Intelligent Verification/Validation for XR Based Systems

Research and Innovation Action

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iv4XR – WP6 – D6.6

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1 Executive Summary

This deliverable presents a summary of the dissemination and exploitation plan designed by the iv4XR project, and later, the dissemination and exploitation activities following that plan, the schedule for the following scientific journal publications, and the exploitation and sustainability plan with special emphasis on the commitment for internal exploitation and the possible activities for external exploitation.

The current report and its content are structured following the online manual describing the guideline and recommendation in the Dissemination & Exploitation of results under Horizon 2020 [1]. This deliverable will also serve as a guideline to the consortium for further exploitation and sustainability activities to be carried out.

2 Dissemination and Exploitation Strategy

2.1 Aims & Objectives

Our dissemination strategy/plan is aimed at making the project results reach the wider public as much as possible, as well as the right stakeholders. Together with the communication actions, they are aimed to create public awareness of the project's potential and to facilitate effective transfer of the knowledge produced in the project to academia and stakeholders. The objectives for all dissemination and communication actions are consistent with the relevant EU policy and are as follows:

- Create awareness about the project, promote the innovative and unique characteristics of the project.
- Maximize the impact of the project activities and ensure that all the derived outcomes will be widely spread among the appropriate stakeholders.
- Promote the project ideas, concepts and results in scientific research and applied research communities and get feedback from relevant stakeholders in these communities.
- Disseminate consolidated project results on the effective automated testing of Extended Reality (XR) based applications.

2.2 Target Groups

The target audiences of iv4XR project are:

- Research communities working in the areas of software engineering, automated game testing, human-computer interaction, artificial intelligence, affective computing, and other related fields.
- Stakeholders, including parties we expect to benefit from our results, such as the XR Industry, companies that build their own XR-based systems to support their business (e.g., to train personnel), or ICT tech companies offering quality assurance services.

- Other H2020 projects working on closely related topics.
- End-users, for their awareness in the access to the new ICT services.

2.3 Planned Dissemination Activities

To support the project to make a real impact by reaching the target audiences, we planned to carry out various dissemination and communication actions aimed at creating public and industry awareness of the project and engaging them to explore collaboration and exploitation of the project's results. Table 1 gives an overview of the planned dissemination and communication actions across the lifespan of the project. Details are presented in subsequent subsections.

Table 1: Overview of planned iv4XR dissemination and communication actions over the project lifespan

Dissemination & communication actions	Year 1		Year 2		Year 3	
Industry dissemination						
● industry articles						
● industry presentation						
● proactive participation in industry events						
Academic publication						
● conferences						
● journals						
Organizing workshops						
General public dissemination						
● website						
● social media						
● conventional media						
● video clips						

2.3.1 Industry Dissemination

To make the XR Industry as well as the broader ICT Industry aware of our results, we published articles in the relevant European trade press, such as, EU researcher Magazine and Open Access Government. We were engaged in discussions and gave presentations in industrial or industry-related platforms and venues, such as national special interest groups (SIGs) and European industrial conferences such as VR Days. We also made targeted presentations detailed below. Our project participated in technical events organized by the European Commission, by other EU projects, or by the Technological Platforms, in order to announce and make our results available to other ICT-related sectors in Europe.

2.3.1.1 Targeted industry presentations

To further promote the project to the industry, we gave presentations and distributed promotional materials at potential outlets, such as venues with industry agendas and business networks with potential interest in our project. Table 2 below shows the different targets we have initially identified, and improved during the progress of the project.

Table 2: List of potential industry presentation targets

	Industry promotion targets
Conferences	● Industry conferences, e.g., EuroVR and EuroSTAR (quality assurance). ● Academic conferences with industry tracks e.g., Interact, ICSE, AAMAS. ● Conferences organized by the EU, e.g., EU ICT conference, VR days. ● National industry conferences with strong industry presence, e.g., Dutch ICT Open ● Developer conferences for the videogame industry, e.g., GDC, EGX, Game Design Expo
Partner networks	● GWE's business networks of UK and international media/games creative industries; and similarly, UU's networks of Dutch creative industry, e.g. the Dutch Game Garden, and GA's networks of Czech Republic's creative industry. ● Spanish Software Testing Innovation Alliance, members of which would be quite interested in accessing iv4XR results to expand their services. Similarly, FBK's networks in the quality assurance and software engineering community in Italy. ● THA's international business networks, in particular in the area of training simulation for mission critical tasks.
Other projects	● Other EU projects with related themes, e.g., REPLICATE, ARIES, and STAMP. ● National projects with related themes, e.g., Golden Agent (NL)

2.3.2 Academic Dissemination

We planned to disseminate our results in leading journals and conferences (e.g. ICST, SSBSE, QUATIC, JSS, STVR), not only in the fields of interaction technology or verification/validation, but also for cross-fertilisation in the broader fields of software engineering and artificial intelligence. Moreover, the iv4XR consortium has compiled a plan for year 3 of the project containing publications that are intended to be presented at international conferences or journals. We followed that plan and Table 6 presents the already published works.

2.3.3 Organizing workshops

We planned to organize two editions of the A-TEST workshop in the light of the iv4XR project. This workshop has been set-up by some of the researchers in this project in 2009 within the context of another EU project (FITTEST). We have kept the workshop running successfully for more than ten editions.

The idea was to use this workshop as a platform for both sharing and promoting our results as well as for attracting academia and industry practitioners/developers from related areas to exchange results, to foster discussions and collaborations, and to promote interdisciplinary collaborations. A-TEST is co-located with the major FSE conference which maximizes the dissemination impact. The workshops were planned for the second halves of the second and third year of the project.

Moreover, the iv4XR consortium identified synergies with other European projects and established contact and cooperation with these projects, e.g. joint activities for exchange, dissemination and workshops. The cooperation aims at exploiting synergies between the projects and increasing the impact of the ICT initiative.

2.3.4 General Public Dissemination

General public dissemination is covered under the following planned communication activities to promote the project and its results.

2.3.4.1 Website

The project website is a useful platform that allows us to provide basic information about the project and its consortium, as well as communicate the various outcomes of the project. It is an important part of the project's digital presence. It also holds appropriate links to resources and results of the project such as source code, publications, deliverables, etc. The information on the website has been regularly updated.

2.3.4.2 Social Media

Social networks enable a direct communication channel with citizens, professionals, EU institutions or anyone interested in the project. The iv4XR consortium is aware that a successful communication through social media is only possible if social media channels are regularly updated with events, news and general information about progress made in the project. We used our social media channels to communicate project activities and to regularly inform the broader public of our progress and results, and encourage wider debate (e.g. regarding the impact of using AI to assure the correctness of virtual environments).

2.3.4.3 Newsletter

A newsletter is an efficient medium to build a network of followers (XR Industry, companies that build their own XR based systems to support their business) eager to get our results for their own application scenarios and deployments. A secondary goal of a newsletter is to collect experiences and lessons learned and share these with the software engineering community. To this end, the iv4XR consortium planned to publish a newsletter regularly every 4 months after the project starts. In total 9 editions of the newsletter were planned to be published in the project duration. The newsletters have been published and distributed through the consortium's professional networks, and to the press, as well as being made available on the project website. These newsletters included more detailed descriptions of the activities performed and the results of the project, as well as other activities, such as project adoption and alliances with external entities.

2.3.4.4 Video media

Video clips are useful tools to effectively communicate various aspects of our project. For instance, they have been used to communicate a compelling introduction to the principles of smart test agents, or to show a short but thought-provoking interview with our researchers, or to give an exciting presentation of our major results. Video clips have been shown to be a very effective way of communicating with the general public and they can be easily made public through the project website and social media channels. The videos make the general public aware that the project is working on techniques and tools that can help to improve the quality of the applications they use daily. We advocate that this greater awareness helps stimulate user demand and promote socio-economic acceptance.

2.4 Pilots showcasing

The project includes three industrial pilots which, in addition to their use in validating solutions produced in the project, have been used as showcases to promote the project. The pilots are developed in parallel with the project's research activities. The development and integration with the iv4XR framework started early, enabling us to produce showcases early in the project which have been shown in various industry events and other dissemination actions throughout the project's duration. Of course in the first year, these showcases had minimal features. Despite this, showing off concrete, lively, and interactable demonstrators is often a much more effective way to promote an idea and spark people's interest than just giving a traditional presentation about it. As the project progresses, the showcases have also grown in features. Towards the end of the project, we show them as instances of minimum viable product (MVP) to the industry, demonstrating the viability of the full spectrum of iv4XR approach.

These demonstrators are publicly available (within reason - the iv4XR framework specific code will be public, but the proprietary code will remain unpublished) in order to facilitate adoption by those who have seen the demonstrations live and wish to attempt to incorporate the framework into their workflow. Two major barriers to the adoption of a new technology into an existing workflow are 1) application to personal use-cases, and 2) ease of adoption. Our two-pronged

approach of using the demonstrators and making salient parts of them available to those interested are intended to tackle both issues.

2.5 Knowledge management - open knowledge sharing

Our knowledge management strategy is to make all results public, except when doing so is not possible due to property rights or privacy reasons, as we believe this is how their impact would be maximized. The strategy for each type of results is shown in Table 3 below. Within the consortium, access to, and exploitation of, project results is regulated by the terms of the Grant Agreement Contract and the Consortium Agreement. This respects the legitimate IP rights and interests of all partners while enabling them to pursue market opportunities that arise from the project. Regardless of partners' exploitation, all project results (minus proprietary background) remain publicly open.

Table 3: Open knowledge sharing strategy

Result type	Knowledge management strategy
Software	All our software, excluding proprietary background provided by the partners, will be made available in a **publicly accessible repository** in the project's github repository: https://github.com/iv4xr-project
Research paper	All published research will be made available to the public via the project's community space on Zenodo: https://zenodo.org/communities/iv4xr-project
Research data	We will participate in the EU Pilot on Open Research Data (**OpenAIRE**). Data generated and maintained by the project as well as how it will be made available to the general public is described in the project data management plan deliverable [2].

Concrete details regarding the storage, discoverability, and accessibility of results will be governed by the FAIR principles as described in our data management plan deliverable [2].

2.5.1 Project deliverables

The project planned to deliver 26 deliverables[1] (listed in Table 4 below), all of which will be publicly available. Out of these, deliverables D6.1, D6.2, D5.1, D1.1, D1.2, D2.1, D2.2, D3.1, D3.2, D3.3, D4.1, D4.2, D6.3, D5.2, D5.3, D6.4 and D6.5 have already been submitted on time. Deliverables D1.3, D2.3, D2.4, D3.4, D3.5, D4.3, D4.4, D5.4 and D6.6 (the current deliverable) will also be submitted on time.

[1] We do not include deliverable D7.1 - "POPD - Requirement No. 1", on Ethics, as it is confidential.

Table 4: Project deliverables planned

Nr	Deliverable name	WP	Lead	Type	Dissem level	Due
D6.1	Project website	6	THA-AVS	DEC	PU	1
D6.2	Data Management Plan	6	THA-AVS	R	PU	6
D5.1	Basic integration of the pilots	5	GA	OTHER	PU	12
D1.1	1st project report	1	INESC	R	PU	15
D2.1	1st prototype of iv4XR Framework	2	UU	OTHER	PU	15
D3.1	Test Specification Language	3	UPV	OTHER	PU	15
D3.2	1st prototype of functional test agents (FTAs)	3	UPV	OTHER	PU	15
D4.1	1st prototype of SETAs	4	INESC	OTHER	PU	15
D6.3	1st Dissemination & Exploitation Plan	6	UPV	R	PU	15
D5.2	Intermediate integration of the pilots	5	GA	OTHER	PU	15
D5.3	Full integration of the pilots	5	GA	OTHER	PU	24
D1.2	2nd project report	1	INESC	R	PU	27
D2.2	2nd prototype of iv4XR Framework	2	UU	OTHER	PU	27
D3.3	2nd prototype of functional test agents (FTAs)	3	UPV	OTHER	PU	27
D4.2	2nd prototype of SETAs	4	INESC	OTHER	PU	27
D6.4	2nd Dissemination & Exploitation Plan	6	UPV	R	PU	27
D6.5	Market Research Report	6	GWE	R	PU	27
D1.3	Final Project Report	1	INESC	R	PU	39
D2.3	Final version of iv4XR Framework	2	UU	OTHER	PU	39
D2.4	Report describing iv4XR Framework	2	UU	R	PU	39
D3.4	Final version of functional test agents (FTAs)	3	UPV	OTHER	PU	39
D3.5	Report describing FTAs	3	UPV	R	PU	39
D4.3	Final version of SETAs	4	INESC	OTHER	PU	39
D4.4	Report describing SETAs	3	INESC	R	PU	39
D5.4	Project validation report	5	GA	R	PU	39
D6.6	3rd Dissemination & Exploitation Plan	6	UPV	R	PU	39

2.6 Dissemination and Communication KPIs

To audit our proposed dissemination and communication activities we have identified several KPIs that help us in tracking progress. Table 5 below presents the KPIs along with the expected goals.

Table 5: Dissemination and communication KPIs and progress initially planned

Planned Key Performance Indicators (KPIs)	
Best paper and presentations prizes	2
Likes on dedicated Facebook page	350
Followers on Twitter	2000
Posts on Facebook	36
Tweets	36
Visits on the project website	1500
Project Newsletter editions	9
Project video clips	3
Dissemination & Exploitation plan (number of iterative versions)	3
Conference publications in target conferences	20
Journal peer reviewed articles	6
Dedicated events (workshop)	2
Presentations at trade events/industrial conferences	3

3 Undertaken Dissemination Activities

In this section, we report the dissemination and communication activities carried out throughout the project in line with the dissemination and communication plan outlined in the previous section.

3.1 Publications

In line with the project's publication plan, we have several publications in international conferences, workshops and journals. We still have submissions in progress and will continue to share the outputs of the project. These publications are listed in Table 6 below. The complete list and full details available from the project website (https://iv4xr-project.eu/publications/) as well as from the project's Zenodo community (https://zenodo.org/communities/iv4xr-project).

Table 6: List of scientific publications of iv4xr project

No	Title & Authors	Venue
1	"iv4XR – Intelligent Verification/Validation for Extended Reality Based System" Wishnu Prasetya, Rui Prada, Tanja E. J. Vos, Fitsum Kifetew, Frank Dignum, Jason Lander, Jean-Yves Donnart, Alexandre Kazmierowski, Joseph Davidson, Fernando Pastor Ricos	RCIS'2020 – The 14th International Conference on Research Challenges in Information Science
2	"Tactical Agents for Testing Computer Games" I. S. W. B. Prasetya, Mehdi Dastani, Rui Prada, Tanja E. J. Vos, Frank Dignum, Fitsum Kifetew	EMAS'2020 – Engineering Multi-Agent Systems workshop
3	"Adoption Dynamics and Societal Impact of AI Systems in Complex Networks" Pedro M. Fernandes, Francisco C. Santos, Manuel Lopes	AIES'2020 – AAAI/ACM Conference on AI, Ethics, and Society
4	"Agent-based Testing of Extended Reality Systems" Rui Prada, I. S. W. B. Prasetya, Fitsum Kifetew, Frank Dignum, Tanja E. J. Vos, Jason Lander, Jean-yves Donnart, Alexandre Kazmierowski, Joseph Davidson, Pedro M. Fernandes	ICST-2020 – IEEE Conference on Software Testing, Validation and Verification
5	"Navigation and Exploration in 3D-Game Automated Play Testing" I.S.W.B. Prasetya, Maurin Voshol, Tom Tanis, Adam Smits, Bram Smit, Jacco van Mourik, Menno Klunder, Frank Hoogmoed, Stijn Hinlopen, August van Casteren, Jesse van	International Workshop on Automating Test case Design, Selection and Evaluation, co-located with ESEC.FSE (ATEST), 9 November, 2020
6	"Aplib: An Agent Programming Library for Testing Games" Wishnu Prasetya, Mehdi Dastani	International Conference on Autonomous Agents and Multiagent Systems (AAMAS), Auckland, New Zealand, 9-13 May, 2020
7	"Toward Automated Assessment of User Experience in Extended Reality" Saba Ansari	ICST-2020 – IEEE Conference on Software Testing, Validation and Verification
8	"Deploying TESTAR to Enable Remote Testing in an Industrial CI Pipeline: A Case-Based Evaluation" Pastor Ricos, Fernando; Aho, Pekka; Vos, Tanja; Torres Boigues, Ismael; Calas Blasco, Ernesto; Martinez Martinez, Hector	ISOLA 2020- International Symposium On Leveraging Applications of Formal Methods, Verification and Validation, LNCS 12476, pp. 543–557, 2020

9	“Validating the plot of interactive Narrative games” Carolina Veloso, Rui Prada	IEEE COG 2021 - Conference on Games, Copenhagen, 2021
10	“Search-based Automated Play Testing of Computer Games: a model-based approach” Ferdous, Raihana; Kifetew, Fitsum; Prandi, Davide; Prasetya, I. S. W. B; Shirzadehhajimahmood, Samira; Susi, Angelo	13th International Symposium on Search-Based Software Engineering (SSBSE), Bari, Italy, October 11-12, 2021
11	“Using an Agent-Based Approach for Robust Automated Testing of Computer Games” Shirzadehhajimahmood, Samira; Prasetya, I. S. W. B.; Dignum, Frank; Dastani, Mehdi; Keller, Gabriele	12th International Workshop on Automating TEST Case Design, Selection, and Evaluation (A-TEST ’21), August 23–24, 2021
12	“A taxonomy of social roles for agents in games” Diogo Rato, Rui Prada	20th International Conference on Entertainment Computing, ICEC 2021, Coimbra, Portugal, November 2-5, 2021
13	“Evaluating TESTAR's effectiveness through code coverage”Aaron van der Brugge, Fernando Pastor Ricos, Pekka Aho, Beatriz Marín, and Tanja E.J. Vos	XXV Jornadas de Ingeniería del Software y Bases de Datos (JISBD 2021)
14	“TESTAR - scriptless testing through graphical user interface” Tanja E. J. Vos, Pekka Aho, Fernando Pastor Ricós, Olivia Rodriguez Valdes, Ad Mulders	Softw. Test. Verification Reliab. 31(3), 2021
15	“30 Years of Automated GUI Testing: A Bibliometric Analysis” Olivia Rodríguez-Valdés, Tanja Vos, Pekka Aho, Beatriz Marín	14th International Conference on the Quality of Information and Communications Technology (QUATIC 2021)
16	“Towards Social Identity in Socio-Cognitive Agents” Diogo Rato, Rui Prada	MDPI Sustainability *13*(20), 11390, 2021
17	“An Agent-based Architecture for AI-Enhanced Automated Testing for XR Systems”. Prasetya, Shirzadehhajimahmood, Ansari, Fernandes, Prada.	Int. Workshop on Artificial Intelligence in Software Testing 2021
18	“Tool Demonstration: iv4XR Agent-based Testing Framework”. Prasetya, Shirzadehhajimahmood, Ansari.	ICST-2021 – IEEE Conference on Software Testing, Validation and Verification
19	“Navigation and Exploration in 3D-Game Automated Play Testing.” Prasetya et al.	11th International Workshop on Automating TEST Case Design, Selection, and Evaluation (A-

		TEST ’20).
20	“Adapting Procedural Content Generation to Player Personas Through Evolution”. Pedro M. Fernandes, Jonathan Jørgensen, Niels N. T. G. Poldervaart	IEEE Symposium Series on Computational Intelligence (IEEE SSCI 2021)
21	“State Model Inference Through the GUI Using Run-Time Test Generation”, Ad Mulders, Olivia Rodriguez Valdes, Fernando Pastor Ricós, Pekka Aho, Beatriz Marín, Tanja E. J. Vos	16th International Conference on Research Challenges in Information Science (RCIS 2022)
22	“Scriptless Testing for Extended Reality Systems”, Fernando Pastor Ricós	16th International Conference on Research Challenges in Information Science (RCIS 2022)
23	“EvoMBT at the SBST 2022 Tool Competition”, Raihana Ferdous, Chia-kang Hung, Fitsum Kifetew, Davide Prandi, Angelo Susi.	IEEE/ACM 15th International Workshop on Search-Based Software Testing (SBST), 2022
24	“Towards Agent-Based Testing of 3D Games using Reinforcement Learning”, Raihana Ferdous, Fitsum Kifetew, Davide Prandi, Angelo Susi	Second International Workshop on Automated Software Engineering for Computer Games (ASE4GAMES 2022)
25	“An Agent-Based Approach to Automated Game Testing: An Experience Report”, Wishnu Prasetya, Fernando Pastor Ricós, Fitsum Kifetew, Davide Prandi, Samira Shirzadeh-hajimahmood, Tanja E. J. Vos, Premysl Paska, Karel Hovorska, Raihana Ferdous, Angelo Susi, Joseph Davidson	13th International Workshop on Automating TEST Case Design, Selection, and Evaluation (A-Test 2022)
26	“An Online Agent-based Search Approach in Automated Computer Game Testing with Model Construction”, Samira Shirzadehhajimahmood, Wishnu Prasteya, Frank Dignum, Mehdi Dastani	13th International Workshop on Automating TEST Case Design, Selection, and Evaluation (A-Test 2022)

As can be observed, we bettered the KPI number of scientific publications on workshops and conferences, which reflects the relevance of the topics researched by iv4XR in the international community. We set the KPI related to publications in conferences and workshops in 20, and we achieved 24 publications so far.

We have fewer journal publications as these require more mature work. Moreover, the review speed is often slower in journals than conferences, and usually this process can take around a year. Table 6 shows that we have two papers already published in peer-reviewed journals (STVR

and Sustainability) during 2021. In 2022, we increased journal submissions. We are still waiting for results from the peer review. Table 7 shows the papers already submitted as well as planned submissions for early 2023. We are confident that the project's results will produce publications in peer reviewed journals beyond the target KPI, as 2 are already published, 5 are already submitted, and 4 more are close to being submitted.

Table 7: List of journal publications in review process and planned

No	Title & Authors	Leading partner	Venue	Tentative date
1	Distributed state model inference for GUI testing	UPV	Submitted to Journal of Systems and Software - in review process	Notification Feb. 2023
2	Evaluating the Complementarity of Scriptless and Scripted Testing in Industry: A web case study	UPV	Submitted to Information and Software Technology Journal - in review process	Notification Feb. 2023
3	EvoMBT: Evolutionary Model Based Testing	FBK	Submitted to journal: Science of Computer Programming, currently in Major revision	Notification Apr. 2023
4	Empirical assessment of solutions for model based game play testing	FBK	Submitted to journal TOSEM	Notification May 2023
5	Assessing Players' Cognitive Load in Games	INESC-ID	Submitted to Computers in Human Behavior	Notification May 2023
6	Towards a comprehensive model of user experience	INESC-ID	Planned to submit to ACM TOCHI	Submission on Jan. 2023
7	Programming Smart Playtesting	UU	Planned submission to the Journal the Art, Science, and Engineering of Programming	Submission on Feb. 2023
8	Extension of Solving test goals through online search and leveraging on-the-fly model construction.	UU	Planned to Journal of Software Testing, Verification and Reliability	Submission on Jan. 2023

9	Reinforcement learning for coverage testing of XR based systems	FBK	Planned submission to journal TOSEM	Submission on Feb. 2023

Regarding the Knowledge repository, all the published research is available in the project's community space on Zenodo: https://zenodo.org/communities/iv4xr-project. This way, all the research activities, experiments, results and challenges of verification and validation of XR systems are publicly available.

Similarly, planned deliverables of the project have been completed and submitted in a timely manner.

3.2 Organization of the A-TEST Workshop

iv4XR has co-organized the 12th and 13th editions of the A-Test workshop. The A-Test workshop is a venue for researchers and industry partners to exchange and discuss trending views, ideas, state of the art, work in progress, and scientific results on automated test case design, selection, and evaluation. The 12th edition was held with a theme focusing on testing of eXtended Reality (XR) based systems. The 12th edition of the workshop was Co-located with ESEC/FSE 2021, held virtually on 23 of August, 2021.

To encourage students' (bachelor, master, or PhD) interest and involvement in themes around automated testing of XR based systems, the 12th edition of A-Test had a student competition where participants were challenged to come up with their own algorithms to solve a set of managed testing problems in the domain of 3D computer games. iv4XR provided the challenge problem and an appropriate environment (JLabGym) that enables participants to easily integrate their solutions to the provided system under test. Winners of the competition were awarded prizes. The workshop received six technical paper submissions, out of which five were accepted for presentation at the workshop. The program featured presentations by the authors of the accepted papers, a hands-on session on the CrashScope Tool, and a panel discussion on Expanding Software Testing to XR Systems.

During 2022, iv4XR has co-organized the 13th edition of the A-Test workshop. The 13th edition of the workshop received 21 submissions from 14 countries around the world. From the submissions, 10 submissions were accepted, out of which 6 were full papers, 3 were short papers, and we have also accepted 1 hands-on proposal. This edition of the workshop also counts with keynotes and a students' competition to involve senior researchers and students in the community of automated software testing. The 13th edition of the workshop was co-located with ESEC/FSE 2022, held in-person on 17-18 of November, 2022 in Singapore. During the first day, an talk about the functional test agents (FTAs) and the challenges to test games was presented with the results obtained by the iv4xr framework. During the second day, a specific talk about the automated inference of the model of a game was presented. The stimulating discussion around these topics allows us to reinforce the novelty of the solutions provided by the iv4xr project to the community.

For more details on the event and the works presented, please visit the A-Test workshop website https://a-test.org.

3.3 Presentations and participation in events

Additionally, to the presentation of scientific papers publications, we have participated in different workshops and conferences where we presented iv4XR's proposed approach, namely:

- **Intelligent Verification/Validation for XR Based Systems**
  Rui Prada
  Research Seminar at the Helmut Prendinger Lab, December 2020
  National Institute of Informatics, Tokyo
  https://www.nii.ac.jp/en/
  http://research.nii.ac.jp/~prendinger/#

- We participated in the **European Researcher's Night** in Portugal, 2020, where we presented a video of the project (https://www.youtube.com/watch?v=UOdwZX2h11o&t=12s)

- **Keynote at Eurostar 2020: GUI testing: from developing scripts to creating AI-enabled agents.**
  Tanja Vos
  https://conference.eurostarsoftwaretesting.com/event/2020/gui-testing-from-developing-scripts-to-creating-ai-enabled-agents/

- **Keynote at RTC 2020: How to make software testing more sexy**
  Tanja Vos
  https://romaniatesting.ro/speakers/tanja-vos/

- **Teaser video for ICST 2020**
  https://www.youtube.com/watch?v=1BzLSfsvruA

- **Keynote at JCC 2021: Intelligent Testing for Industry 4.0 (in spanish).**
  Tanja Vos
  https://jcc2021.cl

- **How AI can help games fulfill their purpose**
  Rui Prada, keynote at EAI ICIDM 2021 - 7th EAI International Conference on Interactive Digital Media, Johor Bahru, Malaysia. July 20, 2021.

- **Teaching and Research on Games at Técnico**
  Rui Prada, Keynote at Sinfo 27, 2021
  Instituto Superior Técnico, Universidade de Lisboa
  https://sinfo.org/

- **We present iv4xr in the tool demonstration session at ICST 2021.** Prasetya. Video: https://zenodo.org/record/4661123#.YHVAsxMzZsM

- **Presentation of Search-Based Automated Play Testing of Computer Games: A Model-Based Approach at International Symposium on Search Based Software Engineering (SSBSE'21)**
  Fitsum Kifetew

- **Using an Agent-based Approach for Robust Automated Testing of Computer Games.** Presentation by Samira Shirzadeh at the *Seminar AI meets Software Engineering* 2021, organized by VERSEN, the Netherlands.

- **An Appraisal Transition System for Event-driven Emotions in Agent-based Player Experience Testing.** Presentation by Saba Ansari at the *Seminar AI meets Software Engineering* 2021, organized by VERSEN, the Netherlands.

- Participation in 7th **VRDays Europe Immersive Tech Week** 2021. We made three presentations focused on the problems of software testing and the iv4XR solution; FTAs and use cases; and on the SETAs and the information they can give to developers. We also had a virtual stand representing the project there. VRDays is a renowned event for connecting XR professionals, governments representatives, corporations, researchers, and artists around the world. See here for the website of the event: https://vrdays.co/

- **Intelligent Verification/Validation for XR Based Systems.** Presented by Rui Prada at modl.ai (https://modl.ai/ - a company that offers automated playtesting solutions). June 8, 2021.

- **Presentation of the EvoMBT tool** at the tool competition organized at the 15th International Workshop on Search-Based Software Testing (SBST'22)
  Fitsum Kifetew

- **Artificial Intelligent Agents to Support Automation of XR Testing.** Presented by Rui Prada in 2022 in Stereopsia Europe - The immersion Forum with XR4Europe held in Belgium.

- **Intelligent Verification/Validation for Extended Reality Based Systems.** Presented by Rui Prada in 2022 at Immersive Tech Week (former VRDays)

Note that some of these presentations were targeted at industry (E.g., VRDays and Stereopsia) or a wider audience (e.g., European Researcher's Night).

3.4 Collaboration with other projects

We have launched efforts to establish collaboration with other projects working in related areas. In particular:

- we have established a collaboration with ARTwin: https://artwin-project.eu/index.php/relevant-initiatives/. In this informal collaboration, both projects help each other with dissemination and communication activities.

- we have contributed towards a green paper with VRInsight: https://www.enter-network.eu/3d-flip-book/focus-europe-vrinsight-greenpaper/. ERASMUS+ project VRinSight, produced a magazine presenting EU projects working on the challenges and chances of VR/AR/XR in the economy, society, research and education; which included our green paper (on page 77).

- we are registered in the VAMrealities website: https://vam-realities.eu/iv4xr/. The VAM realities project aims to build Europe's largest community on VR/AR/MR projects creating long-term sustainable project dissemination at a European level.

- We are in contact with:
    - TACTILITY (Rosa.Banos@uv.es),
    - V4Design (vividrig@iti.gr),
    - ARETE (eleni.mangina@ucd.ie)
    - NEWTON (ended but still interested, gabriel.muntean@dcu.ie)
    - AI4EU (long.pham@insight-centre.org)
    - XR4AL network
    - awesomeIT
    - AR4CUP (barbara.piga@polimi.it)

We also participated in two workshops on Interactive Technologies alongside other European funded projects.

> **Intelligent Verification/Validation for XR Based Systems**
> Rui Prada, Wishnu Prasetya
> Project pitch at Workshop on Interactive Technologies, EC DG CONNECT.G2
> June 26, 2020
> https://pt.slideshare.net/ruiprada/intelligent-verificationvalidation-for-xr-based-systems
>
> **Intelligent Verification/Validation for XR Based Systems** at DG CNECT Workshop
> Rui Prada
> 14 September 2022

The iv4XR and ARETE projects have co-organized a workshop: **The future of XR: Current ecosystem and upcoming opportunities on May 27th, 2021.** The workshop was a successful one with the participation of various EU projects on the field of XR, such as, VR4RehabProject,

TactilityP, AI4EU, PRIME-VR2, HOLOBALANCE, AbleGames, AR4CUP, Mindtooth, VAM realities, FatimaToolkit, Virtual Reality Ireland. It was an enriching experience and a wonderful opportunity to learn about the ongoing activities in the field of XR. A vibrant discussion session was held to discuss and share the possible dissemination plans, research interests within XR and ideas for future collaboration.

During 2022, the iv4XR and ARETE projects have co-organized the second workshop: **The future of XR: Current ecosystem and upcoming opportunities on May 11th, 2022.** The workshop was also a successful online experience, with the participation of different EU projects on the field of XR, such as, CHARITY, ARTwin, INVICTUS, PRIME-VR2, AR4CUP, BRAINSIGNS/ Mindtooth, and VAM realities. An exciting discussion with focus on the requirements and knowledge to use the technologies, the learning curve of users, the validation of the technologies, and the challenges of the sustainability of the project's results. It was a wonderful experience, which resulted in more collaborations with specific projects (such as CHARITY) and a great opportunity to share knowledge among the XR community.

3.5 Social media

Social media channels have been set up to effectively communicate to a wide range of audience the activities and results of iv4XR. In particular, a Twitter handle has been created (https://twitter.com/iv4xr) at the official launching of the project. Furthermore, a Facebook page (https://www.facebook.com/iv4xr/) has also been created at the same time. These two social media platforms together constitute a significant portion of the research community as well as the general public. The Twitter feed is also integrated with the project website via Twitter API so that the tweets from the project as well as tweets referring to the project and re-tweets appear on the project website automatically. Twitter in particular is intensively used by the research community for sharing information and iv4XR has started integrating itself in this community and communicating results. We also use LinkedIn's professional network (https://www.linkedin.com/company/iv4xr-project) to maximise the project's presence and increase reachability of project output.

Furthermore, we also communicate information about the project through the individual researchers and partners along their respective social media platforms and networks, such as LinkedIn, YouTube, etc.

3.6 Website

The iv4XR project website (https://iv4xr-project.eu) was created at the official launch of the project and made immediately operational by providing basic information about the project, the consortium, the objective of the project and proposed solution, as well as the industrial use cases. The details about the structure and content of the website are documented in the deliverable D6.1 [3], released at the end of the first month of the project.

The website is continuously updated and maintained by incorporating information about ongoing activities as well as dissemination and communication of project results, such as, published

articles and releases of different prototypes and code. Furthermore, it includes a multimedia gallery where different multimedia content is presented, documenting the various activities undertaken as part of the project.

The website keeps track of visitors. Since the tracking functionality was set up (August 2020), there were more than 5,000 unique visitors with over 7,000 visits, from different geographical locations. Figure 1 shows a snapshot of the overall growth of visitors and visits over the entire period the website has been active.

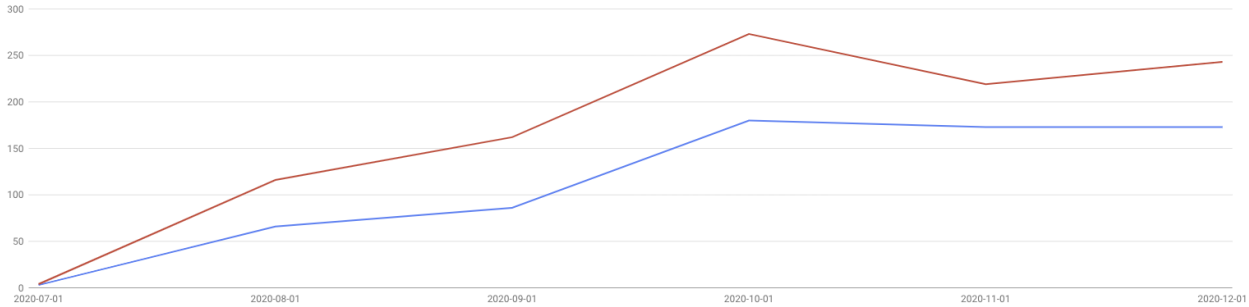

Figure 1: Website traffic growth over the period August, 2020 - December, 2022

Website traffic for each section of the website is also shown in Figure 2.

Rank	Title	Hits	Percent
1	Home	4626	66.21%
2	Consortium	479	6.86%
3	Publications	410	5.87%
4	Use cases	362	5.19%
5	News	270	3.87%
6	Downloads	244	3.50%
7	Newsletter	196	2.81%
8	Media Gallery	180	2.58%
9	Contact	180	2.58%
10	Privacy Policy	40	0.58%

Figure 2: Overall website traffic share for each section of the website

3.7 Newsletter & Press Releases

The eighth edition of the newsletter has been released, and a subsequent edition is in preparation. As we explained previously, the timeline has been shifted by a few months because of the interruption caused by the Covid-19 pandemic. During 2021, we have striven to adhere to the initially planned schedule and number of editions, publishing the fourth newsletter in October

2021. During 2022, newsletters were published in February, June, August, and November. The final one will be published at the end of December 2022.
The list of newsletters is available in the project website at: https://iv4xr-project.eu/newsletter/

We also made a press release and translated it into three languages to share in different media outlets and within our institutions. New press releases will be created when we have more news to share with the general public.

The project had a media appearance in an interview for the Portuguese national radio station Antena 1 in the program “90 seconds of science”.
https://www.90segundosdeciencia.pt/episodes/ep-969-rui-prada/

During the lifetime of the project, we also aimed at reaching a broader audience by publishing in magazines and sharing a white paper. We published an article in EU researcher magazine titled *Autonomous agents to accelerate extended reality testing* (iv4XR | EU Researcher) and another article in Open Access Government titled *Artificial Intelligence Test Agents for Automated Testing of XR* (Artificial Intelligence test agents for automated testing of Extended Reality (XR) (openaccessgovernment.org). Adding to this, we also shared the white paper (an output of task 6.2) via email and social media, and we shared it on Medium in an effort to reach an even broader audience.

3.8 Video media

Videos documenting project meetings as well as prototype demonstrations and conference presentations have been produced and made available via the project website (https://iv4xr-project.eu/media-gallery/).

We have produced a first short video teaser about the project, its approach and tools produced as part of our communication and dissemination activities:
https://www.youtube.com/watch?v=1BzLSfsvruA.

Then we made a series of videos from different partners, using the studio of UPV to record the polimedia videos. These include a project overview and the presentation of two of the project’s pilots: Space Engineers (by GoodAI) and LiveSite (by Gameware).

Finally, we produced a professionally video to present the project’s final achievements: https://www.youtube.com/watch?v=WRMQYKAFKTw. The video was made with a larger audience in mind including potential future users of the iv4XR toolkit (https://iv4xr-project.eu/toolkit). It was used in our booth at Immersive Tech Week in the Netherlands, 2022 (VRDays).

3.9 Dissemination materials

3.9.1 Templates

In order to harmonize the graphical and presentation aspects of all produced online and print material, templates for project deliverables and presentations have been created and made available and are adopted for project wide use.

3.9.2 Logo

One of the first activities of the iv4XR project was the creation of a project logo as part of establishing the project's digital identity. After brainstorming at the project kick-off meeting and different iterations, the following logo has been adopted for the project, as also documented in the deliverable D6.1 [3].

3.9.3 Leaflet

We created a leaflet (brochure) with an example application of the iv4XR solution and distributed it at Immersive Tech Week (former VRDays). Unfortunately, due to the covid-19 pandemic we did not have the opportunity to distribute the leaflet at other venues. Figure 3 presents the leaflet of iv4xr project.

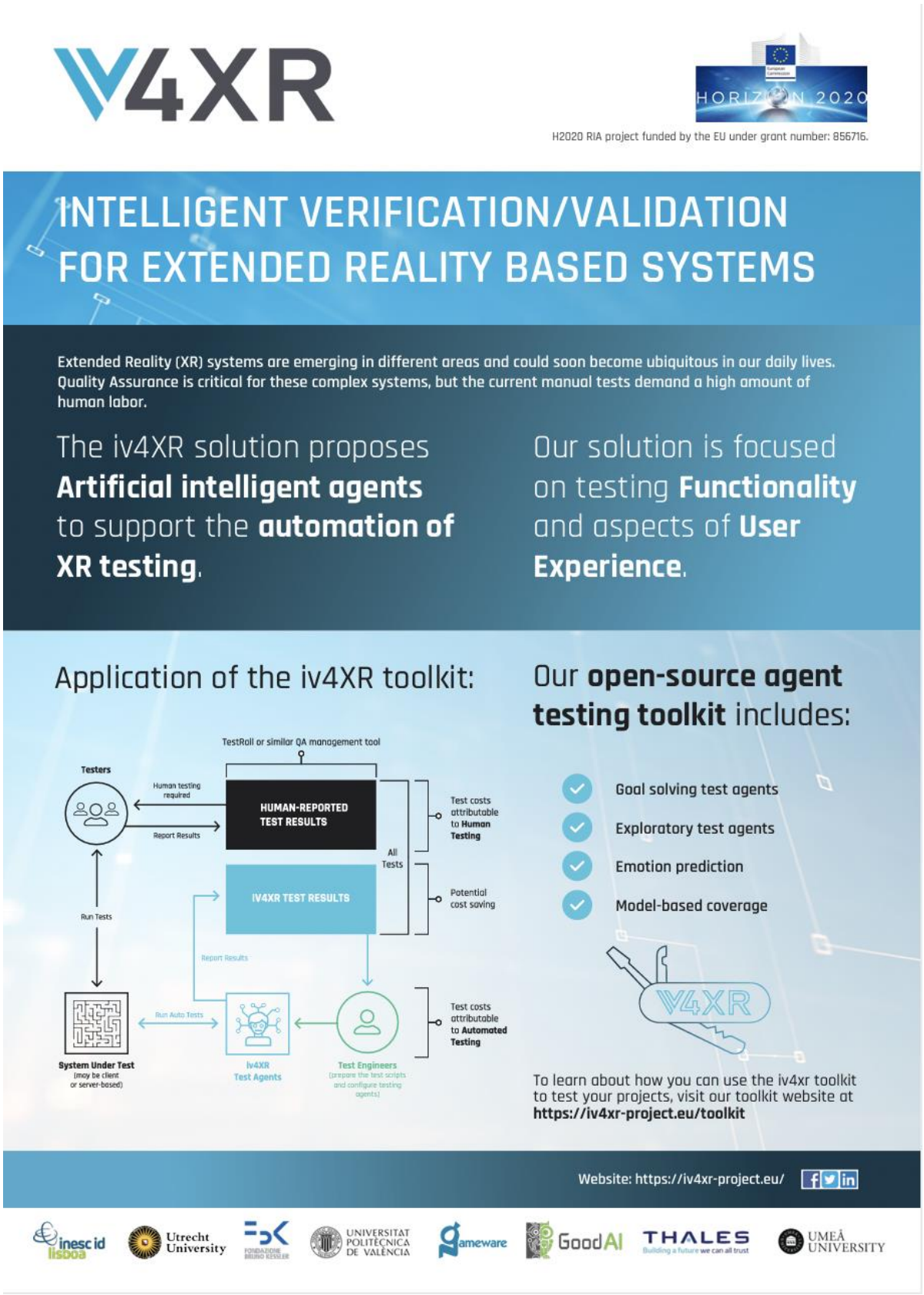

Figure 3: Iv4xr project leaflet

3.10 Dissemination and Communication KPIs

To audit our proposed dissemination and communication activities we have identified several KPIs that help us in tracking progress. Table 8 below presents the KPIs along with the expected final goals as well as the current values.

Table 8: Dissemination and communication KPIs

Key Performance Indicators (KPIs)	
Best paper and presentations prizes	1/2
Likes on dedicated Facebook page	92/350
Followers on Twitter	124/2000
Posts on Facebook	42/36
Tweets	116/36
Visits on the project website	7,013/1500 5,069 visitors
Project Newsletter editions	9/9
Project video clips	5/3
Dissemination & Exploitation plan (number of iterative versions)	3/3
Conference publications in target conferences	24/20
Journal peer reviewed articles	2/6 5 under review
Dedicated events (workshop)	4/2
Presentations at trade events/industrial conferences	3/3

While the KPIs capture important indicators regarding dissemination and communication actions, they do not necessarily capture all the impact generated by the activities undertaken. For instance, even if the number of followers on Twitter is low, our tweets get good engagement and visibility, as can be seen in the figure below from Twitter Analytics (see Figure 4).

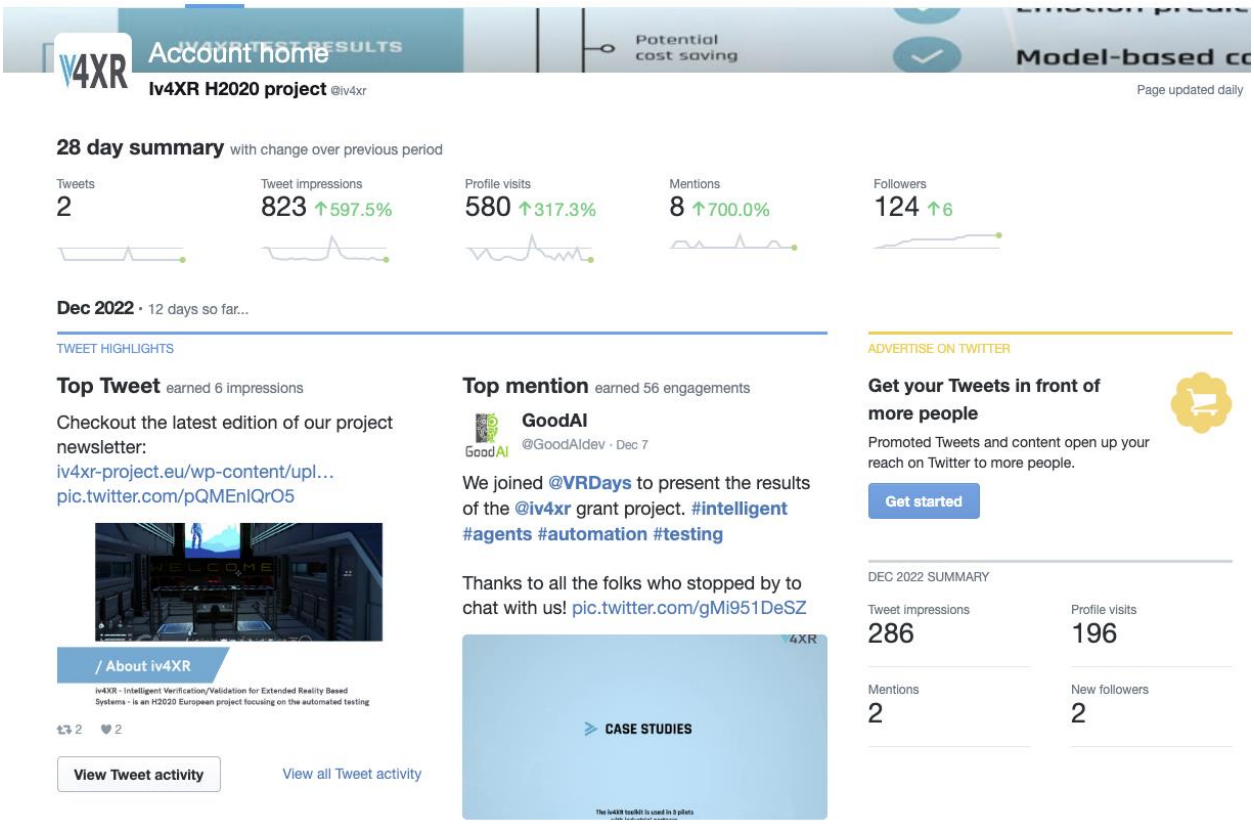

Figure 4: Twitter analytics for iv4xr project

Similarly for Facebook, though the number of likes on our Facebook page is low, the number of people reached from our posts and the number of interactions generated is far greater, as can be seen from the screenshot in Figure 5 below.

Title	Date published	Reach	Engagements	Likes and reactions
This post has no text Iv4XR-project	Sat Dec 3, 10:46am	29 People reached	5 Post engagements	1 Reactions
This post has no text Iv4XR-project	Fri Nov 25, 1:31pm	5 People reached	2 Post engagements	0 Reactions
To enable automated software testing, the ability to automatical... Iv4XR-project	Thu Nov 17, 12:28pm	33 People reached	3 Post engagements	2 Reactions
Watch here a short presentation and demo about the iv4XR fra... Iv4XR-project	Thu Nov 3, 10:53am	11 People reached	4 Post engagements	1 Reactions
Over the last 30 years, GUIs have changed considerably, beco... Iv4XR-project	Sat Oct 29, 6:47pm	19 People reached	1 Post engagements	1 Reactions
Testing is of paramount importance in assuring the quality of so... Iv4XR-project	Mon Oct 24, 10:48...	25 People reached	5 Post engagements	3 Reactions
Modern computer games typically have a huge interaction spac... Iv4XR-project	Fri Oct 21, 8:45am	24 People reached	3 Post engagements	2 Reactions
Find out about our ongoing work applying reinforcement learnin... Iv4XR-project	Wed Oct 19, 12:46...	33 People reached	5 Post engagements	3 Reactions
Modern interactive software, such as computer games, employ ... Iv4XR-project	Thu Oct 13, 10:15pm	11 People reached	3 Post engagements	2 Reactions
Designers of extended reality systems need to predict users fe... Iv4XR-project	Mon Oct 10, 1:19pm	16 People reached	3 Post engagements	2 Reactions

Figure 5: Facebook posts and their reachability (last 90 days)

4 Exploitation Activities

4.1 Aims and objectives

Our exploitation plan aimed at maximizing the post-project exploitation of iv4XR results within and outside the consortium.

Inside the consortium, the project results can be exploited directly by the partners with different objectives depending on their respective missions: Higher education, Professional Training & Public Service; Research & Valorization; Adoption.

Industrial actors outside the consortium may also be interested in the project results to devise new ways to improve the quality of their software and the experience of their users for extended reality applications. The objective of the consortium will be to identify categories of potential users of the iv4XR results, and to sketch the corresponding business models.

A third way to exploit the project results is through cross project collaborations. The consortium partners will target specific European or National projects and define common actions to further leverage the iv4XR results.

4.2 Planned exploitation activities

4.2.1 Exploitation inside the consortium

To measure the direct impact of iv4XR on the consortium partners, we record the actual efforts made by the partners to prepare post-project exploitation of the project results in relation to:

- **Higher education, Professional Training & Public Service**

  Activities of consortium partners to exploit the project results in the context of an educative mission for the benefits of students, professionals or the larger public (INESC-ID, UU, UPV, FBK).

- **Research & Valorization**

  Activities of consortium partners to exploit the project results in order to test research ideas and demonstrate their effectiveness (INESC-ID, UU, FBK, UPV, GA, THA-SIX).

- **Adoption**

  Activities of consortium partners to exploit the project results and improve the quality of their software or the experience of their users (GWE, GA, THA-AVS).

4.2.2 Exploitation outside the consortium

To maximize opportunities for exploitation of the results outside the consortium, we take the following measures:

- **External actor identification**

  List industrial actors potentially interested to invest in further development and exploitation of iv4XR e.g. SMEs that develop XR systems or ICT tech companies that offer QA related tools to the market.

- **Market Analysis**

  Publish a White paper and do a market analysis with the participation of the industrial partners from the consortium, and possibly with the feedback from interested external actors, to describe the identified business opportunities along with the proposed business models.

- **Open Source and Online Demo**

  Make the whole iv4XR stack accessible to the public with an open source license so that parties interested in exploitation will have no impediment to do so. Deploy an instance of iv4XR online as a demo to let the public (developers, students, researchers) interactively try out the concept of declarative XR testing.

4.2.3 Exploitation through cross-project collaboration

In order to further exploit the results of iv4XR, we try to work together with intersecting EU projects by:

- **Target Project Identification**

  Establish relationships with a selection of European or National projects relevant for a collaboration able to strengthen each other's scope.

- **Definition of Synergistic Activities**

  For each of the identified projects, identify opportunities to collaboratively address some aspects in verification and validation, which are less emphasized or left out from the iv4XR scope.

4.3 IV4XR Open source framework

The iv4xr framework is an agent-based system, where a testing task is formulated by a set of goals and tactics that a test agent performs. The iv4xr framework is neutral with respect to the XR technology of the system under test. The test agents correspond to functional test agents (FTAs) and socio-emotional agents (SETAs). The FTAs uses model-based testing, exploratory testing, and search-based goal solvers. The socio-emotional test agents are used to test non-functional properties. The top-level architecture of the iv4xr framework is presented in Figure 6.

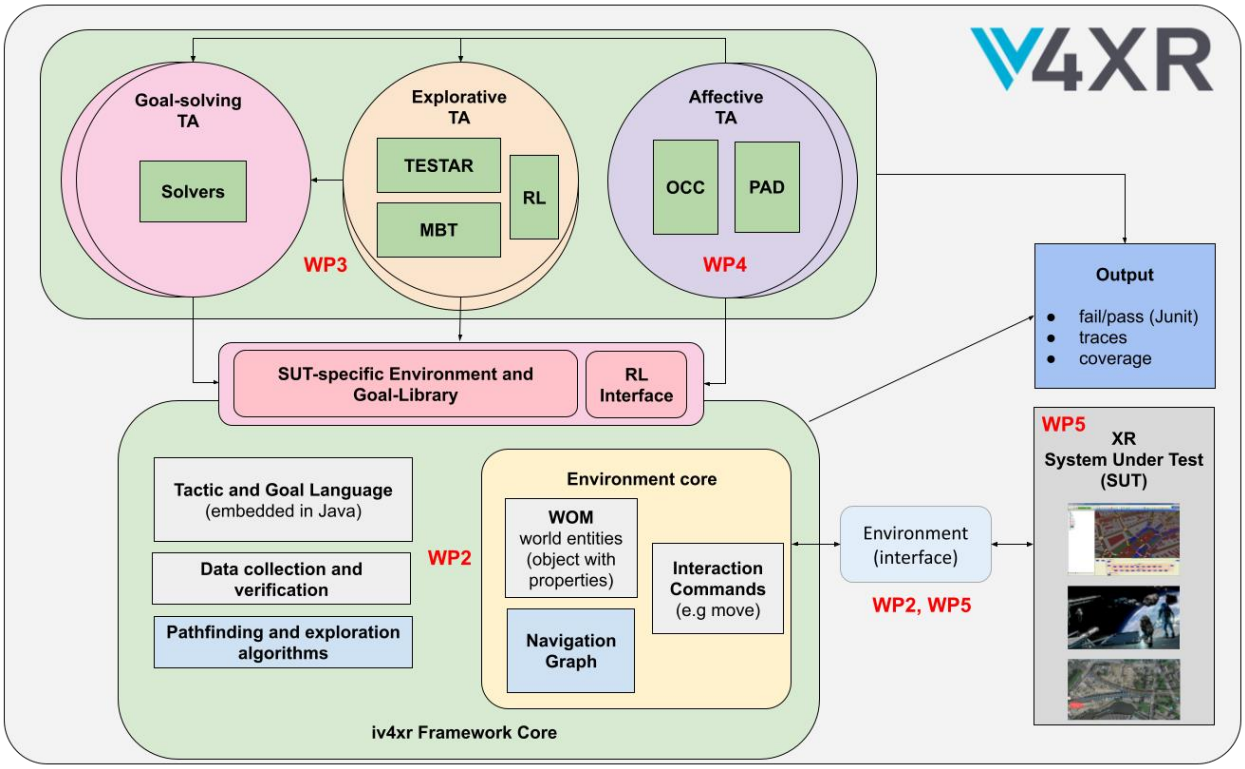

Figure 6: Top-level architecture of the iv4xr framework

An example of the application of the iv4xr framework is presented in Figure 7.

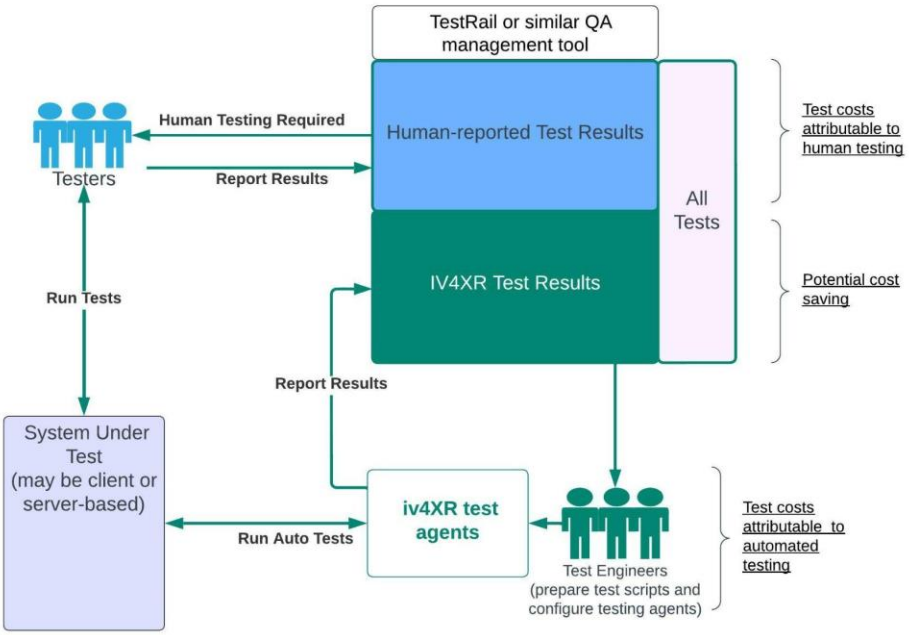

Figure 7: Example of application of the iv4xr framework

As can be depicted from figures 6 and 7, the iv4xr framework is comprised of several tools that we briefly describe below, with the corresponding license and how to access the different tools.

LabRecruits	Lab Recruits is a 3D computer game constructed to allow researchers to define their own game levels and hence allow much more control over the kind of experiments they want to do. This system demonstrates how to integrate different types of iv4XR agents as well as the definition of tactics and goals. https://github.com/iv4xr-project/labrecruits **LICENSE**: BSD 3-Clause
aplib	This java library is the core package of the iv4XR framework. It contains the definition of the interfaces that indicate to the System Under Test (SUT) plugins how to integrate the concept of the World Object Model (WOM) and the definitions of tactics and goals to allow Functional Test Agents (FTAs) and Socio-Emotional Test Agents (SETAs) to test the XR systems. https://github.com/iv4xr-project/aplib **LICENSE**: LGPL3
iv4xrDemo	This project is a plugin that demonstrates how to use the aplib library to integrate FTAs and SETAs to test the LabRecruits game system. This project helps the stakeholders with documentation and examples to learn about how to use the iv4XR interface to observe the SUT environment and execute commands. https://github.com/iv4xr-project/iv4xrDemo **LICENSE**: LGPL3
iv4xr-se-plugin	This project is the plugin that provides integration between the industrial game Space Engineers (SE) and the iv4XR framework. It contains documentation and integrated tests that explains to the stakeholders how to obtain the block entities' information, navigate through the 3D space environment, and execute complex action by using SE tools to interact or build 3D constructions. https://github.com/iv4xr-project/iv4xr-se-plugin **LICENSE**: LGPL-3
TESTAR_iv4xr	The TESTAR tool act as an Exploratory FTA within the iv4XR framework. This agent uses the scriptless approach to automatically observe the environment, execute actions and verify the system's behavior while trying to learn potentially interesting actions. This FTA uses the **iv4xrDemo** and **iv4xr-se-plugin** to explore LabRecruits and Space Engineers XR systems. The complete description and usage instructions can be found in the wiki

	section of the GitHub repository: https://github.com/iv4xr-project/TESTAR_iv4xr **LICENSE**: BSD-3
EvoMBT	EvoMBT implements a model based testing (MBT) approach for the generation of test cases. It supports the generation of tests for LabRecruits and SpaceEngineers, including the generation of models of varying size and complexity. It also supports the execution of the model generated tests on the games themselves. EvoMBT produces different artefacts including tests generated, both abstract and concrete, coverage reports, execution reports, and models. EvoMBT uses the iv4xr agent infrastructure for executing tests on the games under test. Documentation is available as wiki: https://github.com/iv4xr-project/iv4xr-mbt/wiki and the tool source code and necessary artefacts are available from the public GitHub repository: https://github.com/iv4xr-project/iv4xr-mbt **LICENSE**: Apache License 2.0
RLbT	RLbT implements multi-agent Reinforcement Learning (RL) for exploring the game under test through the iv4xr agent framework. The RL actions considered by RLbT are at a high-level of abstraction involving agent actions such as interacting with game objects, rather than atomic agent movements. RLbT then serializes the actions of the RL agents as a series of goals for the test agent, which can be re-executed later. RLbT produces coverage reports stating what percentage of the game elements have been interacted with, as well as the spatial coverage of the game as a result of the agent's movement in the game. Documentation is available as wiki: https://github.com/iv4xr-project/iv4xr-rlbt/wiki and the tool source code and necessary artefacts are available from the public GitHub repository: https://github.com/iv4xr-project/iv4xr-rlbt **LICENSE**: Apache License 2.0
SETAs	The Socio-Emotional Testing Agents developed in the iv4XR project are made out of several different modules, both behavioral and concerning the prediction of user experience metrics.

	PAD Model of Emotion Module GitHub Repository: https://github.com/iv4xr-project/PAD_emotion_game **LICENSE**: Apache License 2.0 OCC Model of Emotion Module GitHub Repository: https://github.com/iv4xr-project/jocc **LICENSE**: LGPL-3 Persona Agents Module GitHub Repository: https://github.com/iv4xr-project/PAD_emotion_game **LICENSE**: Apache License 2.0 Difficulty Estimation Module GitHub Repository: https://github.com/iv4xr-project/difficultysch **LICENSE**: Apache License 2.0 Motion Sickness on VR Module GitHub Repository: https://github.com/iv4xr-project/CSPredictionInVR **LICENSE**: Apache License 2.0 Testing of Interactive Storytelling Module GitHub Repository: https://github.com/iv4xr-project/in-story-validator\ **LICENSE**: Apache License 2.0

4.4 Undertaken Exploitation Activities

Regarding the exploitation outside the consortium, we have identified key industrial sectors, such as automotive and avionics, game development, software design and testing, higher education, among others. We contact different companies in these sectors, and we briefly present the main objective of iv4XR as well as we ask about needs and possibilities that they use the technology of iv4XR. To do that, we created a questionnaire that was distributed to the key sectors during December- 2021 to January 2022. The questionnaire consisted of 12 questions to characterize our sample (industry type and company size) and collect information regarding the extended reality systems used and testing procedures, including costs and participants opinions on agent-based testing and its potential usefulness in their testing procedures. We distributed the questionnaire to some 300 companies. Despite several efforts to encourage a higher response rate we received 34 responses. Nevertheless, the answers give us evidence of valuable feedback.

The answers received correspond to the following industrial sectors (see figure 6). Our findings indicate that the key markets for automated XR testing are as follows: Automotive, Aviation, Education, Training simulations, Gaming and Entertainment.

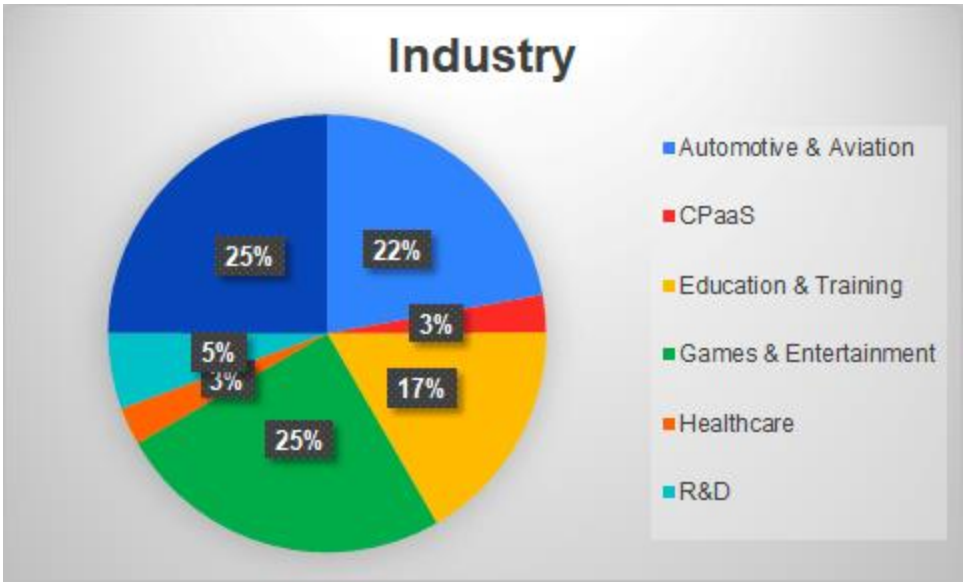

Figure 6: Industrial sectors reached by the survey

Results indicated that 25% of the companies which answered the questionnaire were from companies that develop XR systems. With respect to the type of XR systems that the company use, these were distributed as follows:

- 78% of respondents select Virtual Reality (VR) systems,
- 55% select Augmented Reality (AR) systems,
- 44% of respondents select Mixed Reality (MR) systems,
- 55% select Other 2D Virtual Environments (e.g. browser-based data handling/analytics or 2D simulations),
- 89% select Other 3D Virtual Environments (e.g. simulations, games, or CAD systems).

When we asked if they develop all the software or they use third party companies in their development process, 44% answered that they develop their XR systems in-house, 22% of respondents say that they develop the XR systems as well as third party companies, and 33% of companies only use XR systems developed by third party companies.

Regarding the question about testing the XR systems, 89% state that they have an internal department for testing, and 11% reported that they use a combination of the internal department with an external department.

Regarding the current need for automated testing of XR systems, 44% of companies state that they are not required at present, 11% stated that they might be required, and 44% state that they do require automated solutions for testing their XR systems. The last question was related to the interest of companies for automated testing tools for the future. 44% of companies state that they will require it, 22% state that they could require it, and 33% stated that they will not require the automated testing tools for XR systems.

The results obtained from the market research confirm the need to have tools to improve the verification and validation of XR systems and leave an open path to exploit the results of the project in different industries. Even though we explore commercial options of the iv4xr framework and toolkit, and we found commercial opportunities in the market research as well as competitors (i.e. Game Driver and Modl.ai have received more than $3 million USD during 2022), in a consortium meeting with all the partners we decide that we will not exploit the commercial options and we will use an Open Source license (e.g., BSD-3) for the technology developed during the iv4xr project. More details of the market research can be found in the white paper [5] and in Deliverable 6.5 Market Research [6]. Below we provide details of the exploitation activities per partner with the corresponding sustainability plan of the iv4xr framework.

4.4 Exploitation activities per partner

Partner	INESC-ID
Profile	INESC-ID, “Instituto de Engenharia de Sistemas e Computadores: Investigação e Desenvolvimento em Lisboa” is a Research and Development and Innovation Organization (R&D+i) in the fields of Computer Science and Electrical and Computer Engineering. INESC-ID is a private not for-profit institution, registered in 1999, officially declared of public interest, owned by Instituto Superior Técnico (IST) (51%) and INESC-ID – Instituto de Engenharia de Sistemas e Computadores (49%). Researchers at INESC-ID are in their vast majority university staff and graduate students. And since IST is the main owner of INESC-ID, the majority of researchers also have teaching positions at IST. INESC-ID promotes cooperation between academia and industry by addressing research on daily life issues, such as healthcare, space, mobility, human language technologies, agri-food, industry 4.0, and smart grids. This high level of knowledge transfer is achieved through both competitive research projects and direct contracted research. Therefore, public and private entities have access to a pool of knowledge, resources and services provided through the unique competencies available at the institution.
Internal Exploitation	INESC-ID will exploit the results of the project internally by using the knowledge of the iv4XR project in master courses, guiding final projects of undergraduate students or thesis of master or doctoral students, and using the testing tools developed during the project. INESC-ID is in fact already doing this and has some MSc students and one PhD student

	that will develop work related to automated assessment of User Experience.
External Exploitation	INESC-ID will pursue other projects that can make use of the tools developed in iv4XR.
Sustainability	INESC-ID will continue to develop the tools created and explore new tools that can be used to assess User Experience. The creation and maintenance of the toolkit website (details below the set of tables) will improve exploitation and sustainability by ensuring that new interested parties can be used and understood.

Partner	UPV
Profile	The Universidad Politecnica de Valencia (UPV), is a public, dynamic and innovative university dedicated to researching and teaching. The UPV maintains strong bonds with its social environment and a strong presence abroad. It is important how research can contribute to education to satisfy current society needs. One of the pillars of the UPV has been and will continue to be its research capacity. Its departments, research centres and institutes undertake research projects jointly with national and international bodies and companies. Research is not simply another means of educating, but is a way of maintaining direct contact with society, its reality and needs, while ensuring a permanent fine-tuning of university structures.
Internal Exploitation	UPV will exploit the results of the project internally by using the knowledge of the iv4XR project in master courses, guiding final projects of undergraduate students or thesis of master or doctoral students, and using the testing tools developed during the project.
External Exploitation	UPV will use its networks to pursue the use of the tools developed during the iv4XR project in other competitive EU projects.
Sustainability	The TESTAR tool was born more than 10 years ago, and it has been continuously evolving inside the UPV research team. UPV will continue maintaining the TESTAR exploratory FTA under the license BSD-3 with the corresponding integration to the iv4xr framework. We will continue researching about the scalability of the exploratory agent. Moreover, we will create more oracles and action selection mechanisms to improve navigation and fault detection of XR systems.

Partner	GWE - Gameware Europe
Profile	Gameware is a leading edge SME game and technology development studio based in Cambridge, UK. Gameware have developed a wide range of innovative technologies - from the sensor data monitoring

	testbed deployed by MabeyHire to 3D photorealistic avatars and game and TV products. Gameware has a policy to network and engage across all creative disciplines as we look toward the emerging creative possibilities that the Metaverse is likely to provide.
Internal Exploitation	Gameware will continue to utilise the testing tools developed during the project for rapid assessment of developed code.
External Exploitation	iv4XR has been promoted by Gameware via 'Cambridge Network' and 'Games Eden' - These networks will be made aware of the tools available in the iv4XR public repository and toolkit webpage.
Sustainability	The java tools and script processor developed during iv4XR have been integrated into the commercial Mabey LiveSite system, which now benefits from the techniques developed during the iv4XR project. The tools are also constantly being upgraded, with a view to maximising efficiency and error detections. We are also looking at detecting errors which have not occurred, but may do in the future, due to trends in data for a project. This ongoing development will thereby ensure that the toolset will be maintained and upgraded as future project work requires. We will continue to use some of the techniques of the test case libraries for testing purposes. Where appropriate we will also look to support and sustain the availability of iv4XR developed algorithms via the supported open source sites.

Partner	Thales SIX GTS
Profile	Thales SIX GTS is a branch of Thales that produces secure communication systems and security systems for critical infrastructure and travellers. Thales is developing its activity of designing systems that help decision-making in complex environments for civilian or military markets.
Internal Exploitation	Thales SIX GTS will exploit the results of the project internally, especially, we plan to study the use of smart agents for automatic testing of products and systems in collaboration with the team in charge of providing simulation, UX design and testing services inside Thales.

External Exploitation	Thales SIX GTS will use its networks to pursue the use of the tools developed during the IV4XR project in other competitive EU projects.
Sustainability	Thales SIX GTS will continue developing work on smart agents for automatic testing and will continue collaborating with Thales AVS and their internal exploitation.

Partner	Thales AVS France
Profile	Thales AVS France, thanks to its “Training & Simulation” (T&S), is a world leader in training facilities. T&S proposes a large variety of simulations and simulators to its customers in both civilian and military markets. Its products cover technical skill acquisition to collective training application and certified simulators (for instance, in the helicopter market).
Internal Exploitation	Thales AVS France will exploit the results of the project internally by continuing to modify its interfaces and simulations tools in order to be able to develop automatic testing for Thales simulations. More precisely, we will continue to exploit the Reinforcement Learning tools included in the iv4XR Framework to construct a new testing procedure based on agent testing.
External Exploitation	Thales AVS France is considering using the automatic testing procedure evaluated during the project with the iv4XR Framework in our future customer projects. These new testing facilities will need further developments to become more efficient and, in particular, the modification of the simulation means in order to be able to run AI algorithms much quicker than today without losing the representativity of the simulation results. Based on this increase in the level of maturity (TRL) of the common use of AI and Simulation, we hope to be able to propose these new functionalities to our project developers in the next few years.
Sustainability	The sustainability of the project, for Thales AVS France, relies on the future modifications of the architecture of our simulation means in order to be able to take into account the requirements of the use of Machine Learning tools in our applications. This is in particular the case with the

	test agents we intended to use to partially replace the human testers we currently use in our customer project. iv4XR has proved with our case study that this new testing procedure is possible. We need now to develop the evolved simulations that will be able to exploit such AI functionalities and to follow the evolution of the iv4XR Framework that will help us to achieve this goal.

Partner	Good AI
Profile	Good AI is an AI research company looking into (among other things) artificial general intelligence and fusing deep learning with gameplay experiences. Their sister company Keen Software House is the developer of Space Engineers, which is being used as one of the pilots for this project.
Internal Exploitation	The results of the iv4XR project for the Space Engineers development team has been a suite of tools for automating their tests in scripted and unscripted fashions. These tools are being actively used by the testing teams in order to accelerate the development and release processes for Space Engineers. Additionally, lessons learned from the development of these tools have been communicated to the other departments of the two companies. After discussions with the lead developers, future projects will make automated and autonomous testing one of the development priorities. There are more tests to be automated for Space Engineers, so further work will complete the set of tests that have been planned for the initial implementation. And if possible and feasible, more complex tests will be implemented along with more integration of the exploratory testing systems developed in the project.
External Exploitation	The interfaces created for the purposes of iv4XR have applications beyond testing. As an example, one of GoodAIs external collaborators has made use of Space Engineers as a testbed for their procedural generation algorithms[4]. Further exploitation of these interfaces may take the form of a modification tool for the game, where players would be able to have AI controlled characters in their game. Discussion is currently underway of whether and how to release this.

Sustainability	The internal exploitation plan intends to automate as many of the tests as possible. In doing that, some adjustments to the plugin will need to be made to accommodate functionality that have hitherto not yet been required. It is internally estimated to take another 6-9 months to finish the implementation. If the interfaces are released as a modification tool and they prove popular, then it is likely that development effort will be spent to keep the interfaces up to date. They will be maintained for at least the amount of time required to finish the test implementation, and if there is enough interest in the interface during that time, the interface could be adopted as an official tool, where it would receive regular updates on the same schedule as the game itself.

Partner	FBK
Profile	The Fondazione Bruno Kessler (FBK) is an Italian private research institution dedicated to research excellence in numerous disciplines and designated to keep the Autonomous Province of Trento in the mainstream of European and international research. Each research area is assigned to a specific research centre, eleven in total, ranging from information technology research to microelectronics to human studies.
Internal Exploitation	As a research institution, FBK plans to exploit the outputs of iv4XR mainly in research projects and internal research-driven activities. Some of the practical plans include exploitation of: Know-how on the automated generation of test cases in the case of Model-Driven development exploiting search and machine learning based techniques; Software prototypes implementing agent-based testing techniques to be used in different domains also outside the XR environment; Findings from the validation of the testing tool in the industrial environment.
External Exploitation	FBK plans to include the knowledge developed in the project in the teaching material related to PhD courses in Universities in Italy and abroad. Moreover, FBK will exploit and evolve the techniques in other EU and industrial research projects.
Sustainability	The techniques developed during the iv4XR project are one of the fundamental research assets in FBK. The algorithms and the tools will be continuously maintained and evolved using internal resources and exploiting resources from other research projects. Specifically, we will continue developing novel search-based and machine learning based techniques to be included in the portfolio developed during the project.

	Moreover, we plan to include some of the techniques in the portfolio of test case generation libraries, such as EvoSuite, to further increase the availability of the algorithms developed in the iv4x project in the context of other open source tools and frameworks.

Partner	UU
Profile	Utrecht University (UU) is a public research university with 30.000+ students. It offers bachelor and master programmes in Computing Sciences, or strongly related to Computing Sciences, such as Artificial Intelligence and Game and Media Technology. It maintains active research in areas such as Software Technology, algorithm design, artificial intelligence, and game and media technology.
Internal Exploitation	UU plans to include the knowledge developed in the project in the teaching material for courses related to software testing. We also plan to use the technology from iv4xr for our master thesis projects in the field of automated software testing, both as a tool to aid the projects and as subjects to be improved through research carried out by such projects.
External Exploitation	We are considering to create a C# port of iv4xr with tight integration to the popular game engine Unity.
Sustainability	iv4xr Framework Core, and also main components such as the MBT component, RL component, and Affective component, are important assets for UU's future research. We will continue to maintain at least the Core and will help other partners to maintain the other components.

Partner	UMU
Profile	Umeå University is the largest university in the northern half of Sweden. The university offers courses and study programmes and performs world leading research in a wide range of subjects. The department of Computing Science has 110 employees with a background from more than 20 countries. UMU conducts research on a broad range of topics in the area of Computing Science and offers courses and study programs at bachelor, master and doctoral level. Each year, over 2000 students are taking at least one course at our department.

Internal Exploitation	The topics of Software Engineering, Artificial Intelligence and Human-Computer Interaction are part of the research activities of Umeå University. The outputs of iv4XR will trigger new research directions for the activities of people engaged with SE, AI and HCI research. Additionally, the iv4XR tools will support the research activities that rely on user testing.
External Exploitation	External Exploitation will be done in collaboration with the University of Utrecht.
Sustainability	UMU will continue collaborating with UU and will pursue new research directions inspired by the work developed within this project. Sustainability is ensured by the continuation of research topics like Software Engineering, Artificial Intelligence and Human-Computer Interaction which are part of the university curriculum.

Regarding sustainability, as we state in the DoA of the project, we make the results openly accessible to people from the beginning of the project. Scientific results are openly available in the ZENODO repository, and the iv4xr framework is available to registered users at https://github.com/iv4xr-project/iv4xr-framework. Moreover, taking into account that we still want to submit to journal publications the results of the iv4xr project during the first semester of 2023, we expect that the number of publications in the iv4xr repository of ZENODO will increase.

In order to facilitate understanding of the iv4xr framework and its diverse components, we create a dedicated webpage that presents the iv4XR toolkit: https://iv4xr-project.eu/tookit. The main page contains a video that explains in a simple and entertaining way the problem and the solution provided by the iv4xr. The rest of the website is dedicated to presenting information about how to use the different testing agents and the use cases that demonstrate the feasibility of using the iv4xr solution in agile developments. The webpage is meant to be a frontend to the source code and information provided in the GitHub, to facilitate understanding, and adoption, of the tools provided. The iv4XR toolkit webpage will be maintained and improved in the following years. A new domain name was purchased for this purpose: https://iv4xr-toolkit.eu.

To improve dissemination and sustainability, we will include project information and results in the European AI-on-demand (AIOD) platform. According to AIOD, their platform is a facilitator of knowledge transfer from research to multiple business domains. The platform, created in 2019, with the support of the European Commission, brings together European industry, commerce, research and society to address the fragmentation of the European AI landscape.

Additionally, each partner has the commitment to continuously maintain all the tools of the iv4xr framework during 5 years, as it is presented above. Moreover, the website will be maintained during 5 years to provide a common point to easily access all the results of the iv4xr project.

We are also considering to apply for research funding, e.g. from the Horizon Europe programme, either to improve the TRL level of iv4xr technology, or to apply the accumulated knowledge and technology from iv4xr on related domains (e.g. further into the AR domain, or to use iv4xr for the Robotics domain).

5 Conclusions

This deliverable presented the third version of the project dissemination and communication plan. Summary of central elements of the dissemination and exploitation plan are:

- Description of the strategy for dissemination, communication, and exploitation during the project.
- List of all dissemination, communication and exploitation activities carried out in the first, second and third year of the project.
- Identification of target audiences for exploitation.
- Details of the planned exploitation activities inside and outside of the project.

6 References

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