Impact-Aware Manipulation by Dexterous Robot Control and Learning in Dynamic Semi-Structured Logistic Environments

Minutes of the milestone review consortium meeting (focus BOX and GRAB scenarios)

Dissemination level	Public (PU)
Work package	WP6: Management
Deliverable number	D6.8
Version (D = Draft, F = Final)	F – 1.0
Submission date	30/06/2022
Due date	30/06/2022

www.i.am-project.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871899.

Authors

Authors in alphabetical order		
Name	**Organisation**	**Email**
Maarten JONGENEEL	TU/e	m.j.jongeneel@tue.nl
Jos DEN OUDEN	TU/e	j.h.v.d.ouden@tue.nl
Jari VAN STEEN	TU/e	j.j.v.steen@tue.nl

Control sheet

Version history			
Versio	**Date**	**Modified by**	**Summary of changes**
0.1	13/06/2022	Jos DEN OUDEN	ToC & first contents
0.11	16/06/2022	Maarten JONGENEEL, Jos DEN OUDEN, Jari VAN STEEN	Merged & reviewed minutes from Jari and Maarten
0.12	18/06/2022	Jos DEN OUDEN	Ready for internal review
0.2	21/06/2022	Jos DEN OUDEN, Maarten JONGENEEL, Jari VAN STEEN, Alexander OLIVA	Pre-final version ready for peer-review
0.23	30/06/2022	Jos DEN OUDEN, Stijn DE LOOIJER, Teun BOSCH, Alessandro SACCON, Claude LACOURSIERE, Harshit KHURANA, Abderrahmane KHEDDAR	Peer-review comments addressed
1.0	30/06/2022	Jos DEN OUDEN	Revised version ready for submission, quality check

Peer reviewers		
	Reviewer name	**Date**
Reviewer 1	Jari VAN STEEN	21/06/2022
Reviewer 2	Alexander OLIVA	21/06/2022
Reviewer 3	Alessandro SACCON	22/06/2022

Legal disclaimer

1. TABLE OF CONTENTS

ABBREVIATIONS

Abbreviation	Definition
EC	European Commission
WP	Work Package
TU/e	TECHNISCHE UNIVERSITEIT EINDHOVEN
EPFL	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE
TUM	TECHNISCHE UNIVERSITAET MUENCHEN
CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
AGX	ALGORYX SIMULATION
FRANKA	FRANKA EMIKA GmbH
SR	SMART ROBOTICS BV
VDLANDE	VANDERLANDE INDUSTRIES BV

1. Introduction

1.1. Project background

Europe is leading the market of torque-controlled robots. These robots can withstand physical interaction with the environment, including impacts, while providing accurate sensing and actuation capabilities. I.AM. leverages this technology and strengthens European leadership by endowing robots to exploit intentional impacts for manipulation. I.AM. focuses on impact aware manipulation in logistics, a new area of application for robotics which will grow exponentially in the coming years, due to socio-economical drivers such as booming of e-commerce and scarcity of labour.
I.AM. relies on four scientific and technological research lines that will lead to breakthroughs in modelling, sensing, learning and control of fast impacts:

1. I.Model offers experimentally validated accurate impact models, embedded in a highly realistic simulator to predict post-impact robot states based on pre-impact conditions;
2. I.Learn provides advances in planning and learning for generating desired control parameters based on models of uncertainties inherent to impacts;
3. I.Sense develops an impact-aware sensing technology to robustly assess velocity, force, and robot contact state in proximity of impact times, allowing to distinguish between expected and unexpected events;
4. I.Control generates a framework that, in conjunction with the realistic models, advanced planning, and sensing components, allows for robust execution of dynamic manipulation tasks.

This integrated paradigm, I.AM., brings robots to an unprecedented level of manipulation abilities. By incorporating this new technology in existing robots, I.AM. enables shorter cycle time (10%) for applications requiring dynamic manipulation in logistics. I.AM. will speed up the take-up and deployment in this domain by validating its progress in three realistic scenarios: a bin-to-belt application demonstrating object tossing, a bin-to-bin application object fast boxing, and a case depalletizing scenario demonstrating object grabbing.

1.1. Purpose of the deliverable

Deliverable D6.8 is a document summarizing the reflections and decisions of the whole consortium taken to ensure up the reaching of all milestones up to M30 (in particular, the experimental execution of the BOX and GRAB scenarios), during the MIDYEAR consortium meeting, taking place 15 June 2022 at EPFL (and online in hybrid fashion).
This deliverable is a follow-up of the first deliverable (D6.4) and second deliverable (D6.7) delivered in M1 and M18 respectively. These deliverables will receive a final update in M42 by deliverable D6.9, which focuses on the final validation TOSS, BOX, and GRAB scenarios.

1.2. Intended audience

The dissemination level of D6.8 is 'public' (PU) and available to members of the consortium, the Commission (EC) services and those external to the project.
This document is primarily intended to serve as an internal guideline and reference for all I.AM. beneficiaries, and its scientific and exploitation boards.

2. Participants

During the 15 June 2022 consortium meeting, held at EPFL, Lausanne, Switzerland as well as online via Teams, the following participants were invited to present their progress in the project and discuss next steps on integration and TOSS, BOX and GRAB scenarios. A list of the affiliation / institutes / company short names in the third column can be found in the Abbreviations section at the start of this document.

Table 1: attending participants

Name	Initials	Affiliation
Alessandro Saccon	ASa	TU/e
Jos den Ouden	JdO	TU/e
Maarten Jongeneel	MJo	TU/e
Jari van Steen	JvS	TU/e
Alexander Oliva	AOl	TU/e
Aude Billard	ABi	EPFL
Michael Bombile	MBo	EPFL
Harshit Khurana	HKh	EPFL
Saeed Abdolshah (online)	SAb	TUM
Sami Haddadin (online)	SHa	TUM
Alexander Kurdas	AKu	TUM
Hugo Kussada (online)	HKu	TUM
Abderrahmane Kheddar	AKh	CNRS
Ahmed Zermane	AZe	CNRS
Yuquan Wang	YWa	CNRS
Claude Lacoursiere	CLa	AGX
Fredrik Nordfeldth (online)	FNo	AGX
Heico Sandee (online)	HSa	SR
Teun Bosch	TBo	SR
Sjouke de Zwart	SdZ	SR
Marco Morganti	MMo	FRANKA
Camilo Rey	CRe	FRANKA
Bas Coenen (online)	BCo	VDLANDE
Stijn de Looijer	SdL	VDLANDE

3. Agenda

The consortium meeting's agenda was the following.

08:45 – 09:00h:	Entering
09:00 – 09:15h:	Welcome and general intro
09:15 – 09:30h:	WP6 – Management & WP8 – Ethics (lead: TU/e)
09:30 – 10:15h:	WP1 – Modeling (lead: TU/e)
10:15 – 10:30h:	Break
10:30 – 11:15h:	WP2 – Learning (lead: EPFL)
11:15 – 12:00h:	WP3 – Sensing (lead: TUM)
12:00 – 13:00h:	Lunch
13:00 – 13:45h:	WP4 – Control (lead: CNRS)
13:45 – 14:30h:	WP5 – Integration and scenario validations (lead: Smart Robotics)
14:30 – 15:15h:	WP7 – Dissemination and exploitation (lead: Vanderlande)
15:15 – 15:30h:	Break
15:30 – 17:30h:	General Discussion and Plans

- TOSS scenario wrap-up
- GRAB scenario experimental execution
- BOX scenario experimental execution
- Follow-up on plans for Tutorial Open-Source Software Framework: GLUE (based on BRICK)
- Preparations for upcoming 2nd REVIEW meeting
- Demonstrators

4. Outcome of the meeting - Actions and decisions

4.1. Actions

#	Description	Who	Added	Due	Status (16/06/2022)
1	"Scenario" section and "about" section, "vlogs" and "videos" to be added to the website.	TU/e	25-02-2021	By 1st review period	About section and separate videos added. Update 16/06/2022 now also project results: public deliverables, link to I.AM. dataset & publications. More detailed scenario section to be added
2	Twitter, YouTube, and LinkedIn are up and running. Partners are asked to use this more actively for dissemination of the project.	all	25-02-2021	Ongoing till end of project	Videos of ERFs have been uploaded on I.AM. YouTube channel. Partners' resharing/posting on LinkedIn has increased. I.AM. website also updated with pictures of new members.
3	Ensure compliance with the 'ethics requirements' -> check WP8 deliverables for guides	all	June 2020	Ongoing till end of project	Deliverables written and shared with consortium
4	Creation of a scenario document (continuation of MS1) to ensure up-to-date detailed description and software implementation of the TOSS, BOX, and GRAB scenarios are available to whole consortium	SR, Vanderlande, TU/e, Algoryx	25-02-2021	Continuous effort	TOSS scenario detailed, together with its implementation in Algoryx Dynamics (using BRICK) and simple mc_rtc controller also available as template for the whole consortium. BOX and GRAB scenarios still to be updated (see 4.1 and 4.2)

4.1	Detailed description (specifications) for BOX scenarios (continuation of MS1 document)	SR, Vanderlande	16-06-2022	November 2022	
4.2	Detailed description (specifications) for GRAB scenarios (continuation of MS1 document), focusing in depalletizing with EPFL and Vanderlande	SR, Vanderlande, EPFL	16-06-2022	November 2022	
5	TOSS planner and controller in mc_rtc	CNRS, EPFL	25-02-2021	June 2021	Some planner results have been obtained. Generalization on 3D ongoing. Basic planner implemented; planning for orientation of object is still to be added
6	Create an integration document, to allow the consortium to prioritize activities in view of the milestones M3, M4, M5, M6, and M7 @M30 (June 2021) related to TOSS scenario (request by TUM)	TU/e	25-02-2021	April 2021	Confidential document has been created and shared with consortium members (part of WP5): it contains explanation of each milestone (with must/should/could be done tags)
7	Benchmark Vanderlande Innovation lab setup with pick and place with the current hardware in both infeed and tray sorter scenario	SR	16-06-2022	August 2022	
8	Benchmark current TOSS implementation on the setup in the Innovation Lab at TU/e with current planner	SR	16-06-2022	September 2022	
9	SR and CNRS should come to agreement if planner can be extended to include rotation	SR/CNRS	16-06-2022	September 2022	

	requirement of tossing on the conveyor				
10	Make a timeline for the remainder of the steps on tossing for the benchmark, identifying what tasks each partner has and at what time this task is to be finished	SR	16-06-2022	August 2022	
11	Write down the specifications for the depalletizing (GRAB scenario), discussing with EPFL and Vanderlande	SR, Vanderlande, EPFL	16-06-2022	November 2022	
12	In future consortium meeting and review meeting, start with T7.1 and T7.2 to frame the work in context of the industrial use case	TU/e, Vanderlande	15-06-2022	November 2022	Based on earlier comments from EC Reviewers, it is better to focus on the industrial use case first, to align expectations. In 15-06-2022 meeting already improved WP7 description, but order was still WP7 at the end. Should move to start of meeting.

5. MINUTES

5.1. Meeting goal

Schematically, the main goals of this consortium meeting have been:

- Get project progress updates from all partners, discuss current research progress and future research, and discuss upcoming 5 deliverables.
- Prepare for the BOX and GRAB scenario that should be implemented by the end of 2022.
- Preparation for finalizing 2nd period in December 2022.
- Follow-up on plans for a tutorial on Open-Source Software Framework (GLUE)
- Discussion about the IROS conference (does it make sense for the I.AM. consortium to organize a workshop already?).

5.2. Organizational changes

- **Niels Dehio** (CNRS) – left for a permanent position at KuKa R&D in Germany
- **Ahmed Zermane** (CNRS) – joined as a PhD student
- **Camilo Rey** (Franka Emika) – joined as R&D engineer
- **Alexander Kurdas** (TUM) – is leaving July 2022 for TÜV in Germany
- **Alexander Oliva** (TUE) – joined as Postdoc

5.3. General introduction

The key points of the presentation by Alessandro Saccon were the following:

- The main goal of the I.AM. project is tackling the challenge of speeding up cycle times in logistics by exploiting intentional impacts between robots and its environment. In short: I.AM. enhances traditional pick-and-place with human-like grab-and-toss.
- Three validation scenarios are defined for impact aware manipulation:
  - TOSS: Tossing an item on a conveyor belt
  - BOX: Boxing items using impacts to more efficiently stacking objects
  - GRAB: Grabbing swiftly boxes/cases from a pallet (non-zero contact speed)
- We are finishing up with the TOSS scenario, while shifting the focus more towards BOX and GRAB.
- Focus of next 6 months is on evaluating achievement of milestones M9, M10, M11 & M12 (due in June 2022) and finishing deliverables D6.8 (this deliverable), D1.4, D2.1, D5.3, D5.7 & D5.8.
- Report for the 2nd review period is due in December 2022 as well.

5.4. WP6 (Management) & WP8 (Ethics)

5.4.1. WP6 - Management

The key points of the presentation by Jos den Ouden were the following:

- An overview of the procedures, processes within the project is presented and status on deliverables is given. All deliverables so far have been uploaded. No questions from partners on processes.
- An overview of changes in the project members was given: Niels Dehio (CNRS) has left, Alexander Kurdas will leave TUM in few months, Camilo Rey (Franka Emika), Alexander Oliva (TU/e) & Ahmed Zermane (CNRS) have joined. Michael Bombile to finish his PhD, so also leaving project soon.
  - Overview of team members needs to be updated on the website; A small bug on the website was spotted by AKe, which JdO will try to resolve.
- The procedure for publications is recalled: mention the funding and notify partners.
- The website has been changed: Results section now shows published papers as well as public deliverables.
- The status of the deliverables is recalled including the deliverables that are due at the end of 2022: D1.4 (TU/e), D2.1 (CNRS), D5.3 (SR), D5.7 (FE), D5.8 (AGX). Most of these deliverables will be public, only D5.7 is confidential.
- Status of 4 milestones will be discussed in this meeting, which are due by end of June 2022: M9, M10, M11 & M12 (see complete list on Teams and on EC Portal)
- Governing board & EAB & ESAB status meetings discussed, follow-up with EAB planned for 30 June 2022 and ESAB currently planning for September/October 2022 with ESAB members coming to NL. Invite is sent to all PIs; PIs should confirm their attendance.
- Gender equality: still 1 out of 32 members is female. Everybody is invited to make a proposal to see if consortium wide we can change this and provide reasoning on why it was not possible before

5.4.2. WP8 - Ethics

Regarding WP8, the following points were discussed during the presentation of Jos den Ouden:

- No new updates, deliverables have been finished in the first 6 months of the project. Project members are being referred to those documents.
  Regarding data privacy / human participants a note was made, as a reminder and introduction to new consortium members. New members can get into contact with JdO for further questions.

5.5. WP1 – Modeling (I.Model)

Main updates for WP1 are the following:

- Objective WP1 is recalled
- Tasks: There are 5 tasks: T1.1 (database specification), T1.2 (impact data collection), T1.3 (implementation impact laws in nonsmooth dynamics solver), T1.4 (identification parameters model-based impact laws) and T1.5 (Modeling Benchmarks and Progress Definition)
- Deliverables: There are 4 deliverables: D1.1 (Publication of I.AM. dataset), completed in September 2020. Deliverable D1.2 (Physics Engine API), due in June 2023. Deliverable D1.3 (I.Model), due in June 2023, D1.4 (Publication of I.AM. dataset), due in December 2022.

5.5.1. Presentation T1.1 - Specifications for the impact motion database

The following summarizes the results and discussion during the presentation of Alessandro Saccon:

- Recalled work done, as no further work has been executed after finishing this in M9.

5.5.2. Presentation T1.2 - Data Collection of Robot-Object-Environment Contact Transitions for Robot Manipulation

The following summarizes the results and discussion during the presentation of Alessandro Saccon:

- TU/e are setting up a dual-arm system with Franka Emika Pandas for data collection on the GRAB scenario.
- TU/e hired a research engineer that is concerned with converting data into relevant public format.
- A framework has been developed for teleoperation of tossing motions to collect data and build models for impacts/suction cups, as well as a framework for execution of dual arm grabbing motions.

The following summarizes the results and discussion during the presentations of Maarten Jongeneel:

- The frontend for the database is shown. We now have a web page for objects and environments, detailing the used objects and environments in recordings, to make the data better searchable and usable for other researchers in- and outside of the project.
- A dedicated Git repository is used to store metadata of all objects/environments/robots from which information is automatically crawled to the front-end.

5.5.3. Presentation T1.3 - Physics Engine Interface and impact laws implementation for learning, planning, sensing, and control

The following summarizes the results and discussion during the presentations of Claude Lacoursière:

- A software framework has been developed for interchangeable, reconfigurable components that is used instead of individual interfaces, called **GLUE**.
- For communication, GLUE relies on Click which now allows for synchronous communication between the physics engine and whole-body QP controller (mc_rtc).
- The GLUE framework will be open source, as well as Click and mc_rtc. AGX, however, will remain a paid software, for now. AKe: Suggests considering applying a different business model for academics, by supplying AGX free/reduced costs and having payment for support. CLa: confirms this is something the company is internally discussing. For academics, there is already the possibility to apply for grants and the company is extremely open for collaborations and providing support to committed research groups.
- Work has started on modeling of Franka Emika robotic with flexible joints and low-level torque control loop, according to seminal and now classical work done at DLR (Albu-Schäffer and collaborators), which is to be continued.
- Simulation work shown on implementing a flexible suction cup model in Algoryx Dynamics to allow for the implementation of validated holding and release model developed by the TU/e.
- Future work includes the building of a specific interface for the other members of the consortium to allow for computation of the impact maps based on given a desired ante-impact configuration and velocity.

5.5.4. Presentations T1.4 - Validation and Identification of model-based impact laws

The following summarizes the results and discussion during the presentation of Maarten Jongeneel:

The parameter identification procedure to determine the coefficient of restitution and friction during in the TOSS scenario is described.

The following summarizes the results and discussion during the presentation of Yuquan Wang:

- Interface developed between mc_rtc and Panda robots, as well as AGX and Mujoco.
- High-stiffness model used for prediction of impact-induced joint velocity jumps.
- Joint-space inertia matrix is ill-conditioned at order D^4, which poses problems upon inversion.
    - **CLa**: This is low compared to what we have.
    - **AOl**: We also notice that D^4 is already quite high.
    - **YWa**: Niels Dehio PhD thesis is about avoiding inverting joint-space inertia matrix.
- Comparison with Algebraic impact law or generalized momentum approach shows proposed approach is more accurate.
- Approach described for validation friction method.

The following summarizes the results and discussion during the presentation of Alessandro Saccon:

- Work with Franka Emika shows that inclusion motor inertia and low-level torque control model improves the prediction using an algebraic impact law. **AKh**: big difference can be noticed between torque control or position control, confirming on presented results. There is need to better clarify the matter for the community. **AKh**: Achievable impact velocities for the Franka Emika arm are somehow low. **ASa**: Franka Emika is considering releasing a feature which increases the velocity limits further and overrides the safety limits in the future, to be provided as a special feature for research groups.

5.6. WP2 – Learning (I.Learn)

WP2 contains 4 tasks, regarding learning uncertainty models at impact (T2.1), an impact posture generator (T2.2), learning of impedance and dynamical systems for control with impacts (T2.3), and Learning of QP control weights, gains & impedance (T2.4)

5.6.1. Presentation T2.1 – Learning uncertainty models at impact

The following summarizes the results and discussion during the presentation of Maarten Jongeneel

- Showing Validation suction cup release model. The release dynamics of the object can be learned from experimental data in vertical direction. Learning algorithm used was Locally Weighted Projection Regression (LWPR). Currently submitted paper with results to IROS on this topic.
- Use 3D printed Variable Inertia Object (VIO) developed at the TU/e for extension of the model to a 6D case
- Use Savitzky-Golay filtering on SO(3) for estimation of angular velocity and acceleration vectors from noisy rotational data. Currently submitted paper with results to IROS on this topic.

5.6.2. Presentation T2.2 – Impact Posture Generator for Dynamic Manipulation

The following summarizes the results and discussion during the presentation of Michael Bombile:

- Research goal: learning to toss on a given area of a moving conveyor by finding the desired release pose + velocity of a package.
- There are infinite solutions, even from a given position, the selected solution is the one that minimizes the effort (the release speed).
- Data generated for training and validation GMM/GMR.
- Feasible release states are computed using bilevel optimization.
- Experimental validation of dual-arm toss shown and compared with placing, showing a decrease in cycle time as well as saving energy.
- Future steps include improving the accuracy and robustness by learning uncertainty.
- **SdL**: Do you also consider the rotational error. **MBo**: No, we currently only consider the box position.
- **TBo**: How many tosses were considered for the results on energy consumption? **MBo**: 10 tosses for each of the 8 shown results.

5.6.3. Presentation T2.2 – Impact Posture Generator for Dynamic Manipulation

The following summarizes the results and discussion during the presentation of Ahmed Zemane:

- Research goal: Plan a trajectory containing an impact posture. This is to say, starting from an initiale robot Cartesian state (i.e. position and orientation together with linear and angular velocities), find a trajectory that reaches desired impact pose state in terms of position/orientation plus velocity (angular and linear);
-

- Planning based on BI-RRT considering either minimum acceleration or minimum jerk;
- Configuration task used to track a path in task space.
- Optimization of the whole tossing process by means of a semi-closed form using a ballistic motion model is used to find optimal joint positions and velocities for release. This is, to close the link with the planning part;
- Results are shown for tossing an object using the Panda robot.

5.6.4. Presentation T2.3 – Learning of Impedance and Dynamical Systems for control with impacts

The following summarizes the results and discussion during the presentation of Harshit Khurana.

- Approach is presented on how to use dynamical system to learn how to hit a box with a KUKA robot.
- By controlling the directional inertia of the hitting in combination with a desired velocity, the momentum can be controlled, hence ensuring a desired hit with a given object.
- Approach detailed on how to converge to a specific desired inertia matrix
    - Current research extends this through learning a dynamical system that aligns with the main eigenvector of the inertia matrix.
- Future work includes learning of object dynamics through hitting object back and forth with two robots, as was started through an internship of Daan Stockbroekx from TU/e, who started his master project as collaboration with EPFL and TU/e.
- **YWa**: Does aligning with maximum eigenvector result in problems with manipulability index? **HKu**: Yes, the two conflict, as a straightened arm has maximum inertia, but minimal manipulability, which is a complex problem to tackle.

5.7. WP3 – Sensing (I.Sense)

The following work package is presented by Alexander Kurdas. Main contributing partners are TUM (lead), EPFL CNRS and TUe. Currently finishing MS11.

5.7.1. Presentation T3.1 – Impact Aware Velocity Estimation and Contact Monitoring

T3.1 concerns the collision event pipeline, input is impact models, knowledge of impact, robot state, output is contact timing, contact state, and post-impact contact force and velocity.

- With an IMU mounted at the end-effector, impact experiments are performed and the vibrations in the system are measured.
- Experiments are performed with multiple objects
- Possible use case is putting objects in box (BOXING scenario)
- Knowing from what is happening at the impact we can know if the task was executed successfully. E.g., robot can move away if the impact is different than expected (e.g., when you want to box something, but the container is closed so you hit the surface or discriminating between different materials at impact time)
- Impact classification (internship of Benn Proper, TU/e, at TUM in 2022) is executed to classify expected and unexpected impacts. Classification has been tested on physical setup, under different conditions. Around certain setpoints we can classify that the impact was expected, but if the impact-scenario is different from expected the impact will be classified as unexpected. To be improved: robust multi-impact detection, controller performance, generation of prediction is from data and not automatically generated from model (Algoryx new feature described in T1.3 will become relevant for this). But the classification methods are shown to be effective and sensitivity tunable, confirming previous numerical simulation experiments.

5.7.2. Presentation T3.2 - Aim and impact aware reflex decision tree

- What could go wrong during the impact? Example: objects can be lost during movement. How can this be identified? E.g., the external force is going to zero.
- Next step (this task): what is the reflex according to that?
- If the object is lost slowly, the velocity can be slowed down to not release the object. In instantaneous release of the object, vision can be used to pick the object back up. If not possible, a human can be called to help.
- 3 levels of reflex levels. Reflex motion generator level, reflex task level, and reflex Program level. Level 1: motion generator level (fix the issue there, e.g., slow the robot down). Level 2: Task level: abort the task and go do a new task. Level 3: programming level: the whole program might stop executing.
- Video showing how the different reactions of the robot given the input of the human interaction with the robot, showing the classification of the different levels given the input
- Human level reactions: Call human for help or do not call the human for help. Could mean the robot can solve the problem itself. Could mean the robot has to call the

human for help, but still is actively controlling an object (e.g., preventing it to fall, but cannot recover completely)

- Robot level: Non-path following or path following choices. Maybe the system needs to go on the brakes, slowly, or fast.
- Classification of failure cases, classified in General, and Motion Segment classes, where the Motion Segment classes are further classified in failure cases under Pick, Move, Toss, and Box scenarios.

5.7.3. Presentation T3.3 - Sensing and performance

- A TU/e student under TUM supervision during a 3-month internship has compared physical experiments and Algoryx dynamics simulations to compare and validate the torque sensing in the joints of the Franke Emika robot.
- Conclusion: joint angle and velocities are good, but torque is similar just in the first four joints. For the last 3 joints, things need to be better understood. Part of the comparison was not possible as currently Algoryx Dynamics is missing the possibility to compute gravity induced torque in the GLUE framework. More work is needed also for friction modeling.
- Future work: improve features of GLUE framework and include a payload in the simulations and experiments.

Discussion
ASa: We are also working with friction compensation in the Franka Emika robot, and we experience the same problems when using mc_rtc in torque control mode. Impacts can happen on a different moment in time than expected, because of vision errors.
AKu: We only show the concept. We could do more experiments and define threshold levels on 1 or multiple sensors, or learn neural networks (NN)
SdL: So, could you define that based on the accuracy of the vision sensors?
AKu: Yes, but this really depends on the camera system. If e.g., the object is lost but not visually detected this cannot be done of course. We present the high-level concept, but we need to implement it in the next step.

5.8. WP4 – Robot Control (I.Control)

This work package is presented by Yuquan Wang (CNRS). Objectives are extending mc_rtc task space with impacts, Enhance QP control with short-time horizon model and control theory to assess the stability and robustness of QP based controllers. At the end of next year (2023) there is the D4.1 deliverable on control report (M42).
mc_rtc is successfully applied on multiple robotic systems for control. Interaction is now possible with Algoryx (via GLUE) and, independently, also with MuJoCo.

5.8.1. Presentation T4.1 – Impact aware QP robot control

Tasks:

- Control problems regarding dynamic contact transition:
- Embedding the discrete impact dynamics into the QP controller. Including task-space reference spreading into the QP formulations.
  Metrics for evaluation are: handling complex contact modalities and error in contact position, velocity, and forces

Other points:

- Textbook QP doesn't take impact into account. Impact dynamics model + proper projection models are implemented for QP control with impacts.
- Prediction of the impact highly improved w.r.t. previous shown results.
- Friction cone is intersected by planes based on restitution
- Safe yet fast impact control possible
- Examples is videos show effective use of impact-aware QP control

Conclusions

- Improved impact mechanics model with frictional impact in 3D, analytical solutions, and half-space represented state jumps
- Humanoid grabbing and tossing experiments with two boxes of 0.38kg and 1.09 kg
- Maximal feasible contact velocity of 0.15m/s. More experiments with higher impact velocities are on-going (now up to 0.35m/s).

5.8.2. Presentation T4.2 – Impact model preview and adaptive control for QP control

Contributions:

- Swift bi-manual grab a box (dual arm system)
- Soft pad as end-effectors, modelled as spring-damper systems
- Learning via MPC possible

Overview

- Learn stiffness -> map to joint space constraints -> MPC -> Whole-body QP
- Overview of derivation of the constrained deformation dynamics is shown on the slides

Illustrative example in 2 DOF manipulator

- From feasible joint state constraints -> map to tasks space constraints, -> and that is mapped back to the joint state. So, contact constraints are included in the QP
- Contributions:

- mapping of joint-space limits onto the task-space for a redundant manipulator
    - optimization of future deformations at runtime
    - explicit computation of the maximum safe impact velocity for soft material
    - incremental updates of the soft material model
    - experimental validation at a 1 kHz update rate on a dual-arm Panda manipulator in fast grabbing different objects.

5.8.3. Presentation T4.3 – Stability, robustness, performance study for the impact QP control framework and gain tuning

Closed-loop issue of QP robustness, as it relies heavily on the accuracy of the dynamics model. State of the art used computed torque control, heavily relies on dynamics model, which is not super accurate. Approach often Is kinematic-controlled robot.
Issue: the closed-loop system is prone to instabilities due to non-robustness to non-modelled dynamics.

- **Approach**: robust task and constraint formulations based on integral feedback terms. Shown in recent submitted paper (see slide 28)
- **Video**: Shows effect of the double integration on the system control: the new approach results in stable performance.

The last part of the presentation regarding T4.3 is given by Jari van Steen concerning Reference spreading for QP-control in task-space:
Time-based reference:

- Formulate ante- and post-impact reference trajectory with jump at the nominal time
- Extend trajectories forward and backward in time
- In practice: never able to hit with 2 contact points simultaneously. Therefore, also **interim mode** where it is ensured that the full contact is established, only by position (and not velocity) feedback

Time-invariant reference:

- Pre- and post-impact reference vector fields.
- At the nominal impact surface, the vector fields are consistent with the impact law
- Ante-and post-impact vector fields are extended across the impact surface
- Interim mode: ensure contact completion using position feedback generated from the velocity reference field, without relying on the velocity error signal (as velocity reference is undetermined and velocity signal might be inaccurate in this phase)

Next steps

- Extend to GRAB scenario with mc_rtc control and physics simulations using AGX Dynamics, using the newly proposed GLUE framework.
- Experimental validation on the dual arm Franka Emika system at TU/e and eventually dual arm KUKA iiwa system at EPFL

- Currently experiencing problems with torque control due to lack of complete/sufficient friction compensation on the Franka Emika robots, especially on the last joints.

5.8.4. Presentation T4.4 – Control Benchmarks and Progress Definition and Evaluation

Goals:

- Control framework that will be implemented on all the robots used in the project
- Evaluation in simulation and experiments

Control report at the end of 2022, Deliverable D4.1

- List of publications should be collected
- Grabbing and Boxing experiments will be executed
- Software: impact aware controller established (via mc_rtc)

5.9. WP5 – Integration and Scenario validations

This work package is presented by Teun Bosch (Smart Robotics)
Recap: last meeting the scenario validation was written and updated. Test setups were made for TOSS and BOX scenarios. Integration architecture/policies were written with installation policies.

5.9.1. Presentation T5.1 – Integration and Scenario Validations

Enabling interface of the different software packages (e.g., controlling the IO's via mc_rtc).

5.9.2. Presentation T5.2 – Take-up and Deployment of Scenario 1 (TOSS)

- **Planner** (CNRS) developed by fitting GMM to determine release pose for desired rest stance of the box on the conveyor (not: position/velocity). A set of possible box release poses and velocities sampled and checked for consistency with robot limits. The "best" toss is learned through GMM (via **Algoryx simulations**) and passes to the **dynamical system** (**DS**)
- **Controller** (CNRS + EPFL). Determine joint position/velocity for release pose and use dynamical system to move to join positions.
    - Desired release pose/velocities in cartesian space converted to joint space
    - Modulated join-space **DS** is used to achieve desired release state
    - Enforce desired joint velocity from joint-space **DS** through dedicated mc_rtc tasks
- **Real systems**. Panda at TU/e with SR gripper, I/O controlled via Ethercat and fully integrated via mc_rtc. Video showing integration of the planner and controller described above on the actual setup. Toss is like AGX simulations and toss is repeatable.

Discussions
ABi: Other people at EPFL had problems with torque control at 1Khz for Franka Emika robot
JvS: This is velocity control, not torque control. Problems with torque control are also present at TU/e setup
ABi: are you describing more technical details? What about perturbations in the system? Will the system be able to cope with that?
JvS: Control is done via DS in joint space, so we expect yes. Best to discuss with Michael (EPFL) for details
AKh: The problem with torque sensors affects the impacts you can have. So, people go to position/velocity control.

5.9.3. Presentation T5.3 - Take-up and Deployment of Scenario 2 (BOX)

Implementation is slightly delayed, focus on finalizing TOSS. Steps made on TOSS scenario will however help with integration onto the BOX scenario. The setup is essentially ready, being the same as well as many of the simulation environment (GLUE, mc_rtc, AGX Dynamics, suction cup models during holding phase).

5.9.4. Presentation T5.4 - Take-up and Deployment of Scenario 3 (GRAB)

- Dual-arm setup realized at EPFL
- Everything controlled via ROS (conveyor belt and KUKA robot arms)
- Dual-arm grabbing and tossing DS has been extended to the tossing of objects on a moving target
- Next steps:
  - Learn and compensate uncertainties in release state
  - Implement the controller within mc_rtc
- Alternative dual-arm setup realized at the TU/e, operational through mc_rtc. Numerical simulation of the same scenario possible with Algoryx Dynamics via GLUE framework
- To do:
  - Design and create flat end-effectors with desired damping properties
  - Improve low-level torque controller with proper friction compensation, to allow for testing of the developed control approaches

5.9.5. Presentation T5.5 – Evaluation of human safety in impact aware manipulation

Reflected masses are direction dependent, so if the positioning of the human is incorrect, this may lead to unsafe situations. The student from TUM designed the mean reflected mass over all Euclidean directions. There is no analytical solution to this, so a NN is used. Experimental validation showing that the new approach reduces the measured collision force.

Discussion

HKh: Mean reflected mass: you say it doesn't matter what robot you use, but at the same time you learn for a specific robot?

AKu: The final calculation depends on the robot. But input of the NN is only the vectors (half-lengths of the ellipsoids, for any robot). The NN will give you the mean of the reflected mass in all directions

HKh: Why do you need data from the robot then?

AKu: Learning is only needed once but can now be used for any robot. So, you don't need to retrain the NN if you have a different robot.

5.9.6. Presentation T5.6 – Scenarios Benchmarks and Progress Definition and Evaluation

KPI's revisited and discussed with Vanderlande

- Average cycle time,
- Average pick and place time
- Mean time between failures
- Quality percentage (**NEW**) (how the object quality is after toss)
- Mean intersection over union (**NEW**) (success rate previously, now based on overlapping surfaces)
- Orientation correctness (**NEW**) (e.g., important that the barcode is up)

Discussion:
ASa: this is the vision, but it is important to get concrete implementation of these KPIs, linking it to the WP1-4 technology, e.g., what to measure.
SdL: is more clearly defined in WP7 slides

Benchmarking of the system:

- Vanderlande Innovation lab at TU/e, comparable with real applications at customers
- Compare by replacing tossing with standard placing, with the current planner
- Evaluation with current industry cycle time benchmark must be done, but expectation is that it is currently not faster yet. Clearer definition of industry benchmark (what is considered part of cycle time and what is not) is required.

In short:

- **What:** Testing with Panda tossing vs placing with similar software
- **Where:** Vanderlande innovation lab at TU/e
- **How:** compare tossing vs placing using KPIs and compare with current industry with same objects

To do:

- Deadline tossing scenario report on **2022/12/31**
- Assumptions:
    - Use current planner
    - Initially without payload sensing developed by TUM
    - Focus on Franka Emika robot
- **Now – August**
    - Compare integrate tossing scenario with real world using OptiTrack
    - Quantify repeatability of these tosses
- **October**
    - Compare with standard placing in industry
- **November**
    - Write report

Discussion:
ABi: Would you like to see the target that you have for the KPIs? What are the target values? Then we can see how far we are off
TBo: We have values at SR, but that is hard to beat. We want to benchmark on the system with current industry standards and then make comparisons.
ABi: If you have them, please let them now. Second question: will it be boxes that are used before, are they size and shape that are common?
SdL: Will display this in the next work package.

5.10. WP7 – Dissemination and Exploitation

The following overview was provided by Bas Coenen and Stijn de Looijer (Vanderlande):
Relevant tasks of WP7 are:

- T7.1 - Requirements and recommendations for Exploitation
- T7.2 - Dissemination of the Project Results

Deliverables are

- D7.1: Dissemination plan – released
- D7.2: Roadmap and business cases for developing a torque-controlled robot arm for logistics
- D7.3: Roadmap and business cases for the introduction of I.AM. in logistics

Remark **BCo:** better to start the next consortium meeting with T7.1 as in line with EC Reviewers request. This way is also easier to align work in WP1-5 onto the industry use cases. **JdO** to ensure this is changed for the next consortium meeting as well as for EC review.

5.10.1. T7.1: Requirements and recommendations for Exploitation

- Goal is to show that autonomous decision can reduce the average cycle time of pick-and-put operations for varying packages with 10%
- Different customer groups (airports, parcels, food) have different types of manipulated objects.
- A goal is how to connect the technology developed in I.AM. to the use cases TOSS, BOX, GRAB (and additional use cases such as pushing).
- A cost overview has been presented on manual tossing compared to robot tossing, showing that the return of investment (ROI) is 8.1 years without I.AM. technology, and 6.4 years with I.AM. technology assuming all items can be tossed.
    - About 80% of the parcels is a regular carton box, hence the focus of I.AM. is on this type will be of major relevance.
    - Only handling boxes through tossing results in a ROI of 7.6 years.
- Sensitivity analysis is performed to show how different inertia results in different performance.
- Different manual infeed processes for items are shown.
- Realistic cycle time on an industrial UR10 manipulator increases cycle time from 5.7 seconds to 5.1 seconds.
- Technology gap includes lack of knowledge on parcel inertia or conveyor model.
- In the BOX scenario, the logistic driver for impact-awareness is not just higher throughput, but also higher fill rate.
- Videos shown for robotic picking of varying items, as well as a video on robotic palletizing, with the latter showing significant gaps between items due to collision avoidance and vision uncertainty.
- The GRAB scenario is especially relevant if we manage to grab items out of a densely stacked group of items, again mainly boxes.

Discussion:
YWa: The postal company shown in the video has their own research centre.
BCo: This is indeed true and happens more often, also with Amazon.

5.10.2. T7.2: Dissemination of the Project Results

- Around the time of video post, interest in the I.AM. project really spikes → To all partners: send videos if you think they are relevant and interest.
- Different demos have been given, and Vanderlande, Smart Robotics and TU/e will visit the European Robotics Forum.

Discussion:
BCo: Should we not use the benchmarks for the robots currently used by our research (e.g., torque controllable cobots)?
SdL: This depends on when the robots we will use can compete with industrial robots. Are there any plans within Franka Emika on how to achieve this?
MMo: This does depend on the hardware, e.g., torque sensors.

ASa: It feels like industrial robots or cobots without torque sensing, when coupled with a force torque sensor near the end effector, will be also capable of performing these jobs for the TOSS and BOX use cases. Less clear for the GRAB scenario. However, right now we do not have grippers with integrated force torque sensors from SR, and therefore it will be difficult to assess in the short term.
TBo: Are 1500 picks/hour manageable? Not with a UR10, but with industrial robots yes.

5.11. General Discussion and Plans

5.11.1. Agenda

- TOSS scenario wrap-up
- GRAB scenario experimental execution
- BOX scenario experimental execution
- Follow-up on plans for Tutorial Open-Source Software Framework: GLUE (based on BRICK)
- Preparations for upcoming 2nd REVIEW meeting
- Demonstrators

5.11.1.1. TOSS scenario wrap-up

End of this year MS10: Impact posture generator can compute robot-environment contact postures for Scenario 2 (BOX). CNRS responsible for finalizing.
ABi: Next step in tossing could be to estimate uncertainty on the fly and adapt accordingly before tossing. At the current stage, it is decided this does not seem to be feasible before the end of the project.
ASa: we would like to have an autonomous system. What we can do now: we can tell the system the box properties and run the planner and toss it with the Franka Emika robot as well as with the UR10, both equipped with SR gripper.
What could the consortium do more by the end of the year?

- **SdL**: If the planner is there, we could show this on the setup.
- **ASa**: Performance of the tossing on the system: in terms of position/orientation -> but we do not have a planner that considers box orientation for now
- **SdL**: In the tray sorter application, the orientation around z-axis does not matter. Therefore, **the current planner is good enough**. NOTE: barcode should still not be facing down, also in this application! For in the infeed application instead, the orientation does matter, so there the current **planner not sufficient**. Infeed is sold more, so for Vanderlande business case, value is higher for infeed, therefore is interested in seeing this solved as well.
- The planner can be for sure improved: the question is who will do it, also given the fact that EPFL/CNRS personnel who was focusing on this has left/will leave soon?
- **TUM:** Estimation of the size, mass, inertia (payload identification) -> we'll need more time. KPI: compare with SOTA without payload identification.
- **SdL:** First full integration of the setup -> later speeding up to meet the industrial KPIs. Vanderlande will provide more detailed use case information, so that we can show comparison.

AGREED:

- SR, TU/e and CNRS will benchmark the system with pick and place with the current hardware in both infeed and tray sorter scenarios
- SR, TU/e and CNRS then show how the developed TOSS planner/controller is performing with respect to that baseline, given the status of the data-driven planner and the KPIs of how the object should land on the conveyor/tray sorter (orientation and position). If this is not satisfying, we will attempt to improve the performance through

the ballistic motion planner currently being developed by CNRS. **AKe**: aiming for the end of September.

- Smart robotics will make a timeline for the remainder of the steps on tossing for the benchmark, identifying what tasks each partner has and at what time this task is to be finished.
- Identification of the payload (mass/inertia) will be done after the deadline in November.

5.11.1.2. GRAB scenario experimental execution

SCENARIO Challenge:
SdL: Not only grabbing itself is important (one object), also more on dividing multiple objects from 1 layer ('descrambling') and then afterwards grabbing and placing/tossing (for this later step, result of Michael EPFL can be used).
Challenge: The objects are unknown, the precision of grabbing and descrambling itself is also unknown.
ABi: EPFL has done some prior work in 2015 on this but did not consider this within I.AM. yet. To be considered at the next consortium meeting.

AGREED TO DO: **SR** makes sure to write down the specifications for the depalletizing, discussing with EPFL and Vanderlande. EPFL agrees to extend the work of Michael to do the depalletizing (as shown in the video of Vanderlande). However, only if possible (depends on the specifications, communication with SR needed, from that specific scenario specification the tasks of the individual partners will become clearer).

- **TU/e** will be responsible for models of uncertainty of impact and robot/object interactions.
- **Algoryx** can contribute by allowing for numerical simulations of the scenario

5.11.1.3. BOX scenario experimental execution

SCENARIO Challenge:
The vision is to fill the totes more densely and cycle time. Vision system would be needed to classify where the objects can be placed. Using OptiTrack for now, we'll use that to quantify where the objects can be placed. Only carton boxes or also flexible objects, preferable everything. Robot takes a picture of the place totes and SR starts in one corner, fills the bottom layer, and then starts in the second layer.
Box scenario is mainly on e-commerce, but there we don't know anything about the objects. So, the vision is that we'll use the torque sensors and the impacts to improve the stacking density. Challenge is to increase the stacking density.
ABi: EPFL has done some prior work in 2015 (shown video with homogeneous boxes being put into another box) on this but did not consider this within I.AM. yet. To be considered at the next consortium meeting.

AGREED TO DO:
Could be we have one tote that is filled with sort of boxes for which we can assume via perception the weight and mass distribution and geometry, we already have a system of

taking them and placing them in the other tote. The challenge would be to put them in the same conditions to fill the tote faster and more densely using impacts. This system (SIR) is a product of SR and can be used as benchmark. Feel mainly like sensing and planning activity (so TUM and CNRS). TU/e will focus on the modelling aspect of impacts for objects held by a suction cup, in collaboration with Algoryx to make sure these validated models will be included in their physics engine.

However: Not a clear direction on how the academic partners can support this scenario at this point, besides the already mentioned comparison and validation between numerical simulations and experiment of a robot holding an object with a suction gripper and impacting an empty/filled tote. One research challenge is to plan how to fill a tote in the most efficient employing impacts, assuming object geometry/inertia properties are identified with cameras and force/torque sensing (this last, similar to what is needed for TOSS scenario). However, this overall planning challenge goes beyond the simple technology of impact-aware manipulation we are developing in the I.AM. project. Also, it does not appear there are many open fundamental challenges in control, it appears more an engineering work. If object properties are known, we can move more towards the palletizing scenario, with different challenges, focusing more on impact models. Smart Robotics will need to better clarify to the academic partners in the consortium what the BOX scenario will be, and where the developed impact-aware technology can be used and demonstrated in this context, which is clearly relevant for industry.

5.11.1.4. Follow-up on plans for Tutorial Open-Source Software Framework: GLUE (based on BRICK)

Suggestion of the reviewers (1st EC Review) was to reach out to the robotics community; TU/e, Algoryx , and CNRS set up a tutorial proposal at IROS 2022 for that purpose, but the proposal has been rejected. Main comment was that the topic was too specific according to the reviewer. **CLa** will pick up this topic with PIs to set a new tutorial proposal in 2023.

5.11.1.5. Preparations for upcoming 2nd REVIEW meeting

JdO announced the upcoming EC Review. Period 2 ends by December 2022, so reporting needs to be finalized in December 2022 (coinciding with 4 other deliverables), so the consortium should be aware of this deadline. **JdO** will contact everyone from October onwards.

Proposal to suggest having the EC Review 2 then in March 2023, to provide proper time for reviewers to get all the documentation (60 days after finishing period 2).

Possible locations are discussed: if we want to also show demonstrators, EPFL or TU/e would be good locations. Possibly also Vanderlande to also set clearer the logistics use cases. **JdO** will set Doodle and get into contact with PO and reviewers on location and dates.

All to fill in the Doodle before the end of July, so the first proposal can be sent.

Annex 1: Partners in I.AM. consortium

Table 2: I.AM. beneficiaries

#	ID	Short	Beneficiary name	Country
1	1	TU/e	TECHNISCHE UNIVERSITEIT EINDHOVEN	NL
2	2	EPFL	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	CH
3	3	TUM	TECHNISCHE UNIVERSITAET MUENCHEN	DE
4	4	CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR
5	5	AGX	ALGORYX SIMULATION	SE
6	6	FRANKA	FRANKA EMIKA GmbH	DE
7	7	SR	SMART ROBOTICS BV	NL
8	8	VDLANDE	VANDERLANDE INDUSTRIES BV	NL

Annex 2: Status Actions from D6.7

5.12. Actions

#	Description	Who	Added	Due	Status
1	Check the interactions between WP & tasks and set-up bilat/telcos with the WP leads.	TU/e (ASa/JdO)	30-01-2020	February 2020	done
2	All partners to upload the presentations to the shared folder for internal use. The PowerPoint slides will be uploaded in the I.AM. website, once online (M3), for future reference (password protected).	all	30-01-2020	29-01-2020	done
3	AGX will develop an importer of URDF (eventually, SDF and SRDF) files for AGX dynamics. Furthermore, AGX will create an URDF file for Panda by FRANKA, containing estimated inertia and mass.	AGX	30-01-2020	01-03-2020	Panda available at TU/e with URDF
4	AGX will provide the partners with free licenses of AGX dynamics, under the condition that they will be solely used for the scope of the I.AM. project.	AGX	30-01-2020	15-02-2020	Provided to TU/e. Can be provided on request to AGX.
5	Detailed specifications of Panda: FRANKA will provide missing details about some of the components of	FRANKA	30-01-2020	15-02-2020	done

	Panda (e.g., inertia, motor gear ratios, ...) to allow the creation of a detailed URDF (or similar) format of the robot for dynamic simulation under impact. Andreas Spenninger (FE) will discuss internally what the possibilities are and will report to the consortium.				
6	SR will inform the interested partners about the possibility of obtaining a bellowed suction cup for internal testing. This type of end effector will be used in the TOSS scenario validation.	SR	30-01-2020	15-02-2020	done
7	Study feasibility of mounting FRANKA Panda in existing SIR system (due to the different reach compared to UR10).	SR + FRANKA	30-01-2020	01-04-2020	done
8	Make available to the interested partners the impact data obtained on a tossing UR robot and recorded with an Optitrack Prime 17W 360FPS mocap.	TU/e	30-01-2020	01-03-2020	done
9	Contact the EAB, possibly enlarging its original composition to include other potentially relevant interested businesses. Set up a meeting to introduce the I.AM.	VDLANDE	30-01-2020	15-02-2020	Delayed due to shifting of priorities within Vanderlande. Date agreed: 29 June 2021

	project and collect feedback.				
10	Contact the ESAB. Set up a meeting (ICRA Paris?) to introduce the I.AM. project and collect feedback.	TU/e	30-01-2020	15-02-2020	Done, first ESAB held 2 February 2021
11	TUM will share recent results on combining momentum-based observer (accurate/slow) with direct method observer (noisy/fast), to obtain accurate/fast external torque estimation.	TUM	30-01-2020	15-02-2020	done
12	TU/e will manage WP8 – Ethics and will provide 2 deliverables D8.1 & D8.3	TU/e	30-01-2020	31-01-2020	done
13	TU/e will manage WP8 – Ethics and will provide 2 deliverables D8.2 & D8.4	TU/e	30-01-2020	31-03-2020	done
14	All partners will check (use checklist provided in D8.1, D8.2, D8.3 & D8.4) and follow the guidelines of these 4 ethics deliverables.	all	30-01-2020	28-02-2020	Deliverables discussed and provided to partners via June 2020 consortium meeting.
15	Two Gitlab groups are currently used: TU/e Gitlab and Algoryx Gitlab. Algoryx wants to move all their applications to TU/e Gitlab and need a dedicated computer to have this running. Ongoing discussion about setting up pipeline for	AGX / TU/e	25-02-2021	1-04-2021	Decided to keep both Gitlab groups. Algoryx's Gitlab has now a working CI/CD pipeline in place, that helps in verifying software integrations/updates are working correctly. On TU/e Gitlab, there is now a Git project which is used to track any software and documentation update requests from the whole

	continuous integration.				consortium and provide the current development status
16	Switching to using Algoryx Dynamics for parameter identification in place of MATLAB implementation	Algoryx, TU/e	25-02-2021	June 2021	Done

5.13. Decision / open issues

ID	Decision	Described in:	Remarks
1	ICRA 2020 in Paris will be the venue for the next consortium meeting. To be confirmed via email in early February by each partner.	D6.4 (31/01/2020)	Due to COVID-19 no longer possible. Currently online consortium meetings.
2	Open-source software framework to be developed – type of open-source license to be agreed upon.	D6.4 (31/01/2020)	Ongoing
3	EPFL will explore further grabbing experiments, based on the DS approach when dealing with heavy objects and higher speed of motion of objects and robots. Data will be made available to the consortium as this could be already of interest for the I.AM. impact motion database.	D6.4 (31/01/2020)	done