

Formalizing Criminal Law Using the Catala Programming Language

Luca Arnaboldi*, David Aspinall*, Ronny Bogani* and Burkhard Schafer*

*University of Edinburgh, Scotland

Scott Herman

Conan&Herman, USA

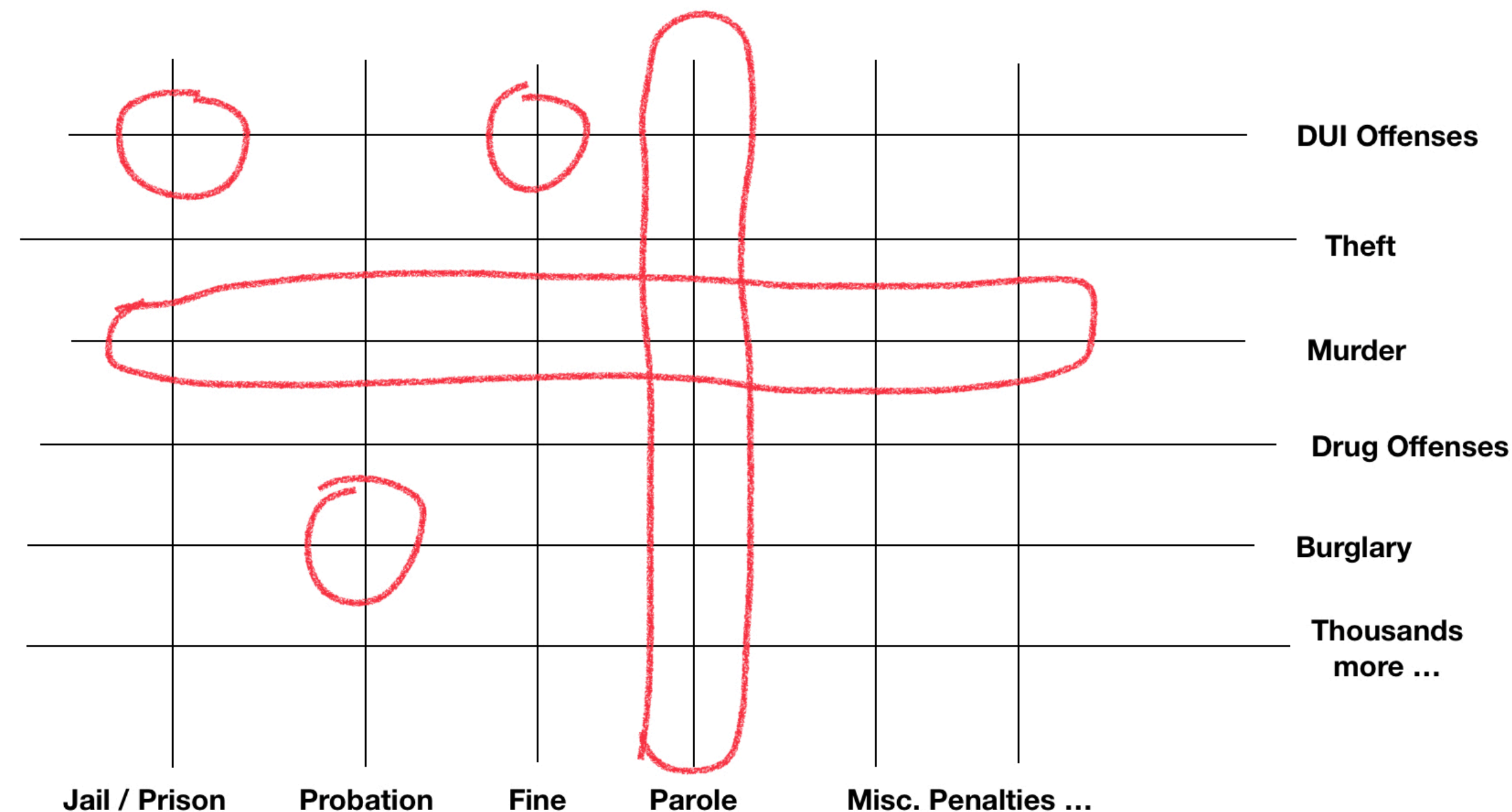
Jonathan Protzenko

Microsoft Research, USA

Ekaterina Komendantskaya**, Yue Li** and Remi Desmartin**

**Heriot-Watt University, Scotland

Longitudes vs. Latitudes of Criminal Law : Source of Complexities of Criminal Law Formalization and How Not to Be Overwhelmed



- Criminal law defines many crimes and prescribes many types of penalties for each crime. Crimes and penalties are respectively latitudes and longitudes.
- A complete formalization covers all crimes and all penalties - all possible locations on the map.
- Partial formalization can be done in various ways.
 - 1) We can follow through a latitude line - computing all legal consequences for a particular kind of crime, eg. a program that computes prison sentence, probation term and fine etc. for murder.
 - 2) We can follow through a longitude line - given any kind of crime, compute a single type of penalty, eg. a program that computes parole rules for burglary, DUI, murder, etc..
 - 3) We can pick one longitude line and one latitude line, and focus on their single intersection, eg. fine for DUI offenses - this is the simplest, suitable as a starting point.

Catala : A Language for Writing Competing Definitions and Resolving Them by Priority Annotations

Def. $x = 1$ (1)

Def. $x = 2$ if $y > 0$ (2)

priority : (2) > (1) (3)

- We introduce the idea of Catala.
- (1) says that x equals to 1 absolutely, under whatever condition.
- (2) says that x equals to 2 if y is greater than 0, otherwise x is undefined.
- When $y = 0$, by (1) x gets a value of 1 and by (2) x is undefined. This is *Conflict A*.
- When $y = 1$, by (1) x gets value 1 and by (2) x has value 2. This is *Conflict B*.
- The difference between conflicts A and B is that B is between defined values, but A is between a defined value and the status of being undefined.
- Implicitly, there is a rule saying that x shall eagerly seek a value, so that if the conflict is not among multiple defined values but between a defined value and a undefined status, it shall take the defined value as final. This resolves conflict A.
- (3) declares a priority rule saying that when x has a value under (1) and also has a value under (2), then it shall take the value as per (2) as final. This resolves conflict B.
- (1), (2) and (3) together constitute a program. It is sound if x has exactly one value without unresolved conflict under all circumstances. Otherwise it is unsound. It is the Catala programmer's responsibility to make use of the implicit rule and provide priority rules and produce sound programs.

Modeling Florida Statutes 316.193 in Catala : A Central Snippet

```
definition fine equals DUI_Fine { -- min : $ 0 -- max : $ 0 }
```

```
definition fine under condition the_person_is_in_violation_of_subsection_1 and first_conviction consequence equals  
DUI_Fine { -- min : $ 500 -- max : $ 1,000 }
```

```
definition fine under condition the_person_is_in_violation_of_subsection_4 and first_conviction consequence equals  
DUI_Fine { -- min : $ 1,000 -- max : $ 2,000 }
```

```
definition fine under condition the_person_is_in_violation_of_subsection_1 and second_conviction consequence equals  
DUI_Fine { -- min : $ 1,000 -- max : $ 2,000 }
```

```
definition fine under condition the_person_is_in_violation_of_subsection_4 and second_conviction consequence equals  
DUI_Fine { -- min : $ 2,000 -- max : $ 4,000 }
```

```
definition fine under condition the_person_is_in_violation_of_subsection_1 and third_offense_within_10_years consequence equals  
DUI_Fine { -- min : $ 0 -- max : $ 5,000 } # F.S. 775.083(1)(c)
```

```
definition fine under condition the_person_is_in_violation_of_subsection_4 and third_offense_within_10_years consequence equals  
DUI_Fine { -- min : $ 4,000 -- max : $ 5,000 } # maximum fine is according to 775.083(1)(c)
```

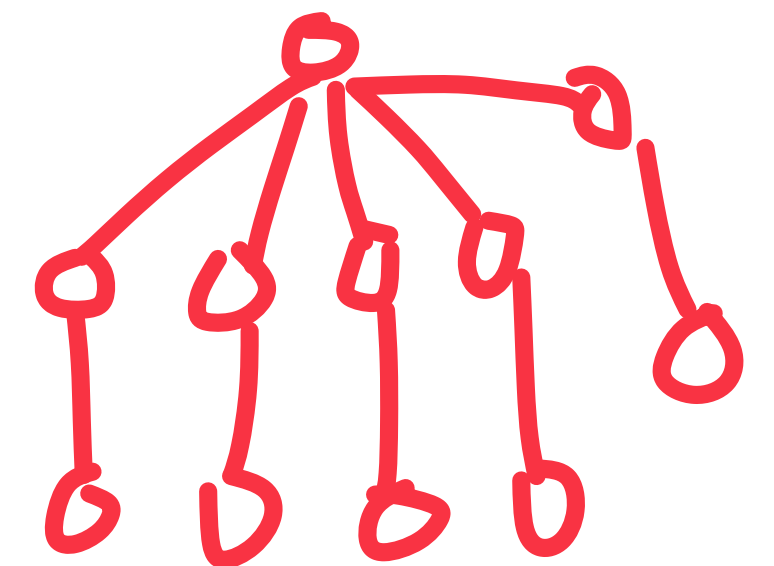
```
definition fine under condition the_person_is_in_violation_of_subsection_1 and third_offense_outwith_10_years consequence equals  
DUI_Fine { -- min : $ 2,000 -- max : $ 5,000 }
```

```
definition fine under condition the_person_is_in_violation_of_subsection_4 and third_offense_outwith_10_years consequence equals  
DUI_Fine { -- min : $ 4,000 -- max : $ 5,000 } # maximum fine is according to (2)(b)2.
```

```
definition fine under condition the_person_is_in_violation_of_subsection_1 and fourth_or_subsequent_conviction consequence equals  
DUI_Fine { -- min : $ 2,000 -- max : $ 5,000 } # maximum fine is according to 775.083(1)(c)
```

```
definition fine under condition the_person_is_in_violation_of_subsection_4 and fourth_or_subsequent_conviction consequence equals  
DUI_Fine { -- min : $ 4,000 -- max : $ 5,000 } # maximum fine is according to 775.083(1)(c)
```

... that is :



Key Result : Curious Situations wrt. the Theory of Compatible Intervals and the Construction Rule as per 775.021(4)

<i>Assume: BAC=.10, No minor on car</i>	No Damage	Damage to Property or Light Injury (1st degree)	Serious Injury (3rd degree)	Death (2nd degree)	Death&NoAid (1st degree)
1st DUI	<u>By(2)(a) 500-1k</u> By(3) undefined	By(2)(a) 500-1k <u>By(3) 0-1k</u>	By(2)(a) 500-1k <u>By(3) 0-5k</u>	By(2)(a) 500-1k <u>By(3) 0-10k</u>	By(2)(a) 500-1k <u>By(3) 0-10k</u>
2nd	<u>By(2)(a) 1k-2k</u> By(3) undefined	<u>By(2)(a) 1k-2k</u> <u>By(3) 0-1k</u>	<u>By(2)(a) 1k-2k</u> <u>By(3) 0-5k</u>	By(2)(a) 1k-2k <u>By(3) 0-10k</u>	By(2)(a) 1k-2k <u>By(3) 0-10k</u>
3rd <=10years (3rd degree)	<u>By(2)(b) 0-5k</u> By(3) undefined	By(2)(b) 0-5k By(3) 0-1k	By(2)(b) 0-5k By(3) 0-5k	By(2)(b) 0-5k By(3) 0-10k	By(2)(b) 0-5k By(3) 0-10k
3rd >10years	<u>By(2)(b) 2k-5k</u> By(3) undefined	<u>By(2)(b) 2k-5k</u> <u>By(3) 0-1k</u>	<u>By(2)(b) 2k-5k</u> <u>By(3) 0-5k</u>	By(2)(b) 2k-5k By(3) 0-10k	By(2)(b) 2k-5k By(3) 0-10k
4th+ (3rd degree)	<u>By(2)(b) 2k-5k</u> By(3) undefined	By(2)(b) 2k-5k By(3) 0-1k	By(2)(b) 2k-5k By(3) 0-5k	By(2)(b) 2k-5k By(3) 0-10k	By(2)(b) 2k-5k By(3) 0-10k
Legend	Curious	Misdemeanor	Felony	Priority Not Specified	Priority Specified

Project Output

Florida DUI Fine Calculator 2022

- We used Catala to write a DUI fine calculator to help non-experts get an idea how much fine is likely due to an offense based on DUI.
- <https://yuelipicasso.github.io/FloridaDUIFine/code/index.html>

This is a calculator for Florida DUI fines. Please select from the statements below which best describe your DUI offense pending before the court for prosecution, and then click the "Submit" button. The computed minimum/maximum fine shall be printed.

Date of the DUI Offense

Blood Alcohol Level (grams of alcohol per 100 milliliters of blood)

Breath Alcohol Level (grams of alcohol per 210 liters of breath)

Count of my previous DUI convictions

Date of the most recent prior DUI offense (if applicable)

☒ I was driving or in actual physical control of a vehicle within Florida.

☐ I was under the influence of alcoholic beverages, any chemical substance set forth in s. 877.111, or any substance controlled under chapter 893, when affected to the extent that my normal faculties are impaired.

☒ At the time of the offense I was accompanied in the vehicle by a person under the age of 18 years.

☐ I operated a vehicle and by reason of such operation, caused or contributed to causing damage to the property of another.

☐ I operated a vehicle and by reason of such operation, caused or contributed to causing damage to the person of another (but neither death nor serious bodily injury, as defined in s. 316.1933).

☐ I operated a vehicle and by reason of such operation, caused or contributed to causing serious bodily injury to another, as defined in s. 316.1933.

☐ I operated a vehicle and by reason of such operation, caused or contributed to causing the death of any human being or unborn child.

☐ At the time of the crash (if any), I knew, or should have known, that the crash occurred.

☐ At the time of the crash (if any) I failed to give information and render aid as required by s. 316.062.

Fine by 316.193(2)&(4):
\$ 4000 ~ \$ 5000

Fine by 316.193(3):
\$ 0 ~ \$ 0

Thanks !

Appendix A

<https://flsenate.gov/Laws/Statutes/2022/316.193>

316.193 Driving under the influence; penalties.—

(1) A person is guilty of the offense of driving under the influence and is subject to punishment as provided in subsection (2) if the person is driving or in actual physical control of a vehicle within this state and:

(a) The person is under the influence of alcoholic beverages, any chemical substance set forth in s. 877.111, or any substance controlled under chapter 893, when affected to the extent that the person's normal faculties are impaired; (b) The person has a blood-alcohol level of 0.08 or more grams of alcohol per 100 milliliters of blood; or

(c) The person has a breath-alcohol level of 0.08 or more grams of alcohol per 210 liters of breath.

(2)(a) Except as provided in paragraph (b), subsection (3), or subsection (4), any person who is convicted of a violation of subsection (1) shall be punished:

1. By a fine of:

a. Not less than \$500 or more than \$1,000 for a first conviction.

b. Not less than \$1,000 or more than \$2,000 for a second conviction; and

2. By imprisonment for:

a. Not more than 6 months for a first conviction.

b. Not more than 9 months for a second conviction.

(b)1. Any person who is convicted of a third violation of this section for an offense that occurs within 10 years after a prior conviction for a violation of this section commits a felony of the third degree, punishable as provided in s. 775.082, s. 775.083, or s. 775.084. In addition, the court shall order the mandatory placement for a period of not less than 2 years, at the convicted person's sole expense, of an ignition interlock device approved by the department in accordance with s. 316.1938 upon all vehicles that are individually or jointly leased or owned and routinely operated by the convicted person, when the convicted person qualifies for a permanent or restricted license.

2. Any person who is convicted of a third violation of this section for an offense that occurs more than 10 years after the date of a prior conviction for a violation of this section shall be punished by a fine of not less than \$2,000 or more than \$5,000 and by imprisonment for not more than 12 months. The portion of a fine imposed in excess of \$2,500 pursuant to this subparagraph shall be remitted by the clerk to the Department of Revenue for deposit into the General Revenue Fund. In addition, the court shall order the mandatory placement for a period of at least 2 years, at the convicted person's sole expense, of an ignition interlock device approved by the department in accordance with s. 316.1938 upon all vehicles that are individually or jointly leased or owned and routinely operated by the convicted person, when the convicted person qualifies for a permanent or restricted license.

3. Any person who is convicted of a fourth or subsequent violation of this section, regardless of when any prior conviction for a violation of this section occurred, commits a felony of the third degree, punishable as provided in s. 775.082, s. 775.083, or s. 775.084. However, the fine imposed for such fourth or subsequent violation may be not less than \$2,000. The portion of a fine imposed in excess of \$1,000 pursuant to this subparagraph shall be remitted by the clerk to the Department of Revenue for deposit into the General Revenue Fund.

(3) Any person:

(a) Who is in violation of subsection (1);

(b) Who operates a vehicle; and

(c) Who, by reason of such operation, causes or contributes to causing:

1. Damage to the property or person of another commits a misdemeanor of the first degree, punishable as provided in s. 775.082 or s. 775.083.

2. Serious bodily injury to another, as defined in s. 316.1933, commits a felony of the third degree, punishable as provided in s. 775.082, s. 775.083, or s. 775.084.

3. The death of any human being or unborn child commits DUI manslaughter, and commits:

a. A felony of the second degree, punishable as provided in s. 775.082, s. 775.083, or s. 775.084.

b. A felony of the first degree, punishable as provided in s. 775.082, s. 775.083, or s. 775.084, if:

(I) At the time of the crash, the person knew, or should have known, that the crash occurred; and

(II) The person failed to give information and render aid as required by s. 316.062.

For purposes of this subsection, the term “unborn child” has the same meaning as provided in s.775.021(5). A person who is convicted of DUI manslaughter shall be sentenced to a mandatory minimum term of imprisonment of 4 years.

(4) Any person who is convicted of a violation of subsection (1) and who has a blood-alcohol level or breath-alcohol level of 0.15 or higher, or any person who is convicted of a violation of subsection (1) and who at the time of the offense was accompanied in the vehicle by a person under the age of 18 years, shall be punished:

(a) By a fine of:

1. Not less than \$1,000 or more than \$2,000 for a first conviction.
2. Not less than \$2,000 or more than \$4,000 for a second conviction.
3. Not less than \$4,000 for a third or subsequent conviction.

(b) By imprisonment for:

1. Not more than 9 months for a first conviction.
2. Not more than 12 months for a second conviction.

For the purposes of this subsection, only the instant offense is required to be a violation of subsection (1) by a person who has a blood-alcohol level or breath-alcohol level of 0.15 or higher. The portion of a fine imposed in excess of \$1,000 pursuant to subparagraph (a)1. and the portion of a fine imposed in excess of \$2,000 pursuant to subparagraph (a)2. or subparagraph (a)3., shall be remitted by the clerk to the Department of Revenue for deposit into the General Revenue Fund.

Appendix B

<https://flsenate.gov/Laws/Statutes/2022/0775.021>

775.021 Rules of construction.—

- (1) The provisions of this code and offenses defined by other statutes shall be strictly construed; when the language is susceptible of differing constructions, it shall be construed most favorably to the accused.
 - (2) The provisions of this chapter are applicable to offenses defined by other statutes, unless the code otherwise provides.
 - (3) This section does not affect the power of a court to punish for contempt or to employ any sanction authorized by law for the enforcement of an order or a civil judgment or decree.
 - (4)(a) Whoever, in the course of one criminal transaction or episode, commits an act or acts which constitute one or more separate criminal offenses, upon conviction and adjudication of guilt, shall be sentenced separately for each criminal offense; and the sentencing judge may order the sentences to be served concurrently or consecutively. For the purposes of this subsection, offenses are separate if each offense requires proof of an element that the other does not, without regard to the accusatory pleading or the proof adduced at trial.
 - (b) The intent of the Legislature is to convict and sentence for each criminal offense committed in the course of one criminal episode or transaction and not to allow the principle of lenity as set forth in subsection (1) to determine legislative intent. Exceptions to this rule of construction are:
 1. Offenses which require identical elements of proof.
 2. Offenses which are degrees of the same offense as provided by statute.
 3. Offenses which are lesser offenses the statutory elements of which are subsumed by the greater offense.
 - (5) Whoever commits an act that violates a provision of this code or commits a criminal offense defined by another statute and thereby causes the death of, or bodily injury to, an unborn child commits a separate offense if the provision or statute does not otherwise specifically provide a separate offense for such death or injury to an unborn child.
 - (a) Except as otherwise provided in this subsection, the punishment for a separate offense under this subsection is the same as the punishment provided under this code or other statute for that conduct had the injury or death occurred to the mother of the unborn child.
 - (b) An offense under this subsection does not require proof that the person engaging in the conduct:
 1. Had knowledge or should have had knowledge that the victim of the underlying offense was pregnant; or
 2. Intended to cause the death of, or bodily injury to, the unborn child.
 - (c) Notwithstanding any other provision of law, the death penalty may not be imposed for an offense under this subsection.
 - (d) This subsection does not permit the prosecution:
 1. Of any person for conduct relating to an abortion for which the consent of the pregnant woman, or a person authorized by law to act on her behalf, has been obtained or for which such consent is implied by law;
 2. Of a person for providing medical treatment of the pregnant woman or her unborn child; or
 3. Of a woman with respect to her unborn child.
 - (e) As used in this subsection, the term “unborn child” means a member of the species *Homo sapiens*, at any stage of development, who is carried in the womb.
- History.**—s. 3, ch. 74-383; s. 1, ch. 76-66; s. 1, ch. 77-174; s. 1, ch. 83-156; s. 7, ch. 88-131; s. 2, ch. 2014-194.