Qt World Summit 2017

October 10-12 | Berlin, Germany

QtIVI: Integrating & Testing vehicle functions with Qt Automotive Suite

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QtIVI

- What is Qt Auto
- QtIVI - Extendable Cross Platform APIs
- Code Generation
- Integration with Gammaray

What is Qt Auto - 1

- Qt HMIs
  - easy to implement stunning user interface with seamless integration of 2D and 3D content
  - scales to different hardware and can leverage GPU-based rendering for smooth 60fps experience even on high-resolution screens
  - easy to use declarative UI description language with graphical tooling, as well as C++ APIs for full native power where needed
- Qt Automative Suite
  - modular vehicle data and multimedia API with comprehensive simulation backends enable development before hardware is available
  - multi-process architecture with app lifecycle management and security enabling a modern modular HMI design and safe integration of 3rd-party applications
  - reference HMI implementation

What is Qt Auto - 1

What is Qt Auto - 2

- Tooling
  - support for emulated or on-target development
  - support for quick target deployment and live development and debugging on target
  - high-level and visual diagnostic tools enabling effective analysis of complex bugs or performance issues
- Custom SDK
  - ensure everyone using exactly the same setup to avoid integration problems
  - single installer with online update support to efficiently deploy your development setup
  - include in-house or 3rd party frameworks

What is Qt Auto - 2

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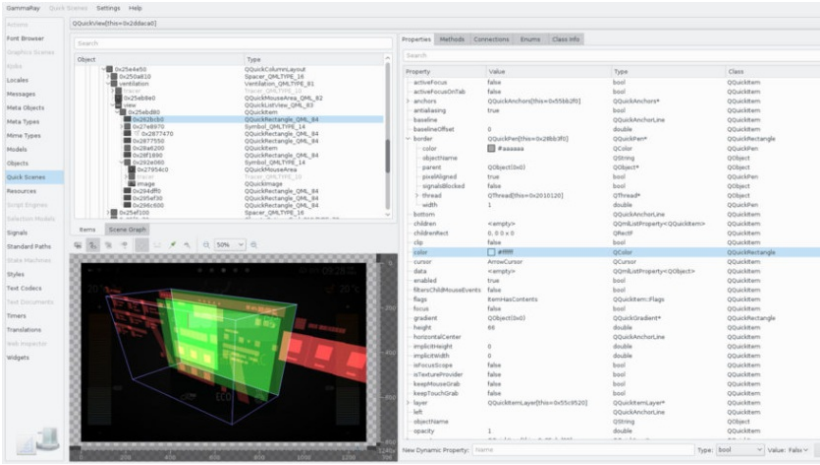
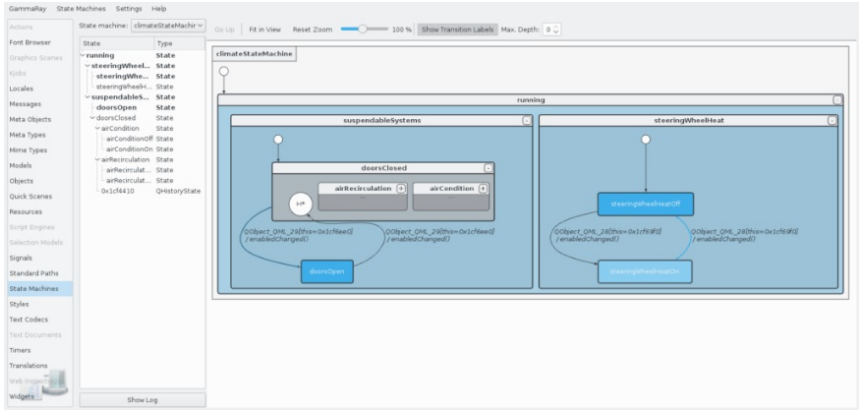
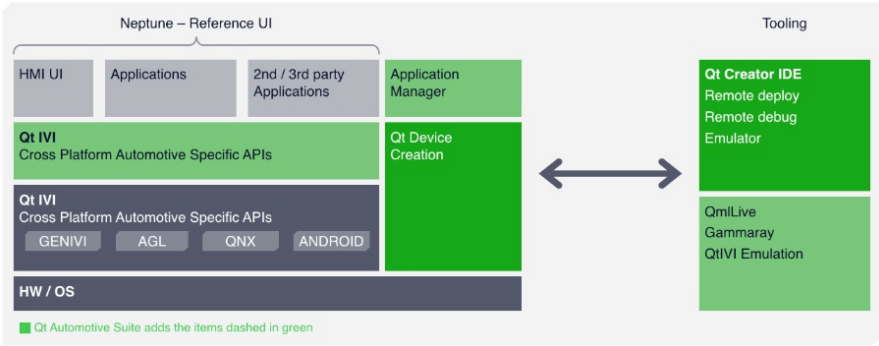


What is Qt Auto - 2



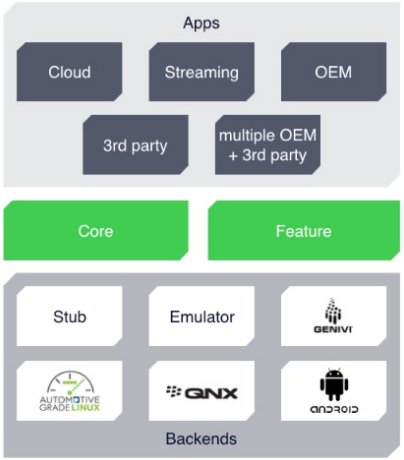
What is Qt Auto - Architecture



What is QtIVI

- Feature Abstraction
  - Provide support for multiple features: climate control, media services, ...
  - Consistant frontend API
  - Multiple manufacturer backend
- Core Library
  - Abstract features, including support for zoning
  - Frontend / Backend setup with dynamic plugin loading
  - Target multiple configurations for deployment, simulation, testing, ...
- C++ and QML interface
- Reference implementations

What is QtIVI - Architecture



Features and Services

- A **Feature** is an API to a subset of functionality
  - derived from `QIviAbstractFeature` and `QIviAbstractZonedFeature`
- Backed by a **Service** which implements the required interface
  - derived from `QIviFeatureInterface` and `QIviZonedFeatureInterface`
- Features are have different backends which are *discovered* at runtime
  - Call `QIviAbstractFeature::startAutoDiscovery()`
  - Possible to set the discovery mode using `QIviAbstractFeature::setDiscoveryMode(DiscoveryMode discoveryMode)`
  - Supports `AutoDiscovery`, `LoadOnlyProductionBackends`, `LoadOnlySimulationBackends`
  - Or use `QIviServiceManager` to find required service object and the right feature

Features and Services

- *Features have properties, signals, slots*
- *Data and functionality is implemented in backend service*
- Backend service may perform validition on incoming values
- Will notify front end for state changes

```
1  int QIviClimateControl::fanSpeedLevel() const
2  {
3      Q_D(QIviClimateControl);
4      return d->m_fanSpeedLevel;
5  }
6
7  void QIviClimateControl::setFanSpeedLevel(int fanSpeedLevel)
8  {
9      if (QIviClimateControlBackendInterface *backend =
10             qobject_cast<QIviClimateControlBackendInterface *>(this->backend()))
11         backend->setFanSpeedLevel(fanSpeedLevel, zone());
12 }
```

Features and Services

- Features have properties, signals, slots
- Data and functionality is implemented in backend service
- *Backend service may perform validition on incoming values*
- Will notify front end for state changes

```
1 void QIviClimateControlBackend::setFanSpeedLevel(int fanSpeedLevel)
2 {
3     if (m_fanSpeedLevel == fanSpeedLevel)
4         return;
5     if (fanSpeedLevel <= 50)
6         m_fanSpeedLevel = fanSpeedLevel;
7
8     emit fanSpeedLevelChanged(m_fanSpeedLevel);
9 }
```


Features and Services

- Features have properties, signals, slots
- Data and functionality is implemented in backend service
- Backend service may perform validition on incoming values
- *Will notify front end for state changes*

```
1 void QIviClimateControlPrivate::onFanSpeedLevelChanged(int fanSpeedLevel)
2 {
3     Q_Q(QIviClimateControl);
4     if (m_fanSpeedLevel != fanSpeedLevel) {
5         m_fanSpeedLevel = fanSpeedLevel;
6         emit q->fanSpeedLevelChanged(fanSpeedLevel);
7     }
8 }
```


Zoned Features

- Features and their properties can be zoned
- Used for features that are available in multiple zones of the vehicle
- List of zones are accessible via `QIviAbstractZonedFeature::availableZones()`
- Zone objects are accessible via `QIviAbstractZonedFeature::zoneAt()`

```
1 QIviClimateControl* climateControl = new QIviClimateControl(QString(), this);
2 climateControl->startAutoDiscovery();
3 QIviClimateControl* frontLeftControl = climateControl->zoneAt("FrontLeft");
```

- All zone objects talk to the same backend service instances
- Some properties may be zoned, some not

QtIVI 1.X: QIviProperties

- Properties are stored as `QIviProperty` objects, values are stored in `QVariant`
- Use `QIviProperty::value()` to get the current value, `QIviProperty::setValue()` to set it
- Possible to define minimum and maximum values via virtual functions `QIviProperty::minimumValue()` and `QIviProperty::maximumValue()`
- `QIviProperty::availableValues()` return the accepted values
- `QIviProperty::isAvailable()` gives information about the property being available in the backend
- Property attributes are accessible as QML grouped properties, like myProperty.available, myProperty.value, etc.
- **Deprecated**
  - Not type safe
  - Lots of overhead
  - Valid ranges only apply to small subset of properties
  - Availability tends to be static

Writting your own

- Lots of code to write
  - Front end, all the properties, listening to backend changes
  - One or more backends
  - Production backend talking to the actual vehicle
  - Simulation backend handling mock data
  - Handling per zone values, valid ranges, etc
- Repeat for each interface

Could this be automated?

QtIVI 2.0: Code Generation

- Define interface
  - Name, properties, signals, slots
  - Associated enums and structures
  - Meta data about ranges, valid values, default values, zones...
- Use generators
  - Frontend generator for the feature API and abstract backend interface
  - Backend simulator generator supporting default values, validity checks, etc

IVI Generator

- QFace - https://github.com/Pelagicore/qface
- IDL designed to support
  - Qt related features such as properties, signals, slots, models...
  - basic data types, structs, enums and flags
  - annotation to provide meta-data about modules, interfaces, properties...
  - structured comments
- Generator
  - Python3 + ANTLR based parser
  - Jinja2 based templates
  - Walk the domain model and produce the required output using the templates
- Templates
  - Frontend and backend templates to generate code

QFace Sample

```
module org.example 1.0

interface Echo {
    string message;
    readonly Status status;
    void echo(string message);
    signal broadcast(string message);
}

enum Status {
    Null, Loading, Ready, Error
}
```

```
class Echo : public QObject
{
    Q_OBJECT
    Q_PROPERTY(QString message READ message WRITE setMessage NOTIFY messageChanged)
    Q_PROPERTY(Example::Status status READ status NOTIFY messageChanged)
public:
    QString message() const;
    void setMessage(const QString& message);
    ...
    Q_INVOKABLE void echo(QString message);
signals:
    void messageChanged(const QString& message);
    void broadcast(QString message);
};
```

QFace Grammar

```
module <module> <version>
import <module> <version>

interface <Identifier> {
    [const] [readonly] <type> <identifier>
    <type> <operation>(<parameter>*) [const]
    signal <signal>(<parameter>*)
}

struct <Identifier> {
    <type> <identifier>;
}

enum <Identifier> {
    <name> [= <value>],
}

flag <Identifier> {
    <name> [= <value>],
}
```

- Builtin types: bool, int, real, string, var
- Models (and lists)
- Structured (JavaDoc) comments

Annotations

- All elements can be annoted

```
@singleton: true
@config: { port: 1234 }
interface Echo {
}
```

- Single value or compound
- Compount values use YAML syntax
- External annotations (`.yaml` file)

```
org.example.Echo:
    service:
        port: 12345
```

- Only relevant to the generator

QtIVI Example

- Entire module defined in single QFace file
- Defines common annotations

```
@config: { qml_name: "QtIvi.VehicleFunctions", \
           interfaceBuilder: "vehicleFunctionsInterfaceBuilder" }
module QtIviVehicleFunctions 1.0;

@config: { zoned: true, id: "org.qt-project.qtivi.ClimateControl/1.0", \
           qml_type: "ClimateControl" }
interface QIviClimateControl {
    /**
     * Holds whether the air conditioning is enabled.
     */
    @config: { getter_name: "isAirConditioningEnabled" }
    bool airConditioningEnabled;

...
```

- `ivivehiclefunctions.qface`
- `ivivehiclefunctions.yaml`

Generators

- Traverse the document model to generate files

```
for module in sytem.modules:
    # generate module related files...

    for interfaces in module.interfaces:
        # generate interface related files...

    for struct in module.structs:
        # generate interface related files...
```

- JINJA based template documents
- YAML file to describe which template file to use for each object in the document model
- `generator.py --format foo bar.qface out_dir`
- Predefined formats:
  - `frontend`, creates `QIviAbstractFeature` and `QIviAbstractZonedFeature` based classes and helper
  - `backend_simulator` creates `QIviFeatureInterface` and `QIviZonedFeatureInterface` based classes with all data and operations
  - `control_panel` creates test app (more later)

Validation

- Annotation define valid ranges, minimum/maximum values, domains...

```
interface QIviClimateControl {
    @config_simulator: { range: [0, 50] }
    int fanSpeedLevel;
    @config_simulator: { minimum: 0 }
    int steeringWheelHeater;
    @config_simulator: { maximum: 30.0 }
    real targetTemperature;
    @config_simulator: { domain: ["cold", "mild", "warm" ] }
    string outsideTemperatureLabel;
...
```

- Used in `backend_simulator` generator to test incoming values
- Information is stored in class meta data as JSON

```
class QIviClimateControl : public QIviAbstractZonedFeature {
    Q_OBJECT
    Q_CLASSINFO("IviPropertyDomains", "{ \
            \"iviVersion\":2.0, \
            \"fanSpeedLevel\": {\"range\":[0,50] }, \
            \"steeringWheelHeater\": {\"minimum\":0}, \
            \"targetTemperature\": {\"maximum\":30.0}, \
            \"outsideTemperatureLabel\": {\"domain\":[\"cold\",\"mild\",\"warm\"]}\
        }")
public:
    ...
```


QMake integration

- QMake has been extended to support QFace files and drive the code generation
- Generator creates code and `.pri` files, not overall project

```
CONFIG += ivigenerator

QFACE_FORMAT = backend_simulator
QFACE_SOURCES = ivivehiclefunctions.qface
QFACE_MODULE_NAME = QtIviVehicleFunctions
```


Customizing Backend

- Backend classes only contain default data members
- Operations only have default implementations
- Full functionality needs specialisation
- Can provide *generator* function to create derived instances
- Annotation applied to module:
  `@config: {interfaceBuilder: "vehicleFunctionsInterfaceBuilder"}`

```
extern QVector<QIviFeatureInterface *>
    vehicleFunctionsInterfaceBuilder(QtIviVehicleFunctionsPlugin *plugin)
{
    const QStringList interfaces = plugin->interfaces();
    QVector<QIviFeatureInterface *> res;
    Q_ASSERT(interfaces.size() == 2);
    Q_ASSERT(interfaces.indexOf(QtIviVehicleFunctions_QIviClimateControl_iid) == 0);
    Q_ASSERT(interfaces.indexOf(QtIviVehicleFunctions_QIviWindowControl_iid) == 1);
    res << new QIviClimateControlBackend(plugin);
    res << new QIviConcreteWindowControlBackend(plugin);
    return res;
}
```


Customizing Templates

- Can more code be generated?
- For backend, can more low level integration code be generated?
- Add special annotations and customize the templates!
- `QFACE_SOURCES` can be a path to a template folder, requires a matching YAML file
- Generate tests, sample UIs, ...

QtSimulator Integration

KDAB

- Based on QtSimulator
  - Part of Boot2Qt (not the old simulator-qt, not the new qt-emulator)
  - Used by various Qt modules (location, ...)
- `control_panel` template generates application
  - Mirrors backend behaviour
  - Useful for testing application in absence of full featured backend

QtSimulator Integration

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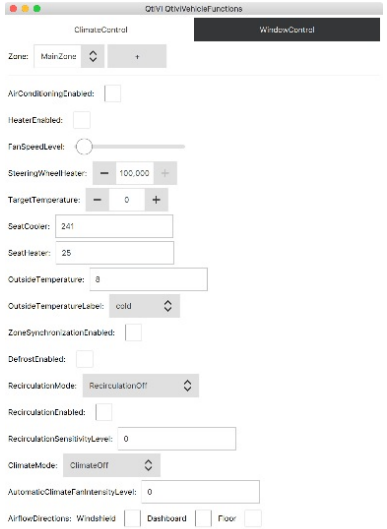

QtSimulator Integration

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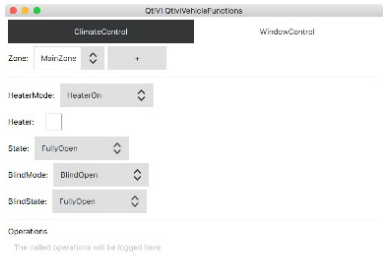

Gammaray Integration

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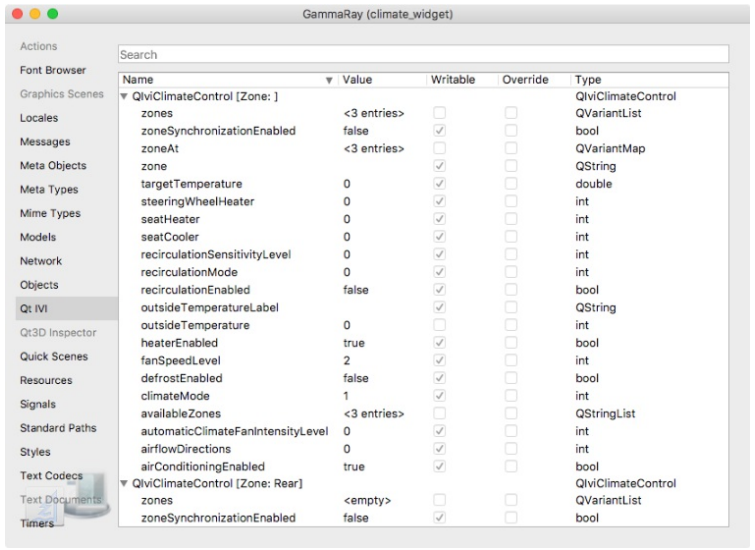

Overriding Properties

- Gammaray's IVI module provides introspection
- Observe and modify property values from `QIviAbstractFeature` derived classes
- Also support **overriding**
  - Change values sent from the backend
  - Modify values without affecting the backend
- Useful to test application behaviour in isolation of any backend

Conclusion

- QtIVI, library and tools for integrating vehicle functions in Qt applications
- IDL and code generator massively simplify the creation of the glue code
- Tooling for testing, debugging and profiling

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Thank you!

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