The Alternating Groups

1 The O'Nan-Scott Theorem

1.1 Some Lemmas

1.2 The proof of the O'Nan-Scott Theorem

Last week we introduced some lemmas and proved part of the O'Nan-Scott Theorem. This week we will finish the proof of the O'Nan-Scott Theorem.

Notation: Let H be a subgroup of S_n not containing A_n, N be a minimal normal subgroup of H, and K be the stabilizer in H of a point.

H intransitive $\implies$ case (i).

H transitive imprimitive $\implies$ case (ii).

Now we assume H primitive. And hence the discussion zoom into $\mathrm{soc}(H)$.

$\exists N$ abelian $\implies$ case (iv)affine.

Additionally we assume $\forall N$ nonabelian.

If H has more than one minimal normal subgroups $N_1 \neq N_2$.

It can be shown that $\exists x \in S_n$ conjugates N_1 to N_2. specify x

By corollary 2.11, x also conjugates $N_2 = C_H(N_1)$ to $N_1 = C_H(N_2)$. (Why?)

Hence $H < \langle H, x\rangle$, which has a unique minimal normal subgroup $N_1 \times N_2$.

Additionally we assume H has a unique minimal normal subgroup N, which is nonabelian.

N simple $\implies C_H(N) = 1 \implies H \overset{\text{conj.}}{\curvearrowright} N$ faithfully $\implies$ case (vi)AS.

$N = T^m = T_1 \times \cdots \times T_m$ with $m > 1 \implies H \overset{\text{conj.}}{\curvearrowright} \{T_1, \cdots, T_m\}$ transitively, and K as well.

Let $K_i := p_i(K \cap N) \leq T_i$ the projection of K onto T_i. Then $K \cap N \leq K_1 \times \cdots \times K_m$.

Case $K_i \neq T_i$ for some i:

Now $K \cap N \leq K_1 \times \cdots \times K_m < N$.

<u>Claim:</u> K normalizes $K_1 \times \cdots \times K_m$.

Since $K \cap N \lhd K$, $\forall k \in K$, $\forall x \in K \cap N$,

we have $x = p_1(x) \cdots p_m(x)$, and $p_1(x)^k \cdots p_m(x)^k = x^k = p_1(x^k) \cdots p_m(x^k) \in K \cap N$.

Then $p_i(x)^k = p_j(x^k)$ whenever $T_i^k = T_j$. (In direct product, equal iff. all coordinates equal.)

$\forall y \in K_1 \times \cdots \times K_m$, $\exists x_1, \cdots, x_m \in K \cap N$ s.t. $y = p_1(x_1) \cdots p_m(x_m)$.

Then $y^k = p_1(x_1)^k \cdots p_m(x_m)^k = p_1(x_{l_1}^k) \cdots p_m(x_{l_m}^k) \in K_1 \times \cdots \times K_m$, where $T_i = T_{l_i}^k$.

By corollary 2.15, $K_1 \times \cdots \times K_m = K \cap N$ and K permutes K_i's transitively. Let $k := |T_i : K_i|$.

Then $H = (T_1 \times \cdots \times T_m) \rtimes K \leq S_k \wr S_m \curvearrowright [T_1 : K_1] \times \cdots \times [T_m : K_m] \implies$ case (iii)PA.

Case $K_i = T_i$ for all i:

Support of $(t_1, \cdots, t_m) \in N$ is defined as $\{i \mid t_i \neq 1\}$.

$\Omega_1 :=$ a non-empty min. supp. of an elt in $K \cap N$. $\implies$ Ω_1 a block of $K, H \curvearrowright [m]$.

1 and all elts in $K \cap N$ with support Ω_1 (i.e. $t_i \neq 1$ and $t_j = 1$ $\forall i \in \Omega_1, \forall j \notin \Omega_1$)

forms a normal subgp of $K \cap N$, which maps onto a normal subgp of hence T_i itself $\forall i \in \Omega_1$.

$\Omega_1 \cap \Omega_2 \neq \emptyset \implies \exists x, y$ s.t. $[x, y] \neq 1$ has support contained in $\Omega_1 \cap \Omega_2$, that is Ω_1

$|\Omega_1| = 1 \implies N \leq K$, a contradiction.

$|\Omega_1| = m \implies K \cap N = \{(t, \cdots, t) \mid t \in T\}$ WLOG. $N \curvearrowright [N : K \cap N] \implies$ case (v)diagonal.

$\forall i, \forall x, y \in K \cap N$, $p_i(x) = p_i(y) \implies p_i(xy^{-1}) = 1 \implies xy^{-1} = 1$ i.e. $p_i|_{K\cap N}$ inj.

$|\Omega_1| = k \neq 1, m \implies N = \left(\bigtimes_{i \in \Omega_1} T_i \right)^l \cong T^{kl}$, $N \cap K = \left(\mathrm{diag} \left(\bigtimes_{i \in \Omega_1} T_i \right) \right)^l \cong T^l$.

The action of each $\bigtimes_{i \in \Omega_1} T_i$ is diagonal of degree $r = |T|^{k-1}$. $H \leq S_r \wr S_l \curvearrowright [r]^l \implies$ case (iii)PA.

2 Covering Groups

2.1 Schur Multiplier

2.2 Double Covers of A_n and S_n

2.3 Triple Covers of A_6 and A_7

3 Coxter Groups