Title

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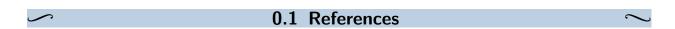
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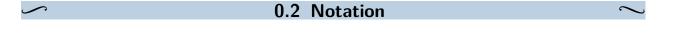
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Prologue



 $\bullet \ \ Gathmann's \ Algebraic \ Geometry \ notes [@Andreas Gathmann 515].$



• If a property P is said to hold **locally**, this means that for every point p there is a neighborhood $U_p \ni p$ such that P holds on U_p .

Notation	Definition
$k[\mathbf{x}] = k[x_1, \dots, x_n]$ $k(\mathbf{x}) = k(x_1, \dots, x_n)$	Polynomial ring in n indeterminates. Rational function field in n indeterminates
$\mathcal{U} \rightrightarrows X$ Δ_X $\mathbb{A}^n_{/k}$	An open cover $\mathcal{U} = \left\{ U_j \mid j \in J \right\}$ The diagonal $\left\{ (x, x) \mid x \in X \right\} \subseteq X \times X$ Affine n -space

 $\[\AA^n_{/k} \ \tx_{tv_{k_1}, \cdots, k_n} \ \t k_j \in \$

0.2 Notation 3

$\mathbb{P}^n_{/k}$	Projective n-space
	$\mathbb{P}^n_{/k} := \left(k^n \setminus \{0\}\right)/x \sim \lambda x$
	$\{f(\mathbf{x}) = p(\mathbf{x})/q(\mathbf{x}), \mid p, q, \in k[x_1, \dots, x_n]\}$
$V(J), V_a(J)$	Variety associated to an ideal $J \leq k[x_1, \dots, x_n]$
	$\coloneqq \left\{ \mathbf{x} \in \mathbb{A}^n \mid f(\mathbf{x}) = 0, \forall f \in J \right\}$
$I(S), I_a(S)$	Ideal associated to a subset $S \subseteq \mathbb{A}^n_k$
	$:= \left\{ f \in k[x_1, \cdots, x_n] \mid f(\mathbf{x}) = 0 \forall \mathbf{x} \in X \right\}$
A(X)	Coordinate ring of a variety
$V_p(J)$	Projective variety of an ideal
	$\coloneqq \left\{ \mathbf{x} \in \mathbb{P}^n_{/k} \mid f(\mathbf{x}) = 0, \forall f \in J \right\}$
$I_p(S)$	Projective ideal?
	$\coloneqq \left\{ f \in k[x_1, \cdots, x_n] \mid f \text{ is homogeneous and } f(x) = 0 \forall x \in S \right\}$
S(X)	Projective coordinate ring
	$:= k[x_1, \cdots, x_n]/I_p(X)$
f^h	Homogenization
	$\coloneqq x_0^{\deg f} f\left(\frac{x_1}{x_0}, \cdots, \frac{x_n}{x_0}\right)$
f^i	Dehomogenization
J^h for $J \leq k[x_1, \cdots, x_n]$	Homogenization of an ideal
	$:= f(1, x_1, \cdots, x_n)$
\overline{X}	Projective closure of a subset
	$:= V_p(J^h) := \left\{ \mathbf{x} \in \mathbb{P}^n \mid f^h(\mathbf{x}) = 0 \forall f \in X \right\}$
	$\coloneqq k[x_1,\cdots,x_n]/I(X)$
\mathcal{O}_X	Structure sheaf $\{f: U \to k \mid f \in k(\mathbf{x}) \text{ locally}\}$
D(f)	Distinguished open set
	$:= V(f)^c = \left\{ x \in \mathbb{A}^n \mid f(x) \neq 0 \right\}$

0.3 Summary of Important Concepts

- What is an affine variety?
- What is the coordinate ring of an affine variety?
- What are the constructions $V(\,\cdot\,)$ and $I(\,\cdot\,)$?

- What is the Nullstellensatz?
- What are the definitions and some examples of:
 - The Zariski topology?
 - Irreducibility?
 - Connectedness?
 - Dimension?
- What is the definition of a presheaf?
 - What are some examples and counterexamples?
- What is the definition of sheaf?
 - What are some examples?
 - What are some presheaves that are not sheaves?
- What is the definition of \mathcal{O}_X , the sheaf of regular functions?
 - How does one compute \mathcal{O}_X for X = D(f) a distinguished open?
- What is a morphism between two affine varieties?
- What is the definition of separatedness?
 - What are some examples of spaces that are and are not separated?
- What is a projective space?
- What is a projective variety?
- What is the projective coordinate ring?
- How does one take the closure of an affine variety X in projective space?
- What is completeness?
 - What are some examples and counterexamples of complete spaces?

0.4 Useful Examples



0.4.1 Varieties

- $V(xy-1) \subseteq \mathbb{A}^2$ a hyperbola
- V(x) a coordinate axis
- V(x-p) a point.

0.4.2 Presheaves / Sheaves

- $C^{\infty}(\cdot, \mathbb{R})$, a sheaf of smooth functions
- $C^0(\cdot,\mathbb{R})$, a sheaf of continuous functions
- $\mathcal{O}_X(\cdot)$, the sheaf of regular functions on X
- $\underline{\mathbb{R}}(\cdot)$, the constant sheaf associated to \mathbb{R} (locally constant real-valued functions)
- $\operatorname{Hol}(\cdot,\mathbb{C})$, a sheaf of holomorphic functions
- K_p the skyscraper sheaf:

$$K_p(U) \coloneqq \begin{cases} k & p \in U \\ 0 & \text{else.} \end{cases}$$

0.5 The Algebra-Geometry Dictionary



Let $k = \bar{k}$, we're setting up correspondences

Algebra	Geometry
$\frac{1}{k[x_1,\cdots,x_n]}$	$\mathbb{A}^n_{/k}$
Maximal ideals $\mathfrak{m} = x_1 - p_1, \cdots, x_n - p_n$	Points $[a_1, \cdots, a_n]$
Radical ideals $J = \sqrt{J} \le k[x_1, \cdots, x_n]$	V(J) the zero locus
Prime ideals $\mathfrak{p} \in \operatorname{Spec}(k[x_1, \cdots, x_n])$	Irreducible subsets
I(S) the ideal of a set	$S \subseteq \mathbb{A}^n$ a subset
I + J	$V(I) \cap V(J)$
$\sqrt{I(V) + I(W)}$	$V \cap W$
$I \cap J, IJ$	$V(I) \cup V(J)$
$I(V) \cap I(W), \sqrt{I(V)I(W)}$	$V \cup W$
I(V):I(W)	$\overline{V\setminus W}$
$k[x_1,\cdots,x_n]/I(X)$	A(X) (Functions on X)
A(X) a domain	X is irreducible
A(X) indecomposable	X is connected
Krull dimension n (chaints of primes)	Topological dimension n (chains of irreducibles)