filipp Dokienko, Nikola Prianikov and Filip Rehburg – described their ongoing research project to implement a visual game editor for Ludii. This is designed to make the steep learning curve when first trying to implement games on the Ludii game description language more tractable. The results are promising and the visual game editor has now been incorporated into official Ludii releases.

- C. Browne and W. Crist *What Games Are We Missing?*: This brief talk introduced a question to the audience: What games should be included in the Digital Ludeme Project database, and which ones have not been added? It was an important question to ask, with a group of scholars with diverse expertise, and also to consider whether other types of strategy games, such as cards, dominoes, and dice, would be fruitful to compare to board games.

2. DAY 2: LUDII SOFTWARE

The second day focussed on aspects of the Ludii system and its use for modelling games.

2.1. Session 5. Introduction to Ludii

This session included an introductory demonstration of the Ludii software and its capabilities.

- E. Piette and M. Stephenson *Demo: Modelling, Playing and Evaluating Games with Ludii*: This talk provided explained how games are modelled within Ludii using the *ludemic* description approach, and demonstrated the wide variety of different types of games that are currently supported. Several other auxiliary features of Ludii were also shown, such as game evaluation, online network play, and AI move visualisations.

2.2. Session 6. Games

This session focussed on the games themselves and game-related research relevant to the DLP. What are the challenges for identifying games archaeologically? What can they do for education? What is the best way to model them digitally?

- V. Dasen and J. Gavin *Games of Abaci Reflecting on the Pente Grammai Structure*: Véronique Dasen and Jérôme Gavin from the Locus Ludii ERC project – which studies play in the Greco-Roman world – discussed an object type that has frequently been identified in the archaeological record as a board game but now appears to be an abacus. They illustrated how the abacus works and stressed that its secondary use as a game cannot be excluded.

- J. N. Silva *An Erasmus+ Project on Games for Education: 8 by 8*: This Erasmus+ project, run by Jorge Nuno Silva, a mathematician at the University of Lisbon, focused on the use of games in education for children. The project researched which games with perfect information were fit for this purpose, and created a manual for scholars and teachers who wish to use games for mathematics education.

- Y. Björnsson *Game Description Languages: The Good, the Bad, and the Ugly*: Yngvi Björnsson from Reykjavic University, Iceland, provided a comparative analysis of various general game languages, including the Stanford group's Game Description Language (GDL), the Ludii language and the Regular Board Game (RBG) grammar. Some strengths/limitations of these approaches were explored and the question raised: how declarative in nature should the ideal game description language be?

2.3. Session 7. Measuring games

This session explored ways to measure games with the Ludii system. This included game concepts, game metrics and concrete examples based on the strategic analysis of games.

- E. Piette *General Board Game Concepts*: DLP team member Éric Piette explained his design and implementation of Ludii's *game concepts* mechanism, which automatically detects hundreds of important concepts relevant to each Ludii game. These concepts are expressed in terms used by game players and designers, making them an interesting mechanism for providing human-understandable explanations and properties. This talk was based on work presented at last year's IEEE Conference on Games (CoG 2021) (Piette et al. (2021)).

- C. Browne *Game Metrics: Estimating Game Quality*: Cameron Browne described how to estimate the typicality, novelty and the quality of a game by computing various metrics. A typical game has a good length, is fair and not drawish. A more subtle estimate of game quality due to a game's estimated *skill trace* was proposed, based on trends observed in win rates between mismatched AI agents at

successively increasing search budgets. This work will be presented at this year's IEEE Conference on Games (CoG 2022).

- L. Rougetet and E. Piette *Analysing Math and Strategy in Games*: This collaboration between DLP team member Éric Piette and Lisa Rougetet, Associate Professor of Science History at the Université de Bretagne Occidentale, described the history, rules, and some mathematical and strategical analysis of the *Jeu Militaire*, the *Game of Dwarfs* and other (probably) related games. Éric showed that Ludii can automatically validate the analysis done by mathematicians of these games and can provide even more information and analysis of these games. This work is still in progress and is looking to establish relations between games through mathematics.

2.4. Session 8. Using Ludii

The day concluded with a session on effective use of the Ludii software from various perspectives and how it might be improved. This included feedback from game designers, AI researchers, historians, and members of the public.

- W. Engelkes *Debugging Ludii Games*: This talk was presented by Wijnand Engelkes, who has been assisting the DLP research team with game debugging since the start of 2020. Due to the large number of games that Ludii supports, there are often many unusual or edge case situations which either ourselves or the person who recorded the games rules didn't consider. Wijnand explained his methodology for systematically identifying and testing such cases, providing an approach that other game designers could follow when evaluating their own games or rules for potential issues.
- Round Table *What Can We Do With Ludii?*: This round table was conducted to further elaborate on the current functionality within Ludii, and what additional functions could be useful in the future. Tiago Hirth suggested that the ability to support a unified move format for puzzles. Thierry Depaulis suggested the ability to automatically categorise games based on their detected concepts.
- Hands-on Practice with Ludii: This tutorial was aimed to help participants create games in Ludii. Exercises involved writing a Ludii *.lud description for Tic-Tac-Toe from scratch, converting this into a description for Breakthrough, then finally into a more complex description for Amazons.

3. DAY 3: RECONSTRUCTING GAMES WITH LUDII

The third day combined historical/cultural and technical aspects of the DLP to explore the reconstruction of incomplete rulesets for historical games using Ludii.

3.1. Session 9. Case studies

This session involved a discussion of various approaches to historical and traditional games, and some of the challenges of reconstructing ancient games, both from a conceptual and a technical perspective. The session as a whole set the stage for the entire day, whose theme was on the methods and issues relating to game reconstruction.

- T. Hirth and L. Rougetet *Tackling Recreational Mathematics Puzzles and their History*: Tiago Hirth, a PhD Candidate at the University of Lisbon, described several types of puzzle that might be suitable for implementation and analysis in Ludii. These included classic puzzles such as Chess board dissections and matchstick puzzles to more contemporary designs.

- W. Crist *Reconstructing Games - Difficulty of Measuring Them* This talk challenged some of the assumptions about the metrics that can be generated for board games by the Ludii software and challenged modern Western expectations for what makes a “good” game. In different times and places, the experience of time was different from what it is in the post-Industrial West, and so games often progress for a much longer time than is expected. Furthermore, some games appear to be designed to favor one player over another, perhaps to give one player more of a challenge, or to allow players of different skill levels to both have a chance at winning. It was suggested that obtaining values for these metrics is merely the first step, further investigation into the variation of behavior across time and space is required to learn what to expect from these metrics.
- U. Schädler *Experience with Reconstructing Games*: Ulrich Schädler, Director of the Swiss Museum of Games, described several examples from his extensive experience with game reconstruction from historical sources. He proposed that the genealogy of ludemes may be compared to the genealogy of ancient manuscripts, emphasised the difficulty of reconstructing games from partial information, and the dangers of making assumptions about what aspects of play and games ancient players may or may not have valued.

3.2. Session 10. Reconstruction methods

This session explored technical aspects of game reconstruction: how to describe reconstructions in the Ludii language, how to situate reconstructions them historically and culturally, and a case study of analysing a locally found “game board” artefact.

- C. Browne *Reconstruction Syntax* Logical descriptions of games for computer play must be very precise, as any ambiguity in any aspect of the description can significantly change the character of the game when it is played. This presents a particular problem when describing partially known rulesets for computer play. The solution taken in the DLP is to provide a *reconstruction syntax* in the Ludii language that allows the author to specify preferred rule choices at certain *completion points* in the game description, which may include enumerations over compatible rule fragments from known rulesets of other games from a similar historical/cultural context. The result is to provide a range of complete game descriptions that match the specified design restrictions.
- M. Stephenson *Game Distance and Cultural Social Network* This talk presented two different ways to measure the distance between games, based on specific gameplay and cultural properties they possess. The gameplay distance between games can be calculated based on the ludemes concepts and/or metrics for each game, while the cultural distance is approximated using a cultural social network. This cultural social network was created based on data provided by the organisation Geacron and can be used to calculate the distance between games based on their associated geo-temporal evidence. Both of these distance measures can be used for reconstruction purposes, by allowing us to find games with a low distance that may provide likely candidate rulesets.
- W. Crist *The Thermenmuseum Game: Oldest Board Game in the Netherlands?* One of the innovative test cases for the DLP is to examine an artifact in the Thermenmuseum in Heerlen, Netherlands. The object is labeled as a game, but shows a pattern not known on any other traditional game. Nevertheless, the stone itself shows use-wear which could be indicative of use as a game. Preliminary research showed promise for identifying playable rules for this board.

3.3. Session 11. Player modelling

This session included talks on several topics related to AI in Ludii, but not focused on topics such as optimising playing strength which are more commonly considered in AI research.

- C. Browne *Human-Level and Human-Like AI*: In this talk, Cameron Browne explored differences between how humans and AI “experience” games and gameplay, and how this may relate to the challenges of developing human-level and human-like AI players. For example, humans often enjoy games more if they have a range of different tactics and strategies, at various skill levels. Some games, for example ones that involve a substantial amount of arithmetic in their rules, can be significantly easier for AI to understand and play than for humans. For the research goals of DLP, the development of human-like as well as human-level AI is of more interest than the development of superhuman AI.
- W. Crist and D. Soemers *AI for Reconstruction Purposes*: DLP members Walter Crist and Dennis Soemers discussed some preliminary research on game reconstruction using Ludii, which was focused on the Roman game of Ludus Latrunculorum. Rules from similar games were applied to Roman boards of various sizes, and challenges in choosing AI agents that could play the resulting rulesets were highlighted. Ultimately, the research concluded that some of the boards were likely not used for this game.
- D. Soemers and É. Piette *Teaching with Ludii*: Dennis Soemers and Éric Piette discussed how Ludii was used for education in the Intelligent Search & Games course of the Master AI program at Maastricht University’s Department of Advanced Computing Sciences in 2021. Over the duration of the course, students are required to develop an agent to play a particular two-player zero-sum game, which must at least include an $\alpha\beta$ -search engine. In this year, for the first time, students could opt to implement the game in Ludii and write agents based on Ludii’s API for AI development, as an alternative to implementing the game and agent from scratch. The talk explored the advantages and disadvantages of using Ludii like this in education.

3.4. Session 12. Defining “DLP games”

This session addressed the questions asked of participants on the first day: What games should we include? After two days of presentations about the goals and content of the project, they were ready with many insights.

- Open Discussion *Guidelines for Including Games in the Study*: This session began with a quick review of the criteria for including games in our study, to introduce the round table discussion which followed. It was reiterated that the database contains traditional board games for which a piece of evidence can be identified to document a ludeme in a place and time.
- Round Table Discussion *Identifying the 1,000 Most Important Games*: The Round Table discussion focused on which games should be included in the Digital Ludeme Project. It did not concentrate as much on specific games, but the discussion mainly revolved around whether it would make conceptual sense to include card games, domino games, and dice games with our analysis of board games, in case any of these could have influenced the ludemes used for board games. The very interesting discussion ended with the conclusion that card games are a separate phenomenon for board games, at least for traditional games, because board games involve movement through space, whereas card games involve making combinations or cards and have no spatial element. Domino games are historically and effectively the same as card games, so the workshop members agreed that card and domino games would not be included. Dice games, however, could overlap with board games because the

dice combinations could inform us about the values of dice in ancient games, so their inclusion was kept open.

4. DAY 4: GAME AI IN LUDII

The fourth day of the Workshop involved talks and discussions on the AI methods used to play and evaluate games in Ludii.

4.1. Session 13. Game AI for General Game Playing (GGP)

The first session of the day included two talks about the development of AI for *General Game Playing* (GGP).

- D. Soemers *Game AI in Ludii*: In this talk, Dennis Soemers discussed how game-playing AI approaches can be developed for Ludii. This included an explanation of the API for AI development in Ludii, but also a more broad discussion of the design of game, state, and action representations in Ludii, how these designs are motivated by various research goals in DLP and GGP, and how they influenced various design choices for the API for AI development in Ludii.
- T. Cazenave *Gold Medals at the 24th Olympiads and General Approach*: Tristan Cazenave and Quentin Cohen-Solal discussed their general *descent* algorithm (Cohen-Solal (2020); Cohen-Solal and Cazenave (2021)), which won many gold medals in many different games at the 24th Computer Olympiad (Iida et al. (2022)). In contrast to the well-known AlphaZero (Silver et al. (2018)) line of work, this program uses a best-first variant of minimax search, rather than MCTS (Kocsis and Szepesvári (2006); Coulom (2007); Browne et al. (2012)), as the search engine. It only learns a (based on deep learning) value function, but no longer needs to learn a policy.

4.2. Session 14. Practical game AI

This session included three talks about practical issues in relevant game AI research.

- H. Wang *Warm-Start MCTS in AlphaZero-like Deep Reinforcement Learning*: In the first talk of this session, Hui Wang discussed his work on warm-start enhancements for MCTS in AlphaZero-like self-play (Wang et al. (2020, 2021)). The key idea is that, at the very beginning of training, an untrained value network produces essentially random value predictions, and this can be easily improved using other value estimators such as random rollouts or RAVE (Gelly and Silver (2007)) values.
- D. Soemers *Spatial State-Action Features for General Games*: Dennis Soemers described his work on using spatial state-action features (Soemers et al. (2022)) for guiding MCTS-based agents in many of the games implemented in Ludii. These features are generally local features that test for particular patterns or configurations of pieces in the neighbourhood of an action, and can be trained to recognise typically “good” and “bad” actions in many games. Even though this approach may be viewed as using a substantial amount of domain knowledge, it has a general level of applicability in the sense that it is applicable to a substantial portion of the many (board) games implemented in Ludii. In practice, spatial reasoning is relevant in many of the board games played by humanity.
- É. Piette *Ludii AI Competition*: In the final talk of this session, Éric Piette explained the organisation of the Ludii GGP AI Competition, to be run as three tracks in July 2022. In the (GGP) track, entrants are expected to submit agents that will be required to play a selection of different games that are

not known in advance. In the (Learning) track, entries are expected to play several different games that have been announced several months prior, which allows for extensive training time. Finally, in the third (Kilothon) track, entrants will submit agents that play *more than 1,000* different games in Ludii against a simple UCT-based baseline AI. €9,000 prize money for the event has been arranged by Tristan Cazenave.

4.3. Session 15. Unified AI for GGP

The final session of the day involved discussions on new approaches for game AI facilitated by Ludii and the DLP, and the possibility of unifying the various current AI approaches for GGP into a single unified approach. These discussions were led by DLP team members and game AI experts including Yngvi Bjornsson, Tristan Cazenave, Hui Wang and Mark Winands.

- **Round Table *New AI Approaches for Ludii*:** This round table was focused on different new possible AI approaches using the Ludii General System. This included, but was not limited to, using the important amount of game data that Ludii can generate to create portfolio approaches, how to unify all game AI techniques, and the potential of recent new AI techniques using deep learning for Ludii.
- **Open Discussion *AI, GGP and General AI*:** New research opportunities and challenges for General Game Playing were discussed. For example, exploiting game concepts and spatial state-action features in different AI techniques, extending Ludii to card games, and new GGP competitions.

5. REFLECTIONS

The Workshop succeeded in its aims of bringing together leading experts in the various research fields relevant to the DLP and fostering open discussion between them. The common ground among all participants was a shared interest in games, from various aspects. Many open questions regarding research directions for the DLP were addressed, some answered, and new questions raised.

A key outcome of the Workshop was to more clearly define the boundary of which games to include in the study as “DLP Games” and to help formulate guidelines for deciding whether a given game should be included or not. This has inspired work towards an upcoming “DLP Manifesto”.

Several new uses for and applications of Ludii were suggested throughout the Workshop, which also helped solidify the fledgeling research field of Digital Archaeoludology.

Most of the presentations are available through the Workshop schedule here: <https://ludii.games/schedule.pdf>.

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