University of Colorado
Anschutz Medical Campus

CLARA Kinematic Data Analysis (KDA)

High-Level Technical Design

Version 1.1

10/16/2022

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1. Introduction

CLARA KDA v1 will serve as a data pipeline that extracts kinematic features from large data sets generated by a closed-loop automated reaching apparatus (CLARA)[1] (Fig. 1). CLARA was designed and built in the BIOElectrics (Welle) Lab to study mice performing a skilled reaching task in various experimental settings. Lab members are in need of a reliable and user-friendly system for preprocessing CLARA-generated data sets, calculating kinematic features, and saving this data in a fashion that can be used with other software. This analysis takes place in a neuroscience laboratory where the ability to code is not a requirement. Integrating current computational methods into a GUI-based program will allow lab members to complete analyses independently.

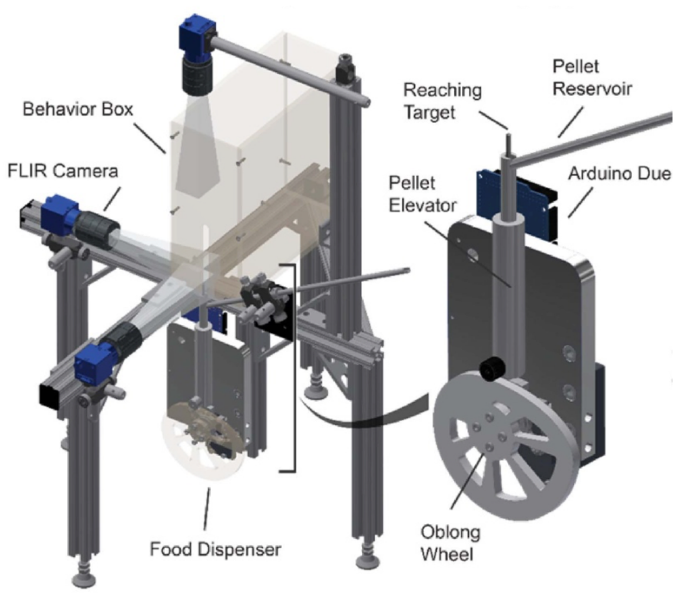

Figure 1. Closed-loop automated reaching apparatus (CLARA)[1]

The purpose of this document is to detail the proposed program design at a high level for users and persons making changes to the program in the future. This document should be updated as design requirements change and new features are implemented. Version 1.1 of the High-Level Technical Design is intended to describe the conceptual design of the proposed system and provides a framework for more detailed requirements and design in later phases of the project.

2. Current System

2.1 Functional Description

The current solution is to load and analyze paw tracking data in a MATLAB script where the user must change individual lines of code depending on the use case.

2.2 User Community Description

The current users are researchers in the BIOElectrics lab who use CLARA for behavioral experiments. Users have a wide range of coding experience.

2.3 Technical Architecture

KDA will integrate into the larger CLARA system as shown in Figure 2. CLARA-generated paw tracking data is stored in .mat (MATLAB) files, and Curator files are .xlsx files which contain indices for reach initiation, reach max, and reach end. The Curator also denotes whether a stimulus was given, the category of each reach end, and the mouse beahvior. Consistent naming conventions allow file matching. The network drive is accessible while on the AMC network or connected to the university's virtual private network (amc-vpn.ucdenver.edu).

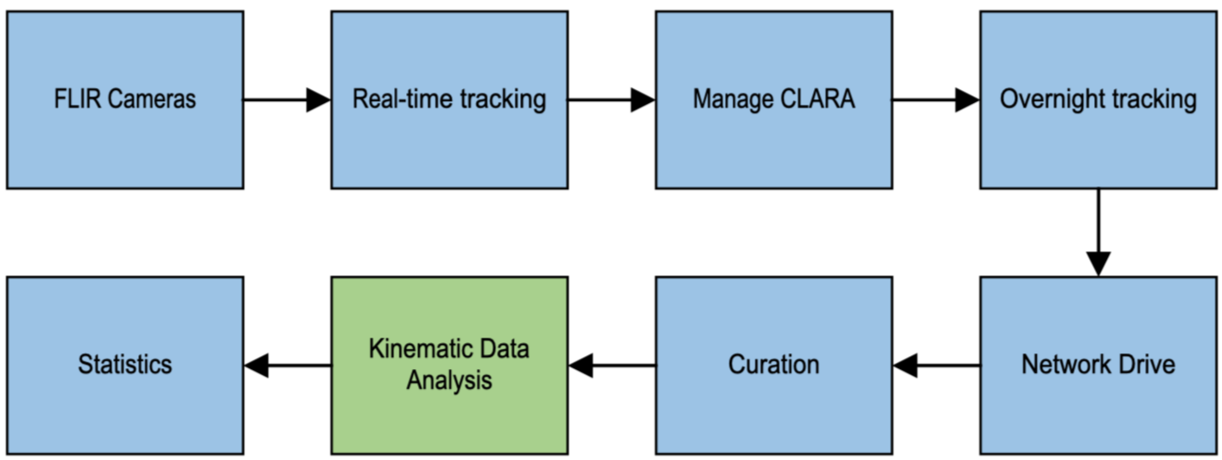

Figure 2. Flowchart of a larger system that KDA fits into within the CLARA system.

3. Goals, Objectives, and Rationale for New or Significantly Modified System

3.1 Project Purpose

The fundamental purpose of this project is to replace an existing kinematic data analysis

3.2 System Goals and Objectives

This program is being designed to output kinematic features and session level data from CLARA behavioral experiments.

3.3 Proposed System

The proposed system is a modular graphical user interface which automates subsystems to extract kinematic features and correlations for later statistical analysis.

3.3.1 System Scope

The scope of the proposed system includes the direct development of the KDA software. Subsystems of the CLARA system other than Curation should not be modified unless it pertains to naming conventions which directly affect software development and ability.

3.3.2 High-Level Functional Requirements

The scope of the proposed system includes developing software capable of loading data, extracting kinematic features from paw tracking data, computing correlations, and exporting data.

4. Factors Influencing Technical Design

4.1 Assumptions and Dependencies

The software will assume a consistent session file naming convention as shown below, the existence of and access to MATLAB_3D and Curator files, and both the “interparc” and “arclength” MATLAB add-ons.

Example curator file name: 20191212_unit02_session001_SKB01.xlsx

Example MATLAB_3D file name: 20191212_unit02_session001_3D.mat

4.2 Constraints

Users will require an active MATLAB license and current version of MATLAB installed on their device. Data storage on the network drive is limited to its available space. Data storage on the personal devices will also be limited by available space. Computers with at least 8GB of RAM are preferred.

4.3 Design Goals

The design should output data comparable to outputs from the previously used script. Methods should remain consistent with previously documented methods. Duplication of data should be minimized.

5. Proposed System

5.1 High-Level Operational Requirements and Characteristics

Table 1. Requirements Table

Requirement ID	Description
REQ-1	Loading raw data results in zero errors.
REQ-2	User canceling prompts results in zero errors.
REQ-3	Extracting kinematic features for mice with 15 or fewer sessions takes less than 5 minutes per mouse.
REQ-4	Extracting kinematic features results in one .json file and one .mat (.kda) file per mouse in the output folder.
REQ-5	Saving trajectory plots results in a folder for each mouse with one plot per session.
REQ-6	A readme file shall be included in the documentation provided with the program files.
REQ-7	The “extract kinematics” feature of the program shall calculate and output the following features: interpolated hand position and velocity, absolute velocity, hand path length, and dynamic time-warped position normalized to pellet location.
REQ-8	The extract kinematics feature will end with displaying final session plots for each mouse showing trajectories and session level mean feature values. The main GUI window will also update with relevant data calculated in the process.
REQ-9	Users will provide paths to MATLAB_3D and Curators folders.
REQ-10	All raw data will have units of pixels, while processed data will have positional units of millimeters and temporal units of seconds.
REQ-11:	The program shall check that data has been loaded and has the correct status prior to running an analysis.
REQ-12:	In the event that an analysis is attempted by the user without the correct data loaded, the program shall prompt the user for steps to take to resolve the issue.

5.1.1 Non-Functional Requirements

5.1.1.1 Security and Privacy Considerations

The MATLAB_3D folder is stored in a network drive to which users must obtain access with a username, password, and server address.

5.1.1.2 Availability Requirements

The software should be available for use for anyone able to access the network drive, either by connecting to the AMC network or using the university virtual private network. If updates to the system are required, users should still be able to access the working version of the software while updates are implemented.

5.1.1.3 Volume and Performance Expectations

The software should be able to load, analyze, and export data for at least 10 mice per day.

5.2 High-Level Architecture

The high-level system architecture is outlined in Figure 3.

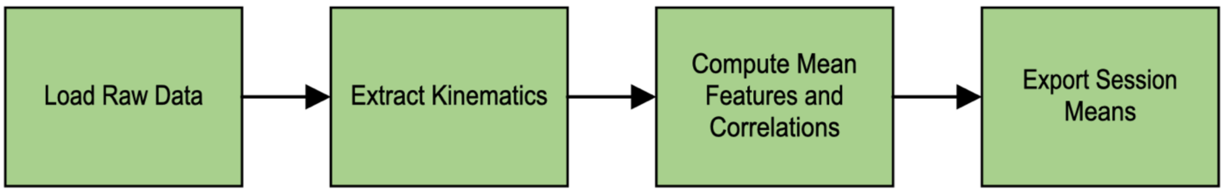

Figure 3. Flowchart of high-level program functions.

Table 1 - Alternatives Considered for the Overall Architecture

Alternative	Description	Pros	Cons	Preferred Alternative?	Rationale
Function-based approach	Utilize a function-based approach to pass data and carry out operations	More experience with this method	Editing code may become cumbersome	Yes	Method with more experience using should be utilized in order to complete before end of the semester.
Class-based approach	Utilize a class-based approach to pass data and carry out operations	Cleaner, faster	Minimal experience coding with classes	No	Too much uncertainty and unfamiliarity with method.

5.2.1 Information Architecture

The organizational structure below indicates which features exist for each mouse in the output data structures.

Per animal	Expert reach
Per session	Correlation to expert reach
	Improvement of failure correlation to expert reach
	Maximum absolute velocity
	Mean Euclidean velocity
	Mean target location
	Success
	Expert reach
Per reach	Raw velocity
	Interpolated velocity
	Absolute velocity
	Interpolated position
	Dynamic time-warped hand position
	Duration
	Pathlength

5.2.2 Technology Architecture

The required infrastructure that will need to be maintained is the network drive, CLARA system, naming conventions, and MATLAB software.

5.2.2.1 Connectivity Requirements

The network drive will need to be maintained so that the software can access necessary data files.

5.2.2.2 Modes of Operation

There will be a mode for each product version, which users should update. There will also be a develop mode which can be cloned for development using GIT.

6. Analysis of the Proposed System

6.1 Impact Analysis

6.1.1 Operational Impacts

This software should allow for data to be processed quicker than previous methods. Data outputs will be organized more clearly for hopefully easier implementation into future methods.

6.1.2 Organizational Impacts

The graphical user interface should allow members of the lab not comfortable with coding to be able to process data equally as fast as other lab members.

6.2 Risks

There is a risk of data loss or corruption between retrieving data from the network drive and exporting processed data back to the network drive.

6.3 Issues to Resolve

CLARA tracking sometimes jumps around. Methods need to be implemented to filter out impossibly fast or short-duration reaches. The CLARA system also has known issues with camera desynchronization

6.4 Critical Success Factors for Remainder of Project

This program should provide an automated system to extract kinematic features from CLARA-generated data and export session-level values for further statistical analysis.

Appendix A: Scenarios Analysis

1) Load raw data
    a. The user may load raw data and go straight to step 2
    b. The user may store the raw data as a .mat file for quicker loading at a later time
        i. saved .mat files can be opened from within the software for further analysis
2) Extract kinematics
    a. The user selects an output directory
    b. If folders for different data types exist already, they are not created
        i. Preexisting data may be overwritten if a previous output directory is provided
    c. If data folders do not exist already, they are created in the output directory
    d. Data stored in appropriate output folders
3) Export session means
    a. The user may decide to group by cohort
        i. The user indicates how many cohorts
        ii. The user indicated which mice belong in each cohort
    b. The user selects an output directory
    c. If folders for different data types exist already, they are not created
        i. Preexisting data may be overwritten if a previous output directory is provided
    d. If data folders do not exist already, they are created in the output directory
    e. Data stored in appropriate output folders

Appendix C: Traceability Matrix

Table 2 - Description of functional requirements

Requirement ID	Function Name	Conceptual Information (Entity)	Description	Data Acquisition Approach (e.g., User Data Entry, Interface)
REQ-1	LoadRawData	Raw Data	Raw, positional data generated by CLARA	Interface with network drive
REQ-3	ExtractKinematics	Kinematic features	Calculated kinematic values from raw data	Interface and calculations
REQ-4	ExportJSON	Encoded json file	Json file encoded to contain raw and processed data	Interface
REQ-4	ExportMAT	MATLAB .mat file	.mat file saved with raw and processed data	Interface
REQ-5	PlotTrajectories	Positional data	Positional data in the x and y directions normalized to pellet location	Interface
REQ-7	ExtractKinematics	Initial-to-max and initial-to-end data structures	interpolated hand position and velocity, absolute velocity, hand path length, and dynamic time-warped position normalized to pellet location	Interface
REQ-8	ReviewFinalTrajectories	Final session trajectories plotted for user to review	Final session trajectories plotted for each mouse in the x and y directions	Interface, user interaction
REQ-9	LoadRawData	Paths to Curator and MATLAB_3D folders	User navigates to Curator and MATLAB_3D folders	User interface
REQ-10	ConvertUnits	Units of seconds and millimeters	Converts units from pixels and frames to millimeters and seconds	interface

Appendix D: Record of Changes

Table 3 - Record of Changes

Version Number	Date	Author/Owner	Description of Change
1.0	10/19/2022	Elise Carter	Created initial document
1.1	12/16/22	Elise Carter	Updated document for release of Version 1.1.

Appendix E: Acronyms

Table 4 - Acronyms

Acronym	Literal Translation
CLARA	Closed-loop automated reaching apparatus
KDA	Kinematic data analysis

Appendix H: Approvals

The undersigned acknowledge that they have reviewed the High-Level Technical Design and agree with the information presented within this document. Changes to this High-Level Technical Design will be coordinated with and approved by, the undersigned, or their designated representatives.

Table 5 - Approvals

Document Approved By	Date Approved
Name: Dr. Brad Smith, University of Colorado	Date
Name: Dr. Cristin Welle, University of Colorado	Date