

## **A GAME THEORY BASED INFORMATION AND DECISION SUPPORT SYSTEM: THE DIGITALIZATION OF RAPOPORT'S TAXONOMY ON 2X2 GAMES**

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### **Abstract**

Due to the increased interconnectedness of systems and sub-systems, decision-making is getting complex. Although decision-makers act rationally, set decisions can lead to irrational results, resulting in lose-lose relationships in the worst. While Operations Research imposes a mathematical structure to decision-making, and Artificial Intelligence is based on heuristics, the Theory of Games promises a fruitful approach to reach the decision-makers aspiration level: systemic collaboration in the pursuit of rational behavior and self-interest of the opponents. Within this paper, a game theory-based information and decision support system is presented and demonstrated. This socio-technical artifact makes use of the research of Anatol Rapoport and its co-authors. To the current state, the artifact can analyze and evaluate 576 interactive situations (games, wherein two actors choose between two strategies (2x2)), represented in 78 payoff sets. Extending the current version from strict ordinal games to ordinal games, the artifact can analyze and evaluate 5.625 games, represented in 732 payoff sets.

### **Keywords**

Game theory, taxonomy, information system, decision support, trivial systems

### **Introduction**

Entrepreneurs are tasked to allocate scarce resources, with the aim of maximizing the difference between revenues and expenditures. Maximizing profits is a focal concern of business and economics (Simon, 1996) and guarantees organizational profitability and resilience as well as economic survivability, thus the system's long term sustainability. Rationality plays a key role, especially in the field of social sciences (i.e., where business and economics belong), represented best in the pursuit of self-interest (i.e., Smith (2005)): it is about rational choices in order to maximize the expected utility of a social interaction/transaction. Rational choices as the pursuit of self-interest and individual behavior (Samuelson, 2016) are linked to information and decision-making, achieving arbitrage effects on the non-informed opponent (Kirzner, 1997). Social systems, such as business, economics and its interactions thus are a net of relationships and related operations and mechanisms (Willke, 2000) wherein social interaction in form of bargains, negotiations, cooperations, conflicts, envy, resentment, etc. occur. Due to the increased interconnectedness of entrepreneurs and economic actors, decision-making is getting more and more complex. Decisions can lead to irrational results, resulting in lose-lose relationships in the worst. There is a need to reduce, transform and regulate complexity and make the operations and social mechanisms resilient.

Simon (1996) discusses the use of Operations Research and/or Artificial Intelligence as supporting tools towards decisions to interact with the system's outer environment and its relations: to other systems and subsystems, to the overall system, as well as in combination with focality (Willke, 2000). The use of Operations Research imposes a strong mathematical structure. It provides algorithms, as Simon (1996) highlights, expressed in linear programming, integer programming, queuing theory, and linear decision rules. Artificial Intelligence in turn is based on heuristics and proposes decisions that satisfy. Artificial Intelligence, as Simon (1996) highlights, provides a powerful tool for problem-solving and decision-

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making, but the solution does not represent the optima: they are just “good enough”. Entrepreneurs must choose between solutions no matter if they correspond to their aspiration level or not.

We go beyond Operations Research and Artificial Intelligence as decision support. We make use of Game Theory (in relation to Aumann (1987): an Interactive Decision Theory) as an epistemological tool for rational decision making in pursuing self-interest and of personal values against other individuals (Harsanyi, 1977). Game Theory, as defined by the Stanford Encyclopaedia of Philosophy (Hankins & Vanderschraaf, 2021), is about the study of interdependent choice and action: how the choices and decisions of a rational actor depend on the choices of other actors. Game Theory was first announced by John v. Neumann in 1928<sup>1</sup> and established as a scientific discipline latest by the publication of the book “Theory of Games and Economic Behavior“ (v. Neumann & Morgenstern, 1944). Since then, the scientific discipline of Game Theory has experienced contributions from various fields of academia, such as mathematics, politics, economics, organizational behavior, psychology, peace research, etc. It is applied to the fields of economics, political sciences (national, and international), military problems, evolutionary biology, computer sciences (Aumann, 1987). Well-known researchers within the discipline of Game Theory were honored with the Noble prize, all ahead John Nash (1950a, 1950b) for introducing the world-famous Nash equilibrium.

As Samuelson (2016) highlights, Game Theory is a standard tool in economics nowadays. It contains a “bag” of analytical tools to understand the phenomena that can be observe when decision-makers act (Osborne & Rubinstein, 1994). Within this paper, we consider Game Theory as a normative (prescriptive) decision theory (i.e., Harsanyi (1977), Rapoport (1985); rather than a positive (descriptive) theory). Every decision revolves around rationality and utility and, in accordance to Rapoport (1985), it purports to prescribe how an actor is to choose among a set of strategies if utilities can be assigned and the actor is rational. Taking over this perspective, Game Theory than, according to Simon (1996), deals with the task on advising economic actors on **how to** [maximize profits] or, as Rapoport (1985) presents in more general: **how to** act in order to promote self-interests most effectively. Game Theory becomes what Foerster (1993) announces as a trivial system: by a chosen input (i.e., a strict ordinal rating of utility and a rational decision towards self-interest), the system's structures and functions (Baraldi et al., 2021) “produces” a predictable output. Game Theory then, as we hypothesize, operates according to a fixed set of rules which are unchangeable. It then contributes to a positive social sciences and support to predict and to explain real-life human behavior in various social situations (Harsanyi, 1977).

Considering Game Theory as a normative decision theory motivates us to progress development in the field and to contribute with the digital transformation and digital materialization of knowledge in an allopoietic system – a technical system that support social interactions (Willke, 2000). In the center of this paper is the conceptualization, design and development of a Game Theory based Information and Decision Support System that supports rational decision making in economic context as well as the demonstration of its material existence (Gregor & Hevner, 2013). The artifact draws from existing theories and knowledge – especially from Rapoport & Guyer (1966), Rapoport et al. (1976), and Rapoport (1985). The guiding research question is about “**How a Game Theory based Information and Decision Support System can look like**”.

We combine the academic discipline of Game Theory with the academic discipline of Information Systems. In designing and developing of the artifact, we make use of Design Science Research (DSR; i.e., Hevner et al. (2004), Peffers et al. (2008), Österle et al. (2010) ...). DSR, a main research methodology in Information Systems. It involves a rigorous process to the design and development of socio-technical artifacts. These are, for example, constructs, models, methods, and instantiations (Hevner et al., 2004) as well as Peffers et

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<sup>1</sup> Ernst Zermelo in 1913 (in reference to: Bonanno (2015))

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al. (2008) cite, new properties of technical, social, or informational resources (Järvinen, 2007) and social innovation (Aken, 2004), that intend to solve (identified and/or observed) organizational problems.

From the perspective of a design-oriented Information System Research, our research contributes to level 1: the situated implementation of an instantiation: describing, presenting, and demonstrating an operational software artifact (Gregor & Hevner, 2013). To respond to the set research question, we adopt the Design Science Research Methodology Process Model of Peffers' et al. (2008). This process model consists of the six process steps of problem identification, solution objectives definition, design and development, demonstration, evaluation, and communication [*of the artifact*].

The process steps are applied in the section of this paper. Section 1 introduces the research problem identified and provides the research motivation as well as the research question. In addition, section 1 justifies the value of the artifact and defines the audience of the paper. Section 2 is about the description about how the artifact is expected to support solutions to the research problem. It investigates into the body of knowledge from practice and theory. Within section 3, the artifact is created. This section presents the artifact's architecture and functionality. In section 4, the use of the artifact is demonstrated and evaluated in section 5. This evaluation depends on the metrics of ISO/IEC 25010 - an international standard on Systems and Software Engineering provided by the International Organization for Standardization (2023). Section 5 concludes the paper and communicates the utility and novelty of the artifact on Game Theory based Information and Decision Support System.

In accordance to Cooper (1985, 1988), the audience of this paper are specialized researchers in (general) systems theory, game theory, and information systems theory. However, the audience of the artifacts are researchers, practitioners, policy makers and the public.

### Design and development: building and presenting the artifact

This section presents the design and development of the artifact on Game Theory based Information and Decision Support System. In accordance to Peffers et al. (2008), the first sub-section investigates into existing theories and knowledge on taxonomies on 2x2 games with the aim to draw the operational logic of the artifact. The second sub-section provides the technical background of the artifact. The third sub-section presents the artifact: its naming, access, and operational functionalities.

### Operational logic of the artifact: narrative literature on taxonomies of 2x2 games

Game Theory, as Rubinstein (2012) argues, is a collection of models of rational decision-making in interactive situations. It provides methods “to analyze strategic and rational patterns of human thought” (Rubinstein, 2012), presented in abstract representations of classes of real-life situations. A representation – an interactive decision problem: a game (Aumann, 1987) – consists of at least two rational actors (opponents) that interact and compete among a (common) resource. The actors' arraign an individually well-defined objective, its decisions affect each other (Aumann, 1987). Especially in social science, two-person-nonzero-sum games are the really important parts of game theory (Harsanyi, 1977).

**Exhibit 1.** Payoff matrix  
(own presentation; adopted from: Rapoport & Guyer (1966)).

Opponents		Actor 2	
		Strategies	
Actor 1	A1	a(1) a(2)	b(1) b(2)
	B1	c(1) c(2)	d(1) d(2)

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To achieve the individual objective, as depicted in Exhibit 1, the two actors can choose between two strategies. As exemplified in Exhibit 1, actor 1 can choose between strategy A1 or B1; actor 2 can choose between strategy A2 or B2. Their decision results in at least four possible payoffs, represented in the payoff matrix. The selection of a strategy is driven by the actors' expected rational behavior and their pursuit of self-interest. The analysis of rational behavior in game situations, as Harsanyi (1977) highlights, is the task of game theory. This, as Aumann (1987) highlights, also underscores the 'cold' and calculating nature of a game and its analysis towards practical behavior. Games can result in win-win, win-lose, lose-win, or lose-lose relationships.

In narratively reviewing the literature on Game Theory, we were able to identify Rapoport's & Guyer's (1966) and Rapoport's et al. (1976) taxonomy of 2x2 games. In their research on Game Theory, these authors present a taxonomy of 2x2 games where two actors chose between two strategies. In a strict ordinal rating of the utilities by the opponents, the taxonomy provides 576 ( $= 4! \times 4!$ ) games: interactive situations of no conflict, interactive situations with no equilibria, stable equilibria, unstable equilibria, force-vulnerable equilibria, threat-vulnerable equilibria and interactive situations with two equilibria, as well as the world-famous Prisoners' Dilemma. Since some games are identical, the taxonomy can be reduced to 66 payoff sets, generating eight equivalent payoff sets and 12 payoff sets, generating four equivalent payoff sets ( $576 \text{ games} = 66 \times 8 + 12 \times 4$ ).

**Exhibit 2.** Payoff sets and number of arrays  
(own presentation; adopted from: Guyer & Hamburger (1968).

Game	Payoff set(s)		Number of corresponding payoff arrays
	Original	Further illustrations	
Strict ordinal	a, b, c, d	b, c, d, a, ...	24 (= 4!)
Ordinal	a, a, c, d	b, b, c, d, ...	12 (= 4! / 2!)
	a, c, c, d	b, c, c, d, ...	12 (= 4! / 2!)
	a, c, d, d	b, c, d, d, ...	12 (= 4! / 2!)
	a, a, d, d	b, b, d, d, ...	6 (= 4! / 2! / 2!)*
	a, a, a, d	b, b, b, d, ...	4 (= 4! / 3!)
	a, d, d, d	b, d, d, d, ...	4 (= 4! / 3!)
	d, d, d, d	a, a, a, a, ...	1 (= 4! / 4!)
	<b>Total</b>		

As presented in Exhibit 2, Guyer & Hamburger (1968) extend the taxonomy from strict ordinal order of utilities to ordinal order of utilities. This extends the taxonomy of 2x2 games to 732 payoff sets, resulting in 6.525 different 2x2 games. The extended taxonomy captures all conceivable payoffs of 2x2 games as well as all classical games and nonclassical games. Harsanyi (1977), for example, is convinced that nonclassical games will have many important applications in the field of social sciences.

We identified and studied a couple of further extensions and adaptations of the taxonomy on 2x2 games, such as provided by Harris (1969), Harris (1972), Kilgour (1974), Kalevar (1975), Brams (1977), Kilgour & Fraser (1988), Robinson & Goforth (2005), etc. However, these extensions and adaptations have little or no impact on the conceptualization, design, and development of the artifact yet. It is highly possible that we fall back on this knowledge once the first version of the artifact is established, justified and validated. The information and knowledge captured in Rapoport & Guyer (1966), Guyer & Hamburger (1968), and Rapoport et al. (1976) act as solid foundation for the technical implementation of the artifact for now.

### Technical background of the artifact: IT infrastructure and software development environment

As Österle et al. (2010) highlight, socio-technical systems involve a huge number of factors and variables. This sub-section presents the factors and variables from a technical perspective and background. It presents the artifact's IT infrastructure and software development environment.

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**Cloud server technology:** the implementation of the artifact is based on a cloud server, a virtual machine hosted “somewhere” in the world. Cloud server technology moves away from the “traditional” server-client infrastructure and makes the resources accessible to users remotely over the internet. The service is rented from a cloud service provider, which also can include the rent of (virtual) machines, databases, storage space, networks, web servers, development tools, etc. The use of cloud server technology guarantees 24 hours, 7 days per week accessibility, availability, and reliability to the artifact. In addition, cloud server technology enables to store information without having to develop, manage, and manage physical devices. Furthermore, cloud server technology allows scalability. Its resources can be easily adjusted to the demand, i.e., by varying processors and memory resources. Further advantages, such as ease of use concept (an administrator can connect other services to the server in a matter of minutes), globalization (i.e., multiple cloud servers at different locations that synchronize), enhanced collaboration (between designers and developers globally), disaster recoverability (i.e., data backups, data replication, failover capabilities), and processing power/high performance computing can be announced. In addition, Cloud services allow us to dynamically customize the services needed (offering, using, and billing of IT services) to run the artifact. In using cloud technology, engineers can shift full concentration on the core – the development of the artifact.

**Webhosting and Domain Name System:** the artifact makes use of a webhosting package composed of the domain and e-mail. The domain is about the accessibility of the artifact on the internet: [www.decisionsupport.at](http://www.decisionsupport.at) (access: 28<sup>th</sup> April 2025, full functionality), and an e-mail service to communicate with the users and stakeholders of the artifact. The domain name system (DNS) is an important part of the internet: it enables the user to reach the artifact without recognizing numeric or alpha-numeric IP addresses. DNS servers translate name requests into IP addresses and thereby control which server an end user reaches. A DNS makes a server to be accessible on the public internet. By entering the domain name “decisionsupport.at” into the command bar of the internet browser, the user can make use of the artifact. This domain can also comprise one or several subordinate domains, such as “anatol.decisionsupport.at” (or other names/sub-domains).

**Software development environment:** the artifact bases on NextJS with PayloadCMS as backend. NextJS is a React framework and is used to build SEO-friendly, high-performance full-stack web applications (i.e., [nextjs.org](https://nextjs.org), Copes (2024)). the artifact is developed on React Native. It is a JavaScript based mobile app framework and allows to design and develop mobile applications. To save the data, a MongoDB database is used. MongoDB is a document-oriented, non-relational, NoSQL database. It stores data in BSON, a type of JSON format: it stores data in flexible documents, keeping all of the related data together.

The artifact's operational logic is transformed into an algorithm. By making use of GitHub, the algorithm is stored in Git. While Git is a free and open-source tool for version control systems for small to very large projects (i.e., it automatically detects changes in the artifact's code and (re-) builds the artifact), GitHub is a web-based, proprietary developer platform and hosting service. GitHub enables IT-engineers to manage code repositories/doing source code management in real time, follow up track changes, and collaborate on the code/algorithm development.

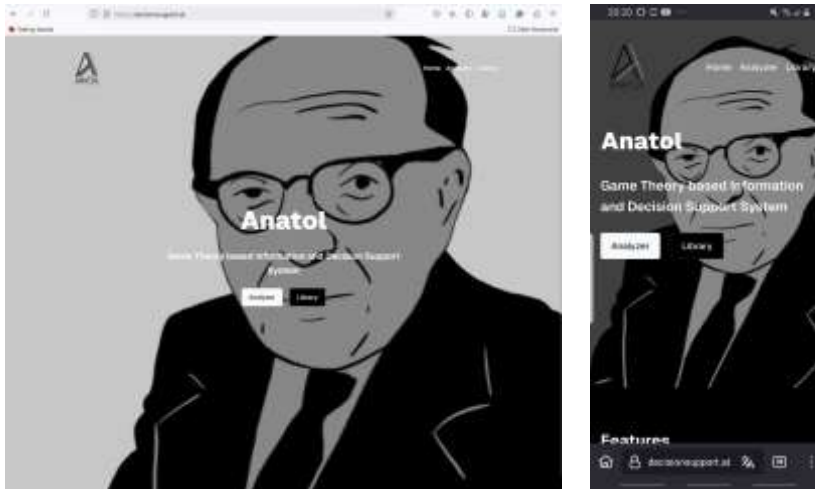
### **Presentation and demonstration of the artifact: naming, access, functionalities**

This sub-section presents the artifact designed and developed. In venerable memory of the innovator of the taxonomy of 2x2 game, Anatol Rapoport (*\*May 22, 1911 – †January 20, 2007*), we entitled the artifact Anatol – Game Theory based Information and Support System. Rapoport is a systems scientist, game theorist, mathematician, social psychologist, and peace researcher. He is considered a pioneer in the field of the analysis of social networks. But also, Rapoport is inextricably linked to Game Theory and experimental Game Theory, especially the Prisoner's Dilemma Game: the conflict between individual rationality and collective rationality as well as the “Tit-for-Tat” strategy (Axelrod, 1984). He was one of

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the first to recognize the importance of merging Game Theory (*theory of strategic action and decision making*) and Systems Theory (*theory of the properties of complex structures*) for a better understanding of natural processes and social interactions.

**Exhibit 3.** Homepage of the artifact  
(left hand side: desktop application; right hand side: mobile application)  
(available under: [www.decisionsupport.at](http://www.decisionsupport.at); accessed: 25<sup>th</sup> April 2025)

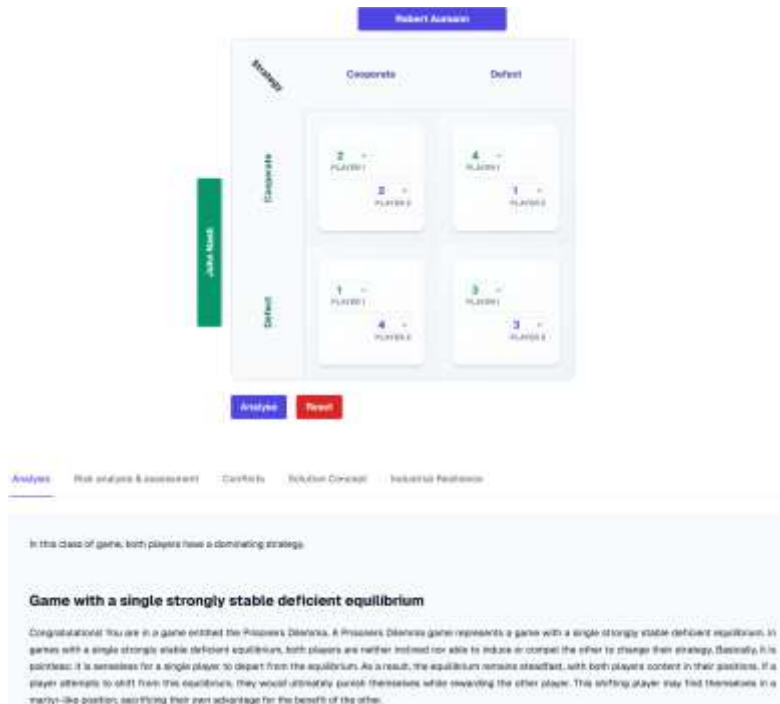


In the current version of the artifact, as presented in Exhibit 3, the user can make use of the functions “Analyze” and “Library”. The analyzer is about the analysis and evaluation of an interactive situation: a game. It is composed of dynamic elements and enables the user to individualize its request. By making use of this function, the user is (t)asked to provide mandatory and voluntary information about the situation. The information are:

- According to the operational logic, the artifact is separated into strict ordinal games and ordinal games. The **game type** (mandatory) defines the game as a strict ordinal game, or an ordinal game. By choosing a strict ordinal game, the user needs to assign unique values by force to a utility in the payoff matrix. By choosing an ordinal game, the values can occur several times in the payoff matrix. Utils can be empty or can also appear twice or more than once.
- The **game title** (voluntary), capturing a first introduction of the interactive situation.
- The **description of the game** (voluntary), providing information about the interactive situation, i.e., the initial situation, the point of contention, possible strategies and payoff functions, etc.
- The **name of the actors** (voluntary, default value: player 1, player 2, which can be replaced with real names)
- The **strategies of the actors** (voluntary, default value: cooperate, defect, which can be replaced with real naming of the strategies)
- The **evaluation of the utility** (mandatory; unique values in case of a strict ordinal game (1-4); multiple selection of identical values possible in case of an ordinal game)

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**Exhibit 4.** Game board: analysis and evaluation of an interactive situation/game (available under: [www.decisionsupport.at/gameboard](http://www.decisionsupport.at/gameboard); accessed: 25<sup>th</sup> April 2025)



Once all (*mandatory*) parameters are set, the user can make use of the analysis function. After pressing/clicking on the analysis button, as presented in Exhibit 4, the artifact analyzes and evaluates the parameters set in the game. As a result, it presents the results of the game, categorized in Analysis, Solution Concepts, Conflicts, Risk Analysis & Assessment, and Sustainability & Resilience.

- The section Analysis is based on Rapoport's & Guyer's (1966) taxonomy of 2x2 games. The artifact presents a general description of the game played.
- In the section Solution Concepts possible solution concepts for the game get presented. The solution concepts are about stability (Nash equilibrium), security (v. Neumann & Morgenstern), efficiency (Pareto-optimum), and risk/venture. Further concepts are the dominant strategy and dominating strategy.
- The section Conflicts presents possible conflicts that can arise in the game.
- The section Industrial Resilience is aimed at announcing strategies and activities for a system to become resilient. This section is based on Maurer (2020) and makes use of the Strategic Management Framework for Engineering of Robustness and Resilience (SMFRR).

The library presents the second function of the artifact. In this section, the user can make use of general information and knowledge about Game Theory, including the name giver, famous games, archetypes of a game, solution concepts, sustainability and resilience.

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## Exhibit 5. Library

(available under: [www.decisionsupport.at/posts](http://www.decisionsupport.at/posts); accessed: 25<sup>th</sup> April 2025)



As presented in Exhibit 5, the library is composed of the section industrial resilience, famous games, characters, and solution concepts. These sections aim to provide additional information about how to increase robustness and resilience in systems (i.e., by making use of the Strategic Management Framework for Engineering of Robustness and Resilience (SMFRR; Maurer (2020)), introduce and present Famous Games (i.e., the Prisoners Dilemma as presented in Exhibit 4), Characters (of an actors; based on: Rapoport (1967)) and Solution Concepts, presenting famous solution concepts to a given interactive situation (i.e., Nash equilibrium, mini-max, etc.).

A function for GDPR and data protection is not installed yet. However, up to date, the artifact has not collected any data or information about the user and/or his/her requests. The artifact is elaborated to analyze interactive situations as described above.

## Evaluation

This section presents the evaluation of the artifact. Doing so, a comparative analysis have been conducted as well as, in relations the ISO/IEC 25010 (2023), an international standard on Systems and Software engineering – Systems and Software Quality Requirements and Evaluation (SQuaRE) – Product quality model, and individual review have been conducted.

In a narrative review and analysis of same or similar artifacts, we investigated into the homepage of the Game Theory Society, which announces 13 tools, and the homepage of [gametheory.online](http://gametheory.online), which announces six tools. 18 tools could be identified and underwent a careful review. Taken together, we were able to identify and classify four tools as Decision Support Tool that make use of or are related to Game Theory. These tools are Abed (Izquierdo et al., 2019) and its extensions: Evo-Dyn-3s and Evoplex (Izquierdo et al., 2018). Abed, Evo-Dyn-3s, and Evoplex are interrelated tools of mathematical scope. These tools provide a modeling framework to simulate the evolution of a population of agents who play a symmetric 2-player game and its graphical-mathematical presentation. The fourth tool identified is the Game Theory Explorer (Avis et al., 2010). The Game Theory Explorer is conceptualized to solve bimatrix games. Furthermore, we could identify Gambit (i.e., McKelvey et al. (2002), Savani & Turocy (2023)) and the Game Theory Explorer (lastly updated: 2016) as tools with the scope of modelling of games. Gambit, as highlighted on the tool's homepage, provides a collection of tools for doing computation in game theory. The Game Theory Explorer provides, according to the homepage, web-based software for the interactive creation and equilibrium analysis of games in extensive and strategic form. Irslib, PDToolbox, and TUGlab are identified as possible extensions to existing tools. They are software packages (C implementation, matlab implementation) about evolutionary dynamics from game theory, scripts that could serve as a complement to the books and other materials used in introductory courses on cooperative game theory, and/or implementation of the reverse search algorithm for vertex enumeration/convex hull problems. Z-Tree, oTree, and nodeGame are classified as tools for doing experiments. formr and Coiceflow are

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questionnaire-based survey tools. GamePlan and iOS Apps for Game Theoretic Concepts are not maintained anymore and lead to bad gateways. To make use of the tools, the user needs a strong mathematical and/or IT/software engineering background. The tools are not applicable for entrepreneurs and managers, or not self-explaining and/or user-friendly. They lack ease in applicability and functional suitability.

**Exhibit 6.** Individual review of the artifact

Sections	Definition provided by ISO/IEC 25010 (2023)	Evaluation <sup>2</sup>
<b>Functional Suitability</b>	... to provide functions that meet stated and implied needs of intended users when it is used under specified conditions; composed of: functional completeness, functional correctness, functional appropriateness	<b>The artifact provides expected functions;</b> the functions provide the promise and contribute to the users satisfaction and service experience; the user can analyze a games and get information about the game, its parameters, solution concepts, etc.; the artifact responds to “ <b>how to act ...</b> ” and provides different solution concepts that respect the aspiration levels of the user: stability, security, efficiency, risk/venture, reciprocity
<b>Performance Efficiency</b>	... perform functions within specified time and throughput parameters; composed of: time behavior, resource utilization, capacity	<b>The artifact keeps promises;</b> analysis of the game played by the users takes place in a matter of milli-seconds; however, the broad mass of users is missing yet
<b>Compatibility</b>	... to exchange information with other products, and/or to perform its required functions; composed of: co-existence, interoperability	<b>Not applicable (yet);</b> concentration of the core service of the artifact; no use case known yet
<b>Interaction Capability</b>	... interaction with specified users to exchange information; composed of: appropriateness recognizability, learnability, operability, user error protection, user engagement, inclusivity, user assistance	<b>The artifact's interaction capability is limited;</b> the user can chose between strict ordinal, ordinal, and cardinal games; insert the name of the game and provide a game description; in addition, the user can insert the players' names and their expectations; by clicking on button analyze, the user get information about the value of the game, including additional information about solution concepts, industrial resilience, etc.; no further interaction
<b>Reliability</b>	... to perform specified functions under specified conditions for a specified period of time without interruptions and failures; composed of: faultlessness, availability, fault tolerance, recoverability	<b>Artifact is running on a cloud server</b> that guarantees 24*7 availability; the artifact provides reliable and faultlessness results
<b>Security</b>	... protect information and data so that persons or other products have the degree of data access appropriate to their types and levels of authorization, and to defend against attack patterns by malicious actors; composed of: confidentiality, integrity, non-repudiation, accountability, authenticity, resistance	<b>Not applicable (yet);</b> although users are able to interact with the artifact, no information and data, incl. cookies, etc. get stored; the user is consumer of the artifact only – no co-creator
<b>Maintainability</b>	... modifications by the intended maintainers with effectiveness and efficiency; composed of: modularity, reusability, analyzability, modifyability, testability, flexibility	<b>Not applicable (yet);</b> artifact at a minimum viable product state; technology readiness level between basic technology research and research to prove feasibility

<sup>2</sup> Self-evaluation by the authors of the paper

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<b>Flexibility</b>	... adaptable to changes in requirements, contexts of use, or system environment; composed of: adaptability, scalability, installability, replaceability	<b>Artifact is adaptable for several extensions;</b> possible extensions are the inclusion of Evolutionary Game Theory (Smith, 1982) (i.e. Falcon-Dove Game), the Newcomb's Problem (Campbell & Sowden, 1985), and Prospect Theory (Kahneman & Tversky, 1979); scalability through sub-domains possible; no installment needed (cloud technology); no other software/services identified (yet)
<b>Safety</b>	... avoid a state in which human life, health, property, or the environment is endangered; to be able to avoid exposures which is not tolerable; composed of: operational constraint, risk identification, fail safe, hazard warning, safe integration	<b>Not applicable;</b> the artifact does not endanger human life, health, property, or the environment. It supports rational decision making, thus increasing mankind to avoid exposures which are not tolerable

As depicted in Exhibit 6, the artifact complies to five out of nine sections of the by ISO/IEC 25010 (2023). The artifact provides two main functionalities: the analysis function and the library, which are self-explanatory and provide ease of use. These services are provided in less than milli-seconds. Since the artifact makes use of cloud technologies, the user of the artifact can rely on 24 hours accessibility, seven days per week. The artifact is adaptable for several extensions. These include, for example, the representation of new social interactions in the artifact (i.e., Newcomb's problem, Prospect Theory, etc.), as well as its interoperability and interaction with other software, i.e. matlab, and generative Artificial Intelligence.

### Discussion

This paper introduces and presents a digital artifact on Game Theory based Information and Decision Support System. Above all, this contributes to the academic discipline of Game Theory. Since Game Theory has a broad field of application, ranging from economics, politics, economics to evolutionary biology, researchers and practitioners can make use of a digital artifact that supports information gathering and decision-making.

The first version of the artifact, presented in this paper, is launched under the domain of [www.decisionsupport.at](http://www.decisionsupport.at) and accessible for external users. The artifact does not have a thematic/industrial limitation; thus, it can be applied in social interactive situations in the context of research and practice. The artifact supports decision-making across system boundaries. It does not make the decision but analyses the interactive situation, announces the solution concepts, and possible conflicts. Furthermore, it highlights strategies to become and remain resilient in interactive situations. In the final version, the artifact shows its applicability to 732 different payoff sets, which are about 5.625 different games. This covers all games wherein two actors compete among two strategies.

### Limitations

Currently, the artifact is able to analyze 2x2 games in which two actors compete among two strategies. Although 2x2 games provide the really important parts of game theory (Harsanyi, 1977), the extension to Braithwaite's arbitration scheme (Kilgour, 1974) could be contemplated. This scheme considers the strategies as polarizing points between which an infinite number of strategies could be possible (and even more adequate as a solution to the interactive situation). In addition, in the conceptualization, design and development of the artifact, it became more and more unclear what rational behavior, and the pursuit of self-interest means. The definition of rational behavior, in line with Harsanyi (1977) (as well as social traps (Rapoport, 1985)), is a fundamental (philosophical) challenge. The aspiration level can be a solution towards it. In the artifact, several solution concepts are presented as a possibility to consider the actors' aspiration level. These solutions concepts deal with different outcomes of a game, represented in stability, efficiency, security, and/or risk and venture.

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### Next steps and future outlook

To the current state, the artifact is in a draft version. The next steps in engineering are determined by the population of the artifact with data and information to provide frictionless user experience. These will be achieved through desk research: reviewing scientific literature and transferring knowledge into the artifact. From a technical perspective, the artifact can be extended in multiple ways. For example, the artifact can be extended by the implementation of iterative game/repeated games. Also, the artifact can be extended to zero-sum games, wherein the one actor pays for the gain of its opponent, evolutionary game theory, wherein an actor gets punished if inactivity and suffers from loss of fitness values, Prospect Theory, and the Newcomb problem. Furthermore, by installation of a game catalogue, the artifact can be used as an instrument for social science and behavioral science. It can be used to survey data about social interactions and provide these data for statistical purposes. In addition, the artifact can be extended with interfaces to external software, such as tools for statistics (i.e., matlab) and generative AI, that provide additional information and decision support.

### Conclusion

In this paper, Design Science Research is used to conceptualize, design and develop a socio-technical artifact for game-based information and decision support in systems. In venerable memory of the innovator of the taxonomy of 2x2 game, the artifact is entitled Anatol. According to a narrative literature, this artifact is a novel solution towards rational decision making in systems. It is an allopoietic system – a technical system that support social-interactive systems with the aim, in relation to Rapoport et al. (1976), to help to shift from “how do I play the game rationally” to “how do WE play the game rationally”.

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### Appendix

Acronym	Title	Description	Homepage	Sources
Abed	agent-based evolutiona	Modeling framework designed to simulate the evolution of a population of agents who play a symmetric 2-player game	<a href="https://luis-r-izquierdo.github.io/abed/">https://luis-r-izquierdo.github.io/abed/</a>	(Izquierdo et al., 2019)

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	ry dynamics			
Evo-Dyn-3s		Mathematica computable document designed to analyze evolutionary dynamics in 3-strategy games	<a href="https://luis-izquierdo.github.io/EvoDyn-3s/">https://luis-izquierdo.github.io/EvoDyn-3s/</a>	(Izquierdo et al., 2018)
Evoplex		agent-based modeling on networks		
GTE	Game Theory Explorer	Solve a Bimatrix Game	<a href="https://cgi.csc.liv.ac.uk/~rahul/bimatrix_solver/">https://cgi.csc.liv.ac.uk/~rahul/bimatrix_solver/</a>	(Avis et al., 2010)
Dynamo	Diagrams for Evolutionary Game Dynamics	generating phase diagrams, vector fields, and other graphics related to evolutionary game dynamics	<a href="https://users.ssc.wisc.edu/~whs/dynamo/">https://users.ssc.wisc.edu/~whs/dynamo/</a>	(Franchetti & Sandholm, 2013)
Gambit		<b>collection of tools for doing computation in game theory</b>	<a href="https://gambit.sourceforge.net/">https://gambit.sourceforge.net/</a>	(Savani & Turocy, 2023)
GTE	Game Theory Explorer	Web-based software for the interactive creation and equilibrium analysis of games in extensive and strategic form	<a href="https://gametheoryexplorer-a68c7.web.app/">https://gametheoryexplorer-a68c7.web.app/</a>	
GamePlan			No homepage	
iOS Apps for Game Theoretic Concepts			Bad gateway	
lrslib		self-contained C implementation of the reverse search algorithm for vertex enumeration/convex hull problems	<a href="https://cgm.cs.mcgill.ca/~avis/C/lrs.html">https://cgm.cs.mcgill.ca/~avis/C/lrs.html</a>	
PDToolbox	Population Dynamics Toolbox	Matlab implementation of some evolutionary dynamics from game theory	<a href="https://github.com/carlobar/PDToolbox_matlab/blob/master/README.md">https://github.com/carlobar/PDToolbox_matlab/blob/master/README.md</a>	(Barreto, 2015)
TUGlab	Transferable Utility Games laboratory	Matlab set of scripts that could serve as a complement to the books and other materials used in introductory courses on cooperative game theory; geometrical aspects of cooperative game theory	<a href="http://mmiras.webs.uvigo.es/TUGlab/">http://mmiras.webs.uvigo.es/TUGlab/</a>	(Miras Calvo & Rodriguez Sanchez, 2008)
z-Tree	Zurich Toolbox for Readymade Economic Experiments	Software package for developing and carrying out economic experiments	<a href="https://www.ztree.uzh.ch/en.html">https://www.ztree.uzh.ch/en.html</a>	(Fischbacher et al., 2021)
oTree		Create controlled behavioral experiments in economics, market	<a href="https://www.otree.org/">https://www.otree.org/</a>	

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		research, psychology, and related fields, multiplayer strategy games		
Nodegame		JavaScript/ HTML5 framework for conducting synchronous experiments; specifically designed to support behavioral research	<a href="https://nodegame.org/">https://nodegame.org/</a>	(Baliatti, 2017)
formr	formr survey framework	surveys into long runs	<a href="https://formr.org/">https://formr.org/</a>	
Choiceflow		tool for creating questionnaire-based surveys	<a href="https://rambollxact.com/">https://rambollxact.com/</a>	