Ged C++ library

v2.0.3

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Overview

C++ **Ged** library designed for automatic detection of changes on videos. The library is implemented in C++ (C++17 standard) and utilizes the OpenMP library (2.5 standard, built in C++ compiler) to facilitate parallel computation. It does not rely on any third-party code and doesn't include additional software libraries. **The library works real-time on low-power CPU**. The library is compatible with any processors and operating systems that support the C++ compiler with built-in support for the OpenMP. Algorithms work with various types of videos, including those from thermal cameras, and it ensures accurate detection of small-sized and low-contrast objects against complex backgrounds. The library performs frame-by-frame video processing and inherits its interface from the **ObjectDetector** class, which defines data structures and interface compatible with other type of detectors designed by ConstantRobotics Ltd. The library has simple interface and can be seamlessly integrated into systems of any complexity.

Versions

Table 1 - Library versions.

Version	Release date	What's new
1.0.0	29.03.2021	First version.
2.0.0	26.09.2023	- Interface changed to ObjectDetector. - Motion mask calculation algorithm optimized. - Added convenient demo, test and example applications. - Added applying detection mask feature.
2.0.1	13.11.2023	- ObjectDetector class updated.
2.0.2	16.11.2023	- Fixed deleting equal object mechanism.
2.0.3	29.12.2023	- Demo application updated. - ObjectDetector class updated. - Code optimized.

Library files

The library is supplied by source code only. The user would be given a set of files in the form of a CMake project (repository). The repository structure is shown below:

```
CMakeLists.txt ------------------- main CMake file
README.md ------------------------ Documentation
```

```
3rdparty ------------------------ folder with 3rdparty libraries
    CMakeLists.txt --------------- CMake file for 3rdpary folder
    ObjectDetector --------------- files of ObjectDetector interface library
src ------------------------------ folder with library source code
    CMakeLists.txt --------------- CMake file
    Ged.h ------------------------ main library header file
    GedVersion.h ----------------- header file with library version
    GedVersion.h.in -------------- file for CMake to generate version header
    Ged.cpp ---------------------- C++ implementation file
demo ----------------------------- folder for demo application files
    CMakeLists.txt --------------- CMake file for demo application
    3rdaprty --------------------- folder with 3rdparty libraries
        CMakeLists.txt ----------- CMake file for 3rdparty folder
        SimpleFileDialog --------- file dialog service library
    main.cpp --------------------- source C++ file of demo application
test ----------------------------- folder with benchmark application
    CMakeLists.txt --------------- CMake file of benchmark application
    main.cpp --------------------- source C++ file of benchmark application
example -------------------------- folder with simple example
    CMakeLists.txt --------------- CMake file of simple example
    main.cpp --------------------- source C++ file of simple example
```

Demo application depends on open source **SimpleFileDialog** library which provide file dialog function and also depends on **OpenCV** library to provide user interface.

Key features and capabilities

Table 2 - Key features and capabilities.

Parameter and feature	Description
Programming language	C++ (standard C++17) using the OpenMP library (version 2.5 and higher).
Supported OS	Compatible with any operating system that supports the C++ compiler (C++17 standard) and the OpenMP library (version 2.5 and higher).
Shape of detected objects	The library is able to detect objects of any shape. The minimum and maximum height and width of the objects to be detected are set by the user in the library parameters.
Supported pixel formats	RGB24, BGR24, GRAY, YUV24, YUYV, UYVY, NV12, NV21, YV12, YU12. The library uses the GRAY format for video processing. If the pixel format of the image is different from GRAY, the library pre-converts the pixel formats to GRAY.
Maximum and minimum video frame size	The minimum size of video frames to be processed is 24x24 pixels, and the maximum size is 8192x8192 pixels. The size of the video frames to be processed has a significant impact on the computation speed.

Parameter and feature	Description
Coordinate system	The algorithm uses a window coordinate system with the zero point in the upper left corner of the video frame.
Calculation speed	The processing time per video frame depends on the computing platform used. The processing time per video frame can be estimated with the demo application. It is possible to scale video frames to provide higher calculation speed.
Discreteness of computation of coordinates	The algorithm calculates the object bounding box for each detected object. The increment for calculation of position and parameters of the bounding box is 1 pixel.
Type of algorithm for detection of events	Gauss Model based algorithm implementer to detect motion in each pixel.
Working conditions	Algorithms implemented in the library are designed to work on fixed cameras mainly. It is possible to work with slight camera movement depending on the background. It is recommended to use a demo application to evaluate the quality of the algorithms in specific situations.

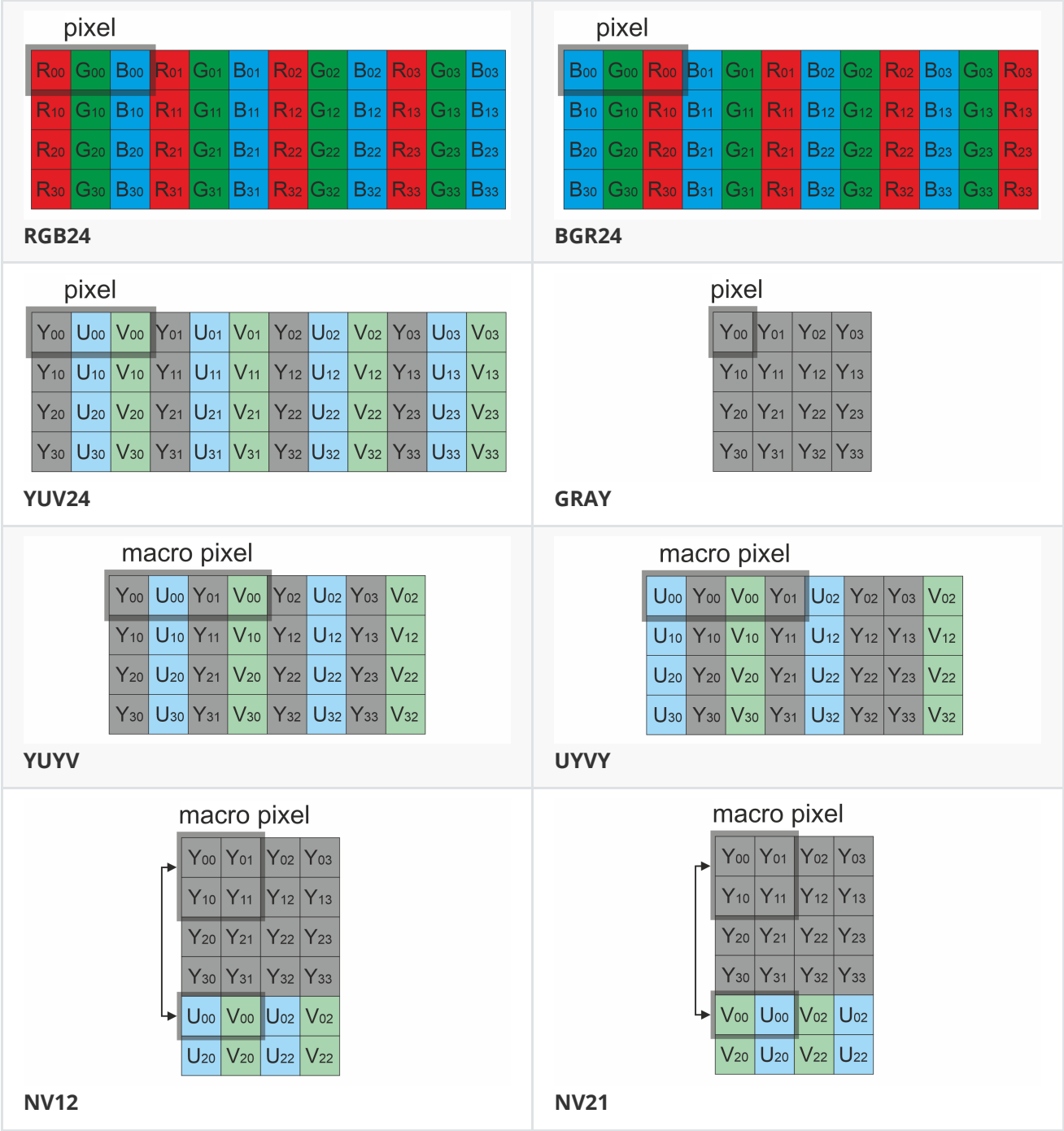
Supported pixel formats

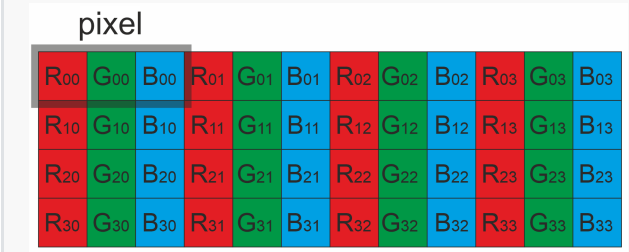
Frame library (included in **Ged** library as source code) contains **Fourcc** enum which defines supported pixel formats (**Frame.h** file). **Ged** library supports RAW pixel formats. For internal processing the library uses **GRAY** pixel format. If the pixel format of the image is different from **GRAY**, the library pre-converts the pixel formats to **GRAY**. **Fourcc** enum declaration:

```
enum class Fourcc
{
    /// RGB 24bit pixel format.
    RGB24 = MAKE_FOURCC_CODE('R', 'G', 'B', '3'),
    /// BGR 24bit pixel format.
    BGR24 = MAKE_FOURCC_CODE('B', 'G', 'R', '3'),
    /// YUYV 16bits per pixel format.
    YUYV  = MAKE_FOURCC_CODE('Y', 'U', 'Y', 'V'),
    /// UYVY 16bits per pixel format.
    UYVY  = MAKE_FOURCC_CODE('U', 'Y', 'V', 'Y'),
    /// Grayscale 8bit.
    GRAY  = MAKE_FOURCC_CODE('G', 'R', 'A', 'Y'),
    /// YUV 24bit per pixel format.
    YUV24  = MAKE_FOURCC_CODE('Y', 'U', 'V', '3'),
    /// NV12 pixel format.
    NV12  = MAKE_FOURCC_CODE('N', 'V', '1', '2'),
    /// NV21 pixel format.
    NV21  = MAKE_FOURCC_CODE('N', 'V', '2', '1'),
    /// YU12 (YUV420) - Planar pixel format.
    YU12 = MAKE_FOURCC_CODE('Y', 'U', '1', '2'),
```

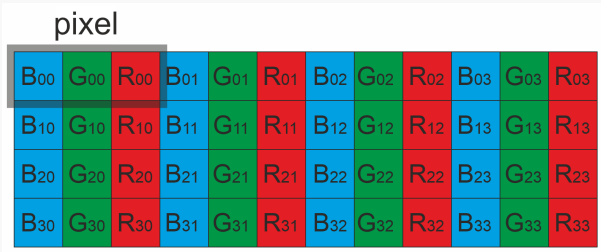
```
    /// YV12 (YVU420) - Planar pixel format.
    YV12 = MAKE_FOURCC_CODE('Y', 'V', '1', '2'),
    /// JPEG compressed format.
    JPEG  = MAKE_FOURCC_CODE('J', 'P', 'E', 'G'),
    /// H264 compressed format.
    H264  = MAKE_FOURCC_CODE('H', '2', '6', '4'),
    /// HEVC compressed format.
    HEVC  = MAKE_FOURCC_CODE('H', 'E', 'V', 'C')
};
```

Table 3 - Bytes layout of supported RAW pixel formats. Example of 4x4 pixels image.

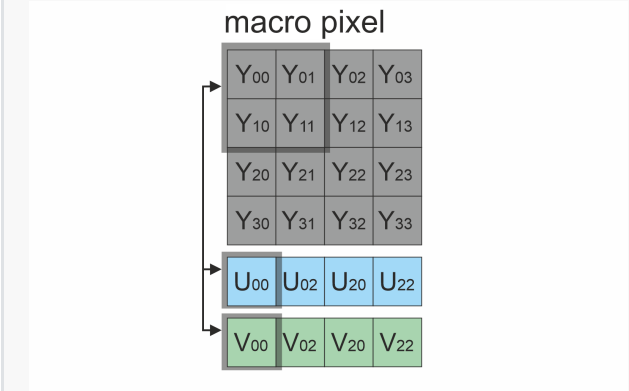




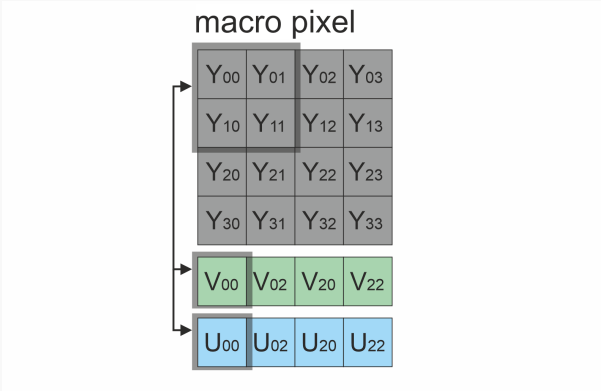
RGB24



BGR24



YU12



YV12

Library principles

The Gaussian event detection algorithm involves the following sequential steps:

1. Acquiring the source video frame, converting it to GRAY format (grayscale) and adding pixels values to summary matrix.
2. Calculating the foreground mask on averaged pixel values image from all of the images in buffer (the most time-consuming operation, which can be multithreaded by setting the num thread parameter).
3. Generating a list of detected objects.
4. The resulting objects for the current frame can be retrieved using the getObjects() method.

The library is available as source code only. To utilize the library as source code, developers must include the library's files into their project. The usage sequence for the library is as follows:

1. Include the library files in the project.
2. Create an instance of the Ged C++ class.
3. If necessary, modify the default library parameters using the setParam() method.
4. Create Frame class object for input frame and a vector of Objects.
5. Call the detect(...) method to identify objects.
6. Fill the created vector of Objects using the getObjects() method.

Ged class description

Ged class declaration

Ged.h file contains **Ged** class declaration. **Ged** class inherits interface from **ObjectDetector** interface class. Class declaration:

```
class Ged : public ObjectDetector
{
public:
    /// Get string of current library version.
    static std::string getVersion();

    /// Class constructor.
    Ged();

    /// Class destructor.
    ~Ged();

    /// Init object detector.
    bool initObjectDetector(ObjectDetectorParams& params) override;

    /// Set object detector param.
    bool setParam(ObjectDetectorParam id, float value) override;

    /// Get object detector param value.
    float getParam(ObjectDetectorParam id) override;

    ///  Get object detector params including list of detected objects.
    void getParams(ObjectDetectorParams& params) override;

    /// Get list of detected objects.
    std::vector<Object> getObjects() override;

    /// Execute command.
    bool executeCommand(ObjectDetectorCommand id) override;

    /// Perform detection.
    bool detect(cr::video::Frame& frame) override;

    /// Set detection mask.
    bool setMask(cr::video::Frame mask) override;

    /// Decode and execute command.
    bool decodeAndExecuteCommand(uint8_t* data, int size) override;

    /// This method retrieves the motion detection binary mask.
    bool getMotionMask(cr::video::Frame& mask);
};
```

getVersion method

getVersion() method return string of current version of **Ged** class. Method declaration:

```
static std::string getVersion();
```

Method can be used without **Ged** class instance. Example:

```
cout << "Ged version: " << Ged::getVersion() << endl;
```

Console output:

```
Ged version: 2.0.3
```

initObjectDetector method

initObjectDetector(...) method initializes detector. Method declaration:

```
bool initObjectDetector(ObjectDetectorParams& params) override;
```

Parameter	Value
params	Object detector parameters class. Object detector should initialize all parameters listed in **ObjectDetectorParams**. The library takes into account only following parameters from **ObjectDetectorParams** class: frameBufferSize (Default value 30) minObjectWidth (Default value 2) maxObjectWidth (Default value 128) minObjectHeight (Default value 2) maxObjectHeight (Default value 128) sensitivity (Default value 10) scaleFactor (Default value 1) numThreads (Default value 1) If particular parameter out of valid range the library will set default values automatically.

Returns: always returns TRUE.

setParam method

setParam(...) method designed to set new Ged parameter value. Method declaration:

```
bool setParam(ObjectDetectorParam id, float value) override;
```

Parameter	Description
id	Parameter ID according to **ObjectDetectorParam** enum (defined by **ObjectDetector** interface class). The library supports not all parameters from **ObjectDetector** interface.
value	Parameter value. Valid values depend on parameter ID.

Returns: TRUE if the parameter was set or FALSE if not (not supported or out of valid range).

getParam method

getParam(...) method returns parameter value. Method declaration:

```
float getParam(ObjectDetectorParam id) override;
```

Parameter	Description
id	Parameter ID according to **ObjectDetectorParam** enum (defined by **ObjectDetector** interface class). The library supports not all parameters from **ObjectDetector** interface.

Returns: parameter value or -1 if the parameter is not supported be Ged library.

getParams method

getParams(...) method returns object detector params structures as well a list of detected objects. Method declaration:

```
void getParams(ObjectDetectorParams& params) override;
```

Parameter	Description
params	Object detector params (**ObjectDetectorParams**). The library supports not all parameters from **ObjectDetector** interface. If the library doesn't support particular parameter it will be not changeable and will have default value.

getObjects method

getObjects() method returns list of detected objects. User can obtain object list of detected objects via **getParams(...)** method as well. Method declaration:

```
std::vector<Object> getObjects() override;
```

Returns: list of detected objects (see **Object** class description). If no detected object the list will be empty.

executeCommand method

executeCommand(...) method designed to execute object detector command. Method declaration:

```
bool executeCommand(ObjectDetectorCommand id) override;
```

Parameter	Description
id	Command ID according to **ObjectDetectorCommand** enum.

Returns: TRUE is the command was executed or FALSE if not (only if command ID not valid).

detect method

detect(...) method performs detection. Method declaration:

```
bool detect(cr::video::Frame& frame) override;
```

Parameter	Description
frame	Video frame for processing. Object detector processes only RAW pixel formats (BGR24, RGB24, GRAY, YUYV24, YUYV, UYVY, NV12, NV21, YV12, YU12, see **Frame** class description). Size of frame must be from 24x24 to 8192x8192.

Returns: TRUE is the video frame was processed FALSE if not. If object detector disabled (see **ObjectDetectorParam** enum description) the method returns TRUE.

setMask method

setMask(...) method designed to set detection mask. The mask indicates the pixels of the image in which object detection is allowed. User can specify any configuration of detection mask and can exclude any areas of the video frame from processing (excluding from detection). Method declaration:

```
bool setMask(cr::video::Frame mask) override;
```

Parameter	Description
mask	Detection mask is see **Frame** object with GRAY pixel format. Detector omits image segments, where detection mask pixel values equal 0. Mask can have any resolution. If resolution of mask (width and height) not equal to video frame resolution the library will scale this mask up to original processed video resolution.

Returns: TRUE if the detection mask was set or FALSE if not.

getMotionMask method

getMotionMask(...) method retrieves the motion detection binary mask, that is utilized by the detector to identify objects in the video stream. Method not included in **ObjectDetector** interface. Method declaration:

```
bool getMotionMask(cr::video::Frame& mask);
```

Parameter	Description
mask	Image of motion mask. Must have GRAY (preferable), NV12, NV21, YV12 or YU12 pixel format. If Frame object not initialised the library will initilise it.

Returns: TRUE if the mask image is filled or FALSE if not (not valid pixel format).

decodeAndExecuteCommand method

decodeAndExecuteCommand(...) method decodes and executes command on object detector side. **decodeAndExecuteCommand(...)** is thread-safe method. This means that the **decodeAndExecuteCommand(...)** method can be safely called from any thread. Method declaration:

```
bool decodeAndExecuteCommand(uint8_t* data, int size) override;
```

Parameter	Description
data	Pointer to input command.
size	Size of command. Must be 11 bytes for SET_PARAM or 7 bytes for COMMAND.

Returns: TRUE if command decoded (SET_PARAM or COMMAND) and executed (action command or set param command).

encodeSetParamCommand method of ObjectDetector class

encodeSetParamCommand(...) static method designed to encode command to change any parameter for remote object detector. To control object detector remotely, the developer has to design his own protocol and according to it encode the command and deliver it over the communication channel. To simplify this, the **ObjectDetector** class contains static methods for encoding the control command. The **ObjectDetector** class provides two types of commands: a parameter change command (SET_PARAM) and an action command (COMMAND). **encodeSetParamCommand(...)** designed to encode SET_PARAM command. Method declaration:

```
static void encodeSetParamCommand(uint8_t* data, int& size, ObjectDetectorParam id, float
value);
```

Parameter	Description
data	Pointer to data buffer for encoded command. Must have size >= 11.
size	Size of encoded data. Will be 11 bytes.
id	Parameter ID according to **ObjectDetectorParam enum**.
value	Parameter value. Value depends on parameter ID.

SET_PARAM command format (11 bytes):

Byte	Value	Description
0	0x01	SET_PARAM command header value.
1	Major version	Major version of ObjectDetector class.
2	Minor version	Minor version of ObjectDetector class.
3	id	Parameter ID **int32_t** in Little-endian format.
4	id	Parameter ID **int32_t** in Little-endian format.
5	id	Parameter ID **int32_t** in Little-endian format.
6	id	Parameter ID **int32_t** in Little-endian format.
7	value	Parameter value **float** in Little-endian format.
8	value	Parameter value **float** in Little-endian format.
9	value	Parameter value **float** in Little-endian format.
10	value	Parameter value **float** in Little-endian format.

encodeSetParamCommand(...) is static and used without **ObjectDetector** class instance. This method used on client side (control system). Command encoding example:

```
// Buffer for encoded data.
uint8_t data[11];
// Size of encoded data.
int size = 0;
// Random parameter value.
float outValue = (float)(rand() % 20);
// Encode command.
ObjectDetector::encodeSetParamCommand(data, size, ObjectDetectorParam::MIN_OBJECT_WIDTH,
outValue);
```

encodeCommand method of ObjectDetector class

encodeCommand(...) static method designed to encode command for remote object detector. To control object detector remotely, the developer has to design his own protocol and according to it encode the command and deliver it over the communication channel. To simplify this, the **ObjectDetector** class contains static methods for encoding the control command. The **ObjectDetector** class provides two types of commands: a parameter change command (SET_PARAM) and an action command (COMMAND). **encodeCommand(...)** designed to encode COMMAND (action command). Method declaration:

```
static void encodeCommand(uint8_t* data, int& size, ObjectDetectorCommand id);
```

Parameter	Description
data	Pointer to data buffer for encoded command. Must have size >= 7.
size	Size of encoded data. Will be 7 bytes.
id	Command ID according to **ObjectDetectorCommand enum**.

COMMAND format (7 bytes):

Byte	Value	Description
0	0x00	COMMAND header value.
1	Major version	Major version of ObjectDetector class.
2	Minor version	Minor version of ObjectDetector class.
3	id	Command ID **int32_t** in Little-endian format.
4	id	Command ID **int32_t** in Little-endian format.
5	id	Command ID **int32_t** in Little-endian format.
6	id	Command ID **int32_t** in Little-endian format.

encodeCommand(...) is static and used without **ObjectDetector** class instance. This method used on client side (control system). Command encoding example:

```
// Buffer for encoded data.
uint8_t data[7];
// Size of encoded data.
int size = 0;
// Encode command.
ObjectDetector::encodeCommand(data, size, ObjectDetectorCommand::RESET);
```

decodeCommand method of ObjectDetector class

decodeCommand(...) static method designed to decode command on object detector side (edge device). Method declaration:

```
static int decodeCommand(uint8_t* data, int size, ObjectDetectorParam& paramId,
ObjectDetectorCommand& commandId, float& value);
```

Parameter	Description
data	Pointer to input command.
size	Size of command. Should be 11 bytes.
paramId	Parameter ID according to **ObjectDetectorParam enum**. After decoding SET_PARAM command the method will return parameter ID.
commandId	Command ID according to **ObjectDetectorCommand enum**. After decoding COMMAND the method will return command ID.
value	Parameter value (after decoding SET_PARAM command).

Returns: 0 - in case decoding COMMAND, **1** - in case decoding SET_PARAM command or **-1** in case errors.

Data structures

ObjectDetectorCommand enum

Enum declaration:

```
enum class ObjectDetectorCommand
{
    /// Reset.
    RESET = 1,
    /// Enable.
    ON,
    /// Disable.
    OFF
};
```

Table 4 - Object detector commands description. Some commands maybe unsupported by particular object detector class.

Command	Description
RESET	Reset algorithm.
ON	Enable object detector.
OFF	Disable object detector.

ObjectDetectorParam enum

Enum declaration:

```
enum class ObjectDetectorParam
{
    /// Logging mode. Values: 0 - Disable, 1 - Only file,
    /// 2 - Only terminal (console), 3 - File and terminal (console).
    LOG_MODE = 1,
    /// Frame buffer size. Depends on implementation.
    FRAME_BUFFER_SIZE,
    /// Minimum object width to be detected, pixels. To be detected object's
    /// width must be >= MIN_OBJECT_WIDTH.
    MIN_OBJECT_WIDTH,
    /// Maximum object width to be detected, pixels. To be detected object's
    /// width must be <= MAX_OBJECT_WIDTH.
    MAX_OBJECT_WIDTH,
    /// Minimum object height to be detected, pixels. To be detected object's
    /// height must be >= MIN_OBJECT_HEIGHT.
    MIN_OBJECT_HEIGHT,
    /// Maximum object height to be detected, pixels. To be detected object's
    /// height must be <= MAX_OBJECT_HEIGHT.
    MAX_OBJECT_HEIGHT,
    /// Minimum object's horizontal speed to be detected, pixels/frame. To be
    /// detected object's horizontal speed must be >= MIN_X_SPEED.
    MIN_X_SPEED,
    /// Maximum object's horizontal speed to be detected, pixels/frame. To be
    /// detected object's horizontal speed must be <= MAX_X_SPEED.
    MAX_X_SPEED,
    /// Minimum object's vertical speed to be detected, pixels/frame. To be
    /// detected object's vertical speed must be >= MIN_Y_SPEED.
    MIN_Y_SPEED,
    /// Maximum object's vertical speed to be detected, pixels/frame. To be
    /// detected object's vertical speed must be <= MAX_Y_SPEED.
    MAX_Y_SPEED,
    /// Probability threshold from 0 to 1. To be detected object detection
    /// probability must be >= MIN_DETECTION_PROPABILITY.
    MIN_DETECTION_PROPABILITY,
    /// Horizontal track detection criteria, frames. By default shows how many
    /// frames the objects must move in any(+/-) horizontal direction to be
    /// detected.
    X_DETECTION_CRITERIA,
    /// Vertical track detection criteria, frames. By default shows how many
    /// frames the objects must move in any(+/-) vertical direction to be
    /// detected.
    Y_DETECTION_CRITERIA,
    /// Track reset criteria, frames. By default shows how many
    /// frames the objects should be not detected to be excluded from results.
    RESET_CRITERIA,
    /// Detection sensitivity. Depends on implementation. Default from 0 to 1.
    SENSITIVITY,
    /// Frame scaling factor for processing purposes. Reduce the image size by
    /// scaleFactor times horizontally and vertically for faster processing.
```

```
    SCALE_FACTOR,
    /// Num threads. Number of threads for parallel computing.
    NUM_THREADS,
    /// Processing time for last frame, mks.
    PROCESSING_TIME_MKS,
    /// Algorithm type. Depends on implementation.
    TYPE,
    /// Mode. Default: 0 - Off, 1 - On.
    MODE,
    /// Custom parameter. Depends on implementation.
    CUSTOM_1,
    /// Custom parameter. Depends on implementation.
    CUSTOM_2,
    /// Custom parameter. Depends on implementation.
    CUSTOM_3
};
```

Table 5 - Ged class params description (from **ObjectDetector** interface class). Some params are not supported by Ged class.

Parameter	Access	Description
LOG_MODE	read / write	**Not used.** Can have any values.
FRAME_BUFFER_SIZE	read / write	Frame buffer size. Valid values from 1 to 128. Defines how many frames are summed up before motion mask calculation.
MIN_OBJECT_WIDTH	read / write	Minimum object width to be detected, pixels. Valid values from 1 to 8192. Must be < MAX_OBJECT_WIDTH. To be detected object's width must be >= MIN_OBJECT_WIDTH. Default value is 4.
MAX_OBJECT_WIDTH	read / write	Maximum object width to be detected, pixels. Valid values from 1 to 8192. Must be > MIN_OBJECT_WIDTH. To be detected object's width must be <= MAX_OBJECT_WIDTH. Default value is 128.
MIN_OBJECT_HEIGHT	read / write	Minimum object height to be detected, pixels. Valid values from 1 to 8192. Must be < MAX_OBJECT_HEIGHT. To be detected object's height must be >= MIN_OBJECT_HEIGHT. Default value is 4.
MAX_OBJECT_HEIGHT	read / write	Maximum object height to be detected, pixels. Valid values from 1 to 8192. Must be > MIN_OBJECT_HEIGHT. To be detected object's height must be <= MAX_OBJECT_HEIGHT. Default value is 128.
MIN_X_SPEED	read / write	**Not used.** Can have any values.
MAX_X_SPEED	read / write	**Not used.** Can have any values.

Parameter	Access	Description
MIN_Y_SPEED	read / write	**Not used.** Can have any values from 0 to 256.
MAX_Y_SPEED	read / write	**Not used.** Can have any values from 0 to 256.0.
MIN_DETECTION_PROPABILITY	read / write	**Not used.** Can have any values from 0 to 1.
X_DETECTION_CRITERIA	read / write	**Not used.** Can have any values from 0 to 128.
Y_DETECTION_CRITERIA	read / write	**Not used.** Can have any values from 0 to 128.
RESET_CRITERIA	read / write	**Not used.** Can have any values from 0 to 128.
SENSITIVITY	read / write	Detection sensitivity. For Ged library this parameters means pixel brightness deviation threshold from 0 to 255 for calculation motion mask. The first processing step is the computation of the binary motion mask. The algorithm makes a decision about the presence of motion in a particular pixel also on the basis of changes in pixel brightness. The brightness threshold is determined by the SENSITIVITY parameter. The lower this parameter is, the less contrasty objects will be detected, but there will be more influence of video noise. The larger this parameter is, the more contrast objects must have in order to be detected. The recommended value for thermal cameras is **15**. The recommended value for daylight cameras is **10**.
SCALE_FACTOR	read / write	Frame scaling factor for processing purposes. Reduce the image size by scaleFactor times horizontally and vertically for faster processing. Allows to increase calculation speed but slightly reduces sensitivity.
NUM_THREADS	read / write	Num threads. Number of threads for parallel computing. Multiple threads are used to compute the binary motion mask.
PROCESSING_TIME_MKS	read only	Processing time for last frame, mks. The library independently calculates the processing time for each frame of video.
TYPE	read / write	**Not used.** Can have any value.
MODE	read / write	Mode. Default: 0 - Off, 1 - On. If the detector is not activated, frame processing is not performed - the list of detected objects will always be empty.

Parameter	Access	Description
CUSTOM_1	read / write	**Not used.** Can have any value.
CUSTOM_2	read / write	**Not used.** Can have any value.
CUSTOM_3	read / write	**Not used.** Can have any value.

Object structure

Object structure used to describe detected object. Object structure declared in **ObjectDetector.h** file. Structure declaration:

```
typedef struct Object
{
    /// Object ID. Must be uniques for particular object.
    int id{0};
    /// Frame ID. Must be the same as frame ID of processed video frame.
    int frameId{0};
    /// Object type. Depends on implementation.
    int type{0};
    /// Object rectangle width, pixels.
    int width{0};
    /// Object rectangle height, pixels.
    int height{0};
    /// Object rectangle top-left horizontal coordinate, pixels.
    int x{0};
    /// Object rectangle top-left vertical coordinate, pixels.
    int y{0};
    /// Horizontal component of object velocity, +-pixels/frame.
    float vX{0.0f};
    /// Vertical component of object velocity, +-pixels/frame.
    float vY{0.0f};
    /// Detection probability from 0 (minimum) to 1 (maximum).
    float p{0.0f};
} Object;
```

Table 6 - Object structure fields description.

Field	Type	Description
id	int	Object ID. Unique for particular object. The library assigns a unique ID to the frame of a new detected object and does not change it from frame to frame. If the object disappears and reappears, the library can assign a new ID. This is necessary for control algorithms to distinguish different objects from frame to frame. Object id is reset after detector reset.
frameId	int	Frame ID. Will be the same as frame ID of processed video frame.

Field	Type	Description
type	int	**Not used.** Will have value 0.
width	int	Object rectangle width, pixels. Must be MIN_OBJECT_WIDTH <= width <= MAX_OBJECT_WIDTH (see **ObjectDetectorParam** enum description).
height	int	Object rectangle height, pixels. Must be MIN_OBJECT_HEIGHT <= height <= MAX_OBJECT_HEIGHT (see **ObjectDetectorParam** enum description).
x	int	Object rectangle top-left horizontal coordinate, pixels.
y	int	Object rectangle top-left vertical coordinate, pixels.
vX	float	**Not used.** Will have value 0.0.
vY	float	**Not used.** Will have value 0.0.
p	float	**Not used.** Will have value 0.0.

ObjectDetectorParams class description

ObjectDetectorParams class declaration

ObjectDetectorParams class used for object detector initialization (**initObjectDetector(...)** method) or to get all actual params (**getParams()** method). Also **ObjectDetectorParams** provide structure to write/read params from JSON files (**JSON_READABLE** macro, see **ConfigReader** class description) and provide methods to encode and decode params. Class declaration:

```
class ObjectDetectorParams
{
public:
    /// Init string. Depends on implementation.
    std::string initString{""};
    /// Logging mode. Values: 0 - Disable, 1 - Only file,
    /// 2 - Only terminal (console), 3 - File and terminal (console).
    int logMode{0};
    /// Frame buffer size. Depends on implementation.
    int frameBufferSize{1};
    /// Minimum object width to be detected, pixels. To be detected object's
    /// width must be >= minObjectWidth.
    int minObjectWidth{4};
    /// Maximum object width to be detected, pixels. To be detected object's
    /// width must be <= maxObjectWidth.
    int maxObjectWidth{128};
    /// Minimum object height to be detected, pixels. To be detected object's
    /// height must be >= minObjectHeight.
    int minObjectHeight{4};
    /// Maximum object height to be detected, pixels. To be detected object's
    /// height must be <= maxObjectHeight.
    int maxObjectHeight{128};
```

```
    /// Minimum object's horizontal speed to be detected, pixels/frame. To be
    /// detected object's horizontal speed must be >= minXSpeed.
    float minXSpeed{0.0f};
    /// Maximum object's horizontal speed to be detected, pixels/frame. To be
    /// detected object's horizontal speed must be <= maxXSpeed.
    float maxXSpeed{30.0f};
    /// Minimum object's vertical speed to be detected, pixels/frame. To be
    /// detected object's vertical speed must be >= minYSpeed.
    float minYSpeed{0.0f};
    /// Maximum object's vertical speed to be detected, pixels/frame. To be
    /// detected object's vertical speed must be <= maxYSpeed.
    float maxYSpeed{30.0f};
    /// Probability threshold from 0 to 1. To be detected object detection
    /// probability must be >= minDetectionProbability.
    float minDetectionProbability{0.5f};
    /// Horizontal track detection criteria, frames. By default shows how many
    /// frames the objects must move in any(+/-) horizontal direction to be
    /// detected.
    int xDetectionCriteria{1};
    /// Vertical track detection criteria, frames. By default shows how many
    /// frames the objects must move in any(+/-) vertical direction to be
    /// detected.
    int yDetectionCriteria{1};
    /// Track reset criteria, frames. By default shows how many
    /// frames the objects should be not detected to be excluded from results.
    int resetCriteria{1};
    /// Detection sensitivity. Depends on implementation. Default from 0 to 1.
    float sensitivity{0.04f};
    /// Frame scaling factor for processing purposes. Reduce the image size by
    /// scaleFactor times horizontally and vertically for faster processing.
    int scaleFactor{1};
    /// Num threads. Number of threads for parallel computing.
    int numThreads{1};
    /// Processing time for last frame, mks.
    int processingTimeMks{0};
    /// Algorithm type. Depends on implementation.
    int type{0};
    /// Mode. Default: false - Off, on - On.
    bool enable{true};
    /// Custom parameter. Depends on implementation.
    float custom1{0.0f};
    /// Custom parameter. Depends on implementation.
    float custom2{0.0f};
    /// Custom parameter. Depends on implementation.
    float custom3{0.0f};
    /// List of detected objects.
    std::vector<Object> objects;

    JSON_READABLE(ObjectDetectorParams, initString, logMode, frameBufferSize,
                  minObjectWidth, maxObjectWidth, minObjectHeight,
                  maxObjectHeight, minXSpeed, maxXSpeed, minYSpeed,
                  maxYSpeed, minDetectionProbability, xDetectionCriteria,
                  yDetectionCriteria, resetCriteria, sensitivity,
                  scaleFactor, numThreads, type, enable, custom1,
                  custom2, custom3);
```

```
    /// operator =
    ObjectDetectorParams& operator= (const ObjectDetectorParams& src);

    /// Encode params.
    bool encode(uint8_t* data, int bufferSize, int& size,
                ObjectDetectorParamsMask* mask = nullptr);

    /// Decode params.
    bool decode(uint8_t* data, int dataSize);
};
```

Table 7 - ObjectDetectorParams class fields description.

Field	Type	Description
initString	string	**Not used.** Can have any value.
logMode	int	**Not used.** Can have any value.
frameBufferSize	int	Frame buffer size. Valid values from 1 to 128. Defines how many frames are summed up before motion mask calculation.
minObjectWidth	int	Minimum object width to be detected, pixels. To be detected object's width must be >= minObjectWidth.
maxObjectWidth	int	Maximum object width to be detected, pixels. To be detected object's width must be <= maxObjectWidth.
minObjectHeight	int	Minimum object height to be detected, pixels. To be detected object's height must be >= minObjectHeight.
maxObjectHeight	int	Maximum object height to be detected, pixels. To be detected object's height must be <= maxObjectHeight.
minXSpeed	float	**Not used.** Can have any values.
maxXSpeed	float	**Not used.** Can have any values.
minYSpeed	float	**Not used.** Can have any values.
maxYSpeed	float	**Not used.** Can have any values.
minDetectionProbability	float	**Not used.** Can have any values.
xDetectionCriteria	int	**Not used.** Can have any values.
yDetectionCriteria	int	**Not used.** Can have any values.
resetCriteria	int	**Not used.** Can have any values.

Field	Type	Description
sensitivity	float	Detection sensitivity. For Ged library this parameters means pixel brightness deviation threshold from 0 to 255 for calculation motion mask. The first processing step is the computation of the binary motion mask. The algorithm makes a decision about the presence of motion in a particular pixel also on the basis of changes in pixel brightness. The brightness threshold is determined by the SENSITIVITY parameter. The lower this parameter is, the less contrasty objects will be detected, but there will be more influence of video noise. The larger this parameter is, the more contrast objects must have in order to be detected. The recommended value for thermal cameras is **15**. The recommended value for daylight cameras is **10**.
scaleFactor	int	Frame scaling factor for processing purposes. Reduce the image size by scaleFactor times horizontally and vertically for faster processing. Allows to increase calculation speed but slightly reduces sensitivity.
numThreads	int	Number of threads for parallel computing. Multiple threads are used to compute the binary motion mask.
processingTimeMks	int	Processing time for last frame, mks. The library independently calculates the processing time for each frame of video.
type	int	**Not used.** Can have any value.
enable	bool	Mode: false - Off, true - On.
custom1	float	**Not used.** Can have any values.
custom2	float	**Not used.** Can have any values.
custom3	float	**Not used.** Can have any values.
objects	std::vector	List of detected objects.

None: *ObjectDetectorParams class fields listed in Table 7* ***must*** *reflect params set/get by methods setParam(...) and getParam(...).*

Serialize object detector params

ObjectDetectorParams class provides method **encode(...)** to serialize object detector params (fields of ObjectDetectorParams class, see Table 5). Serialization of object detector params necessary in case when you need to send params via communication channels. Method provides options to exclude particular parameters from serialization. To do this method inserts binary mask (3 bytes) where each bit represents particular parameter and **decode(...)** method recognizes it. Method doesn't encode initString. Method declaration:

```
void encode(uint8_t* data, int& size, ObjectDetectorParamsMask* mask = nullptr);
```

Parameter	Value
data	Pointer to data buffer. Buffer size should be at least **43** bytes.
size	Size of encoded data. 43 bytes by default.
mask	Parameters mask - pointer to **ObjectDetectorParamsMask** structure. **ObjectDetectorParamsMask** (declared in ObjectDetector.h file) determines flags for each field (parameter) declared in **ObjectDetectorParams** class. If the user wants to exclude any parameters from serialization, he can put a pointer to the mask. If the user wants to exclude a particular parameter from serialization, he should set the corresponding flag in the ObjectDetectorParamsMask structure.

ObjectDetectorParamsMask structure declaration:

```
typedef struct ObjectDetectorParamsMask
{
    bool logMode{true};
    bool frameBufferSize{true};
    bool minObjectWidth{true};
    bool maxObjectWidth{true};
    bool minObjectHeight{true};
    bool maxObjectHeight{true};
    bool minXSpeed{true};
    bool maxXSpeed{true};
    bool minYSpeed{true};
    bool maxYSpeed{true};
    bool minDetectionProbability{true};
    bool xDetectionCriteria{true};
    bool yDetectionCriteria{true};
    bool resetCriteria{true};
    bool sensitivity{true};
    bool scaleFactor{true};
    bool numThreads{true};
    bool processingTimeMks{true};
    bool type{true};
    bool enable{true};
    bool custom1{true};
    bool custom2{true};
    bool custom3{true};
    bool objects{true};
} ObjectDetectorParamsMask;
```

Example without parameters mask:

```
// Prepare random params.
ObjectDetectorParams in;
in.logMode = rand() % 255;
in.objects.clear();
for (int i = 0; i < 5; ++i)
{
```

```
    Object obj;
    obj.id = rand() % 255;
    obj.type = rand() % 255;
    obj.width = rand() % 255;
    obj.height = rand() % 255;
    obj.x = rand() % 255;
    obj.y = rand() % 255;
    obj.vX = rand() % 255;
    obj.vY = rand() % 255;
    obj.p = rand() % 255;
    in.objects.push_back(obj);
}

// Encode data.
uint8_t data[1024];
int size = 0;
in.encode(data, size);
cout << "Encoded data size: " << size << " bytes" << endl;
```

Example with parameters mask:

```
// Prepare random params.
ObjectDetectorParams in;
in.logMode = rand() % 255;
in.objects.clear();
for (int i = 0; i < 5; ++i)
{
    Object obj;
    obj.id = rand() % 255;
    obj.type = rand() % 255;
    obj.width = rand() % 255;
    obj.height = rand() % 255;
    obj.x = rand() % 255;
    obj.y = rand() % 255;
    obj.vX = rand() % 255;
    obj.vY = rand() % 255;
    obj.p = rand() % 255;
    in.objects.push_back(obj);
}

// Prepare mask.
ObjectDetectorParamsMask mask;
mask.logMode = false;

// Encode data.
uint8_t data[1024];
int size = 0;
in.encode(data, size, &mask)
cout << "Encoded data size: " << size << " bytes" << endl;
```

Deserialize object detector params

ObjectDetectorParams class provides method **decode(...)** to deserialize params (fields of ObjectDetectorParams class, see Table 5). Deserialization of params necessary in case when you need to receive params via communication channels. Method automatically recognizes which parameters were serialized by **encode(...)** method. Method doesn't decode initString. Method declaration:

```
bool decode(uint8_t* data);
```

Parameter	Value
data	Pointer to encode data buffer.

Returns: TRUE if data decoded (deserialized) or FALSE if not.

Example:

```
// Prepare random params.
ObjectDetectorParams in;
in.logMode = rand() % 255;
for (int i = 0; i < 5; ++i)
{
    Object obj;
    obj.id = rand() % 255;
    obj.type = rand() % 255;
    obj.width = rand() % 255;
    obj.height = rand() % 255;
    obj.x = rand() % 255;
    obj.y = rand() % 255;
    obj.vX = rand() % 255;
    obj.vY = rand() % 255;
    obj.p = rand() % 255;
    in.objects.push_back(obj);
}

// Encode data.
uint8_t data[1024];
int size = 0;
in.encode(data, size);
cout << "Encoded data size: " << size << " bytes" << endl;

// Decode data.
ObjectDetectorParams out;
if (!out.decode(data))
{
    cout << "Can't decode data" << endl;
    return false;
}
```

Read params from JSON file and write to JSON file

ObjectDetector library depends on **ConfigReader** library which provides method to read params from JSON file and to write params to JSON file. Example of writing and reading params to JSON file:

```
// Prepare random params.
ObjectDetectorParams in;
in.logMode = rand() % 255;
in.objects.clear();
for (int i = 0; i < 5; ++i)
{
    Object obj;
    obj.id = rand() % 255;
    obj.type = rand() % 255;
    obj.width = rand() % 255;
    obj.height = rand() % 255;
    obj.x = rand() % 255;
    obj.y = rand() % 255;
    obj.vX = rand() % 255;
    obj.vY = rand() % 255;
    obj.p = rand() % 255;
    in.objects.push_back(obj);
}

// Write params to file.
cr::utils::ConfigReader inConfig;
inConfig.set(in, "ObjectDetectorParams");
inConfig.writeToFile("ObjectDetectorParams.json");

// Read params from file.
cr::utils::ConfigReader outConfig;
if(!outConfig.readFromFile("ObjectDetectorParams.json"))
{
    cout << "Can't open config file" << endl;
    return false;
}

ObjectDetectorParams out;
if(!outConfig.get(out, "ObjectDetectorParams"))
{
    cout << "Can't read params from file" << endl;
    return false;
}
```

ObjectDetectorParams.json will look like:

```
{
    "ObjectDetectorParams": {
        "custom1": 57.0,
        "custom2": 244.0,
        "custom3": 68.0,
        "enable": false,
        "frameBufferSize": 200,
        "initString": "sfsfsfsfsf",
```

```
        "logMode": 111,
        "maxObjectHeight": 103,
        "maxObjectWidth": 199,
        "maxXSpeed": 104.0,
        "maxYSpeed": 234.0,
        "minDetectionProbability": 53.0,
        "minObjectHeight": 191,
        "minObjectWidth": 149,
        "minXSpeed": 213.0,
        "minYSpeed": 43.0,
        "numThreads": 33,
        "resetCriteria": 62,
        "scaleFactor": 85,
        "sensitivity": 135.0,
        "type": 178,
        "xDetectionCriteria": 224,
        "yDetectionCriteria": 199
    }
}
```

Build and connect to your project

Typical commands to build **Ged** library:

```
cd Ged
git submodule update --init --recursive
mkdir build
cd build
cmake ..
make
```

If you want to connect **Ged** library to your CMake project as source code, you can do the following. For example, if your repository has structure:

```
CMakeLists.txt
src
    CMakeList.txt
    yourLib.h
    yourLib.cpp
```

You can add repository **Ged** as git submodule by commands (only if you have access to GitHub repository, if no, copy repository files):

```
cd <your respository folder>
git submodule add https://github.com/ConstantRobotics-Ltd/Ged.git 3rdparty/Ged
git submodule update --init --recursive
```

In your repository folder, a new **3rdparty/ObjectDetector** folder will be created, which contains files from **ObjectDetector** repository along with its subrepositories **Frame** and **ConfigReader**. If you don't have access to GitHub repository, copy **Ged** repository folder to **3rdparty** folder to your repository. The new structure of your repository will be as follows:

```
CMakeLists.txt
src
    CMakeList.txt
    yourLib.h
    yourLib.cpp
3rdparty
    Ged
```

Create CMakeLists.txt file in **3rdparty** folder. CMakeLists.txt should be containing:

```
cmake_minimum_required(VERSION 3.13)

###############################################################################
## 3RD-PARTY
## dependencies for the project
###############################################################################
project(3rdparty LANGUAGES CXX)

###############################################################################
## SETTINGS
## basic 3rd-party settings before use
###############################################################################
# To inherit the top-level architecture when the project is used as a submodule.
SET(PARENT ${PARENT}_YOUR_PROJECT_3RDPARTY)
# Disable self-overwriting of parameters inside included subdirectories.
SET(${PARENT}_SUBMODULE_CACHE_OVERWRITE OFF CACHE BOOL "" FORCE)

###############################################################################
## CONFIGURATION
## 3rd-party submodules configuration
###############################################################################
SET(${PARENT}_SUBMODULE_GED                                 ON  CACHE BOOL "" FORCE)
if (${PARENT}_SUBMODULE_GED)
    SET(${PARENT}_GED                                       ON  CACHE BOOL "" FORCE)
    SET(${PARENT}_GED_TEST                                  OFF CACHE BOOL "" FORCE)
    SET(${PARENT}_GED_DEMO_APP                              OFF CACHE BOOL "" FORCE)
    SET(${PARENT}_GED_EXAMPLE                               OFF CACHE BOOL "" FORCE)
endif()

###############################################################################
## INCLUDING SUBDIRECTORIES
## Adding subdirectories according to the 3rd-party configuration
###############################################################################
if (${PARENT}_SUBMODULE_GED)
    add_subdirectory(Ged)
endif()
```

File **3rdparty/CMakeLists.txt** adds folder **Ged** to your project and excludes test applications and examples from compiling. The new structure of your repository will be:

```
CMakeLists.txt
src
    CMakeList.txt
    yourLib.h
    yourLib.cpp
3rdparty
    CMakeLists.txt
    Ged
```

Next, you need to include the '3rdparty' folder in the main **CMakeLists.txt** file of your repository. Add the following string at the end of your main **CMakeLists.txt**:

```
add_subdirectory(3rdparty)
```

Next, you have to include Ged library in your **src/CMakeLists.txt** file:

```
target_link_libraries(${PROJECT_NAME} Ged)
```

Done!

Simple example

A simple application shows how to use the **Ged** library. The application opens a video file "test.mp4" and copies the video frame data into an object of the Frame class and performs event detection.

```
#include <opencv2/opencv.hpp>
#include "Ged.h"

int main(void)
{
    // Open video file "test.mp4".
    cv::VideoCapture videoSource;
    if (!videoSource.open("test.mp4"))
        return -1;

    // Create detector and set params.
    cr::detector::Ged detector;
    detector.setParam(cr::detector::ObjectDetectorParam::MIN_OBJECT_WIDTH, 4);
    detector.setParam(cr::detector::ObjectDetectorParam::MAX_OBJECT_WIDTH, 96);
    detector.setParam(cr::detector::ObjectDetectorParam::MIN_OBJECT_HEIGHT, 4);
    detector.setParam(cr::detector::ObjectDetectorParam::MAX_OBJECT_HEIGHT, 96);
    detector.setParam(cr::detector::ObjectDetectorParam::SENSITIVITY, 10);

    // Create frames.
    cv::Mat frameBgrOpenCv;

    // Main loop.
    while (true)
    {
        // Capture next video frame.
        videoSource >> frameBgrOpenCv;
```

```
        if (frameBgrOpenCv.empty())
        {
            // Reset detector.
            detector.executeCommand(cr::detector::ObjectDetectorCommand::RESET);
            // Set initial video position to replay.
            videoSource.set(cv::CAP_PROP_POS_FRAMES, 0);
            continue;
        }

        // Create Frame object.
        cr::video::Frame bgrFrame;
        bgrFrame.width = frameBgrOpenCv.size().width;
        bgrFrame.height = frameBgrOpenCv.size().height;
        bgrFrame.size = bgrFrame.width * bgrFrame.height * 3;
        bgrFrame.data = frameBgrOpenCv.data;
        bgrFrame.fourcc = cr::video::Fourcc::BGR24;

        // Detect objects.
        detector.detect(bgrFrame);

        // Get list of objects.
        std::vector<cr::detector::Object> objects = detector.getObjects();

        // Draw detected objects.
        for (int n = 0; n < objects.size(); ++n)
        {
            rectangle(frameBgrOpenCv, cv::Rect(objects[n].x, objects[n].y,
                      objects[n].width, objects[n].height),
                      cv::Scalar(0, 0, 255), 1);
        }

        // Show video.
        cv::imshow("VIDEO", frameBgrOpenCv);

        // Wait ESC.
        if (cv::waitKey(1) == 27)
            return -1;
    }

    return 1;
}
```