DnnOpenCvDetector C++ library

v1.0.1

Table of contents

Overview

DnnOpenCvDetector C++ library version **1.0.1** is designed for automatic detection of objects on videos through the utilization of neural networks. The library is implemented in C++ (C++17 standard) and exclusively relies on **OpenCV** library (version 4.5.0 and higher). The library supports various neural network models, if only model is supported by **OpenCV** and has a standard one-batch output (eg. yolov5). Neural network model can be specified in detector parameters, library inherits its interface from the **ObjectDetector** class, offering flexible and customizable parameters. It seamlessly integrates into systems of any complexity.

Versions

Table 1 - Library versions.

Version	Release date	What's new
1.0.0	27.09.2023	First version.
1.0.1	07.01.2024	- Demo application updated. - Documentation updated. - ObjectDetector interface class updated.

Library files

The library 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
    DnnOpenCvDetector.h ------------ Main header file of the library
    DnnOpenCvDetectorVersion.h ------ Header file with library version
    DnnOpenCvDetectorVersion.h.in --- File for CMake to generate version header
    DnnOpenCvDetector.cpp ---------- C++ implementation file
demo ------------------------------- Folder for demo application files
    CMakeLists.txt ----------------- CMake file for demo app
    3rdaprty ----------------------- Folder with 3rdparty libraries
        CMakeLists.txt ------------- CMake file for 3rdparty folder
        SimpleFileDialog ----------- File dialog service library
    main.cpp ----------------------- Source C++ file of demo app
example ---------------------------- Folder for simple example
    CMakeLists.txt ----------------- CMake file of example
    main.cpp ----------------------- Source C++ file of example
test ------------------------------- Folder with test app (benchmark)
    CMakeLists.txt ----------------- CMake file of test app (benchmark)
    main.cpp ----------------------- Source C++ file of test app
```

Demo application depends on open source **SimpleFileDialog**, which provides file dialog function and open source **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 **OpenCV** library (version 4.5.0 and higher).
Supported OS	Compatible with any operating system that supports the C++ compiler (C++17 standard) and the OpenCV library (version 4.5.0 and higher).
Shape of detected objects	The library is capable to detect objects of various shapes. It depends on neural network used. Users can set the minimum and maximum height and width of the objects to be detected through library parameters.
Supported pixel formats	RGB24, BGR24, GRAY, YUV24, YUYV, UYVY, NV12, NV21, YV12, YU12. The library uses the RGB format for video processing. If the pixel format of the image is different from RGB, the library pre-converts the pixel formats to RGB24.
Maximum and minimum video frame size	The minimum size of video frames to be processed is 32x32 pixels, and the maximum size is 8192x8192 pixels. The size of the video frames to be processed doesn't have a significant impact on the computational speed, because input images are resized to input network size (usually 640x640 pixels).
Coordinate system	The algorithm uses a window coordinate system with the zero point in the upper left corner of the video frame.

Parameter and feature	Description
Calculation speed	The processing time per video frame depends mostly on loaded neural network model and also on the computing platform used. The processing time per video frame can be estimated with the demo application.
Type of algorithm for detection of objects	To detect different objects on current frame interface for obtaining neural network model was implemented. This interface relies on OpenCV implementation and utilizes its features such as: pre-processing of input data, reading and launching neural network model and obtaining output results. Output data is cleaned up from overlapping boxes and correct types are assigned to output vector of objects.
Discreteness of computation of coordinates	The library utilizes the object bounding box for each detected object. If boxes are overlapping and have the same object type, they are merged into one combined. This means discreteness of library is strongly depended on loaded neural network model.
Working conditions	The library is designed to function on a variety of devices. It is optimized for GPU hardware support, which can significantly enhance processing speed. The detector processes each frame independently, so camera movement does not impact the results.

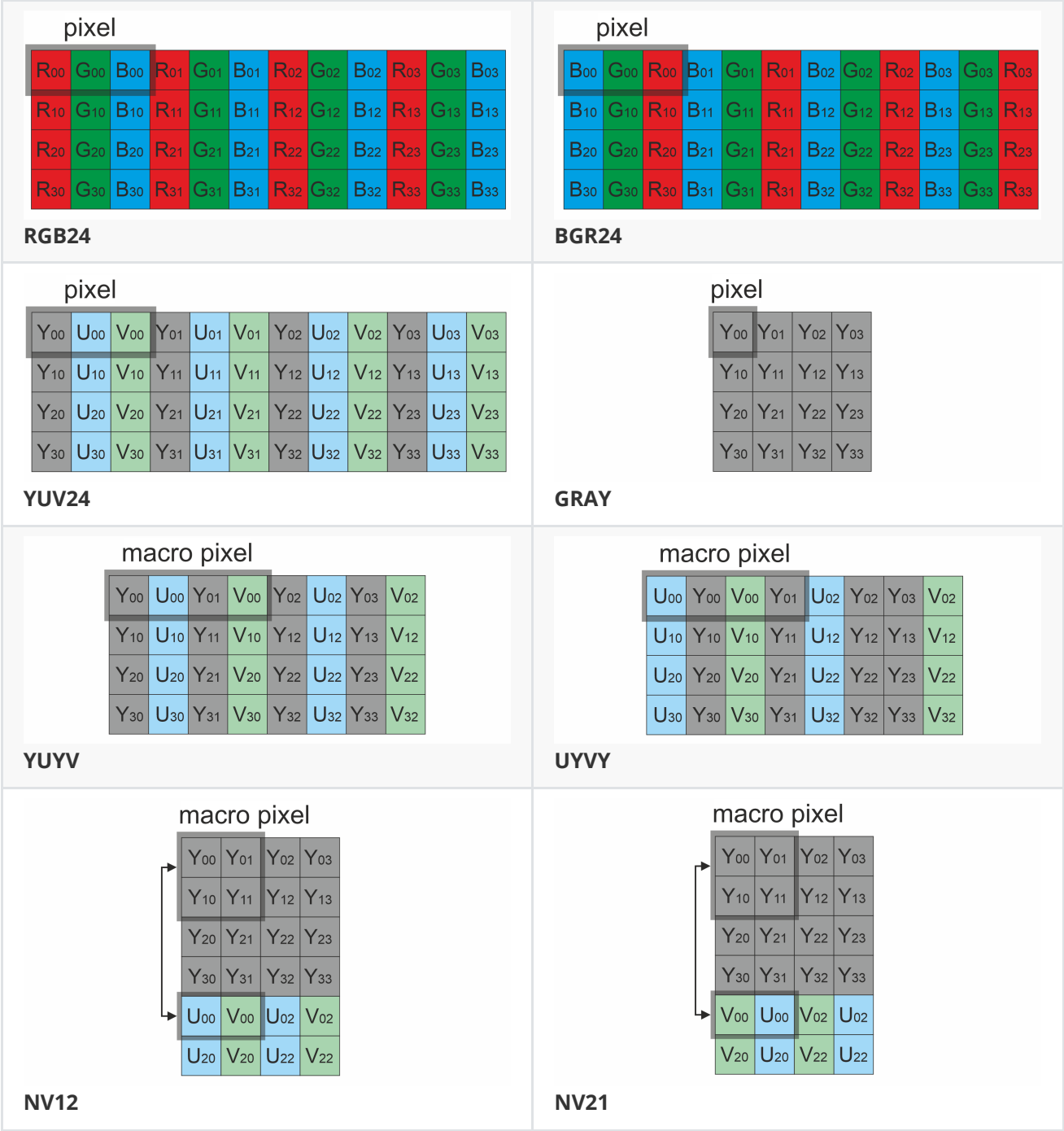
Supported pixel formats

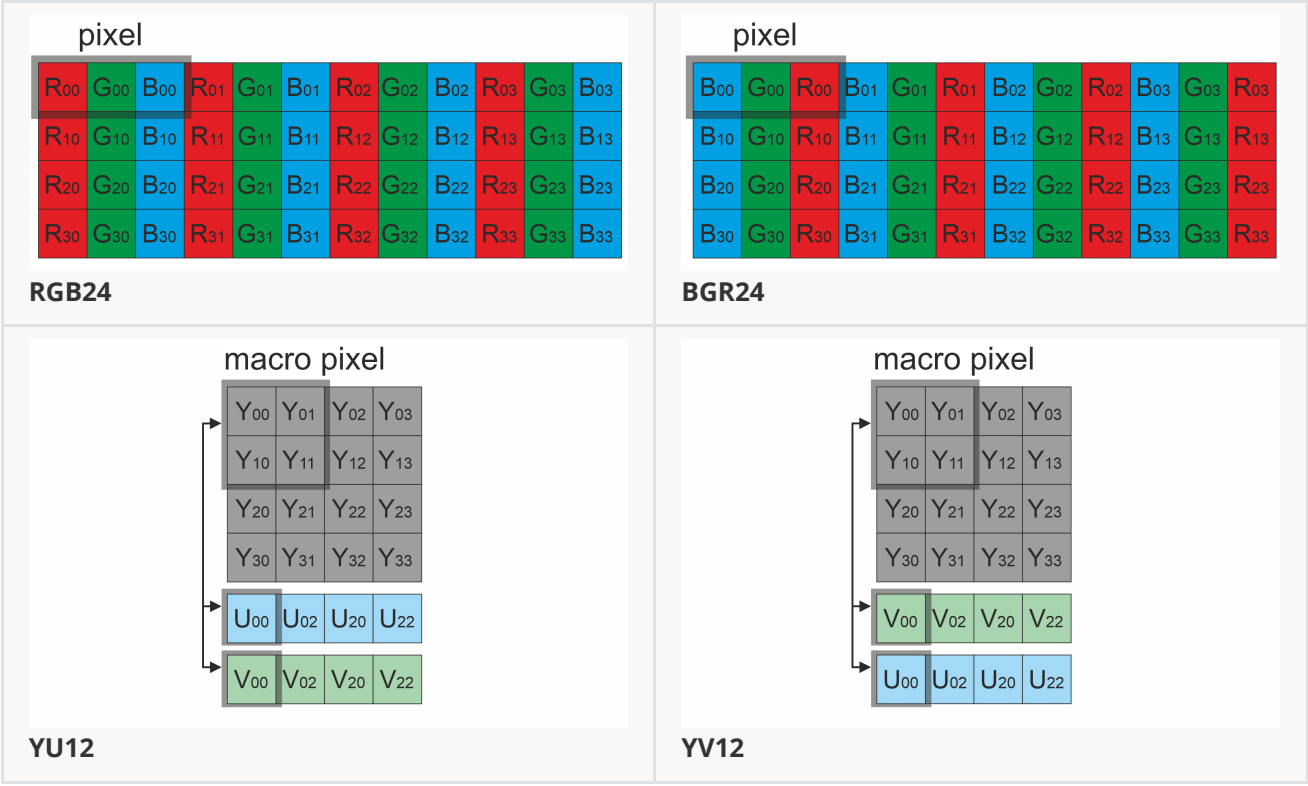
Frame library (included in **DnnOpenCvDetector** library) contains **Fourcc** enum, which defines supported pixel formats (**Frame.h** file). **DnnOpenCvDetector** library supports RAW pixel formats only. The library uses the **RGB24** format for detection. If the pixel format of the image is different from **RGB24**, the library pre-converts the pixel formats to **RGB24**. **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.





Library principles

The object detection feature within this library is seamlessly integrated with **OpenCV** support, designed to facilitate efficient object detection based on neural network models. The library simplifies the process and provides a straightforward usage sequence for developers. The algorithm primarily consists of the following steps:

1. The library accepts input frames directly and sets proper inputs for compiling neural network model, eliminating the need for any preprocessing.
2. Neural network object is created in initialization method with given path to model and its input size.
3. According to type, set via parameters, preferable Backend and Target are set, on which neural network model will be working. More information: check description of parameters.
4. Computing results in vector of output blobs, which are converted (according to detector parameters) to the final vector of objects.
5. Results store not only coordinates but also probability and type - which can be assigned to particular item, according to current network labels.

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 recommended usage sequence for the library is as follows:

1. **Integration**: Include the library files in your project, either by incorporating the source code or linking to the compiled application, depending on your preference and project setup. Connect OpenCV to your project. If you need GPU utilization you probably need rebuild OpenCV with GPU support.
2. **Initialization**: Create an instance of the `DnnOpenCvDetector` C++ class for each camera or input source you wish to process. The library supports multiple instances for parallel camera processing.
3. **Customization**: If needed, you can customize the library's behavior by using the `setParam()` method. This allows you to adapt the library to specific requirements.

4. **Object detection**: Create a `Frame` object to represent the input frame, and prepare a vector to store the detected objects.
5. **Detection process**: Call the `detect(...)` method to initiate the object detection process.
6. **Object retrieval**: Retrieve the detected objects by using the `getObjects()` method. The library provides a vector of `Objects` containing information about the detected objects, such as their positions and attributes.

DnnOpenCvDetector class description

DnnOpenCvDetector class declaration

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

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

    /// 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 structure.
    void getParams(ObjectDetectorParams& params) override;

    /// Get list of 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 command and execute command.
    bool decodeAndExecuteCommand(uint8_t* data, int size) override;
}
```

getVersion method

getVersion() method returns string of current version of **DnnOpenCvDetector** class. Method declaration:

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

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

```
std::cout << "DnnOpenCvDetector version: " << DnnOpenCvDetector::getVersion();
```

Console output:

```
DnnOpenCvDetector version: 1.0.1
```

initObjectDetector method

initObjectDetector(...) method initializes object detector. Inside this method also reading network model takes place, because of that it can consume much time when loading big NN models. 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: initString minObjectWidth (Default value 4) maxObjectWidth (Default value 128) minObjectHeight (Default value 4) maxObjectHeight (Default value 128) minDetectionPropability(Default value 0.5f) type(Default value 0) If particular parameter out of valid range the library will set default values automatically.

Returns: TRUE if the object detector was initialized or FALSE if not.

setParam method

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

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

Parameter	Description
id	Parameter ID according to **ObjectDetectorParam** enum. The library support not all parameters from **ObjectDetectorParam** enum.
value	Parameter value. Value depends on parameter ID.

Returns: TRUE if the parameter was set or FALSE if not.

getParam method

getParam(...) method designed to obtain object detector parameter value. Method declaration:

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

Parameter	Description
id	Parameter ID according to **ObjectDetectorParam** enum.

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

getParams method

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

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

Parameter	Description
params	Object detector params object (ObjectDetectorParams)

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 if the command was executed or FALSE if not.

detect method

detect(...) method designed to perform detection algorithm. 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). The library uses the **RGB24** format for detection. If the pixel format of the image is different from **RGB24**, the library pre-converts the pixel formats to **RGB24**.

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

setMask method

setMask(...) method designed to set detection mask. The user can disable detection in any areas of the video frame. For this purpose the user can create an image of any size and configuration with GRAY (preferable), NV12, NV21, YV12 or YU12 pixel format. Mask image pixel values equal to 0 prohibit detection of objects in the corresponding place of video frames. Any other mask pixel value other than 0 allows detection of objects at the corresponding location of video frames. The mask is used for detection algorithms to compute a binary motion mask. The method can be called either before video frame processing or during video frame processing. Method declaration:

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

Parameter	Description
mask	Image of detection mask. Must have GRAY (preferable), NV12, NV21, YV12 or YU12 pixel format. The size and configuration of the mask image can be any. If the size of the mask image differs from the size of processed frames, the mask will be scaled by the library for processing.

Returns: TRUE if the the mask accepted or FALSE if not (not valid pixel format or empty).

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 of the **ObjectDetector** interface designed to encode command to change any parameter for remote object detector (including motion detectors). 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:

Byte	Value	Description
0	0x01	SET_PARAM command header value.

Byte	Value	Description
1	Major	Major version of ObjectDetector class.
2	Minor	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 of the **ObjectDetector** interface designed to encode command for remote object detector (including motion detectors). 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 >= 11.
size	Size of encoded data. Will be 11 bytes.

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

COMMAND format:

Byte	Value	Description
0	0x00	COMMAND header value.
1	Major	Major version of ObjectDetector class.
2	Minor	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[11];
// Size of encoded data.
int size = 0;
// Encode command.
ObjectDetector::encodeCommand(data, size, ObjectDetectorCommand::RESET);
```

decodeCommand method of ObjectDetector class

decodeCommand(...) static method of the **ObjectDetector** interface 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.

Parameter	Description
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

ObjectDetector.h file defines IDs for parameters (**ObjectDetectorParam** enum) and IDs for commands (**ObjectDetectorCommand** enum).

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. Clears the list of detected objects and resets all internal filters.
ON	Enable object detector. If the detector is not activated, frame processing is not performed - the list of detected objects will always be empty.
OFF	Disable object detector. If the detector is not activated, frame processing is not performed - the list of detected objects will always be empty.

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 - DnnOpenCvDetector class params description (from ObjectDetector interface class). Some params may be unsupported by DnnOpenCvDetector class.

Parameter	Access	Description
LOG_MODE	read / write	**Not used.** Can have any value.
FRAME_BUFFER_SIZE	read / write	**Not used.** Can have any value.
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 value.
MAX_X_SPEED	read / write	**Not used.** Can have any value.
MIN_Y_SPEED	read / write	**Not used.** Can have any value.
MAX_Y_SPEED	read / write	**Not used.** Can have any value.
MIN_DETECTION_PROPABILITY	read / write	Defines threshold for object detection probability. Only objects with probability greater than MIN_DETECTION_PROPABILITY will be detected. Can have any values from 0 to 1.

Parameter	Access	Description
X_DETECTION_CRITERIA	read / write	**Not used.** Can have any value.
Y_DETECTION_CRITERIA	read / write	**Not used.** Can have any value.
RESET_CRITERIA	read / write	**Not used.** Can have any value.
SENSITIVITY	read / write	**Not used.** Can have any value.
SCALE_FACTOR	read / write	**Not used.** Can have any value.
NUM_THREADS	read / write	**Not used.** Can have any value.
PROCESSING_TIME_MKS	read only	**Not used.** Can have any value.
TYPE	read / write	Type defines kind of device for neural network model computation. Default 0 - DEFAULT Backend and CPU target, 1 - DEFAULT Backend and OPENCL target(GPU), 2 - CUDA backend and CUDA target. More information - Supported Backends, Supported Targets.
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.
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 and also included in **ObjectDetectoParams** structure. 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 on a current frame.
frameId	int	Frame ID. Will be the same as frame ID of processed video frame.
type	int	Object type according to probability for particular label that was returned from neural network model inference output.
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 0.0f.
vY	float	**Not used.** Will have value 0.0f.
p	float	Probability value for object label, NOT probability of whole set of labels.

ObjectDetectorParams class description

ObjectDetectorParams class declaration

ObjectDetectorParams class used for object detector initialization (**initObjectDetector(...)** method) or to get all actual params (**getParams()** method) including list of detected objects. Also **ObjectDetectorParams** provides structure to write/read params from JSON files (**JSON_READABLE** macro, see **ConfigReader** class description) and provide methos 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.
    void encode(uint8_t* data, int& size,
                ObjectDetectorParamsMask* mask = nullptr);

    /// Decode params. Method doesn't decode initString.
    bool decode(uint8_t* data);
};
```

Table 7 - ObjectDetectorParams class fields description. Some params may be unsupported by DnnOpenCvDetector class.

Field	Type	Description
initString	string	In initString, path to neural network model, that is supported by **OpenCV** and has standard one-batch layout have, to be included. Also there should be included dimensions (width and height) of neural network input images, everything separated by semicolon. E.g.: "./model.onnx;640;640". If neural network model consists of 2 files it should be as this example: "./model.xml;./model.bin;256;480".
logMode	int	**Not used.** Can have any value.

Field	Type	Description
frameBufferSize	int	**Not used.** Can have any value.
minObjectWidth	int	Minimum object width to be detected, pixels. Valid values from 1 to 8192. Must be < maxObjectWidth. To be detected object's width must be >= minObjectWidth. Default value is 4.
maxObjectWidth	int	Maximum object width to be detected, pixels. Valid values from 1 to 8192. Must be > minObjectWidth. To be detected object's width must be <= maxObjectWidth. Default value is 128.
minObjectHeight	int	Minimum object height to be detected, pixels. Valid values from 1 to 8192. Must be < maxObjectHeight. To be detected object's height must be >= minObjectHeight. Default value is 4.
maxObjectHeight	int	Maximum object height to be detected, pixels. Valid values from 1 to 8192. Must be > minObjectHeight. To be detected object's height must be <= maxObjectHeight. Default value is 128.
minXSpeed	float	**Not used.** Can have any value.
maxXSpeed	float	**Not used.** Can have any value.
minYSpeed	float	**Not used.** Can have any value.
maxYSpeed	float	**Not used.** Can have any value.
minDetectionProbability	float	Defines threshold for object detection probability. Only objects with probability greater than MIN_DETECTION_PROPABILITY will be detected. Can have any values from 0 to 1.
xDetectionCriteria	int	**Not used.** Can have any value.
yDetectionCriteria	int	**Not used.** Can have any value.
resetCriteria	int	**Not used.** Can have any value.
sensitivity	float	**Not used.** Can have any value.
scaleFactor	int	**Not used.** Can have any value.
numThreads	int	**Not used.** Can have any value.
processingTimeMks	int	**Not used.** Can have any value.

Field	Type	Description
type	int	Type defines kind of device for neural network model computation. Default 0 - DEFAULT Backend and CPU target, 1 - DEFAULT Backend and OPENCL target(GPU), 2 - CUDA backend and CUDA target. More information - Supported Backends, Supported Targets.
enable	bool	Mode: false - Off, true - On. If the detector is not activated, frame processing is not performed - the list of detected objects will always be empty.
custom1	float	**Not used.** Can have any value.
custom2	float	**Not used.** Can have any value.
custom3	float	**Not used.** Can have any value.
objects	std::vector	List of detected objects.

Note: *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 dataBufferSize, int& size, ObjectDetectorParamsMask* mask = nullptr);
```

Parameter	Value
data	Pointer to data buffer. Buffer size should be at least **99** bytes.
dataBufferSize	Size of data buffer. If the data buffer size is not large enough to serialize all detected objects (40 bytes per object), not all objects will be included in the data.
size	Size of encoded data. 99 bytes by default.

Parameter	Value
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

Build library

```
cd DnnOpenCvDetector
mkdir build
cd build
cmake .. -D CMAKE_PREFIX_PATH=<OpenCV-ROOT-DIR>/build
make
```

IMPORTANT: Ensure that you have correctly applied the OpenCV build folder with the selected additional GPU support to your project, otherwise, the detector will only work on the CPU. A necessary step before building the **DnnOpenCvDetector** library is to download the **OpenCV** library. The next steps depend on the devices you want to use. The **OpenCV** library should be built correctly to enable GPU hardware support. For instance, you should build the library with CUDA software for NVIDIA GPUs or OpenVino software for Intel GPUs. A comprehensive tutorial on how to build OpenCV with the aforementioned libraries can be found in the 'doc' folder.

Connect as source code

If you want to connect **DnnOpenCvDetector** 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
```

Create 3rdparty folder in your repository. Copy **DnnOpenCvDetector** repository to **3rdparty** folder. Remember to specify path to selected OpenCV library build as above. The new structure of your repository will be as follows:

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

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(${PARENT}_SUBMODULE_DNN_OPENCV_DETECTOR             ON  CACHE BOOL "" FORCE)
if (${PARENT}_SUBMODULE_DNN_OPENCV_DETECTOR)
    SET(${PARENT}_DNN_OPENCV_DETECTOR                   ON  CACHE BOOL "" FORCE)
    SET(${PARENT}_DNN_OPENCV_DETECTOR_TEST              OFF CACHE BOOL "" FORCE)
    SET(${PARENT}_DNN_OPENCV_DETECTOR_DEMO_APP          OFF CACHE BOOL "" FORCE)
    SET(${PARENT}_DNN_OPENCV_DETECTOR_EXAMPLE           OFF CACHE BOOL "" FORCE)
endif()

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

File **3rdparty/CMakeLists.txt** adds folder **DnnOpenCvDetector** 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
    DnnOpenCvDetector
```

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 DnnOpenCvDetectorlibrary in your **src/CMakeLists.txt** file:

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

Done!

Simple example

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

```
#include <opencv2/opencv.hpp>
#include "DnnOpenCvDetector.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::DnnOpenCvDetector detector;
    cr::detector::ObjectDetectorParams params;
    params.initString = "./yolov7s.onnx;640;640";
    params.maxObjectHeight = 96;
    params.maxObjectWidth = 96;
    params.minObjectHeight = 4;
    params.minObjectHeight = 4;
    params.type = 1;
    detector.initObjectDetector(params);

    // Main loop.
    cv::Mat frameBgrOpenCv;
    while (true)
    {
```

```
        // Capture next video frame.
        videoSource >> frameBgrOpenCv;
        if (frameBgrOpenCv.empty())
        {
            // If we have video file we can set initial position to replay.
            detector.executeCommand(cr::detector::ObjectDetectorCommand::RESET);
            videoSource.set(cv::CAP_PROP_POS_FRAMES, 0);
            continue;
        }

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

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

        // 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);
            putText(frameBgrOpenCv, std::to_string(objects[n].p),
                    cv::Point(objects[n].x, objects[n].y),
                    1, 1, cv::Scalar(0, 0, 255));
        }

        // Show video.
        cv::imshow("VIDEO", frameBgrOpenCv);
        // Wait ESC.
        if (cv::waitKey(1) == 27)
            return -1;
    }
    return 1;
}
```

Build OpenCV library

With OpenVINO

On Windows

1. Create directory "C:\Program Files (x86)\Intel".
2. Download OpenVINO ver. 2022.3.1(or higher) compressed library from this link -> OpenVino-2023.3.1
3. Extract .zip file to "C:\Program Files (x86)\Intel\openvino_2022".
4. Add paths to Path in "Edit the system environment variables":
   • C:\Program Files (x86)\Intel\openvino_2022\runtime\bin\intel64\Release
   • C:\Program Files (x86)\Intel\openvino_2022\runtime\bin\intel64\Debug
   • C:\Program Files (x86)\Intel\openvino_2022\runtime\3rdparty\tbb\bin
   • C:\Program Files (x86)\Intel\openvino_2022\runtime\3rdparty\hddl\bin
5. Download compressed .zip file of OpenCV library (source code) from this link -> OpenCV-4.8.0
6. Extract to your destination folder, e.g. "C:\Libs\OpenCVWithOpenVINO".
7. Create 'build' folder inside.
8. Open terminal in "C:\Program Files (x86)\Intel\openvino_2022". Run ".\setupvars.bat".
9. In the same terminal run command "cmake-gui.exe" (assuming you've installed CMake).
10. In visual CMake editor specify variables:

- Where is the source code: "C:\Libs\VinoOpenCv\opencv-4.8.0"
- Where to build the binaries: "C:\Libs\VinoOpenCv\build"

11. Hit Configure button. Confirm default inputs.
12. Set CMake variables:

- OPENCV_DNN_OPENVINO: ON
- WITH_OPENVINO: ON
- BUILD_opencv_world: ON (if not set by default)

13. Hit Configure again and set up last variable:

- OpenVINO_DIR: "C:\Program Files (x86)\Intel\openvino_2022\runtime\cmake"

14. Hit Configure button.
15. Make sure if output message contains such a line:
    OpenVINO: YES (2022.3.1)
16. Hit Generate button.
17. Hit Open Project button.
18. In Visual Studio in Solution Explorer find
    CMakeTargets
    ALL_BUILD
19. Right click and hit Compile for Debug and Release (It can take more than 15 min, depending on platform).

20. In Visual Studio in Solution Explorer find
    CMakeTargets
      INSTALL
21. Compile for Debug and Release.
22. Add paths to Path in "Edit the system environment variables":

- C:\Libs\OpenCVWithOpenVINO\build\install\x64\vc17\bin

23. Add new environment variable or specify path while running CMake:

- OpenCV_DIR: C:\Libs\OpenCVWithOpenVINO\build

On Linux

1. Make sure you have the latest updates.

```
sudo apt-get update
sudo apt-get upgrade
```

2. Get OpenVINO 2022.3.1(or higher) and place it in opt/intel directory.

```
cd <user_home>/Downloads
sudo apt-get install curl
curl -L
https://storage.openvinotoolkit.org/repositories/openvino/packages/2022.3.1/linux/l_o
penvino_toolkit_ubuntu20_2022.3.1.9227.cf2c7da5689_x86_64.tgz --output
openvino_2022.3.1.tgz
tar -xf openvino_2022.3.1.tgz
sudo mkdir /opt/intel
sudo mv l_openvino_toolkit_ubuntu20_2022.3.1.9227.cf2c7da5689_x86_64
/opt/intel/openvino_2022.3.1
```

3. Install required system dependencies on Linux.

```
cd /opt/intel/openvino_2022.3.1
sudo -E ./install_dependencies/install_openvino_dependencies.sh
```

4. Configure the environment. This command must to be re-run every time you start a new terminal session.

```
source /opt/intel/openvino_2022.3.1/setupvars.sh
```

5. Add libs for GPU devices.

```
sudo apt-get install -y ocl-icd-libopencl1 intel-opencl-icd
```

6. OpenVINO is ready, start configuring OpenCV. Get all the dependencies.

```
sudo apt-get install \
build-essential \
cmake \
libgtk-3-dev \
libopenblas-dev \
libx11-dev \
libavutil-dev \
libavcodec-dev \
libavformat-dev \
libswscale-dev \
libtbb2 \
libssl-dev \
libva-dev \
```

7. Create folder for opencv library and clone.

```
mkdir ~/opencv
cd opencv
git clone --recurse-submodules https://github.com/opencv/opencv.git
mkdir build
```

8. Compile and install OpenCV.

```
cmake \
-D BUILD_INFO_SKIP_EXTRA_MODULES=ON \
-D BUILD_JPEG=ON \
-D BUILD_APPS_LIST=version \
-D BUILD_opencv_apps=ON \
-D ENABLE_CXX11=ON \
-D INSTALL_PDB=ON \
-D INSTALL_TESTS=ON \
-D INSTALL_C_EXAMPLES=ON \
-D CMAKE_INSTALL_PREFIX=install \
-D OPENCV_SKIP_PKGCONFIG_GENERATION=ON \
-D OPENCV_BIN_INSTALL_PATH=bin \
-D OPENCV_INCLUDE_INSTALL_PATH=include \
-D OPENCV_LIB_INSTALL_PATH=lib \
-D OPENCV_CONFIG_INSTALL_PATH=cmake \
-D OPENCV_3P_LIB_INSTALL_PATH=3rdparty \
-D OPENCV_SAMPLES_SRC_INSTALL_PATH=samples \
-D OPENCV_DOC_INSTALL_PATH=doc \
-D OPENCV_OTHER_INSTALL_PATH=etc \
-D OPENCV_LICENSES_INSTALL_PATH=etc/licenses \
-D OPENCV_INSTALL_FFMPEG_DOWNLOAD_SCRIPT=ON \
-D BUILD_opencv_world=ON \
-D PYTHON3_PACKAGES_PATH=install/python/python3 \
-D PYTHON3_LIMITED_API=ON \
-D HIGHGUI_PLUGIN_LIST=all \
-D OPENCV_PYTHON_INSTALL_PATH=python \
-D OPENCV_IPP_GAUSSIAN_BLUR=ON \
-D WITH_OPENVINO=ON \
-D CMAKE_EXE_LINKER_FLAGS=-Wl,--allow-shlib-undefined \
-D CMAKE_BUILD_TYPE=Release \
-S ./ \
-B ./build && \
```

```
cmake --build ./build --parallel $(nproc) &&
cmake --install ./build
```

9. Set up global variables to allow compiling applications (assuming your current directory is opencv root folder) or specify path while running your project cmake.

```
export OpenCV_DIR="./install/cmake"
export LD_LIBRARY_PATH="./install/lib${LD_LIBRARY_PATH:+:$LD_LIBRARY_PATH}"
```

With CUDA

On Windows

1. Download CUDA Toolkit version, that will be supported with your operating system. Choose as latest as possible from this link CUDA. Install to chosen directory, eg. "C:/Libs/CUDA".
2. Download CUDNN Toolkit from this link CUDNN (you have to login to NVidia account). Extract files and copy all folders (include, lib and bin) to CUDA directory.
3. Download compressed .zip file of OpenCV library (source code) from this link (latest) -> OpenCV-4.8.0.
4. Download compressed .zip file of OpenCV CONTRIB library (source code) from this link -> CONTRIB.
5. Unzip both folders.
6. Open CMake GUI (assuming its installed).
7. Select source code directory, e.g. "C:/Libs/OpenCv/opencv-4.8.0".
8. Select directory where to build the binaries: "C:/Libs/OpenCv/build'.
9. Hit 'Configure' button and confirm default options.
10. Set CMake variables:

- OPENCV_DNN_CUDA: ON
- WITH_CUDA: ON
- BUILD_opencv_world: ON (if not set by default)
- OPENCV_EXTRA_MODULES_PATH: "<OpenCv_contrib_DIR>/modules".

11. Hit 'Configure' button and set CMake variables again:
    - WITH_CUDNN: ON
    - CUDA_ARCH_BIN: remove all the versions, except supported version
12. To get supported version of CUDA_ARCH_BIN variable you have to visit this website and find version that is related to your hardware. For example, Jetson Orin NX hardware is supported with version 8.7.
13. Hit 'Configure' again and then 'Generate'.
14. Make sure if output message contains such a line:
    NVIDIA CUDA: YES (ver 12.2, CUFT CUBLAS)
    NVIDIA GPU arch: 8.7
    NVIDIA PTX archs:
    cuDNN: YES
15. The last step is to open generated project

16. Hit Generate button.
17. Hit Open Project button.
18. In Visual Studio in Solution Explorer find
    CMakeTargets
      ALL_BUILD
19. Right click and hit Compile for Debug and Release (It can even take a couple of hours, depending on platform).
20. In Visual Studio in Solution Explorer find
    CMakeTargets
      INSTALL
21. Compile for Debug and Release.
22. Add paths to Path in "Edit the system environment variables":

- C:\Libs\OpenCV\build\install\x64\vc17\bin

23. Add new environment variable or specify path while running CMake:

- OpenCV_DIR: C:\Libs\OpenCV\build

On Linux

1. Make sure you have the latest updates.

```
sudo apt-get update
sudo apt-get upgrade
```

2. Start configuring OpenCV. Get all the dependencies.

```
sudo apt-get install \
build-essential \
cmake \
libgtk-3-dev \
libopenblas-dev \
libx11-dev \
libavutil-dev \
libavcodec-dev \
libavformat-dev \
libswscale-dev \
libtbb2 \
libssl-dev \
libva-dev \
```

3. Create folder for opencv library and clone.

```
mkdir ~/opencv
cd opencv
git clone --recurse-submodules https://github.com/opencv/opencv.git
mkdir build
cd build
```

4. Compile and install OpenCV.

```
 cmake -D CMAKE_BUILD_TYPE=RELEASE \
-D CMAKE_INSTALL_PREFIX=/usr/local \
-D WITH_TBB=ON \
-D ENABLE_FAST_MATH=1 \
-D CUDA_FAST_MATH=1 \
-D WITH_CUBLAS=1 \
-D WITH_CUDA=ON \
-D BUILD_opencv_cudacodec=OFF \
-D WITH_CUDNN=ON \
-D OPENCV_DNN_CUDA=ON \
-D CUDA_ARCH_BIN=<supported_version> \
-D WITH_V4L=ON \
-D WITH_QT=OFF \
-D WITH_OPENGL=ON \
-D WITH_GSTREAMER=ON \
-D OPENCV_GENERATE_PKGCONFIG=ON \
-D OPENCV_PC_FILE_NAME=opencv.pc \
-D OPENCV_ENABLE_NONFREE=ON \
-D OPENCV_EXTRA_MODULES_PATH=<OpenCV_contrib_DIR>/modules \
-D INSTALL_PYTHON_EXAMPLES=OFF \
-D INSTALL_C_EXAMPLES=OFF \
-D BUILD_EXAMPLES=OFF ..
```

5. To get supported version of CUDA_ARCH_BIN variable you have to visit this website and find version that is related to your hardware. For example, Jetson Orin NX hardware is supported with version 8.7.

6. Make sure if output message contains such a line:

NVIDIA CUDA: **YES (ver 12.2, CUFT CUBLAS)**
NVIDIA GPU arch: **8.7**
NVIDIA PTX archs:
cuDNN: **YES**

7. Compile library:

```
make -j$(nproc)
sudo make install
```

8. Set up global variables to allow compiling applications (assuming your current directory is opencv root folder) or specify path while running your project cmake.

```
export OpenCV_DIR="./install/cmake"
export LD_LIBRARY_PATH="./install/lib${LD_LIBRARY_PATH:+:$LD_LIBRARY_PATH}"
```