Cpp North 2025

Bridging C++ and Java with Qt JNI

An Android Application for On-Device Landmine Detection

Oleksandr Kunichik

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An Android Application for On-Device Landmine Detection

Oleksandr Kunichik

The view from my balcony

About me:

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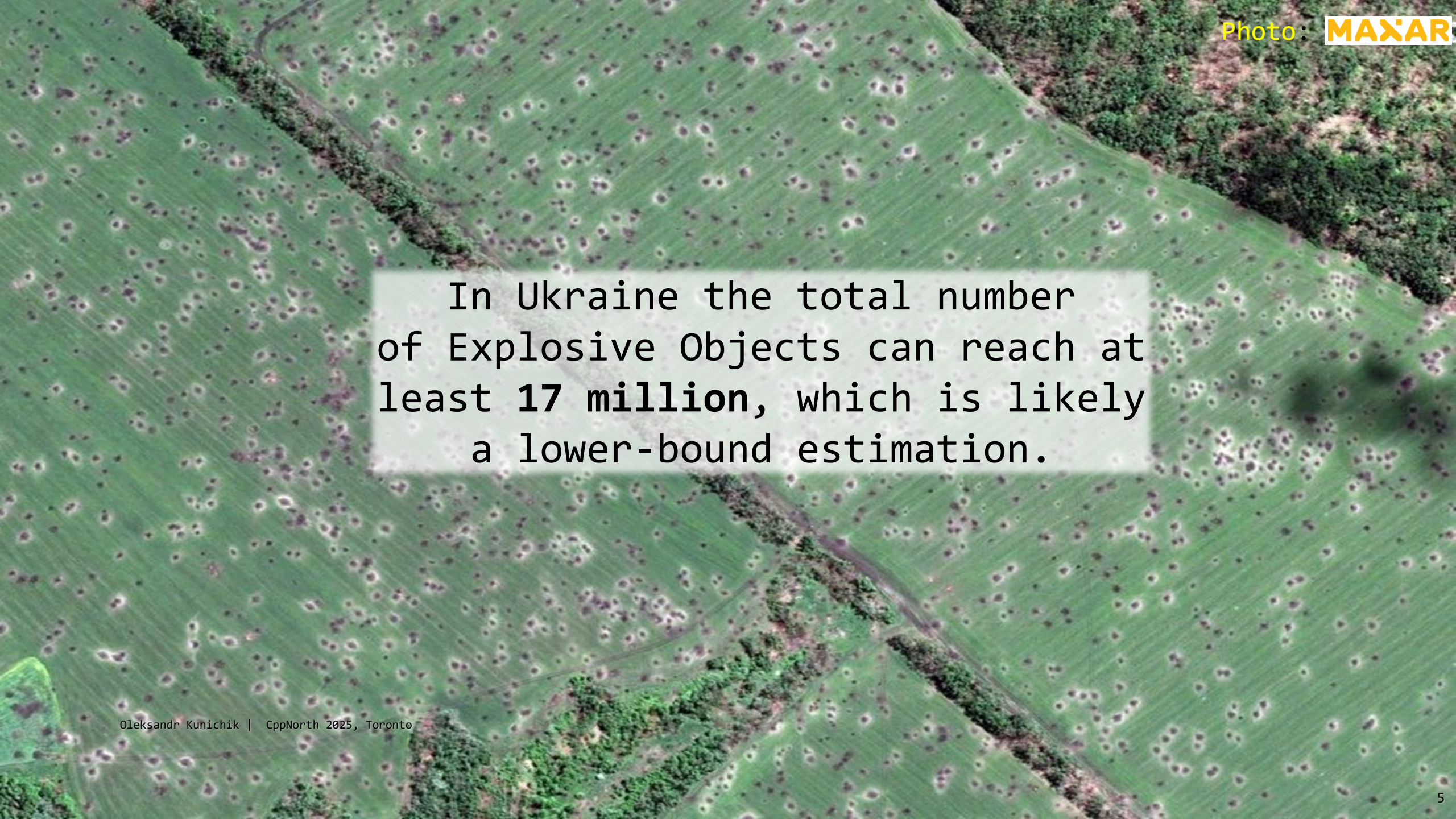
Why This Project Matters

"Technology should solve real problems"



In Ukraine the total number of Explosive Objects can reach at least **17 million**, which is likely a lower-bound estimation.

What we built

The models for landmine detection

What we needed

The data from deminers

Nobody will give you data

You must offer something

Therefore, we offered:

- Mine detection app

(using cloud detection)

Therefore, we offered:

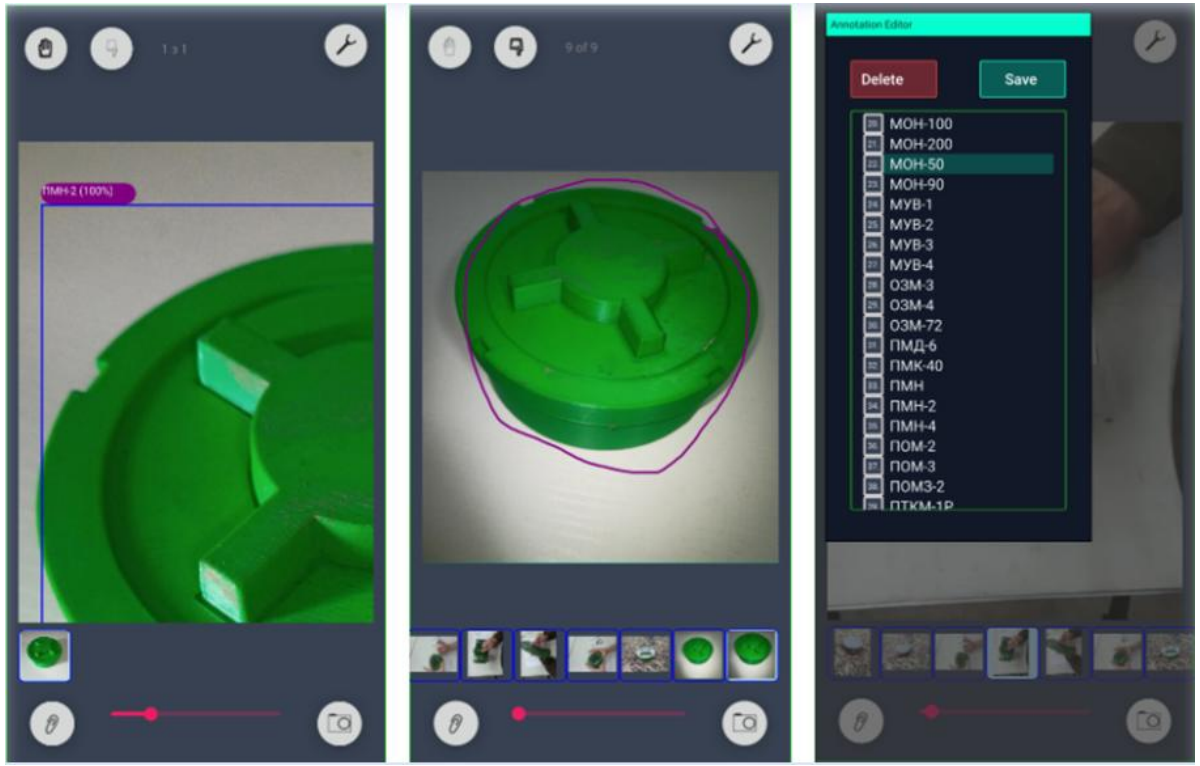
- Works on Linux,

Windows, Android, iOS*

*iOS is not tested yet

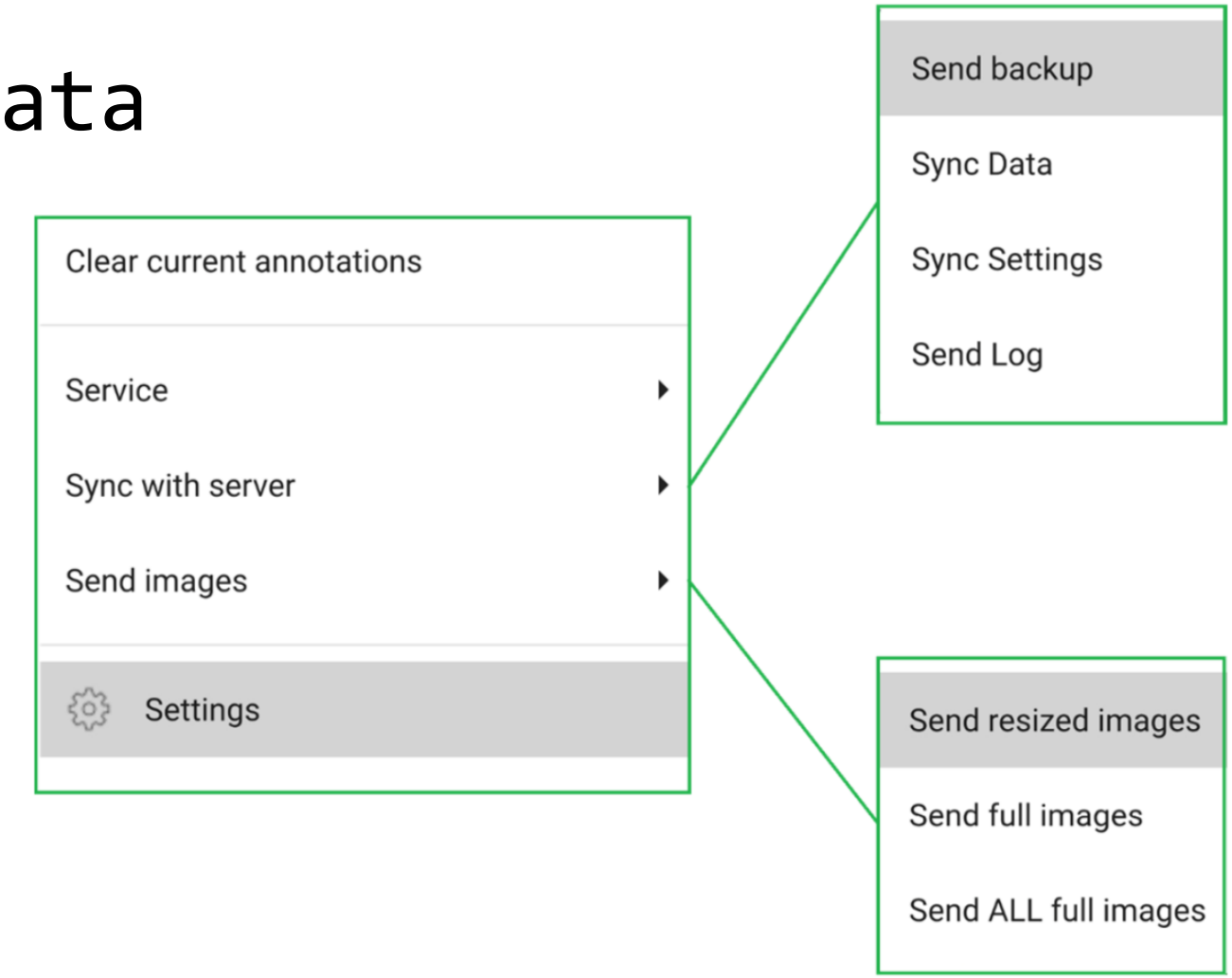
Therefore, we offered:

- Ability to edit detected mines



Therefore, we offered:

- Option to send data



We needed offline inference

On Android as it is the

most popular mobile OS*

*74% according to https://gs.statcounter.com/os-market-share/mobile/worldwide

The Stack

[QML UI*] ← QQuickView, UI bindings

```
ApplicationWindow {
    width: 400
    height: 400
    visible: true

    Button {
        id: button
        text: "A Special Button"
        background: Rectangle {
            implicitWidth: 100
            implicitHeight: 40
            color: button.down ? "#d6d6d6" : "#f6f6f6"
            border.color: "#26282a"
            border.width: 1
            radius: 4
        }
    }
}
```

*QML is a Java-script like declarative language https://doc.qt.io/qt-6/qmlapplications.html

The Stack

[QML UI] ← QQuickView, UI bindings

[C++ Logic] ← Image capture, processing

The Stack

[QML UI] ← QQuickView, UI bindings

[C++ Logic] ← Image capture, processing

[QtConcurrent] ← Async processing

The Stack

[QML UI] ← QQuickView, UI bindings

[C++ Logic] ← Image capture, processing

[QtConcurrent] ← Async processing

[Qt JNI Bridge] ← Calls to Java

[Java Wrapper] ← ONNX Runtime integration

[“ONNX[1] Runtime[2]”] ← Actual inference engine

[1] Open Neural Network Exchange (ONNX) – https://onnx.ai/

[2] ONNX Runtime – https://onnxruntime.ai/

The Challenge

```
// What we wanted:
QImage image = camera.capture();
auto detections = onnxRuntime.detect(image);
// Simple, right?
```

Java Native Interface (JNI)

- Core Android tech since API level 1
- Enables Java ⇔ C++ interaction
- We use it via QJniObject (Qt)

Android NDK (Native Development Kit)

- Toolchain for building .so libraries
- Allows native C/C++ code on Android
- Needed if you want C++ recognition

Android Integration Challenges

- ONNX Runtime C++
- Camera access
- Scoped storage
- JNI complexity

The Architecture

C++ Application (Qt)

↓ ???

AI inference

(Java/Android Layer)

Why Java ONNX Runtime?

Initial attempt: Pure C++ ONNX

3 Weeks Later...

Problem	Impact
🔥 **NDK Build Hell**	Days lost fighting cmake configurations
📱 **Device Compatibility**	Worked on Pixel, crashed on Samsung
📦 **APK Bloat**	+50MB for native libraries
⏰ **Time Crunch**	MVP deadline approaching fast

Why Java ONNX Runtime?

Initial attempt: Pure C++ ONNX

The Pragmatic Choice

	C++ ONNX	Java ONNX
Time to Working Solution	3+ weeks	30 minutes
Performance	200ms	230ms
Risk	High	Low
For MVP	❌	✅

ONNX Runtime – C++ vs Java

Feature	ONNX C++ (NDK)	ONNX Java (our setup)
Android Support	✅ But complex build	✅ Works out of the box
GPU Acceleration	⚠️ Not trivial	✅ With NNAPI delegate
Tensor Conversion	Manual (C++)	Managed (Java)
Integration Speed	Slow (days)	Fast (hours)

Qt’s JNI Wrapper or JNI

- QJniObject and QJniEnvironment
- Safer than raw JNIEnv*
- Easier type conversion

Tradeoff: Simplicity vs Purity

Option	Pros	Cons
C++ & ONNX Runtime C++	Single-language	NDK pain, memory bugs
C++ & JNI & ONNX Runtime Java	Stable API, easy access	JNI complexity
C++ & Qt JNI & ONNX Runtime Java	Reuse logic, clear layers	Some overhead

What Makes This Hard?

- 2MB+ images crossing JNI boundary
- Performance target: 800ms-1.3s
- Memory constraints on devices
- Thread safety complexities
- Error handling across languages

JNI Basics

```
// Calling Java from C++
QJniObject
```

JNI Basics

```
// Qt 6+ JNI approach:
QJniObject activity = QJniObject::callStaticObjectMethod(
    "org/qtproject/qt/android/QtNative",
    "activity",
    "()Landroid/app/Activity;");
```

JNI Basics

Full Java class name

(slashes instead of dots)

```
// Qt 6+ JNI approach:
QJniObject activity = QJniObject::callStaticObjectMethod(
    "org/qtproject/qt/android/QtNative",
    "activity",
    "()Landroid/app/Activity;");
```

JNI Basics

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Method name

```
// Qt 6+ JNI approach:
QJniObject activity = QJniObject::callStaticObjectMethod(
    "org/qtproject/qt/android/QtNative",
    "activity",
    "()Landroid/app/Activity;");
```

JNI Basics

Method signature:

- `()` – no parameters
- `L…Activity;` – returns an object

```
// Qt 6+ JNI approach:
QJniObject activity = QJniObject::callStaticObjectMethod(
    "org/qtproject/qt/android/QtNative",
     "activity",
    "()Landroid/app/Activity;");
```

JNI Basics

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     "activity",
    "()Landroid/app/Activity;");
```

JNI Basics

```
// Qt 6+ JNI approach:
QJniObject activity = QJniObject::callStaticObjectMethod(
    "org/qtproject/qt/android/QtNative",
    "activity",
    "()Landroid/app/Activity;");
```

```
QJniObject context = activity.callObjectMethod(
    "getApplicationContext",
    "()Landroid/content/Context;");
```

JNI Basics

```
// Get current Activity (for UI-related calls)
QJniObject activity = QJniObject::callStaticObjectMethod(
    "org/qtproject/qt/android/QtNative",
    "activity",
    "()Landroid/app/Activity;");

// Application Context (for system services)
QJniObject context = activity.callObjectMethod(
    "getApplicationContext",
    "()Landroid/content/Context;");
```

JNI Basics

```
// Qt 6+ JNI approach:
QJniObject activity = QJniObject::callStaticObjectMethod(
    "org/qtproject/qt/android/QtNative",
    "activity",
    "()Landroid/app/Activity;");

QJniObject context = activity.callObjectMethod(
    "getApplicationContext",
    "()Landroid/content/Context;");
```

```
jint result = QJniObject::callStaticMethod<jint>(
    "ca/mineeye/InternetConnectionChecker",// Java class name
    "checkConnection",                     // Method name
    "(Landroid/content/Context;)I", // Method signature
    context.object<jobject>() // Passing context as jobject
);
```

JNI Basics

```
// Qt 6+ JNI approach:
QJniObject activity = QJniObject::callStaticObjectMethod(
    "org/qtproject/qt/android/QtNative",
    "activity",
    "()Landroid/app/Activity;");

QJniObject context = activity.callObjectMethod(
    "getApplicationContext",
    "()Landroid/content/Context;");


jint result = QJniObject::callStaticMethod<jint>(
    "ca/mineeye/InternetConnectionChecker",
    "checkConnection",
    "(Landroid/content/Context;)I",
    context.object<jobject>() // Passing context as jobject
);
```

Qt Solution: Template Unification

```
// Static methods
callStaticObjectMethod(…)
callStaticMethod<jint>(…)
callStaticMethod<jbool>(…)

// Instance methods
obj.callObjectMethod(…)
obj.callMethod<jint>(…)
obj.callMethod<jbool>(…)
```

Plain JNI – Without Any Wrapper ?

```cpp
// env is a valid JNIEnv*
// context is jobject (we'll get it below)

jobject getAndroidContext(JNIEnv* env) {
    // Step 1: Get QtNative class
    jclass qtNativeClass = env->FindClass("org/qtproject/qt/android/QtNative");
    if (!qtNativeClass) {
        __android_log_print(ANDROID_LOG_ERROR, "JNI", "Failed to find QtNative class");
        return nullptr;
    }

    // Step 2: Get static method ID for activity()
    jmethodID activityMethod = env->GetStaticMethodID(qtNativeClass, "activity", "()Landroid/app/Activity;");
    if (!activityMethod) {
        __android_log_print(ANDROID_LOG_ERROR, "JNI", "Failed to get method ID for activity()");
        return nullptr;
    }

    // Step 3: Call QtNative.activity() to get Activity instance
    jobject activity = env->CallStaticObjectMethod(qtNativeClass, activityMethod);
    if (!activity) {
        __android_log_print(ANDROID_LOG_ERROR, "JNI", "Failed to get Activity object");
        return nullptr;
    }

    // Step 4: Get Activity class to call getApplicationContext()
    jclass activityClass = env->GetObjectClass(activity);
    jmethodID getContextMethod = env->GetMethodID(activityClass, "getApplicationContext", "()Landroid/content/Context;");
    if (!getContextMethod) {
```

Never Write Signatures by Hand!

```
// Your Java method
public String processImage(byte[] data) { return ""; }
public float[] detect(String path, int threshold) { return null; }
```

javap Magic

```
# Run javap on your compiled class
javap -s TestJNI
```

```
// Your Java method
public String processImage(byte[] data);
    descriptor: ([B)Ljava/lang/String;    ← COPY THIS!
public float[] detect(String path, int threshold);
    descriptor: (Ljava/lang/String;I)[F   ← AND THIS!
```

Step 1 - QML Camera Capture

```
// QML - Start capture
onClicked: function() {
    captureSession.imageCapture.captureToFile("");
    // Empty string = let camera choose location
}
```

Step 1 - QML Camera Capture

```
// Signal when saved
onImageSaved: (id, path) => {
    console.log("Image saved to:", path)
    // Path: /…/cache/IMG_20231215_143022.jpg
    onQmlCapturedImageSavedSignal(path)
}
```

Step 2 - Process in C++

```
// C++ - Process and create permanent copy
QString DataController::saveCopyImage(const QString& path) {
    QImage image(QQmlFile::urlToLocalFileOrQrc(path));

    // Optional: resize for AI processing
    if (needsResize) {
        image = resizeImage(image, 640, 640);
    }

    // Save to Gallery (saveImageToGallery)
    // ...
}
```

Step 3 - Save to Gallery

```
// C++ - Prepare for JNI
QByteArray imageData;
QBuffer buffer(&imageData);
image.save(&buffer, "JPEG");

jbyteArray byteArray = env->NewByteArray(imageData.size());
env->SetByteArrayRegion(byteArray, 0, imageData.size(),
                        reinterpret_cast<const jbyte *>(imageData.constData()));

QJniObject javaReturnString = QJniObject::callStaticMethod<jstring>(
    "ca/mineeye/ImageSaver",
    "saveImageToGallery",
    "(Landroid/content/Context;[BLjava/lang/String;ZII)Ljava/lang/String;",
    context.object<jobject>(),
    byteArray, jTitle.object<jstring>(),
    jResized, jImageWidth, jImageHeight);

env->DeleteLocalRef(jData);
```

Step 4 - Java MediaStore

```
// Java - Save to gallery
ContentValues values = new ContentValues();
values.put(MediaStore.Images.Media.DISPLAY_NAME, title);
values.put(MediaStore.Images.Media.MIME_TYPE, "image/jpeg");
//...
Uri uri = context.getContentResolver()
    .insert(MediaStore.Images.Media.EXTERNAL_CONTENT_URI, values);

try (OutputStream out = context.getContentResolver()
                              .openOutputStream(uri)) {
    out.write(imageData);
}
return uri.toString();
```

Step 4 - Java MediaStore

/storage/emulated/0/Android/data/ca.mine/files/Pictures/image_0001.jpg

↓

file:///storage/emulated/0/Pictures/Mineeye/20250713_221525.jpg

Step 5 - Cleanup

```
// Back in QML - cleanup temp file
function onQmlCapturedImageSavedSignal(path) {
    // Process image
    var newImage = dataController.saveCopyOfImageFromQml(path);

    // Remove temporary file
    console.log("Removing temp file:", path);
    qmlRemoveImage(path);

    // Continue with the gallery copy
    qmlProcessFirstImage(newImage);
}
```

Step 5 - Cleanup

```
Q_INVOKABLE void scheduleRemoveImage(const QString &imgPath) {
    // Run the removeImage function in a background thread
    auto v = QtConcurrent::run([this, imagePath]() {
        this->removeImage(imagePath);
    });
}
```

Send Image to Java

```
// Back in QML - cleanup temp file
function onQmlCapturedImageSavedSignal(path) {
    // Process image
    var newImage = dataController.saveCopyOfImageFromQml(path)

    // Remove temporary file
    console.log("Removing temp file:", path);
    qmlRemoveImage(path);

    // Continue with the gallery copy
    qmlProcessFirstImage(newImage);
}
```

Java Side - Decode the Image

```
// From PNG bytes to Android Bitmap
Bitmap bitmap = BitmapFactory.decodeByteArray(
    imageData, 0, imageData.length
);

// Original: 1920x1080 (2MP)
// Model needs: 640x640
bitmap = Bitmap.createScaledBitmap(
    bitmap, 640, 640, true
);
```

The Pixel Format Conversion

```
// Android stores pixels as ARGB in one integer:
// [Alpha][Red][Green][Blue] = 0xAARRGGBB

int pixel = intValues[i];
float red   = ((pixel >> 16) & 0xFF) / 255.0f;
float green = ((pixel >> 8)  & 0xFF) / 255.0f;
float blue  = ((pixel)       & 0xFF) / 255.0f;

// But wait... there's more!
```

The Pixel Format Conversion

```
// Android bitmap: Height x Width x Channels (HWC)
// pixels[y][x] = [R, G, B]

// ONNX wants: Channels x Height x Width (CHW)
// tensor[channel][y][x]

// So we reorganize 640x640x3 = 1,228,800 values:
for (int i = 0; i < pixels.length; i++) {
    floatValues[i] = red[i];                  // Reds first
    floatValues[i + 640*640] = green[i];  // All greens
    floatValues[i + 2*640*640] = blue[i]; // All blues
}
```

The Pixel Format (Height/Width/Channels)

```
[
  [ [R,G,B], [R,G,B], [R,G,B] ],   ← 1st row (y = 0)
  [ [R,G,B], [R,G,B], [R,G,B] ],   ← 2nd row (y = 1)
  [ [R,G,B], [R,G,B], [R,G,B] ]    ← 3rd row (y = 2)
]
```

The Pixel Format (Channels/Height/Width)

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```
Channel R
(All reds):
[
  [R, R, R],
  [R, R, R],
  [R, R, R]
]
```

```
Channel G
(All greens):
[
  [G, G, G],
  [G, G, G],
  [G, G, G]
]
```

```
Channel B
(All blues):
[
  [B, B, B],
  [B, B, B],
  [B, B, B]
]
```

Add Batch Dimension

```
// Model expects 4D tensor: [batch, channels, height, width]
// We have: [channels, height, width]
// Solution: Add batch dimension of 1

float[] batchedValues = new float[1 * 3 * 640 * 640];
System.arraycopy(floatValues, 0, batchedValues, 0, length);

// Create ONNX tensor
OnnxTensor tensor = OnnxTensor.createTensor(
    environment,
    FloatBuffer.wrap(batchedValues),
    new long[]{1, 3, 640, 640}
); // Ready for inference! Total preprocessing: ~80ms
```

Wait, but how many copies have we made?

The Full Journey of One Image

1. QML Camera Capture → …/myapp/files/Pictures/0001.jpg
2. C++ Crop image → same location
3. Java Save Cropped Image → /Pictures/Mineeye/20231215_143022.jpg
4. C++ Load → QImage from app storage
5. C++ → JNI → byte[] for inference
6. HWC → CHW transformation
7. Add batch dimension

Plus, the result copies

Copy #1: Java ONNX → detected objects

Copy #2: Results → JSON → C++ → QML

And what about inference?

```
OrtSession.Result output = session.run(
    Collections.singletonMap(
        session.getInputNames().iterator().next(),
        tensor)
);
```

Have to transpose (j,i swap)

```
// Original ONNX output: [1, N, M]
// Actually means:
// 1 = batch size
// N = attributes per detection (6-7 values)
// M = number of detections

// After transpose: [M, N]
// M = number of detections (rows)
// N = attributes per detection (columns)
```

Results Processing

```
// Shape: [1, N, M], transpose to [M,N].
float[][][] array3d = (float[][][]) onnxValue.getValue();
float[][] transformedOutput = new float[M][N];

for (int i = 0; i < M; i++) {
    for (int j = 0; j < N; j++) {
        transformedOutput[i][j] = array3d[0][j][i];
    }
}
```

Extract Detections

```
for (int i = 0; i < transformedOutput.length; i++) {
    float[] outputRow = transformedOutput[i];
    MaxClassScore maxClassScore = getMaxClassScore(outputRow);

    if (maxClassScore.score >= threshold) {
        // Apply scaling to bounding box coordinates
        float x = outputRow[0] * xScale;
        float y = outputRow[1] * yScale;
        ...
```

The Architecture We Shipped

```
1  QString processNewPhoto(QString path) {
2      path = cropImage(path);
3
4      QString galleryPath = saveToGallery(path);
5
6      QImage image(galleryPath);
7      QByteArray bytes = imageToBytes(image);
8
9      auto detections = detectViaJNI(bytes);
10
11     QFile::remove(path);
12
13     return galleryPath;
14 }
```

Lessons Learned

✗ Don’t forget to delete arrays, temporary images

✗ Can't avoid MediaStore on Android 10+

✗ Multiple copies are inevitable

✓ Embrace the platform constraints

✓ Ship first, optimize later

✓ Document why it's complex

"Perfect is the enemy of good" - Voltaire

Let's recap the problems we faced

What is a local reference?

C++ code	JNI Layer	Java Heap
array (invalid)	Local Ref Table [ref -> object]	byte[] object [actual data]

↓

```
env->DeleteLocalRef(array);
```

↓

C++ code	JNI Layer	Java Heap
array (invalid)	Local Ref Table [empty]	byte[] object [still exists!]

Why the byteArray still exists?

```
QJniObject::callStaticMethod<jstring>(
    "ca/mysite/ImageSaver",
    "saveImageToGallery",
    "...[B...",  // [B means byte[]
    byteArray    // Pass an array to Java
);
```

```
env->DeleteLocalRef(byteArray);
```

```
public class ImageSaver {
    private static byte[] lastImage;

    public static String saveImageToGallery(Context ctx, byte[] data, ...) {
        // Java code received the array and stores a reference
        lastImage = data; // Now Java holds a reference!

        new Thread(() -> {      // Asynchronous save operation
            saveToFile(data);   // Uses the array later
        }).start();

        return "OK";
    }
}
```

PushLocalFrame/PopLocalFrame

```
// Main frame: 512 slots available
for (int i = 0; i < 1000; i++) {
    // Create a new local frame with 20 slots
    if (env->PushLocalFrame(20) < 0) { return; } // Out of memory

    // Create multiple references within this frame
    jbyteArray imageData = env->NewByteArray(1024 * 1024);
    jstring fileName = env->NewStringUTF("image.jpg");

    // Process the image
    jobject result = env->CallStaticObjectMethod( ...
        imageData,
        fileName
    );

    // All local references created in this frame are automatically freed!
    env->PopLocalFrame(NULL); // No need for individual DeleteLocalRef calls
}
```

PushLocalFrame/PopLocalFrame

```
// Main frame: 512 slots available
for (int i = 0; i < 1000; i++) {
    // Create a new local frame with 20 slots
    if (env->PushLocalFrame(20) < 0) { return; } // Out of memory

     // Create multiple references within this frame
     jbyteArray imageData = env->NewByteArray(1024 * 1024);
     jstring fileName = env->NewStringUTF("image.jpg");

    // Process the image
    jobject result = env->CallStaticObjectMethod( ...
        imageData,
        fileName
    );

    // All local references created in this frame are automatically freed!
    env->PopLocalFrame(NULL); // No need for individual DeleteLocalRef calls
}
```

Memory Management

```
for (int i = 0; i < 1000; i++) {
    jbyteArray array = env->NewByteArray(size);
    // Process array...
}
```

Memory Management

```
for (int i = 0; i < 1000; i++) {
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    // Process array...
}
```

Memory Management

```
for (int i = 0; i < 1000; i++) {
    jbyteArray array = env->NewByteArray(size);
    // Process array...
}
```

Reference Table (512 slots)
Loop iteration 1: [ref1]
Loop iteration 2: [ref1][ref2]
...

Memory Management

```
for (int i = 0; i < 1000; i++) {
    jbyteArray array = env->NewByteArray(size);
    // Process array...
}
```

Reference Table (512 slots)

```
Loop iteration 1: [ref1]
Loop iteration 2: [ref1][ref2]
...
Loop iteration 512: [ref1]...[ref512]
Loop iteration 513: CRASH!
```

Memory Management

```
// Problem – JNI local reference table overflow
for (int i = 0; i < 1000; i++) {
    jbyteArray array = env->NewByteArray(size);
    // Process array...
    // Local ref table fills up → CRASH!
}
```

Memory Management

```
// Solution – Delete JNI local reference in loops
for (int i = 0; i < 1000; i++) {
    jbyteArray array = env->NewByteArray(size);
    // Process array...
    env->DeleteLocalRef(array); // Free table slot
}
```

Memory Management

```
jbyteArray array = env->NewByteArray(imageData.size());
// ... use array
```

Memory Management

```
// Memory leak
jbyteArray array = env->NewByteArray(imageData.size());
// ... use array
// ... Missing: DeleteLocalRef
```

Memory Management

```
// Memory leak fixed
jbyteArray array = env->NewByteArray(imageData.size());
// ... use array
env->DeleteLocalRef(array);     // Critical!
```

Similar issue:
stackoverflow.com/questions/8574241/jni-newbytearray-memory-leak

Other tips:
developer.android.com/training/articles/perf-jni

Memory Management

```
// RAII wrapper for jbyteArray with
DeleteLocalRef
class JniByteArrayWrapper {
private:
    jbyteArray array;
    QJniEnvironment env;

public:
    explicit JniByteArrayWrapper(jsize size) {
        array = env->NewByteArray(size);
    }

    // Dtor calls DeleteLocalRef automatically
    ~JniByteArrayWrapper() {
        if (array != nullptr) {
            env->DeleteLocalRef(array);
        }
    }
//...
};
```

Memory Management

```
{
    // Removed after going out of the scope
    JniByteArrayWrapper byteArray(imageData.size());

    // Copying the data
    QJniEnvironment env;
    env->SetByteArrayRegion(byteArray, 0, imageData.size(),
        reinterpret_cast<const jbyte*>(imageData.constData()));

    // Call Java method
    QJniObject result = QJniObject::callStaticMethod<jstring>(
        "com/myapp/ImageProcessor", "processImage",
        "([B)Ljava/lang/String;",
        byteArray.get()
    );
}
```

JNI Memory Rules

- Always delete local refs in loops
- Use Push/PopLocalFrame operations
- Use RAII wrapper
- Don't assume GC will save you

JNI and threads – core problem

```
// main thread
{
    JniByteArrayWrapper arr(data.size());
    // ...`
    // QtConcurrent thread - CRASH!
    QJniObject::callStaticMethod<void>(
        "org/example/Helper", "save", "([B)V",
        arr.get()
    );
}
```

Solution – run in lambda

```
QtConcurrent::run([=]() {
    JniByteArrayWrapper arr(data.size());

    QJniObject::callStaticMethod<void>(
        "org/example/Helper", "save", "([B)V",
        arr.get()
    );
    // arr automatically cleaned up when lambda ends
});
```

Cache across threads

```
// Qt Core pattern - global static cache
typedef QHash<QString, jclass> JClassHash;
Q_GLOBAL_STATIC(JClassHash, cachedClasses)
Q_GLOBAL_STATIC(QReadWriteLock, cachedClassesLock)

// Inside callStaticMethod - check cache first
jclass clazz = nullptr;
{
    QReadLocker locker(cachedClassesLock);
    clazz = cachedClasses->value(className, nullptr);
}

if (!clazz) {
    clazz = env.FindClass(className);
    clazz = static_cast<jclass>(env->NewGlobalRef(clazz));

    QWriteLocker locker(cachedClassesLock);
    cachedClasses->insert(className, clazz);
}
```

Cache across threads

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}

if (!clazz) {
    clazz = env->FindClass(className);
    clazz = static_cast<jclass>(env->NewGlobalRef(clazz));

    QWriteLocker locker(cachedClassesLock);
    cachedClasses->insert(className, clazz);
}
```

A local ref is created here

A global ref is created here

Global references for sharing across threads

```
// Convert local reference to global
QJniEnvironment env;
QJniObject localCtx = env->NewByteArray(imageData.size());
jobject globalCtx = env->NewGlobalRef(localCtx.object<jobject>());

// Now safe to use in any thread
// When done (e.g., in destructor):
env->DeleteGlobalRef(globalCtx);
```

https://stackoverflow.com/questions/30721635/must-i-deletelocalref-an-object-i-have-called-newglobalref-on

Check what has been returned

```
// Qt JNI returns default values on exception!
auto result = QJniObject::callStaticMethod<jint>(
    "com/example/Class", "method", "()I"
);
// result = 0 on exception, no crash!

// Always check:
if (QJniEnvironment::checkAndClearExceptions()) {
    qWarning() << "JNI exception occurred!";
    return; // handle error
}
```

Check what has been returned

```
QJniEnvironment env;
jbyteArray arr = env->NewByteArray(data.size());
if (!arr) { // check if nullptr
    qWarning() << "Failed to allocate byte array";
    return;
}
```

Error Handling Strategy

```
// Strategic checking - not after every call
QJniEnvironment env;
jbyteArray data = env->NewByteArray(size);
// Skip check - NewByteArray rarely fails

// Group related operations
auto result = QJniObject::callStaticMethod<jobject>(
    "com/myapp/Processor", "analyze", "([B)Ljava/lang/String;", data
);

// Check once after the risky operation
if (!result.isValid() || env.checkAndClearExceptions()) {
    qWarning() << "Processing failed";
    return;
}

env->DeleteLocalRef(data);
// No check needed - cleanup rarely fails
```

Threading Performance Problem

```
// Naive approach - new thread for each task
for (auto& imageData : images) {
    std::thread([=]() {
        QJniEnvironment env; // AttachCurrentThread happens here!

        jbyteArray arr = env->NewByteArray(imageData.size());
        QJniObject::callStaticMethod<void>(
            "...", "process", "([B)V", arr);
        env->DeleteLocalRef(arr);

        // DetachCurrentThread happens in destructor
    }).detach();
}
// Problem: 100 images = 100 attach/detach cycles!
```

Use ThreadPool for tasks

```
class JniTask : public QRunnable {
    QByteArray data;
public:
    void run() override {
        // Thread attaches on first task only!
        QJniEnvironment env;

        jbyteArray arr = env->NewByteArray(imageData.size());
        QJniObject::callStaticMethod<void>(
            "...", "process", "([B)V", arr);
        env->DeleteLocalRef(arr);
    }
};
// Submit tasks - threads are reused
for (auto& data : dataList) {
    QThreadPool::globalInstance()->start(new JniTask(data));
}
```

Delegate threading to Java

```cpp
// C++ side - single JNI call
QJniObject::callStaticMethod<void>(
    "org/example/BatchProcessor", "runAsync", "([Ljava/lang/String;)V", paths
);


// Java side - handles threading
public static void runAsync(String[] paths) {
    ExecutorService executor = Executors.newFixedThreadPool(4);

    for (String path : paths) {
        executor.submit(() -> {
            processFile(path);
            // Careful with callbacks to C++ here!
        });
    }
}
```

Camera Without Permissions

```
void takePicture() {
    // No permission check - will crash!
    QJniObject::callStaticMethod<void>(
        "org/example/Camera", "capture", "()V"
    );
}

// Android logcat:
// java.lang.SecurityException: Permission Denial:
// camera requires android.permission.CAMERA
```

Android Permissions

```
void takePicture() {
    auto permission = QtAndroidPrivate::checkPermission(
        "android.permission.CAMERA").result();

    if (permission == QtAndroidPrivate::Denied) {
        permission = QtAndroidPrivate::requestPermission(
            "android.permission.CAMERA").result();
    }

    if (permission == QtAndroidPrivate::Authorized) {
        // NOW it's safe to call camera
        QJniObject::callStaticMethod<void>(
            "org/example/Camera", "capture", "()V"
        );
    }
}
```

Android Permissions

```
bool PermissionsManager::checkAndRequestCameraPermission()
{
    bool granted = true;
    auto cameraPermission = QtAndroidPrivate::checkPermission(\
        QString("android.permission.CAMERA")).result();
    if (cameraPermission == QtAndroidPrivate::Denied)
    {
        cameraPermission = QtAndroidPrivate::requestPermission(
            QString("android.permission.CAMERA")).result();
        if (cameraPermission == QtAndroidPrivate::Denied) {
            granted = false;
        }
    }
    return granted;
}
```

Where Can We Write Files?

```
// Where to save captured images?
QString savePath = ???;  // What path works on Android?

// These all fail:
savePath = "/sdcard/DCIM/";           // ❌ Permission denied
savePath = "/storage/Pictures/";       // ❌ Doesn't exist
savePath = QDir::homePath() + "/pics"; // ❌ Not accessible

// We need the RIGHT path for THIS device!
```

Android Scoped Storage

```
// C++ side - ask Java for the correct path
QString savePath = QJniObject::callStaticObjectMethod(
    "org/example/StorageHelper",
    "getPicturesDirectoryPath",
    "(Landroid/content/Context;)Ljava/lang/String;",
    context
).toString();
// Returns: /storage/emulated/0/Android/data/com.myapp/files/Pictures/

// Java helper:
public static String getPicturesDirectoryPath(Context context) {
    if (Environment.MEDIA_MOUNTED.equals(
            Environment.getExternalStorageState())) {
        return context.getExternalFilesDir(
            Environment.DIRECTORY_PICTURES).getAbsolutePath();
    } else {
        return context.getFilesDir().getAbsolutePath();
    }
}
```

Performance Optimization

Initial: 4 seconds per image

→ Bitmap scaling: -400ms

→ QtConcurrent usage -1500ms

Final: 2.1s per image

Performance Optimization

- ONNX tensor reuse

- Batch processing

Beyond Landmines

The same architecture works for:

- Quality control in manufacturing
- Medical image analysis
- Infrastructure inspection
- Agricultural monitoring

Key Takeaways

1. Qt JNI bridges C++ and Android effectively
2. Data marshalling is critical for performance
3. QtConcurrent simplifies threading
4. Real-world AI needs hybrid architectures

Code and Resources

Sample Code and These Slides:

github.com/kunichik/conferences/cppnorth2025

Documentation:

doc.qt.io/qt-6/qjniobject.html

Deep dive: Qt's JNI internals

JNI Method Signatures

Rules:
"(parameters)returnType"

Examples:

```
()V                    → void method()
(I)Z                   → boolean method(int)
(Ljava/lang/String;)V  → void method(String)
([B)Ljava/lang/String;    → String method(byte[])
```

Common types:

Z=boolean, B=byte, I=int, J=long, F=float, D=double

[=array, L...;=object

Data Type Mapping

C++ → JNI → Java

---

int	→ jint	→ int
bool	→ jboolean	→ boolean
std::string	→ jstring	→ String
std::vector<uint8_t>	→ jbyteArray	→ byte[]

Qt specifics:

QString → jstring (via toUtf8())

QByteArray → jbyteArray (via data())

QImage → jbyteArray (via JPG encoding)

Raw JNI: Function Explosion

```
// Static methods
CallStaticObjectMethod(...)    // for Java objects
CallStaticIntMethod(...)       // for jint primitives
CallStaticBooleanMethod(...)   // for jbool primitives

// Instance methods
CallObjectMethod(...)          // for Java objects
CallIntMethod(...)             // for jint primitives
CallBooleanMethod(...)         // for jbool primitives
```

Under the Hood: Compile-Time Macros

```
#define MAKE_CALLER(Type, Method) \
template <typename T> \
struct Caller<T, std::enable_if_t<sameTypeForJni<T, Type>>> \
{ \
    static constexpr void callMethodForType(JNIEnv *env, T &res, \
        jobject obj, jmethodID id, va_list args) \
    { \
        res = T(env->Call##Method##MethodV(obj, id, args)); \
    } \
//...
}
```

Type-to-Signature Mapping

```
template <typename T>
struct Traits {
    static constexpr auto signature() {
        if constexpr (std::is_same_v<T, int>) {
            return CTString("I");
        } else if constexpr (std::is_same_v<T, jbooleanArray>) {
            return CTString("[Z");
        } else if constexpr (std::is_same_v<T, jstring>) {
            return CTString("Ljava/lang/String;");
        }
        // ... more type mappings
    }
};
```

Type Detection: Primitive Magic

```cpp
template<typename T>
static constexpr bool isPrimitiveType()
{
    return Traits<T>::signature().size() == 2;
}

template<typename T>
static constexpr bool isArrayType()
{
    constexpr auto signature = Traits<T>::signature();
    return signature.startsWith('[') && signature.size() > 2;
}

template<typename T>
static constexpr bool isObjectType()
{
    if constexpr (std::is_convertible_v<T, jobject>) {
        return true;
    } else {
        constexpr auto signature = Traits<T>::signature();
        return (signature.startsWith('L') && signature.endsWith(';')) || isArrayType<T>();
    }
}
```

```cpp
template <typename T>
struct Traits {
    static constexpr auto signature() {
        if constexpr (std::is_same_v<T, int>) {
            return CTString("I");
        } else if constexpr (std::is_same_v<T, jbooleanArray>) {
            return CTString("[Z");
        } else if constexpr (std::is_same_v<T, jstring>) {
            return CTString("Ljava/lang/String;");
        }
        // ... more type mappings
    }
};
```

Type Detection: Array Patterns

```
template<typename T>
static constexpr bool isPrimitiveType()
{
    return Traits<T>::signature().size() == 2;
}
```

```
template<typename T>
static constexpr bool isArrayType()
{
    constexpr auto signature = Traits<T>::signature();
    return signature.startsWith('[') && signature.size() > 2;
}
```

```
template<typename T>
static constexpr bool isObjectType()
{
    if constexpr (std::is_convertible_v<T, jobject>) {
        return true;
    } else {
        constexpr auto signature = Traits<T>::signature();
        return (signature.startsWith('L') && signature.endsWith(';')) || isArrayType<T>();
    }
}
```

```
template <typename T>
struct Traits {
    static constexpr auto signature() {
        if constexpr (std::is_same_v<T, int>) {
            return CTString("I");
        } else if constexpr (std::is_same_v<T, jbooleanArray>) {
            return CTString("[Z");
        } else if constexpr (std::is_same_v<T, jstring>) {
            return CTString("Ljava/lang/String;");
        }
        // ... more type mappings
    }
};
```

Type Detection: Object Signatures

```cpp
template<typename T>
static constexpr bool isPrimitiveType()
{
    return Traits<T>::signature().size() == 2;
}

template<typename T>
static constexpr bool isArrayType()
{
    constexpr auto signature = Traits<T>::signature();
     return signature.startsWith('[') && signature.size() > 2;
}

template<typename T>
static constexpr bool isObjectType()
{
    if constexpr (std::is_convertible_v<T, jobject>) {
        return true;
    } else {
        constexpr auto signature = Traits<T>::signature();
        return (signature.startsWith('L') && signature.endsWith(';')) || isArrayType<T>();
    }
}
```

```cpp
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struct Traits {
    static constexpr auto signature() {
        if constexpr (std::is_same_v<T, int>) {
            return CTString("I");
        } else if constexpr (std::is_same_v<T, jbooleanArray>) {
            return CTString("[Z");
        } else if constexpr (std::is_same_v<T, jstring>) {
            return CTString("Ljava/lang/String;");
        }
        // ... more type mappings
    }
};
```

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Boris Tkatch

Let's Connect!

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Happy to discuss:

- Your JNI challenges
- Mobile AI applications
- Performance optimizations
- Similar detection problems