Measure Theory

Classes of sets

Definition1.1(**σ-algebra**):A class of sets A ⊂ 2Ω if it fulfils the following three conditions: (i) Ω ∈ A. (ii) A is closed under complements. (iii) A is closed under countable unions.

Defitinition1.2(**algebra**):A class of sets A ⊂ 2Ω is called an algebra if the following three conditions are fulfilled: (i) Ω ∈ A. (ii) A is \-closed. (iii) A is ∪-closed

Definition 1.3(**ring**):A class of sets A ⊂ 2Ω is called a ring if the following three condi- tions hold: (i) ∅ ∈ A. (ii) A is \-closed. (iii) A is ∪-closed. A ring is called a **σ-ring** if it is also σ-∪-closed

Definition 1.4(**semiring**): A class of sets A ⊂ 2Ω is called a semiring if (i) ∅ ∈ A, (ii) for any two sets A, B ∈ A the difference set B \ A is a finite union of mutually disjoint sets in A, (iii) A is ∩-closed.

Definition 1.5(**Dynkin-system**):A class of sets A ⊂ 2Ω is called a λ-system (or Dynkin's λ-system) if (i) Ω ∈ A, (ii) for any two sets A, B ∈ A with A ⊂ B, the difference set B \ A is in A, and (iii) ⊎∞ n=1 An ∈ A for any choice of countably many pairwise disjoint sets A1, A2, . . . ∈ A.

Definition 1.6 (**liminf & limsup**):Let A1, A2, . . . be subsets of Ω. The sets lim inf n→∞ An := ∞∪ n=1 ∞∩ m=n Am and lim sup n→∞ An := ∞∩ n=1 ∞∪ m=n Am are called limes inferior and limes superior, respectively, of the sequence (An)n∈N.

Theorem 1.1(**Intersection of classes of sets**):Let I be an arbitrary index set, and assume that Ai is a σ-algebra for every i ∈ I. Hence the inters- ection AI := {A ⊂ Ω : A ∈ Ai for every i ∈ I} = ∩ i∈I Ai is a σ-algebra. The analogous statement holds for rings, σ-rings, algebras and λ- systems. However, it fails for semirings

Theorem 1.2 (**Generated σ-algebra**):Let E ⊂ 2Ω . Then there exists a smallest σ-algebra σ(E) with E ⊂ σ(E): σ(E) := ∩ A⊂2Ω is a σ-algebra A⊃E A.

Theorem 1.3(**∩-closed λ-system**):Let D ⊂ 2Ω be a λ-system. Then D is a π-system ⇐⇒ D is a σ-algebra.

Theorem 1.4(**Dynkin's π-λ theorem**): If E ⊂ 2Ω is a π-system, then σ(E) = δ(E).

Definition 1.7(**Topology**): Let Ω = ∅ be an arbitrary set. A class of sets τ ⊂ Ω is called a topology on Ω if it has the following three properties: (i) ∅, Ω ∈ τ . (ii) A ∩ B ∈ τ for any A, B ∈ τ . (iii) (∪ A∈F A) ∈ τ for any F ⊂ τ . The pair (Ω, τ) is called a **topological space**. The sets A ∈ τ are called open, and the sets A ⊂ Ω with Ac ∈ τ are called closed.

Definition 1.8(**Borel σ-algebra**):Let (Ω, τ) be a topological space. The σ- algebra B(Ω) := B(Ω, τ) := σ(τ) that is generated by the open sets is called the Borel σ-algebra on Ω. The elements A ∈ B(Ω, τ) are called Borel sets or Borel measurable sets.

Definition 1.8 (**Trace of a class of sets**):Let A ⊂ 2Ω be an arbitrary class of subsets of Ω and let A ∈ 2Ω \ {∅}. The class A| |A := {A ∩ B : B ∈ A} ⊂ 2A is called the trace of A on A or the restriction of A to A.

Set Functions

Set Functions (cont)

σ-finite	if there exists a sequence of sets Ω1, Ω2, . . . ∈ A such that Ω = ∞∪ n=1 Ωn and such that μ(Ωn) < ∞ for all n ∈ N.
Examples	
Dirac measure	Let ω ∈ Ω and δω (A) = 1A(ω) . Then δω is a probability measure on any σ-algebra A ⊂ 2Ω . δω is called the
uniform distri- bution	Let Ω be a finite nonempty set. By μ(A) := #A #Ω for A ⊂ Ω, we define a probability measure on A = 2Ω

Let $\mathcal{A} \subset 2^\Omega$ and let $\mu : \mathcal{A} \to [0, \infty]$ be a set function. We say that μ is	
monoton	$\mu(A) \leq \mu(B)$ for any two sets $A, B \in \mathcal{A}$ with $A \subset B$,
additiv	if $\mu\left(\bigcup_{i=1}^{n} A_i\right) = \sum_{i=1}^{n} \mu(A_i)$ for any choice of finitely many mutually disjoint sets $A_1, \ldots, A_n \in \mathcal{A}$ with $\bigcup_{i=1}^{n} A_i \in \mathcal{A}$,
σ-additive	if $\mu\left(\bigcup_{i=1}^{\infty} A_i\right) = \sum_{i=1}^{\infty} \mu(A_i)$ for any choice of countably many mu- tually disjoint sets $A_1, A_2, \ldots \in \mathcal{A}$ with $\bigcup_{i=1}^{\infty} A_i \in \mathcal{A}$,
subadditive	if for any choice of finitely many sets $A, A_1, \ldots, A_n \in \mathcal{A}$ with $A \subset \bigcup_{i=1}^{n} A_i$, we have $\mu(A) \leq \sum_{i=1}^{n} \mu(A_i)$, and
σ-suba- dditive	if for any choice of countably many sets $A, A_1, A_2, \ldots \in \mathcal{A}$ with $A \subset \bigcup_{i=1}^{\infty} A_i$, we have $\mu(A) \leq \sum_{i=1}^{\infty} \mu(A_i)$
Let $\mathcal{A}$ be a semiring and let $\mu : \mathcal{A} \to [0, \infty]$ be a set function with $\mu(\emptyset) = 0$. μ is called a	
content	if μ is additive,
premeasure	if μ is σ-additive,
measure	if μ is a premeasure and $\mathcal{A}$ is a σ-algebra
probability measure	if μ is a measure and $\mu(\Omega) = 1$
Let $\mathcal{A}$ be a semiring. A content μ on $\mathcal{A}$ is called	
finite	if $\mu(A) < \infty$ for every $A \in \mathcal{A}$

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Not published yet.
Last updated 15th August, 2023.